AN ECONOMETRIC ANALYSIS OF THE SUPPLY-DEMAND FOR U.S. SOYBEANS

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Soybeans, a multi-utilized crop, have been grown in the United States since the late 1920s. The performance of U.S. soybeans in the domestic and world markets has been remarkable in the last two decades. The U.S. is now the largest producer of soybeans, producing approximately 65 percent of the world average annual production. Moreover, the U.S. is the world's leading exporter of soybeans, accounting for four-fifths of the world soybean trade. In this country, soybeans have ranked second to corn in cash value among field crops since 1973. The annual nominal farm value of soybeans increased from 500 million dollars during World War II to about 14 billion dollars in the 1980s. Total soybean production increased from 300 million bushels in 1950 to more than 2 billion bushels in the 1980s. The annual growth rate is higher for soybeans than any other crop.

The Corn Belt and the southern states are the two major regions. Although acreage planted for soybeans in the southern states is much less than that in the Corn Belt, evidence indicates that this region has potential to produce more soybeans. The planted acreage expansion has been faster than that in the Corn Belt. This is a result of that much of the marginal cropland in the U.S. lies in the southern region.

Prior to 1972, the U.S. satisfied both the domestic and export markets for soybean and soybean products with relatively low and fairly stable domestic prices. Since 1972, this picture changed dramatically. The prices of U.S. soybeans and soybean products have increased sharply since 1972 and have exhibited wide fluctuation independent of whether nominal or real prices are examined.

The variation in soybean prices has important ramifications both economically and politically since it strongly influences the level of farm income, the welfare of domestic consumers and the amount of export earnings in the U.S. In addition, the influence of soybean prices and exchange rate changes on regional soybean supply, particularly on the southern region, and the export markets is of great concern. Directly and indirectly raised questions are: "How will the export markets of soybeans and soybean meal be affected?"; "What will be the regional share structure of acreage planted and/or production of soybeans?" and "Will the southern region gain or lose its importance in producing soybeans?" Thus, it is necessary, at least from a policy point of view, to understand how those factors affect demand and supply of U.S. soybeans.

The purpose of the study is to formulate an econometric model of the U.S. soybean sector so as to explain the economic behavior of the U.S. soybean market in the last decade and to trace how changes in prices and exchange rates impact on the markets over a period of time. However, due to the page constraint, the economic model is not presented in detail but the reader may obtain it from the authors upon request. The following section provides a brief overview of the model and the statistical results. An analysis of the findings are reported next with conclusions and implications based on the results last.

Model

Most previous studies of the U.S. soybean sector concentrated on either supply or demand for whole soybeans, or the supply and demand for one soybean product (e.g., Vandeborre; Houck, Ryan and Subotnik; Houck and Mann). Only a few studies investigated the entire soybean sector with the primary emphasis on the soybean demand component of the model (e.g.

Matthews, Womack and Hoffman; Meyers and Hacklander). This model differs from most previous soybean models in that the supply side is emphasized.

Due to the time lag existing between the decision to produce soybeans and the realization of the final products, this model adopts the recursive block system. The supply of soybeans and the demand for soybeans are two separate blocks to be statistically investigated. The supply and demand blocks are linked by soybean supply and price. The current total supply, determined within the supply block, is a predetermined variable in the demand block. The current soybean price through a lagged relationship influences the supply in the next period.

The soybean supply block is principally comprised of an acreage supply response and a yield per acre behavioral function. The U.S. is divided into three soybean producing regions: the southern region, the Corn Belt and other states. This delineation allows for a more accurate examination of market and government impacts on soybean farmers in different regions.

The demand block is constructed as a simultaneous equation system. The system includes six behavioral equations and seven identities which will determine thirteen endogenous (jointly determined) variables: domestic oil demand, domestic meal demand, ending inventory of oil, ending inventory of soybeans, soybean exports, meal exports, meal production as well as the real and nominal prices of beans, meal and oil. Demand for oil exports is not endogenous in this model because PL480 dominated most of the oil exported. In addition, demand for ending inventory of soybean meal is treated as a predetermined variable due to the quantity of meal stocks is always relatively low. The predetermined variables include two lagged endogenous variables and sixteen exogeneous variables.

