Impacts of Expanded Biodiesel Production on the World Soybean Market

by

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The emergence of biodiesel as an important alternative fuel has increased interest in its likely impact on the international trade. Questions about how much the biodiesel sector will impact the soybean market have increased in importance as this sector has grown globally.

The European Union is the largest biodiesel producer in the world followed by Brazil and the United States (IEA, 2009). However, the U.S. and Brazil are the leading soybean-based biodiesel producers as well as the largest soybean producers and exporters. Further, the Renewable Fuels Standard (RFS) of the 2007 Energy Independence and Security Act (EISA) has been a boost to biodiesel production since it requires fuel producers to use large quantities of advanced biofuels as a source U.S alternative fuel. According to FAPRI (2009), it is expected that biodiesel production will rise from 677 million gallons to 1.18 billion gallons in 2018. In Brazil, biodiesel production is regulated by the government through the National Biodiesel Production Program (PNPB). The PNPB established a legal mandate for the use of biodiesel as a fuel. Estimates from FAPRI (2009) indicate that Brazil will increase biodiesel production from 290 million gallons in 2008 to 875 million gallons by 2018.

The purpose of this paper is to provide an estimate of how much the biodiesel sector in the U.S. and Brazil could impact international soybean trade and estimate how changes will occur regarding trade flows, export revenues, and international prices. To achieve these goals, the paper will utilize a previously developed world soybean spatial

equilibrium model (Costa, 2007; Costa and Rosson, 2008). The model divides Brazil in 18 excess supply regions and 8 excess demand regions. The competing exporting countries are the United States, Argentina, Rest of South America (Bolivia, Paraguay, and Uruguay), Canada, and India. The importing countries are composed of China, European Union, Southeast Asia, Mexico, and the Rest of the World.

The results assess the impacts on the U.S. and Brazil's soybean producers by indicating changes in world price and projected exports. Different scenarios will be analyzed to assess increases in consumption of soybeans due to the biodiesel expansion in the analyzed countries. Emphasis will also be given to the impacts on the major soybean importing countries. It is expected that the increase in domestic consumption will have direct impact on the world price and export levels.

METHODOLOGY

International spatial, intertemporal model for soybeans was developed by Costa (2007) on the basis of quadratic programming model. The model is formed by spatial and temporal dimensions which allow soybeans to move from Brazil producing areas to domestic demand regions and importing countries for each quarter. Initially, base models are formulated that feature transportation and marketing costs: the solution to the model is a benchmark or a measure of conditions prior to the introduction of changes in the respective countries. The effects generated by the increase in biodiesel production in each country are measured by introducing modified crushing levels, solving these modified models, and then contrasting their solutions with those of the base model. By contrasting the U.S., Brazil and other exporting countries soybean prices, revenues, and exports *ex ante* and *ex post* changes in crushing levels, the effects on international trade are

evaluated. It is important to mention that this is a static model which only takes into account initial changes in the parameters. Subsequent changes in important variables, such as soybean production are assumed to remain constant for this analysis. Although this assumption poses limitations for conducting a long run analysis, the short run results appear fairly robust based on findings of previous research.

Spatial Models

The spatial equilibrium model was first developed by Samuelson (1952) and later was improved by Takayama and Judge (1971). The spatial equilibrium model is a quadratic programming model that features regional excess supply and excess demand regions relationships. The solution to such model generates interregional flows and prices that result from maximizing producer plus consumer surplus minus transportation and marketing costs. Spatial equilibrium models have been previously developed to analyze transportation improvements on international agricultural commodities trade (Fellin, 1993; Fuller et al, 1998; Fuller et al, 2000; and Fuller et al, 2001).

