The U.S. Supply of Soybeans: Regional Acreage Functions

By James P. Houck and Abraham Subotnik

Some recent analytical and empirical work on regional supply relationships for U.S. soybeans is described in this paper. This work is part of an ongoing research project sponsored jointly by the U.S. Department of Agriculture and the Agricultural Economics Department of the University of Minnesota.[1]

Of particular interest here are (1) the manner in which support prices and acreage restrictions for competing crops have been introduced into the regional supply relations for soybeans and (2) the estimated effects of changes in the soybean price support rate on acreage. With the estimates presented here, it is possible to investigate the implications on soybean acreage of policy changes in both soybean price support procedures and in price supports and acreage restrictions for other competing crops. It is anticipated that, ultimately, supply relationships for U.S. soybeans can be combined with the simultaneous demand model developed earlier (3).[2] This modification will give the system a dynamic dimension it now lacks.

First, a theoretical model of the "effective support price" is developed. This involves combining into one quantitative measure the support price and acreage restrictions which jointly represent Government policy for several crops. Second, a distributed lag estimation model is presented which incorporates both actual prices and effective support prices in a soybean acreage supply function. Third, empirical estimates of this model, based on annual data for 1946-66, are presented for the major soybean-growing regions of the Nation. Finally, an application of this model shows the net impact over several years of a specified decrease in the soybean support price.

Theoretical Model of Effective Support

Price support programs for a number of important crops in U.S. agriculture involve a guaranteed minimum support price in return for which participating farmers agree to reduce acreage relative to some historically established base. The guaranteed minimum price may include several elements--the basic price support loan rate, a direct payment based on participation level, and a direct payment based on production from permitted acreage under the program. It is clear, therefore, that supply analyses which utilize only the basic support rate for several competing commodities will be less useful than those into which the mandatory or voluntary acreage restrictions imposed on farmers can be incorporated.

One approach to this question of incorporating both price support and acreage restrictions in a supply analysis involves the weighting or "normalization" of announced support rates by means of the acreage restrictions imposed on participating farmers. For this discussion, a rather simple analytical framework is developed. A more complete treatment of these ideas is contained in the appendix.

Let a simple acreage supply function be represented by

(1) $$A = a_0 + a_1 P$$

where A is the harvested acreage and P is the relevant supply-inducing price. All other supply shifters are held fixed and incorporated in a_0.

[1] Technical advice and consultation are provided by the Economic Research Service through the Economic and Statistical Analysis Division. Robert M. Walsh, deputy director of this division, serves as technical coordinator for the project and chairman of an informal advisory committee consisting of USDA personnel. Responsibility for the material in this article is clearly that of the authors.

[2] Underscored numbers in parentheses indicate items in the References, p. 107.

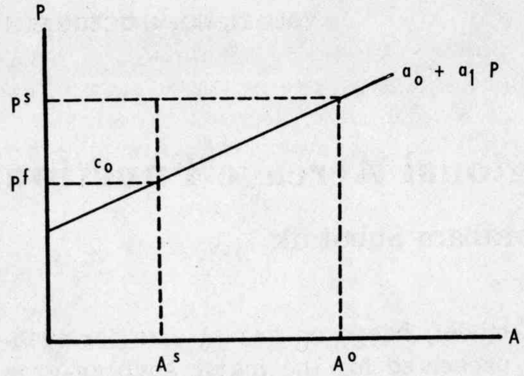

Figure 1

Assume now that a support price p^s is offered to the farmers only if they are willing to reduce acreage to A^s, compared to A^o which would be harvested without restriction at p^s. This is shown in figure 1. The price p^f is that which would induce farmers to hold acreage at A^s without restrictions. For this discussion, p^f is called the "effective support price" and is the alternative cost of committing A^s to this commodity. This effective support rate is the variable which will be taken into account by farmers in planning production patterns among alternative crop enterprises.

The announced support rate p^s may be higher than p^f because policy makers wish to maintain farm income above the level which would occur under p^f (area c_o in figure 1). This added income is only available to farmers when their acreage is held at A^s.[3]

For analytical purposes, it is useful to find a function which transforms p^s into p^f by normalizing or deflating the announced support rate. Consider equation (1) evaluated at two points, p^s and p^f. At each of these points

(2) $$a_1 = \frac{A^o - a_o}{p^s} = \frac{A^s - a_o}{p^f}$$

This relationship implies that

(3) $$p^f = \frac{A^s - a_o}{A^o - a_o} p^s$$

If $a_o = 0$ or is small relative to A^s and A^o, then

(4) $$p^f \cong (A^s/A^o)\ p^s$$

[3] For additional discussion of this general topic, see (1).