The crop year period (October-September) 1960-83 is the sample period for the supply analysis. The time series 1960-83 is the sample period for the demand block. All the data utilized are on the annual basis and have been published by the U.S. government agencies or world agencies (see references for list).

Results

The estimated results of the supply block were generally satisfactory. Over 97 percent of farmers' soybean supply response variation in each region is explained. The Dubin-Watson statistic indicated that there was no first-order autoregressive error structure. The estimated results for the demand block are satisfactory and all the signs are consistent with a priori expectations. A pseudo-R^2 of the system indicates that 93 percent of the variation in soybean and soybean product demand is explained.

Once a model has been estimated, the subsequent question is: "How valid is the model?" One simple way is via the ex-post forecast which is made after the event occurred but outside the sample period. Root mean square error is one of the most commonly used measures for comparing the performance of forecast for different models (Tomek and Robinson; Granger). However, in this case there is no available alternative model except the naive model for comparison. Theil proposed the coefficient of inequality as the standard of comparison with a value between zero and infinity. Thus, the last five years, 1979-83, and this measure were used for the ex-post forecasting and evaluation.

The ex-post forecasting process for the supply block starts in 1979. The forecasting starts by substituting the lagged regional soybean price and yield into the regional acreage response equation to obtain the predicted

acreage planted for each region. The lagged soybean price is generated from the demand block the previous forecast period. Total production of soybeans is then calculated by summing the regional productions of predicted acreage times yield. This soybean production forecast is fed into the demand block. The predictions for the thirteen endogenous variables in the demand block are based on their reduce form equations. The soybean price forecast generated from the demand block is then fed into next period's supply forecast. The process is repeated. Actual data were used for the rest of the variables in the model.

The predictions and the Theil U statistics are reported in Table 1. Only acreage and production are reported for the supply block while for the demand block, only soybean price, meal export and bean export forecasts are reported. All the values of the U statistic for the supply block are less than one. In terms of the demand forecasts, the forecasting performance of soybean exports and soybean meal exports was superior to a naive model. However, the U value for soybean price was greater than one which implies that the price equation's ability to forecast is poorer than the naive model.

Application of the Model

In this section, an impact analysis based on the estimated results of this model are presented. The main point is to trace how soybean price and exchange rate shocks impact on regional soybean supply, particularly on the southern region, and the export markets. Using the estimated model, the price and exchange rate influences can be investigated.

In examining the price effects, an assumption is made that the soybean price increased or decreased by ten percent in 1978. This scenario is examined for the endogenous variables in both the supply and demand blocks

Table 1. Predictions for acreage, production, price and exports based on the recursively linked soybean supply-demand model, 1979-83[a]

Year	$\hat{A}_1$	$\hat{A}_2$	$\hat{A}_3$	$\hat{SBP}$	$\hat{PS}$	$\hat{SBE}$	$\hat{SME}$
	1,000 acres	1,000 acres	1,000 acres	mil. bu.	dol./bu.	mil. bu.	1,000 acres
1979	23,849 (24,010)[b]	31,609 (32,500)	15,630 (15,122)	2,145 (2,261)	6.86 (6.28)	784 (875)	8,503 (7,932)
1980	24,765 (23,755)	32,386 (31,500)	15,253 (14,782)	1,907 (1,798)	8.60 (7.57)	741 (724)	6,988 (6,784)
1981	23,862 (22,255)	33,392 (30,930)	15,594 (14,625)	2,285 (1,989)	3.04 (6.04)	1,005 (929)	7,531 (6,908)
1982	22,968 (23,023)	30,471 (32,020)	14,440 (16,487)	2,218 (2,190)	6.50 (5.65)	809 (905)	7,650 (7,109)
1983	19,007 (19,060)	28,834 (29,500)	14,617 (14,920)	1,672 (1,567)	9.32 (7.75)	674 (760)	7,085 (5,350)
Theil U	0.386	0.903	0.677	0.430	1.248	0.552	0.808

[a]The subscripts 1, 2, and 3 refer to the southern region, Corn Belt and other states, respectively. The definition for the variables are: A = acreage, SBP = U.S. soybean production, PS = soybean price, SBE = U.S. soybean exports and SME = U.S. soybean meal exports.