The Quadratic Programming Model

Given linear supply and demand equations for all regions, the objective function and balance restrictions are expressed as:

$$
\begin{aligned}
(1)\ Max\ NW\ = \{ & \sum_q \{ -\sum_i (\alpha_{iq} + 0.5\beta_{iq} S_{iq}) S_{iq} - \sum_f (\alpha_{fq} + 0.5\beta_{fq} S_{fq}) S_{fq} \\
& + \sum_j (\alpha_{jq} - 0.5\beta_{jq} D_{jq}) D_{jq} + \sum_d (\alpha_{dq} - 0.5\beta_{dq} D_{dq}) D_{dq} \} \\
& - \{ \sum_m (\sum_i (\sum_j C_{ijm} T_{ijqm} + \sum_b C_{ibm} T_{ibqm} + \sum_r C_{irm} T_{irqm} \\
& + \sum_p C_{ipm} T_{ipqm})) + \sum_u \sum_p C_{upm} T_{upm}) \} \\
& - \{ \sum_b (\sum_u C_{bu} T_{buq} + \sum_p C_{bp} T_{bpq}) \\
& - \sum_r (\sum_p C_{rp} T_{rpq}) \\
& - \sum_d (\sum_p C_{pd} T_{pd} + \sum_f C_{fd} T_{fdq}) \} \}
\end{aligned}
$$

subject to:

(2) $\sum_m (\sum_j T_{ijqm} + \sum_b T_{ibqm} + \sum_r T_{irqm} + \sum_p T_{ipqm}) + G_{qq+1} \le S_{iq} + G_{q-1q}$ for all i and q;

(3) $\sum_p T_{bpq} + \sum_u \sum_m T_{buq} \le \sum_i \sum_m T_{ibqm}$ for all b and q;

(4) $\sum_p T_{rpq} \le \sum_i \sum_m T_{irqm}$ for all r and q;

(5) $\sum_d T_{pdq} \le \sum_m \sum_i T_{ipmq} + \sum_b T_{bpq} + \sum_r T_{rpq} + \sum_u T_{upq}$ for all p and q;

(6) $\sum_m \sum_u T_{ujmq} \ge D_{jq}$ for all j and q;

(7) $\sum_p T_{pdq} + \sum_f T_{fdq} \ge D_{dq}$ for all d and q;

(8) $\sum_d T_{fdq} + R_{qq+1} \le S_{fq} + R_{qq-1}$ for all f and q;

(9) $\sum_p T_{pd} \le PC_p$ for all p;

(10) $T, S, D \ge 0$ for all i, j, f, q, d, b, p, and r

where equation (1) is the net welfare interpreted as consumer surplus plus producer surplus minus transportation costs. From (2) to (5), all equations are supply balance constraints. Equation (2) constrains the soybean flow from i excess supply region to all receiving and transhipment points that is less than or equal to the quantity supplied at location i for all four quarters of the year. Equation (3) limits transhipments at barge-loading location so that the quantity shipped from each location is less than or equal to total quantities received for every quarter. Equation (4) constrains transhipments at rail-loading terminals so that the quantity shipped from each location is less than or equal to total quantities received for every quarter. Equation (5) constrains soybean shipments at

each Brazil port to be less than or equal to quantity received at the ports by different inland transportation modes for every quarter.

From equation (6) to (8), all equations are demand balanced constraints. Equation (6) limits quantity shipped by different inland modes to each demand location to be at least equal to or greater than the quantity demanded at each demand location for every quarter of the year. Equation (7) constrains quantity imported by each importing country to be at least equal to or greater than the quantity demanded for each quarter. Equation (8) limits quantity shipped from exporters f to all importing countries to be less than or equal to the quantity supplied at f for all quarters of the year. Equation (9) constrains soybean exports by port to less than or equal to its capacity. Equation (10) represents the non-negativity conditions. Table 3 shows the subscripts, parameters, and variables included in the formulated model.