In this case, the effective support rate can be expressed as a function of announced support rate and a ratio of the permitted to the desired acreage. Where no acreage restrictions are employed, p^s and p^f are identical since $(A^s/A^o) = 1$.

The Estimation Model

Since World War II, the farm price of soybeans has been supported, but no acreage restrictions have been attached to these supports (5). In most years, average market prices have been above support levels. However, crops which compete for soybean acreage have been influenced not only by support prices but also by acreage restrictions of one sort or another. These competitive crops are mainly corn, oats, wheat, and cotton.

Under these conditions, it is hypothesized that the expected prices of various crops which effect the soybean acreage supply in year t are

(5) $$P^*_{it} = w_{i1}\ P_{i\ t-1} + w_{i2}\ p^f_{it}.$$

where P^*_{it} is the expected price in year t for crop i, P_{it-1} is actual farm price in year (t-1) for crop i, and p^f_{it} is the effective support price in year t for crop i. As mentioned previously, the effective support rate is equal to the announced support rate when no acreage compliance is required to obtain the announced rate. This formulation of price expectation also is assumed to be appropriate for both mandatory and voluntary acreage control programs.

The basic model for acreage supply response used in this analysis is

(6) $$A_t = b_o + b_1\ A_{t-1} + b_2\ P^*_{1t} + b_3\ P^*_{2t} + u_t$$

where A is acreage harvested, P^*_{1t} is the expected price for the crop in question, P^*_{2t} is the expected price for a competing commodity, and u_t is a random, mean-zero disturbance with finite variance. Although the expected price for only one competing commodity is included in equation (6), the method can easily be extended to incorporate numerous others. Notice that the model is of the lagged adjustment type developed by Nerlove (4). Substituting in equation

(6) for the values of P_1^* and P_2^* from equation (5):

$$(7) \quad A_t = c_o + c_1 A_{t-1} + d_1 P_{1t-1} + e_1 P_{1t}^f + d_2 P_{2t-1} + e_2 P_{2t}$$

where

$c_o = b_o$ $\quad$ $e_1 = b_2 w_{12}$

$c_1 = b_1$ $\quad$ $d_2 = b_3 w_{21}$

$d_1 = b_2 w_{11}$ $\quad$ $e_2 = b_3 w_{22}$

In equation (7), there are two variables that cannot be observed--P_{1t}^f and P_{2t}^f. Using the relationships developed in the previous section and elaborated in the appendix, the effective support prices for the relevant commodities can be calculated and used in the estimation process. They are

$$P_{1t}^f = (A_1^s/A_1^o)\, P_{1t}^s \quad \text{and}$$

$$P_{2t}^f = (A_2^s/A_2^o)\, P_{2t}^s.$$

Effective support prices for several commodities--wheat, corn, oats, and cotton--were calculated for 1945-66 and used in the empirical analysis (table 1). No special calculation was needed for soybeans since effective and announced support prices were equivalent during this period, no acreage restrictions having been imposed. Other methods of computing the A^s/A^o ratios for the various commodities surely could be developed and used in the formulation of effective support prices. The series shown in table 1 indicate the underlying concepts.

In the table, there are three columns of figures for each of the four commodities. The first column is simply the announced support price. In recent years, this announced price also includes direct payments to program participants. The second column is an estimate of the A^s/A^o ratio. This estimate is based on the ratio of permitted acreage for program participants relative to some actual or historical allotment base. It is designed to reflect the ratio of the acreage desired by policy makers to the acreage desired by farmers at the announced support rate. These ratios are to be regarded as estimates of A^s/A^o and not the precise calculation of A^s or A^o.[4] Finally, the third column is the product of the first two. It is the announced support rate weighted or "normalized" by the estimate of A^s/A^o. It is the effective support price.

Empirical Results

Supply functions in terms of harvested soybean acreage were estimated by least squares for six regions of the United States: the Lake States, the Corn Belt, the Plains States, the Delta States, the Atlantic States, and all other States grouped together. These correspond to the soybean-producing regions identified by the Economic Research Service in recent statistical series (6, p. 69). Crop year data for 1946-66 were used. The Nerlove distributed lag model was used in each region except the Atlantic States. The specification of individual equations differed from region to region because of the differing importance of alternative crops. A number of different specifications were tested for each region. In each case, the inclusion of the effective support price series described earlier yielded markedly better results than similar equations without the adjustment of support rates. One seemingly most appropriate equation for each region was selected for presentation here. In virtually all cases, the choice among estimated equations was not difficult--one specification seemed to stand out clearly in each region.

The regression equations are presented here in a standard format. The t-values appear in parentheses directly below the estimated coefficients. (None of the t-values for the estimated intercepts were absolutely larger than 1.0.) There was no evidence of serial correlation in any of the residuals. The variables used are identified below each equation. An aggregate national supply equation and a summary of direct and cross elasticities of acreage response are presented following the regional results.