[b]Actual value of the variable appears in parenthesis.

by utilizing the forecasting process discussed in the previous section. Note that the soybean prices to be fed into the supply block are the predicted prices generated from the demand block.

The response of export markets to the changes of U.S. soybean price is one of the primary concerns today. To simplify the analysis, the ratio of the new forecasted quantities of soybeans exported and soybean meal exported under bean price changes to the respective base forecast are presented in Table 2. Under the scenario of a soybean price decrease in 1978, both exports in 1979 would decline relative to the base. In contrast, exports of beans and meal in 1979 would increase if the predicted price of soybeans had increased in 1978. While this may seem contradictory, price change influenced total production relatively more which feeds into the demand block. On the whole, the magnitude of the changes in the two export markets are not very sizeable. Furthermore, the soybean export market is more responsive to soybean price changes than the meal export market.

The regional shares of acreage planted and production are found in Table 3. The southern region had been expected to be the region with the most potential to supply soybeans. However, the southern region was relatively less responsive to changes in price though the absolute level of acreage positively responded to the price change. This was particularly true with the 1979 forecast. This relationship did not seem to hold for succeeding years but this is not surprising since prices used for supply changes after 1979 were generated from the demand block. That is, for example, a 1978 price decrease would lead to a reduction in total soybean production. This latter reduction fed into the demand block would result in a price increase which is then fed into the next period's supply block.

Table 2. Percentage of soybeans exported and soybean meal exported under the effect of changes in soybean price and SDR to their base values under no price change and no SDR change using the recursively linked soybean supply-demand model, 1979-83[a]

Year	Impact of	SBE	SME
		percent	
1979	$PS_{1978}^{\downarrow}10\%$	95.92	99.35
	$PS_{1978}^{\uparrow}10\%$	104.46	100.68
1980	$PS_{1978}^{\downarrow}10\%$	98.65	99.80
	$PS_{1978}^{\uparrow}10\%$	101.08	100.14
1981	$PS_{1978}^{\downarrow}10\%$	100.20	100.07
	$PS_{1978}^{\uparrow}10\%$	99.10	99.79
1982	$PS_{1978}^{\downarrow}10\%$	100.49	100.11
	$PS_{1978}^{\uparrow}10\%$	99.14	—99.86
1983	$PS_{1978}^{\downarrow}10\%$	100.30	100.01
	$PS_{1978}^{\uparrow}10\%$	100.30	100.04
1979	$SDR_{1978}^{\downarrow}10\%$	88.71	98.26
—	$SDR_{1978}^{\uparrow}10\%$	113.28	102.05
1980	$SDR_{1978}^{\downarrow}10\%$	95.50	99.31
	$SDR_{1978}^{\uparrow}10\%$	101.94	100.22
1981	$SDR_{1978}^{\downarrow}10\%$	100.96	100.28
	$SDR_{1978}^{\uparrow}10\%$	96.71	99.22
1982	$SDR_{1978}^{\downarrow}10\%$	100.95	100.18
	$SDR_{1978}^{\uparrow}10\%$	97.17	99.53
1983	$SDR_{1978}^{\downarrow}10\%$	99.79	99.96
	$SDR_{1978}^{\uparrow}10\%$	100.89	99.83

[a]Symbols, "↓" and "↑", are used to represent the decrease and increase of change in soybean price and SDR, respectively.

Table 3. Regional shares of acreage planted and production for soybeans under the effect of changes in soybean price based on the recursively linked soybean supply-demand model, 1979-83[a]

Year	Impact of	Southern region		Corn Belt		Other states	
		SA[b]	SP[c]	SA[b]	SP[c]	SA[b]	SP[c]
		percent					
1979	Base[d]	33.55	27.03	44.46	51.25	21.99	21.72
	PS_{1978}↓10%	34.16	27.53	43.74	50.57	22.10	21.90
	PS_{1978}↑10%	32.87	26.45	45.35	52.10	21.78	21.45
1980	Base	34.20	21.05	44.73	58.12	21.07	20.83
	PS_{1978}↓10%	34.10	20.94	44.95	58.37	20.95	20.69
	PS_{1978}↑10%	34.25	21.05	44.57	57.98	21.18	20.97
1981	Base	32.76	25.45	45.84	53.66	21.40	20.89
	PS_{1978}↓10%	32.60	25.31	45.97	53.79	21.43	21.90
	PS_{1978}↑10%	32.88	25.52	45.72	53.58	21.40	20.90
1982	Base	33.84	27.20	44.89	52.39	21.27	20.41
	PS_{1978}↓10%	33.66	27.01	45.06	52.57	21.28	20.42
	PS_{1978}↑10%	33.98	27.34	44.68	52.17	21.34	20.49
1983	Base	30.43	21.61	46.17	53.54	23.40	24.85
	PS_{1978}↓10%	30.33	21.50	46.23	53.62	23.44	24.89
	PS_{1978}↑10%	30.42	21.61	46.20	53.57	23.38	24.82