Table 3. Subscripts, Parameters and Variables Included in Formulated Model

Subscripts	***Definition (quantity)***
q	quarter (1,2,3,4)
i	Brazil excess supply locations (1,2,3…18)
f	foreign exporting regions (1,2,3…6)
j	Brazil excess demand locations (1,2,3…8)
d	Foreign importing countries (1,2,3…5)
m	Inland modes of transportation (1,2,3)
b	Barge loading locations (1,2,3)
u	Barge unloading locations (1)
r	Rail-loading terminal (1,2,3…8)
p	Brazil ports (1,2,3…8)
Parameters	***Definition***
C	Transportation costs per MT by the various modes
Variables	***Definition***
S_i	Brazil excess supply regions
S_f	Foreign excess supply regions
D_j	Brazil excess demand regions

D_d	Foreign excess demand regions
T	Soybean flow in MT between nodes
G	Quarterly quantities stored in Brazil
R	Quarterly quantities stored in other major exporting countries
PC	Port capacity

Data

The data utilized in this spatial equilibrium model to specify the soybean international market were retrieved from the Foreign Agricultural Service/USDA (FAS/USDA, 2007). Data consist of quantity produced, consumed, exported, imported by each analyzed country. The model also used data for inland and ocean transportation costs to depict the soybean flows in the world market which were sourced from SIFRECA (2007) and AMS/USDA (2007a). For more detailed information regarding data required to develop such model can be found in Costa (2007).

SIMULATION ANALYSIS

In this section, simulation results of three different scenarios are presented: (i) small; (ii) medium, and (iii) large increase in biodiesel production for the U.S. and Brazil.

Scenario 1 – Increase of 10 percent in Biodiesel Production in the U.S. and Brazil

To take into account the increase of 10 percent in biodiesel production in the U.S. and Brazil, it is assumed that the soybean crushed domestically increases which concurrently add up total consumption. Therefore, in this scenario, the total soybean consumed in the U.S. and Brazil is assumed to go up by 4,732 and 2,828 thousand MT, respectively, which is equivalent to a 10 percent increase in crushing for each country. According to Gray (2006), one bushel of soybean produces 1.49 gallons of biodiesel. Hence, a 10 percent increase in crushed soybeans in the U.S. would result in an additional

259 million gallons of biodiesel. As for Brazil, the mentioned increase in crushed soybeans would induce an additional 154 million gallons of biodiesel.

Table 4 below presents the base model soybean prices and a comparison with prices generated from Scenario 1. As was expected, the increase in soybean crushed due to the increase in biodiesel production induces a higher price in the U.S. and in Brazil. The largest percentage increase occurs in Brazil followed by the U.S. The other exporting countries such as Argentina and Canada also undergo a price increase. This price increase might be explained due to less available soybeans in the world which induces a higher world soybean price. Similarly, a price increase was observed for all importing countries.

Table 4. Comparison of Soybean Prices Base Model and Scenario 1: 10% Increase in Crushed Soybean in the U.S. and Brazil ($/MT)

Exporting Country	Base model	Scenario 1	Deviation (%)
United States	234.06	269.73	15.24
Brazil*	200.62	236.46	17.86
Argentina	234.14	269.81	15.23
Rest of South America	234.14	269.81	15.23
Canada	244.18	279.85	14.61
India	246.27	281.94	14.48
Importing Country			
China	278.94	314.61	12.79
European Union	271.05	306.72	13.16
Southeast Asia	278.94	314.61	12.79
Mexico	268.02	303.69	13.31
Rest of the World	267.77	303.44	13.32

*Farm prices.

Regarding changes in quantity exported, the U.S. and Brazil undergo a decline of 7.87 and 5.84 percent, respectively (Table 5). This decrease in exports by both countries was expected since an increase in crushed soybean reduces the available amount to be exported. On the other hand, Argentina, rest of South America, and Canada increase the

export quantities. Argentina is the country which has the largest percentage increase in exported quantity. It is important to mention that, in the base model, India was not exporting soybeans although it is considered as an exporter. Now, India starts to be present in the world market by exporting a very small amount (22.14 thousand MT). Overall, the soybean traded in the world declines due to higher crushing levels among the major producers and exporters, the U.S. and Brazil.