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[4] Further refinements of these ratios could be developed to account for trends in yields among several crops as well as the cross-compliance features of some past and present programs. In the case of corn and soybeans, some adjustments could be made to allow for the provision that, in some years, soybeans could be grown on permitted corn acreage without forfeiture of the direct support payments for corn.

(6) for the values of P_1^* and P_2^* from equation (5):

$$(7) \quad A_t = c_o + c_1 A_{t-1} + d_1 P_{1t-1} + e_1 P_{1t}^f + d_2 P_{2t-1} + e_2 P_{2t}$$

where

$c_o = b_o$ $\qquad e_1 = b_2 w_{12}$

$c_1 = b1$ $\qquad d_2 = b_3 w_{21}$

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Table 1.--Announced support prices and effective support prices

Year	Corn			Oats			Wheat			Cotton		
	Support price[a]	A^s/A^o	Effective support price	Support price[a]	A^s/A^o	Effective support price	Support price[a]	A^s/A^o	Effective support price	Support price[a]	A^s/A^o	Effective support price
	Dol./bu.		*Dol./bu.*	*Dol./bu.*		*Dol./bu.*	*Dol./bu.*		*Dol./bu.*	*Dol./bu.*		*Dol./bu.*
1945	1.01	[b] 1.00	1.01	0.48	1.00	0.48	1.38	1.00	1.38	0.20	1.00	0.20
1946	1.15	[b] 1.00	1.15	0.53	1.00	0.53	1.49	1.00	1.49	0.23	1.00	0.23
1947	1.37	[b] 1.00	1.37	0.63	1.00	0.63	1.84	1.00	1.84	0.26	1.00	0.26
1948	1.44	[b] 1.00	1.44	0.70	1.00	0.70	2.00	1.00	2.00	0.29	1.00	0.29
1949	1.40	[b] 1.00	1.40	0.69	1.00	0.69	1.95	1.00	1.95	0.27	1.00	0.27
1950	1.47	[b] 0.44	0.65	0.71	1.00	0.71	1.99	[e] 0.85	1.69	0.28	[h] 0.63	0.18
1951	1.57	[b] 1.00	1.57	0.72	1.00	0.72	2.18	[e] 0.90	1.96	0.30	1.00	0.30
1952	1.60	[b] 1.00	1.60	0.78	1.00	0.78	2.20	1.00	2.20	0.31	1.00	0.31
1953	1.60	[b] 1.00	1.60	0.80	1.00	0.80	2.21	1.00	2.21	0.31	1.00	0.31
1954	1.62	[b] 0.57	0.92	0.75	1.00	0.75	2.24	[f] 0.79	1.77	0.32	[h] 0.76	0.24
1955	1.58	[b] 0.62	0.98	0.61	1.00	0.61	2.08	[f] 0.70	1.46	0.32	[h] 0.65	0.21
1956	1.50	[b] 0.54	0.81	0.65	1.00	0.65	2.00	[f] 0.70	1.40	0.29	[h] 0.62	0.18
1957	1.40	[b] 0.51	0.71	0.61	1.00	0.61	2.00	[f] 0.70	1.40	0.29	[h] 0.63	0.18
1958	1.36	[b] 0.53	0.72	0.61	1.00	0.61	1.82	[f] 0.70	1.27	0.31	[h] 0.63	0.20
1959	1.12	[b] 1.00	1.12	0.50	1.00	0.50	1.81	[f] 0.70	1.27	0.30	[h] 0.62	0.19
1960	1.06	[b] 1.00	1.06	0.50	1.00	0.50	1.78	[f] 0.70	1.25	0.29	[h] 0.63	0.18
1961	1.20	[b] 1.00	1.20	0.62	1.00	0.62	1.79	[f] 0.70	1.25	0.32	[h] 0.66	0.21
1962	1.20	[c] 0.90	1.08	0.62	[c] 1.00	0.62	2.00	[f] 0.84	1.68	0.32	[h] 0.65	0.21
1963	1.25	[c] 0.84	1.05	0.65	[c] 1.00	0.65	2.00	[f] 0.84	1.68	0.32	[h] 0.58	0.19
1964	1.25	[d] 0.84	1.05	0.65	[d] 1.00	0.65	1.73	[f] 0.71	1.23	0.33	[h] 0.58	0.19
1965	1.25	[d] 0.84	1.05	0.60	[d] 0.84	0.50	1.69	[f] 0.63	1.06	0.33	[h] 0.58	0.19
1966	1.30	[d] 0.65	0.85	0.60	[d] 0.80	0.48	1.84	[f] 0.61	1.12	0.30	[h] 0.58	0.17

[a] From Agr. Handb. 345(5).
[b] Allotment acreage/Actual acreage.
[c] Based on data in Feed Situation, U.S. Dept. Agr., Aug. 1963.
[d] Based on data in Feed Situation, U.S. Dept. Agr., Feb. 1966.
[e] Allotment acreage/Actual average acreage 1948-49.
[f] Allotment acreage/Actual average acreage 1952-53.
[g] Based on data in Wheat Situation, U.S. Dept. Agr., May 1965 and Nov. 1967.
[h] Allotment acreage/Actual average acreage 1951-53.

