# Acreage Response and Production Supply Functions for Soybeans

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## SUMMARY

This study deals with response and supply functions for soybean acreage and production. The analysis relates to the nation, to major producing regions and to states important in soybean production. Supply relationships are estimated for the original values of observations and for logarithmic transformations. The time series data used cover the period 1929-1963. Several regression models are used in estimation.

### Acreage Response Functions

Including and excluding a lagged endogenous variable, two types of soybean acreage response relationships are presented. A number of explanatory or independent variables are used in these response or supply relations and include: total planted acreages for each of the competing crops, oats, corn, wheat and cotton; the price ratios of soybeans to competing crops; the average yield ratios of soybeans to competing crops; a time-trend variable; and a dummy variable to express the influence of acreage allotments and feed grain programs.

Based on functions for both the original values and the logarithmic values of observations, the following conclusions prevail for the nation: Soybean acreage is significantly associated with the price ratio of soybeans to corn, and this association is statistically significant at the 5-percent level in most functions. Yield ratios especially associated with soybean acreage response are those for soybeans-oats and soybeans-corn. Generally, an increase in the soybean-corn yield ratio of a given year is associated with an increase in the soybean acreage for the next year. Among cash crops considered, soybeans are more competitive with corn than with oats, wheat or cotton. Acreage allotment and feed-grain programs have had a significant influence on soybean acreage response.

Supply elasticities for soybean acreage with respect to important price ratios are estimated for selected states and regions. The supply elasticities based on logarithmic functions, used as averages over the entire period, are generally higher than those estimated from mean values of observations from nonlogarithmic functions. However, since they proved more efficient in statistical estimation, the nonlogarithmic functions are generally used for analysis. Based on the best nonlogarithmic function, which does not include the variable for lagged soybean acreage, the estimated supply elasticity for the nation's soybean acreage, with respect to the soybean-corn price ratio, is 0.443.

### Production Supply Functions

In the analysis of soybean production, including and excluding the lagged endogenous variable, two types of soybean production response relationships are presented. The variables included are similar to those for acreage response, except that they do not include acreage variables for competing crops but do include weather variables. Weather is represented by four variables: July precipitation, August average temperature and the squared terms of these two variables. Another independent variable not included for acreage response functions is the national index of prices paid by farmers for fertilizers.

In the functions in which lagged production is included as a variable, it has a significant and positive influence on the soybean production for the given year. Among the weather variables, also nondecision variables, only July rainfall was generally significant.

The most important decision variable relating to soybean production is the price ratio of soybeans to corn. The rapid increase in soybean production is partly explained by the high ratio of soybean prices relative to corn prices over the past 3 decades.

The variable for the fertilizer price index is significant in the nonlogarithmic function, but not in the logarithmic functions. Fertilizer price is associated negatively with soybean output.

The price variables, though high in statistical significance, frequently account for only a small part of the variation in soybean output throughout the period studied. Strong production trends over time frequently appear independent of price movements and reflect technological changes that have favored soybeans over other crops. A significant portion of the increase in the soybean production over the years also is associated with government programs. Government programs that restrict the acreage for corn, wheat and cotton divert land to soybeans where cross compliance is not required. (In the case of cross compliance, the land sometimes could not be shifted to corn, wheat or cotton but could be shifted to soybeans. Programs have varied greatly in the amount of cross compliance required.)

The national soybean supply functions account for 94 to 98 percent of the variance in production over the period, depending on the variables included. The Durbin-Watson d statistic for regressions selected for prediction generally indicates that there is no evidence of serial correlation in the residuals.

# Acreage Response and Production Supply Functions For Soybeans[1]

by Earl O. Heady and V. Y. Rao[2]

The major economic problems of agriculture are directly or indirectly related to supply functions and relationships. Consequently, improved knowledge of agricultural supply is necessary for a better understanding of these problems and for formulation and implementation of effective price and production policies. A greater knowledge of supply response can also help extension specialists provide improved information for farmers' decisions. Farmers then can use their individual resources more efficiently for higher profits.

Improved knowledge of supply response also is of great importance to processing and marketing firms who must forecast the timing and magnitude of commodity supplies. Supply information can also aid in a better understanding of problems related to interregional competition and area development. In short, greater knowledge of supply responses and relationships for individual and aggregate agricultural commodities is important in all sectors of the agricultural industry.