[a]Symbols, "↓" and "↑", are used to represent the decrease and increase of change in soybean price, respectively.

[b]Percentage of regional planted acreage to U.S. total planted acreage for soybeans.

[c]Percentage of regional production of soybeans to U.S. total production of soybeans.

[d]Predictions without soybean price change.

Now, let's consider an external shock to the demand block via the exchange rate. In this scenario the assumption is made that the SDR has increased or decreased by ten percent in 1978. The impacts of changes in SDR on the prediction of the endogenous variables in this model will be traced out individually, just as in the price shock case. That is, a change in SDR in 1978 affects the demand block directly. From the demand block, the impact was passed to the supply block for the next period by means of the price of soybeans. Then, the aggregated soybean production was fed into the demand block. Following this path year by year a set of predictions for those interested endogenous variables were obtained.

The ratio of the new forecasted quantities of soybeans exported and soybean meal exported under the different exchange rate changes to the respective base forecast are presented in Table 2. If the SDR decreased ten percent in 1978, both the beans and meal exports in 1979 would decline 11.29 percent and 1.74 percent, respectively, relative to the base. On the other hand, exports of soybeans and soybean meal in 1979 would have increased 13.28 percent and 2.05 percent, respectively, relative to the base if the SDR had increased in 1978. The changes in the soybeans export market, independent of which period examined, were more active than that of the meal export market.

The regional supply response in terms of the share of acreage planted and production for the three regions given a SDR change are shown in Table 4. An examination of the regional planted acreage production shares given exchange rate shocks indicates that the supply responses of the three regions are not identical. This is obvious since a change in the SDR must feed through the soybean price in order to influence acreage planted and

Table 4. Regional shares of acreage planted and production for soybeans under the impact of changes in SDR based on the recursively linked soybean supply-demand model, 1979-83[a]

Year	Impact of	Southern region		Corn Belt		Other states	
		SA[b]	SP[c]	SA[b]	SP[c]	SA[b]	SP[c]
		percent					
1979	Base[d]	33.55	27.03	44.46	51.25	21.99	21.72
	$SDR_{1978}\downarrow 10\%$	35.09	28.20	42.88	49.85	22.03	21.95
	$SDR_{1978}\uparrow 10\%$	31.43	25.16	47.40	54.12	21.17	20.72
1980	Base	34.20	21.05	44.73	58.12	21.07	20.83
	$SDR_{1978}\downarrow 10\%$	33.77	20.48	45.55	59.10	20.68	20.42
	$SDR_{1978}\uparrow 10\%$	34.21	20.78	44.47	58.05	21.32	21.17
1981	Base	32.76	25.45	45.84	53.66	21.40	20.89
	$SDR_{1978}\downarrow 10\%$	31.81	24.49	46.58	54.45	21.61	21.06
	$SDR_{1978}\uparrow 10\%$	32.75	25.19	45.78	53.78	21.47	21.03
1982	Base	33.84	27.20	44.89	52.39	21.27	20.41
	$SDR_{1978}\downarrow 10\%$	33.05	26.27	46.11	53.75	20.84	19.98
	$SDR_{1978}\uparrow 10\%$	33.89	27.20	44.51	52.03	21.60	20.77
1983	Base	30.43	21.61	46.17	53.54	23.40	24.85
	$SDR_{1978}\downarrow 10\%$	29.79	20.99	46.92	54.32	23.29	24.69
	$SDR_{1978}\uparrow 10\%$	30.01	21.26	46.54	53.88	23.45	24.86

[a]Symbols, "↓" and "↑", are used to represent the decrease and increase of change in SDR, respectively.