THE LAKE STATES

This region contains Minnesota, Wisconsin, and Michigan. Soybean acreage harvested was expressed as a linear function of the previous year's acreage, the average market price for soybeans in the previous year, the soybean support rate, market prices of alternative crops in the previous year, and effective support prices for alternative crops. In the Lake States, corn and wheat emerged as the most significant competitors for acreage which can be devoted to soybeans.

The estimated function is

$$A_t^L = -244.3531 + \underset{(7.1)}{0.6611}\, A_{t-1}^L + \underset{(2.2)}{826.9820}\, p_{t-1}^s$$

$$- \underset{(1.7)}{820.0772}\, p_{t-1}^c + \underset{(2.3)}{899.9078}\, p_t^{ss}$$

$$- \underset{(3.5)}{877.7295}\, p_t^{sc} - \underset{(1.5)}{496.8078}\, p_t^{sw}$$

$\bar{R}^2 = 0.95$

where

- A_t^L = soybean acreage harvested in the Lake States (1,000 acres)
- p_{t-1}^s = lagged soybean price (dollars per bushel)
- p_{t-1}^c = lagged corn price (dollars per bushel)
- p_t^{ss} = effective support price of soybean (dollars per bushel)
- p_t^{sc} = effective support price of corn (dollars per bushel)
- p_t^{sw} = effective support price of wheat (dollars per bushel)

The estimated coefficients are reasonable in sign and magnitude. A given change in either market or effective support prices for soybeans or corn seems to have a similar impact on Lake States acreage, with corn appearing as a strong competitor. The competitive impact of changes in the wheat support rate is less strong. About 95 percent of the regional variation in soybean acreage is associated with changes in the specified independent variables.

THE CORN BELT

This region contains Illinois, Iowa, Indiana, Ohio, and Missouri. The same general specification was utilized for this region as for the Lake States, and a variety of equations were tested. In this region, corn was found to be the only significant crop alternative within the context of the model.

The estimated function is

$$A_t^{cb} = 2{,}781.764 + \underset{(10.3)}{0.7792}\, A_{t-1}^{cb} + \underset{(2.3)}{2{,}767.006}\, p_{t-1}^s$$

$$-\underset{(3.1)}{5{,}019.287}\, p_{t-1}^c + \underset{(1.1)}{1{,}010.428}\, p_t^{ss}$$

$$- \underset{(2.7)}{1{,}623.752}\, p_t^{sc}$$

$\bar{R}^2 = 0.97$

where the price variables are same as used previously and

- A_t^{cb} = soybean acreage harvested in the Corn Belt (1,000 acres).

Again the estimated coefficients are reasonable in sign and magnitude. The impact of changes in corn prices or corn support rate relative to those for soybeans is much stronger in the Corn Belt than in the Lake States, as one might expect. About 97 percent of the regional variation in soybean acreage in the Corn Belt is associated with variation in the specified independent variables.

THE PLAINS STATES

This region contains Kansas, Nebraska, North Dakota, and South Dakota. Equations similar to those for the Lake States and Corn Belt were tested. However, in the Plains States, oats emerged along with corn as significant competitors for acreage in soybeans.

The estimated equation is

$$A_t^p = -189.6314 + \underset{(3.1)}{0.5644\,A_{t-1}^p} + \underset{(2.5)}{834.4143\,p_{t-1}^s}$$

$$- \underset{(2.8)}{1{,}239.135\,p_{t-1}^c} + \underset{(1.6)}{563.3366\,p_t^{ss}} - \underset{(1.4)}{243.5887\,p_t^{sc}}$$

$$- \underset{(1.4)}{1{,}056.619\,p_t^{so}}$$

$$\bar{R}^2 = 0.92$$

where the variables are as indicated before and

A_t^p = soybean acreage harvested in the Plains States (1,000 acres)

p_t^{so} = effective price support rate for oats (dollars per bushel)

Here again, appropriate direct and competitive relationships emerged. The net impact of changes in the oats price support variable seem to be quite large, although the coefficient is not highly significant in comparison with the coefficients on lagged market prices of soybeans and corn. About 92 percent of the variation in Plains States soybean acreage is accounted for in this equation by the specified independent variables.