## OBJECTIVES AND REGIONS

This study has been undertaken with the principal objective of improving knowledge of soybean supply response in the United States. Soybean acreage and production response functions are estimated on national, regional and state bases. The factors or variables that influence soybean acreage and production are investigated, and the quantitative influence of these factors also is estimated. Elasticities of soybean supply are derived for important geographic regions.

Currently, soybeans are grown in 31 states. These 31 states are grouped into eight agricultural regions (table 1) for the study. Supply functions are estimated individually for the nation, for the eight regions and for a number of selected states, including the five states of the Corn Belt and Arkansas and Minnesota. These seven states produce about 80 percent of the United States' total soybean output.

## FACTORS INFLUENCING SOYBEAN ACREAGE AND PRODUCTION

This section includes a discussion of the variables or factors expected to influence soybean acreage and production. Although the list may not exhaust the totality of the factors, the important variables expected to serve in an explanatory role are discussed. These variables then are incorporated into the empirical models in a manner expected to eliminate multicollinearity among them. Dummy variables are introduced for some of the factors influencing soybean acreage and production.

### Competing Crops

Corn, oats, wheat and cotton mainly compete for the tillable acreage in the major soybean-producing states. The competing crops vary from state to state. The rapid increases in soybean acreage since 1930 have mostly been offset by decreases in the acreage of competing crops. One reason for this replacement has been the growing profitability of soybeans relative to competing crops. Relative profitability depends on yield coefficients and prices, variables used later in the empirical analysis.

### Government Programs

Since agricultural output has "exceeded" demand, in the sense of prices and incomes acceptable to farmers, a number of programs have been used in attempts to control agricultural production. One such program is the acreage allotment, whereby acreage of a basic commodity on which a farmer may harvest a crop and be eligible for price supports, is restricted. Table 2 gives the years and acreages for which national acreage allotments were proclaimed for wheat, corn and cotton. Acreage allotments or their equivalent have been in effect in most years since 1933. Acreage allotments, if they reduce the output of crops to which they apply, must divert land and other resources to alternative crops or uses. Diversion of land from wheat, corn and cotton to soybeans is expected to be an important reason for increases in soybean acreage and production.

Feed grain programs of 1961, 1962 and 1963 also favored reducing corn acreages in favor of soybeans. Hence, feed grain programs also are included in the study of soybean acreage and production.

In the empirical investigation, a dummy variable is used to represent government programs such as acreage allotments, marketing quotas and feed grain programs. The dummy variable takes a value of zero in years when none of these programs applied to the competing crops. If programs existed for the three competing crops, (wheat, corn and cotton), the dummy variable takes a value of 3. Hence, the value of the dummy variable

[1]Project 1406 of the Iowa Agricultural and Home Economics Experiment Station, Center for Agricultural and Economic Development cooperating.

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ranges from zero through 3. The years for which these programs were announced but terminated during the year are considered the same as those years in which the programs were not in effect.

### Technology

Technological improvements have increased the physical productivity of resources used in soybean production, as well as in other crops. Some of these changes have been more recent for soybeans since research was originally oriented to the competing crops. Mechanization has especially affected the growth of the soybean industry. During the 1920's and 1930's, most of the soybean crop was harvested for hay. However, through mechanical improvements, harvesting of the crop for soybeans has become relatively easy as capital has been substituted for labor.

New varieties, improved cultural methods and other technologies have increased greatly the per-acre yields of soybeans. Starting from a national average yield of 13.8 bushels per acre in 1930, the average yield of soybeans increased to 24.5 bushels per acre in 1963. In the empirical analysis that follows, technological changes for soybeans are measured by a time-trend variable. This "gross variable" is used because more suitable ones were not easily devised.