Table 5. Comparison of Soybean Exports and Imports Base Model and Scenario 1: 10% Increase in Crushed Soybean in the U.S. and Brazil (thousand MT)

Exporting Country	Base model	Scenario 1	Deviation (%)
United States	25127.39	23149.98	-7.87
Brazil	26123.19	24599.88	-5.83
Argentina	7325.89	7710.23	5.25
Rest of South America	3229.46	3351.75	3.79
Canada	1323.40	1377.11	4.06
India	0	22.14	-
Total	63129.33	60211.09	-4.62
Importing Country			
China	28319.05	27180.22	-4.02
European Union	13810.65	13308.79	-3.63
Southeast Asia	11146.23	10461.96	-6.14
Mexico	3535.14	3322.52	-6.01
Rest of the World	6318.26	5937.60	-6.02
Total	63129.33	60211.09	-4.62

Scenario 2 – Increase of 20 percent in Biodiesel Production in the U.S. and Brazil

In this scenario, an increase in biodiesel production of 20 percent represents an increase in crushed soybeans in the U.S. and in Brazil of 9,464 and 5,657 thousand MT, respectively. For the U.S., this would represent an additional 518 million gallons of biodiesel in the market. As for Brazil, this increase induces more than 309 million gallons of biodiesel.

The consequences of such increase in biodiesel production in the world soybean market are presented in Tables 6 and 7. Similarly to Scenario 1, all exporting and importing countries undergo an increase in price when compared to the base model. The countries which have the largest price increase are Brazil followed by the U.S. This was expected since those countries are the ones going through the increase in soybean crushing.

Table 6. Comparison of Soybean Prices Base Model and Scenario 2: 20% Increase in Crushed Soybean in the U.S. and Brazil ($/MT)

Exporting Country	Base model	Scenario 2	Deviation (%)
United States	234.06	300.90	28.56
Brazil*	200.63	267.21	33.19
Argentina	234.14	300.98	28.55
Rest of South America	234.14	300.98	28.55
Canada	244.18	311.02	27.37
India	246.27	313.11	27.14
Importing Country			
China	278.94	345.78	23.96
European Union	271.05	337.89	24.66
Southeast Asia	278.94	345.78	23.96
Mexico	268.02	334.86	24.94
Rest of the World	267.77	334.61	24.96

*Farm price

As we can see on Table 7 below, similarly to Scenario 1, the U.S. and Brazil decrease the exports while Argentina and other competing exporters increase. The quantity exported by the U.S. goes down the most (3,553 thousand MT) followed by Brazil (3,007 thousand MT). Once again Argentina is the exporting country which gains the most from the reduction in exports by the top two soybean producers. Soybean exports in India almost double when compared to Scenario 1 going from 22 thousand MT to 41.7 thousand MT. With respect to the importing countries, all undergo a reduction in

imports. Note that China had one of the lowest percentage changes but its imports decreased the most in absolute value (2,134.18 thousand MT). As was expected, the soybean traded in the world reduces even further than in Scenario 1, going from 63,129 thousand MT to 57,660, which is equivalent to a reduction of 5,469.26 thousand MT.

Table 7. Comparison of Soybean Exports and Imports Base Model and Scenario 2: 20% Increase in Crushed Soybean in the U.S. and Brazil (thousand MT)

Exporting Country	Base model	Scenario 2	Deviation (%)
United States	25127.39	21573.65	-14.14
Brazil	26123.19	23115.89	-11.51
Argentina	7325.89	8046.15	9.83
Rest of South America	3229.46	3458.63	7.10
Canada	1323.40	1424.05	7.61
India	0	41.7	-
Total	63129.33	57660.07	-8.66
Importing Country			
China	28319.05	26184.87	-7.54
European Union	13810.65	12870.15	-6.81
Southeast Asia	11146.23	9863.93	-11.50
Mexico	3535.14	3136.6	-11.27
Rest of the World	6318.26	5604.52	-11.30
Total	63129.33	57660.07	-8.66

Scenario 3 – Increase of 30 percent in Biodiesel Production in the U.S. and Brazil

An increase in biodiesel production of 30 percent represents an increase in crushed soybeans in the U.S. and in Brazil of 14,196 and 8,485 thousand MT, respectively. For the U.S., this would represent an additional 777 million gallons of biodiesel in the market. As for Brazil, this increase induces more than 464 million gallons of biodiesel.