THE DELTA STATES

This region contains Arkansas, Mississippi, and Louisiana. Using the same general specification as before, corn fell away as a significant alternative, but cotton and oats emerged.

The estimated equation is

$$A_t^d = 747.3894 + \underset{(10.8)}{0.8713\,A_{t-1}^d} + \underset{(1.6)}{831.9335\,p_{t-1}^s}$$

$$- \underset{(1.4)}{2{,}702.658\,p_{t-1}^o} + \underset{(1.3)}{749.1897\,p_t^{ss}} - \underset{(1.4)}{1{,}565.446\,p_t^{so}}$$

$$- \underset{(1.4)}{4{,}214.172\,p_t^{s\,ct}}$$

$$\bar{R}^2 = 0.98$$

where the variables that have not appeared before are:

A^d = soybean acreage harvested in the Delta States (1,000 acres)

p_{t-1}^o = lagged price of oats (dollars per bushel)

$p_t^{s\,ct}$ = effective price support of cotton (dollars per pound)

Reasonable direct and cross relationships emerged for the variables involved. The very rapid growth of soybean production in this region is reflected in the large and highly significant coefficient associated with lagged acreage. Changes in market prices of soybeans and oats have relatively more impact on acreage than do their respective support rates. An extremely large proportion--about 98 percent--of the variation in Delta soybean acreage is captured by the specified variables.

THE ATLANTIC STATES

This region contains North Carolina, South Carolina, Virginia, Maryland, and Delaware. In this region, the distributed lag model did not produce useful results.[5] Therefore, the lagged acreage variable was dropped from the function. Among the several other specifications tested, two emerged as potentially useful. In the first, oats and cotton emerged as significant alternative crops. In the other, oats and corn appear as alternatives.

The two equations are

(I)
$$A_t^a = 1{,}483.435 + \underset{(1.4)}{939.9202\,p_{t-1}^s}$$

$$- \underset{(1.4)}{3{,}464.083\,p_{t-1}^o} + \underset{(1.9)}{1{,}434.114\,p_t^{ss}}$$

$$- \underset{(2.0)}{2{,}637.900\,p_t^{so}} - \underset{(1.7)}{6{,}761.531\,p_t^{s\,ct}}$$

$$\bar{R}^2 = 0.70$$

(II)
$$A_t^a = 1{,}424.855 + \underset{(3.4)}{1{,}843.204\,p_{t-1}^s}$$

$$- \underset{(4.4)}{2{,}995.110\,p_{t-1}^c} + \underset{(1.1)}{647.4396\,p_t^{ss}} - \underset{(2.2)}{2{,}565.618\,p_t^{so}}$$

$$- \underset{(1.1)}{356.3632\,p_t^{sc}}$$

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[5] The estimated coefficient on lagged acreage in the region was consistently larger than +1.0. This suggests instability in the adjustment processes assumed by the Nerlove-type model. Hence, other specifications of the acreage response for this region were investigated.

The estimated equation is

$$A_t^p = -189.6314 + 0.5644\ A_{t-1}^p + 834.4143\ p_{t-1}^s$$
$$(3.1) \qquad (2.5)$$

$$- 1{,}239.135\ p_{t-1}^c + 563.3366\ p_t^{ss} - 243.5887\ p_t^{sc}$$
$$(2.8) \qquad (1.6) \qquad (1.4)$$

$$- 1{,}056.619\ p_t^{so}$$
$$(1.4)$$

$$\bar{R}^2 = 0.92$$

where the variables are as indicated before and

A_t^p = soybean acreage harvested in the Plains States (1,000 acres)
p_t^{so} = effective price support rate for oats (dollars per bushel)

Here again, appropriate direct and competitive relationships emerged. The net impact of changes in the oats price support variable seem to be quite large, although the coefficient is not highly significant in comparison with the coefficients on lagged market prices of soybeans and corn. About 92 percent of the variation in Plains States soybean acreage is accounted for in this equation by the specified independent variables.

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This region contains Arkansas, Mississippi, and Louisiana. Using the same general specification as before, corn fell away as a significant alternative, but cotton and oats emerged.