### Weather

Several recent studies, made to assess the influence of weather on crop yields, suggest that weather has been a contributing factor in increased agricultural production over a period of several years. Because of contin-

**Table 1. Soybean production: 1963 regional distribution of and acreage by states.**

| Region | States | Soybean production (1,000 bu.) | | Soybean planted acreage (1,000 A.) | |
|---|---|---|---|---|---|
| 1. Corn Belt | | 455,928 | (65.00)[a] | 16,504 | (55.66) |
| | Illinois | 164,462 | (23.45) | 5,620 | (18.95) |
| | Iowa | 109,290 | (15.58) | 3,654 | (12.32) |
| | Indiana | 74,470 | (10.62) | 2,731 | ( 9.21) |
| | Missouri | 65,586 | ( 9.35) | 2,724 | ( 9.19) |
| | Ohio | 42,120 | ( 6.00) | 1,775 | ( 5.99) |
| 2. Mississipi Delta | | 82,687 | (11.79) | 4,715 | (15.90) |
| | Arkansas | 51,152 | ( 7.29) | 2,965 | (10.00) |
| | Mississippi | 25,023 | ( 3.57) | 1,387 | ( 4.68) |
| | Louisiana | 6,512 | ( 0.92) | 363 | ( 1.22) |
| 3. Lake States | | 67,074 | ( 9.56) | 2,865 | ( 9.65) |
| | Minnesota | 58,236 | ( 8.30) | 2,412 | ( 8.13) |
| | Michigan | 6,930 | ( 0.99) | 336 | ( 1.13) |
| | Wisconsin | 1,908 | ( 0.27) | 117 | ( 0.39) |
| 4. Appalachian | | 36,049 | ( 5.14) | 2,059 | ( 6.94) |
| | N. Carolina | 14,328 | ( 2.04) | 754 | ( 2.54) |
| | Tennessee | 11,088 | ( 1.58) | 607 | ( 2.05) |
| | Kentucky | 5,733 | ( 0.82) | 289 | ( 0.97) |
| | Virginia | 4,900 | ( 0.70) | 403 | ( 1.36) |
| | W. Virginia | | | 6 | ( 0.02) |
| 5. Northern Plains | | 27,971 | ( 3.98) | 1,509 | ( 5.09) |
| | Kansas | 12,064 | ( 1.72) | 861 | ( 2.90) |
| | Nebraska | 9,291 | ( 1.32) | 329 | ( 1.11) |
| | S. Dakota | 3,576 | ( 0.51) | 151 | ( 0.51) |
| | N. Dakota | 3,040 | ( 0.43) | 168 | ( 0.57) |
| 6. Southeast | | 17,973 | ( 2.56) | 1,179 | ( 3.98) |
| | S. Carolina | 12,070 | ( 1.72) | 776 | ( 2.62) |
| | Alabama | 3,276 | ( 0.47) | 181 | ( 0.61) |
| | Georgia | 1,502 | ( 0.21) | 171 | ( 0.58) |
| | Florida | 1,125 | ( 0.16) | 51 | ( 0.17) |
| 7. Northeast | | 9,229 | ( 1.32) | 541 | ( 1.83) |
| | Maryland | 4,551 | ( 0.65) | 256 | ( 0.86) |
| | Delaware | 3,672 | ( 0.52) | 210 | ( 0.71) |
| | New Jersey | 828 | ( 0.12) | 53 | ( 0.18) |
| | Pennsylvania | 114 | ( 0.12) | 17 | ( 0.06) |
| | New York | 64 | ( 0.01) | 5 | ( 0.02) |
| 8. Southern Plains | | 4,554 | ( 0.65) | 283 | ( 0.95) |
| | Texas | 2,604 | ( 0.37) | 92 | ( 0.31) |
| | Oklahoma | 1,950 | ( 0.28) | 191 | ( 0.64) |
| United States | All 31 states | 701,465 | (100.00) | 29,655 | (100.00) |

[a]Figures in parentheses indicate the percentages of United States totals.

Source: U. S. Department of Agriculture. Agricultural Statistics 1963.

**Table 2. National acreage allotments for wheat, corn and cotton, 1938-1963.**

| Year | In thousands of acres Wheat | Corn | Cotton[a] |
|---|---|---|---|
| 1938 | 62,500 | 40,491 | 27,493 |
| 1939 | 55,000 | 41,240 | 27,863 |
| 1940 | 62,000 | 36,638 | 27,545 |
| 1941 | 62,000 | 37,300 | 27,399 |
| 1942 | 55,000[b] | 41,388 | 27,281 |
| 1943 | 55,000[b] | 43,423[b] | 27,203[b] |
| 1944[c] | | | |
| 1945[c] | | | |
| 1946[c] | | | |
| 1947[c] | | | |
| 1948[c] | | | |
| 1949[c] | | | |
| 1950 | 72,776 | 46,247 | 21,000 |
| 1951 | 72,785[b] | | |
| 1952[c] | | | |
| 1953[c] | | | |
| 1954 | 68,809 | 46,996 | 21,420 |
| 1955 | 55,802 | 49,843 | 18,159 |
| 1956 | 56,226 | 43,281 | 17,436 |
| 1957 | 55,000 | 37,289 | 17,674 |
| 1958 | 55,000 | 38,818 | 17,637 |
| 1959 | 55,000 | c | 17,398 |
| 1960 | 55,000 | c | 17,598 |
| 1961 | 55,000 | c | 18,522 |
| 1962 | 49,603 | c | 18,202 |
| 1963 | 55,000 | c | 16,460 |