As was expected, the largest impact on prices is presented in this scenario. For the exporting countries, the average increase in price is around 40 percent (Table 8). Brazil is

the country which has the highest change in price, approximately a 47 percent increase. The U.S. follows as the second largest increase in price with Argentina and the rest of South America not far behind. The importing countries undergo an average price increase of 35 percent.

Table 8. Comparison of Soybean Prices Base Model and Scenario 3: 30% Increase in Crushed Soybean in the U.S. and Brazil ($/MT)

Exporting Country	Base model	Scenario 3	Deviation (%)
United States	234.06	329.45	40.75
Brazil*	200.63	295.75	47.41
Argentina	234.14	329.53	40.74
Rest of South America	234.14	329.53	40.74
Canada	244.18	339.57	39.07
India	246.27	341.66	38.73
Importing Country			
China	278.94	374.33	34.20
European Union	271.05	366.44	35.19
Southeast Asia	278.94	374.33	34.20
Mexico	268.02	363.41	35.59
Rest of the World	267.77	363.16	35.62

*Farm price

With respect to soybean exports, table 9 below indicates that the U.S. is the country that experiences the largest decrease in exports (reduction of 4,945 thousand MT). Brazil comes in second with a decrease in exports equivalent to 4,416 thousand MT. Similarly to previous scenarios, Argentina increases its export by 14 percent (1,027 thousand MT more soybeans exported). All the other exporting countries also increase their exports. As for the importing countries, China experiences a decrease in soybean imports of 3,045 thousand MT which is equivalent to the largest decrease in absolute

value between the importing countries. Overall, the total soybean quantity traded in the world market decreases by 12.36 percent (reduction of 7,804 thousand MT)

Table 9. Comparison of Soybean Exports Base Model and Scenario 3: 30% Increase in Crushed Soybean in the U.S. and Brazil (thousand MT)

Exporting Country	Base model	Scenario 3	Deviation (%)
United States	25127.39	20181.60	-19.68
Brazil	26123.19	21706.43	-16.91
Argentina	7325.89	8353.66	14.03
Rest of South America	3229.46	3556.47	10.13
Canada	1323.40	1467.02	10.85
India	0	59.63	-
Total	63129.33	55324.81	-12.36
Importing Country			
China	28319.05	25273.69	-10.75
European Union	13810.65	12468.60	-9.72
Southeast Asia	11146.23	9316.44	-16.42
Mexico	3535.14	2966.44	-16.09
Rest of the World	6318.26	5299.64	-16.12
Total	63129.33	55324.81	-12.36

CONCLUSIONS

The main objective of this study was to estimate the impacts of increasing biodiesel production in the U.S. and Brazil how it would impact the international soybean trade. Results indicate that as the quantity of soybeans crushed increases due to greater biodiesel production, the U.S. and Brazil experience higher prices, but lower exports. On the other hand, competing exporting countries such as Argentina and Canada experience an increase in both exports and prices. As for the importing countries, China and the European Union reduce their imports due to fewer soybeans available in the world market. World soybean trade also declines.

It is important to mention that biodiesel production might be an attractive economic alternative for fossil fuels as well as for corn ethanol. However, the development of a stronger biodiesel industry will depend on changes in the petroleum prices. If the price of gasoline reaches the record levels of 2008, the economic returns to biodiesel production will increase. Meanwhile, if the converse holds, biodiesel fuel production will likely lag.

For future research, the model could be improved and made more precise with further division of the excess supply and demand regions in Brazil. In addition, more detailed specification on importing countries would also assist to better assess international trade flows. Development of a new model allowing for production response, and changes in consumption, exports and imports in a dynamic setting would also improve our ability to assess the impacts of biodiesel production on the world soybean market.

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