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$$A_t^d = 747.3894 + 0.8713\ A_{t-1}^d + 831.9335\ p_{t-1}^s$$
$$(10.8) \qquad (1.6)$$

$$- 2{,}702.658\ p_{t-1}^o + 749.1897\ p_t^{ss} - 1{,}565.446\ p_t^{so}$$
$$(1.4) \qquad (1.3) \qquad (1.4)$$

$$- 4{,}214.172\ p_t^{s\,ct}$$
$$(1.4)$$

$$\bar{R}^2 = 0.98$$

where the variables that have not appeared before are:

A^d = soybean acreage harvested in the Delta States (1,000 acres)
p_{t-1}^o = lagged price of oats (dollars per bushel)
$p_t^{s\,ct}$ = effective price support of cotton (dollars per pound)

Reasonable direct and cross relationships emerged for the variables involved. The very rapid growth of soybean production in this region is reflected in the large and highly significant coefficient associated with lagged acreage. Changes in market prices of soybeans and oats have relatively more impact on acreage than do their respective support rates. An extremely large proportion--about 98 percent--of the variation in Delta soybean acreage is captured by the specified variables.

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This region contains North Carolina, South Carolina, Virginia, Maryland, and Delaware. In this region, the distributed lag model did not produce useful results.[5] Therefore, the lagged acreage variable was dropped from the function. Among the several other specifications tested, two emerged as potentially useful. In the first, oats and cotton emerged as significant alternative crops. In the other, oats and corn appear as alternatives.

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$$(1.4) \qquad (1.9)$$

$$- 2{,}637.900\ p_t^{so} - 6{,}761.531\ p_t^{s\,ct}$$
$$(2.0) \qquad (1.7)$$

$$\bar{R}^2 = 0.70$$

$$\text{(II)} \qquad A_t^a = 1{,}424.855 + 1{,}843.204\ p_{t-1}^s$$
$$(3.4)$$

$$- 2{,}995.110\ p_{t-1}^c + 647.4396\ p_t^{ss} - 2{,}565.618\ p_t^{so}$$
$$(4.4) \qquad (1.1) \qquad (2.2)$$

$$- 356.3632\ p_t^{sc}$$
$$(1.1)$$

[5] The estimated coefficient on lagged acreage in the region was consistently larger than +1.0. This suggests instability in the adjustment processes assumed by the Nerlove-type model. Hence, other specifications of the acreage response for this region were investigated.

$\bar{R}^2 = 0.76$

where all of the variables have been introduced before except

A_t^a = soybean acreage harvested in the Atlantic States (1,000 acres)

The weakest of the estimated coefficients in equation (I) is stronger than the weakest in equation (II). However, the coefficient of multiple determination ($\bar{R}^2$) in equation (II) is larger than in equation (I). Moreover, the market price coefficients on soybeans and corn are stronger in equation (II) and larger than the coefficients estimated for their effective support rates. Because of the omission of lagged acreage in the estimated equations, the $\bar{R}^2$ for both equations is substantially lower in this region than is typical for the other States.

OTHER STATES

This grouping includes all other States that produce soybeans in any quantity: New York, New Jersey, Pennsylvania, West Virginia, Georgia, Florida, Kentucky, Tennessee, Alabama, Oklahoma, and Texas. In this widely dispersed grouping, corn and oats appeared as significant competitors.

The estimated equation is

$$A_t^m = 92.9566 + \underset{(10.3)}{0.9248}\, A_{t-1}^q + \underset{(1.8)}{255.3745}\, p_{t-1}^s$$

$$- \underset{(1.4)}{275.9034}\, p_{t-1}^c + \underset{(1.9)}{248.4233}\, p_t^{ss} - \underset{(1.1)}{66.5647}\, p_t^{sc}$$

$$- \underset{(3.8)}{1,043.640}\, p_t^{so}$$

$\bar{R}^2 = 0.98$

The only new variable here is

A_t^m = soybean acreage harvested in other States (1,000 acres)

The strong upward trend in acreage in this region is captured by the lagged acreage variable whose estimated coefficient is large and highly significant. The estimated relationship of the effective support rate for oats with soybean acreage is surprisingly strong. About 98 percent of the variation in acreage for this region is associated with variation in the specified independent variables.

AN AGGREGATE FUNCTION

A national acreage supply function can be developed by summing the six regional functions and collecting terms where appropriate (equation (II) for the Atlantic States was used). This function is

$$A_t^T = 4,612.99 + 0.8713\, A_{t-1}^d + 0.6611\, A_{t-1}^L$$

$$+ 0.7792\, A_{t-1}^{cb} + 0.5644\, A_{t-1}^p + 0.9248\, A_{t-1}^m$$

$$+ 7,358.913\, p_{t-1}^s - 10,349,512\, p_{t-1}^c$$

$$- 2,702.658\, p_{t-1}^o + 4,118.723\, p_t^{ss}$$

$$- 3,168.588\, p_t^{sc} - 6,231.326\, p_t^{so}$$

$$- 4,214.172\, p_t^{s\,ct} - 496.808\, p_t^{sw}$$

$\bar{R}^2 = 0.96$

where

A_t^T = total soybean acreage harvested in the United States (1,000 acres)

This aggregate $\bar{R}^2$ was derived by weighting the computed $\bar{R}^2$ for each region by the proportion of that region's acreage variance to the total acreage variance for the Nation. This aggregate function reflects the total direct and cross supply relationships associated with market prices and effective support rates for soybeans, corn, oats, wheat, and cotton.