[a]Includes upland and extra long staple.

[b]Indicates allotments were terminated during the year.

[c]Blank space means allotments not in effect.

Source: U. S. Department of Agriculture. Acreage allotment and marketing quota summary. Commodity Stabilization Service, Price Division. Washington, D. C. 1963.

uously changing technology, determination of the relation between weather and yield is complicated.

Thompson[3] studied the relation of weather to the yield trend in 11 states for corn, soybeans, wheat and grain sorghums. He concluded that half of the trend upward in yield since 1950 can be attributed to improvement in weather and about half to adoption of technology. His results show that July rainfall and August temperatures are the most significant weather variables for soybeans.

Shaw and Durost consider a weather index a better indicator of the relative effects of weather factors on yields than variables such as average precipitation, temperature, humidity and others.[4] Although a weather index is well suited to supply analysis, it also has certain disadvantages. Computed for one crop and region, it does not apply readily to other crops and regions. Also, a large amount of experimental data must be collected and considerable time must be spent constructing the weather index series. In the present study, based on the findings of Thompson just cited, July rainfall and August temperatures are used as weather variables related to soybean yields.

#### Fertilizer

Fertilizer use in the United States has increased more than four times since 1940. Soybeans are less responsive to direct fertilizer treatments than are crops such as corn and cotton. However, since some fertilizer is used on soybeans, this variable was considered relevant in the response functions estimated.

Even though fertilizer price is considered as a variable affecting soybean production in this study, it is difficult to measure. Data on fertilizer use on individual crops are not available. In terms of price also, fertilizer mixes vary among crops and their prices differ from state to state. Hence, a national index of average price paid by farmers for fertilizers is used as a "crude" variable to express the relative effects of fertilizer and soybean prices.

#### Other Variables

Numerous other variables may help account for the rapid increase in soybean production, but separately, are not necessarily variables to be incorporated in supply functions. The increase in demand, through its price effects, naturally stimulates further increases in production. Demand has increased rapidly as processing methods have encouraged use of soybeans in a variety of food, feed and industrial items in the United States and other countries. Important technological changes in the soybean processing industry also have contributed significantly to the development of the market and, hence, to demand and price effects.

United States soybean exports increased rapidly after World War II. The failure of mainland China, the world's only other major soybean producer, to expand soybean exports also indirectly stimulated increased production and export of United States soybeans.

## DATA AND ANALYSIS

The data used in this study cover the period 1929 to 1963 inclusive.[5] Since some data are not available for all years, certain observations are estimated. Data are sometimes lacking mainly for the acreage planted for all purposes. The following section indicates (a) the simple estimation procedures used to fill gaps in data and (b) the methods used in deriving weather and price statistics at national and regional levels.

#### Acreage Planted

Data on total planted soybean acreages are available for all the years under study, and hence, no estimation is involved. For two competing crops, oats and corn, data on total planted acreage for all purposes are available only for 1940 and following years. Data on total acreage seeded for wheat and total planted acreage for cotton are available for 1941 and later. However, statistics on harvested acreage for grain are available for 1929 through 1963 for all crops.

In estimating the acreage for all purposes in years of missing data, a simple linear relation of the following type is assumed between the total planted acreage and the acreage harvested for grains, where

(1) $Y_t = a + bx_t$

$Y_t$ denotes the acreage planted or seeded for all purposes for the year t, $x_t$ denotes the acreage harvested for grain for the year t, and t takes the value of zero in 1941 for corn and oats and zero in 1942 for wheat and cotton. Given the harvested acreage of a crop for a given year, the total planted acreage is predicted by the equation. The coefficients a and b are estimated individually for each of the four crops for all soybean-growing states. The national and regional figures on total planted acreages for these crops are obtained by summing appropriate individual state figures derived as shown in equation 1.