[b]Percentage of regional planted acreage to U.S. total planted acreage for soybeans.

[c]Percentage of regional production of soybeans to U.S. total production of soybeans.

[d]Predictions without SDR change.

production. The southern region is the least responsive to changes in exchange rate. The response of the Corn Belt to the exchange rate changes is stronger than the other two regions for its shares vary in the same direction as the SDR shocks.

Conclusions

The purpose of this economic study was to investigate the behavior of the soybean industry in the United States for the period of 1960 through 1983. Based on economic theory and practical knowledge of soybeans, an econometric framework for the supply-demand of U.S. soybeans was constructed such that the supply and demand were formulated as two individual blocks of a recursive block system.

The estimated model can be applied for different purposes of analysis, such as simulation for one or several periods under given scenarios. This approach helps one to explore what would happen to soybean supply and/or demand or to the domestic markets and/or international markets. Thus, this model may be used to aid policy decision-makers to sort out the impact from external and internal changes. For example, the model was used to examine the impact of exchange rate change on the regional soybean supply, U.S. soybean exports and soybean meal exports for the period of 1979-83. Results indicated that the southern region is less responsive compared to the other regions in soybean production in response to exchange rate changes. These findings should be considered when developing government programs and policies influencing soybeans.

References

Granger, C. W. J., Forecasting in Business and Economics, Academic Press, Inc., 1980.

Houck, J. P. and J. S. Mann, An Analysis of Domestic and Foreign Demand for U.S. Soybeans and Soybean Products, Tech. Bull. No. 256, Agr. Exp. Sta., Univ. of Minnesota, 1968.

Houck, J. P., M. E. Ryan, and A. Subotnik, Soybeans and Their Products: Markets, Models, and Policy, Univ. of Minnesota Press, Minneapolis, 1972.

International Monetary Fund, International Financial Statistics, Washington, D.C., various issues.

Matthews, J. L., A. W. Womack, and E. G. Hoffman, "Formulation of Market Forecasts for the U.S. Soybean Economy with an Econometric Model," Fats and Oils Situation, FOS-260, USDA, November 1971.

Meyers, W. H. and D. D. Hacklander, An Econometric Approach to the Analysis of Soybean and Soybean Product Markets, NED Staff Report, USDA, June 1979.

Theil, H., Economic Forecasts and Policy, 2nd rev. ed., North-Holland, New York, 1965.

Tomek, W. G. and K. L. Robinson, Agricultural Product Prices, Second Edition, Cornell Univ. Press, Ithaca, New York, 1981.

U.S. Department of Agriculture, Agricultural Prices Annual Summary, Washington, D.C., various issues.

U.S. Department of Agriculture, Agricultural Statistics, U.S. Government Printing Office, Washington, D.C., various issues.

U.S. Department of Agriculture, Crop Production Annual Summary, Washington, D.C., various issues.

U.S. Department of Agriculture, Fats and Oils Situation, Washington, D.C., various issues.

U.S. Department of Agriculture, Food Consumption, Prices, and Expenditures: 1960-79, Stat. Bull. No. 656, Washington, D.C., 1981.

U.S. Department of Agriculture, Food Consumption, Prices, and Expenditures: 1963-83, Stat. Bull. No. 713, Washington, D.C., 1984.

U.S. Department of Agriculture, Foreign Agriculture Circular, Washington, D.C., various issues.

U.S. Department of Agriculture, Oil Crops Situation, Washington, D.C., various issues.

U.S. Department of Agriculture, U.S. Fats and Oils Statistics: 1963-78, Stat. Bull. No. 631, Washington, D.C., 1980.

U.S. Department of Commerce, Bureau of the Census, Statistical Abstract of the United States, U.S. Government Printing Office, Washington, D.C., various issues.

U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data Service, Climatological Data, Washington, D.C., all issues, 1965-83.

U.S. Department of Labor, Labor Statistics, Washington, D.C., various issues.

Vandeborre, R. J., An Econometric Analysis of the Markets for Soybean Oil and Soybean Meal, Bull. 723, Agr. Exp. Sta., Univ. of Illinois, Champaign, Illinois, 1967.