SUPPLY ELASTICITIES[6]

For a clearer comparison of the relative sizes of price effects on soybean acreage, the relevant direct and cross short-run elasticities of supply were computed at the data means. They are shown in table 2. The estimated supply elasticities for the national aggregate function are displayed along the bottom row of the table.

[6] It can be easily shown that the theoretical model used in this analysis implies that the acreage elasticity with respect to the announced support price is equal to the acreage elasticity with respect to the effective support price.

Table 2.--Short-run acreage supply elasticities for soybeans, estimated from regional functions, 1946-66

Regional function: Elasticity of--	With respect to--							
	p^{s}_{t-1}	p^{ss}_{t}	p^{c}_{t-1}	p^{sc}_{t}	p^{o}_{t-1}	p^{so}_{t}	p^{sw}_{t}	p^{sct}_{t}
A^{L}........................	0.91	0.87	-0.49	-0.44	--	--	-0.35	--
A^{cb}........................	0.50	0.17	-0.50	-0.13	--	--	--	--
A^{p}........................	2.10	1.20	-1.70	-0.27	--	-0.69	--	--
A^{d}........................	0.75	0.64	--	--	-0.81	-0.31	--	-0.38
A^{a}(I)........................	1.70	2.40	--	--	-1.70	-1.30	--	-1.14
A^{a}(II)........................	3.30	1.10	-3.00	-0.28	--	-1.28	--	--
A^{m}........................	0.69	0.62	-0.41	-0.10	--	-0.75	--	--
A^{T}........................	0.84	0.43	-0.65	-0.17	-0.09	-0.19	-0.04	-0.04

The aggregate direct short-run price elasticity for the Nation as a whole is similar to some earlier estimates made by Vandenborre (7) and to several national estimates developed by Heady and Rao (2, p. 1054). However, it is higher than the estimates made by Houck and Mann (3, p. 47). None of these other studies included price supports and acreage restrictions for substitute crops jointly in the analysis. The independent variables were mostly acreages of competing crops and various price ratios.

The relationships among the elasticities in table 2 are reasonable, with market price elasticities generally exhibiting larger values than effective support price elasticities. Long-run elasticity estimates can be computed for each region except the Atlantic by dividing the short-run estimates by $(1-\hat{c}_1)$ where $\hat{c}_1$ is the estimated coefficient on lagged acreage, equation (7) (4, p. 309). Since most of the regions display substantial upward trend in soybean acreage, the estimates of $\hat{c}_1$ are fairly large, making the long-run elasticity estimates much larger than those for the short run.

An Application of the Results

As carryover stocks of soybeans continue to grow and as market prices continue to hang on support levels, the impact of lower soybean support prices is being analyzed and debated. One crucial problem is to estimate the change in soybean production which would follow any given change in the support price. The regional supply equations presented here can be used to estimate the impact of contemplated support rate changes.

As an illustrative example, consider the estimated impact of the recent drop in the soybean price support loan rate for the 1969/70 crop year. On March 6, 1969, the national average price support for No. 2 grade soybeans to be harvested in the fall of 1969 was reduced

Table 3.--Estimated regional and national decreases in harvested soybean acreage annually following a $0.30/bu. decrease in the soybean price support rate for the 1969 crop, 1969-73[a]

Region	1969	1970	1971	1972	1973
	1,000 acres				
Corn Belt......	270	426	281	185	122
Lake States....	303	1,066	831	648	505
Plains States..	169	345	193	108	60
Delta States...	225	445	387	337	293
Atlantic States	194	553	--	--	--
Other States...	75	146	134	123	113
Nation.........	1,236	2,981	1,826	1,401	1,093

[a] Based on No. 2 grade soybeans.

from the 1968/69 level of $2.50 per bushel to $2.20--a 30-cent decrease.[7] Further assume that market prices drop during the 1969/70 crop year, to the new loan rate as the large carryover indicated for September 1969 is worked off. The impact of these assumed conditions within the framework of this supply model would be as follows: First, the support rate decrease of 30 cents per bushel would discourage some plantings for the 1969 crop; second, the drop in the 1969/70 market price would continue to discourage production in 1970; third, the lagged adjustment feature for each region, except the Atlantic States, would continue to operate causing further but decreasing acreage drops in subsequent years. The data in table 3 show the annual adjustments that would occur in soybean acreage in 1969-73 if nothing else in the system changed and the market price remained at $2.20. Since other things will undoubtedly be changing during this period, these figures can be viewed as the net downward pressure annually on soybean acreage due to the specified support rate change, and not as a prediction of what will in fact occur. If a yield of 25.5 bushels per acre is assumed, the national production decrease each year would be as follows:

	Million bushels
1969	31.5
1970	76.0
1971	46.6
1972	35.7
1973	27.9

This exercise is only one of many that could be investigated with these estimates. It is suggestive of the kinds of analyses that are possible. Changes in support levels and acreage restrictions attached to other commodity programs also can be evaluated in terms of their impact on soybean acreage and production.

Concluding Comments

The regional supply functions presented and discussed here are of interest not only because of the empirical estimates but also because of the apparently successful application of the effective support price idea. Time series supply analyses of several U.S. crops have been limited because of the operation of supply-restricting acreage controls. Hence, wider application of the effective support price concept might prove useful in analysis for crops other than soybeans.

The method of calculating effective support rates suggested here might well be modified and improved. But, given the method used in this analysis, the empirical results were clearly superior to results using only announced support rates. Moreover, the estimates provide a means of evaluating acreage responses given changes in market price, announced support prices, and nonprice restrictions for soybeans and related crops.

[7] The 1968-69 average price support loan rate was $2.50 per bushel applied to No. 2 grade soybeans. The 1968-70 loan rate is $2.25 per bushel applied to No. 1 grade soybeans. The price discount for No. 2 grade soybeans relative to No. 1 is about 5 cents per bushel. Hence the support rate decrease for all soybeans is approximately 30 cents per bushel.

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Appendix

The transformation of announced support prices into effective support prices can be generalized to a supply function including both market and support prices for several competing crops.

For example, let

(A1) $$A_1 = a_0 + a_1 P_1 + a_2 P_1^f + a_3 P_2 + a_4 P_2^f$$

where P_1 and P_2 are supply-affecting market prices, and P_1^f and P_2^f are effective support prices which cannot be observed directly if acreage restrictions are involved. More competing commodities can be introduced if desired, but one is sufficient for illustration. Then

(A2) $$a_2 = (A_1^o - a_0 - a_1 P_1 - a_3 P_2 - a_4 P_2^f) / P_1^s \quad \text{and}$$

$$a_2 = (A_1^s - a_0 - a_1 P_1 - a_3 P_2 - a_4 P_2^f) / P_1^f$$

where A^o, A^s, and P^s are as defined in the text of the paper (see equation (2)). From the equations in (A2) it follows that

(A3) $$P_1^f = (A_1^s / A_1^o)(P_1^s) + (a_0 + a_1 P_1 + a_3 P_2 + a_4 P_2^f)(P_1^s - P_1^f) / A_1^o$$

Let A_1^n be the acreage intercept in equation (A1) when $P_1^f = 0$. Then

(A4) $$P_1^f = (A_1^s / A_1^o)(P_1^s) + (A_1^n / A_1^o)(P_1^s - P_1^f)$$

If a supply equation for commodity 2 comparable to equation (A1) is assumed then with a similar line of reasoning it follows that

(A5) $$P_2^f = (A_2^s / A_2^o)(P_2^s) + (A_2^n / A_2^o)(P_2^s - P_2^f)$$

Substituting (A4) and (A5) into (A1) and collecting terms

(A6) $$\begin{aligned} A_1 = a_0 + a_1 P_1 &+ a_2 \left[(A_1^s / A_1^o) P_1^s\right] \\ &+ a_3 P_2 + a_4 \left[(A_2^s / A_2^o) P_2^s\right] \\ &+ a_2 \left[(A_1^n / A_1^o)(P_1^s - P_1^f)\right] \\ &+ a_4 \left[(A_2^n / A_1^o)(P_2^s - P_2^f)\right] \end{aligned}$$

Consider the last two terms in equation (A6). First A^n / A^o is less than + 1.0, and if the commodities are sensitive to support price changes, the ratio will be much less than + 1.0. The expression $(P^s - P^f)$, though unobserved, is positive and smaller than P^s in the other expressions with the coefficients of a_2 and a_4. Finally, a_2 and a_4 will be of opposite sign if the commodities are substitutes in production. Hence, A_1 is approximated by

(A7) $$\begin{aligned} A_1 \cong a_0 + a_1 P_1 &+ a_2 \left[(A_1^s / A_1^o) P_1^s\right] \\ &+ a_3 P_2 + a_4 \left[(A_2^s / A_2^o) P_2^s\right] \end{aligned}$$

This is the basic function fitted by least squares in this supply study of soybean acreage. The most difficult empirical problem, of course, is the estimation of A^s/A^o for several crops over a period of years in which support programs have changed markedly.