Nearly 140 regressions of the type in equation 1 were fitted for the crops and states under study. In al-

[3]L. M. Thompson, Multiple regression techniques in the evaluation of weather and technology in crop production. pp. 75-91. In: Weather and our food supply. (Mimeo.) Center for Agricultural and Economic Development, Iowa State University of Science and Technology, Ames. CAED Report 20. 1964.

[4]L. H. Shaw and D. D. Durost. The weather index approach. pp. 93-102. In: Weather and our food supply. (Mimeo.) Center for Agricultural Development, Iowa State University of Science and Technology, Ames. CAED Report 20. 1964.

[5]For sources of information and data used see the following United States Department of Agriculture reports: U.S. Dept. of Agriculture. Acreage allotment and marketing quota summary. Commodity Stabilization Service, Price Division. 1960; U.S. Dept. of Agriculture. Agricultural statistics, 1937-63; U.S. Dept. of Agriculture. ASCS production adjustment programs. Agricultural stabilization and conservation service background information 5. 1963; U.S. Dept. of Agriculture Crop Reporting Board. Crop production, annual summary by states. 1963; U.S. Dept. of Agriculture Crop Reporting Board. Crop values by states. 1963; U.S. Dept. of Agriculture Crop Reporting Board. Fluctuations in crops and weather, 1866-1948; U.S. Dept. of Agriculture Stat. Bul. 101. 1951; U.S. Dept. of Agriculture. Yearbook of Agriculture, 1930-37. Also see U.S. Dept. of Commerce, Weather Bureau. Climatological Data, 1955-1963.

most all cases, the regression coefficients were satisfactory, and the values of the correlation coefficients were higher than 0.90. In about a dozen cases, however, the regression results were quite poor. Most of the unsatisfactory regressions were for oats grown in states outside of the Corn Belt. However, even if errors exist under this method of estimation, they are minor and do not affect the general results and conclusions of the study.

#### Price Series

The actual market prices for different crops are available on a state level. The market price is the average price received by farmers for the crop year. These prices for different crops are estimated for regions and the nation. The regional price of a crop is calculated by using equation 2, where P indicates the regional price of a given crop,

$$(2) \quad P = \sum_{i=1}^{m} S_i P_i \; / \; \sum_{i=1}^{m} S_i \qquad (i = 1, 2, \ldots m)$$

$P_i$ is the average price received by farmers in the ith state and $S_i$ denotes the quantity sold during the crop year in the same states. In these calculations, the regional price of a crop is the weighted average of state prices where the weights are the quantities sold. Before 1941, however, the quantities sold are not available. Regional prices for crops before 1941 are obtained by the same formula, but the weights used are state production figures. For cotton, the weights used throughout the entire period, 1929-1963, are the state production figures.

#### Weather Statistics

The two important weather variables considered for soybean production are July precipitation and August temperature. These statistics, up to 1948, are from Statistical Bulletin 101 of the United States Department of Agriculture[6] and are monthly averages for all soybean-growing states. The state averages are the simple averages of the divisional averages. After 1948, the state averages are the weighted averages of the divisional values, the weights being the areas under the divisions. The weather statistics, for 1949 to 1963, are taken from Agricultural Statistics[7] and Climatological Data.[8] The state averages for the later years are computed by weights from the divisional averages. The main source for the divisional averages of weather statistics is the climatological data published by United States Department of Commerce for all the states and years. The weather statistics after 1948 may not be exactly compared with the weather statistics up to 1948 because the difference in weighting exists between two periods. However, the analysis is unlikely to be affected importantly by minor differences resulting from the weighting procedures.

After assembling monthly averages of July precipitation and August temperatures for all the years, 1930 to 1963, for the 31 soybean-growing states, these weather statistics were used to construct regional variables. The regional weather variables are obtained by weighting the state figures by the harvested acres for soybeans as

$$(3) \quad W = \sum_{i=1}^{m} H_i W_i \; / \; \sum_{i=1}^{m} H_i \qquad (i = 1, 2, \ldots, m)$$

where $W_i$ represents the weather statistic (either July rainfall or August temperature) for the ith state, $H_i$ represents the harvested acres for soybeans for the same state and W represents the regional weather statistic. The summation is over the m states in the region.

#### Supply Relationships for Soybean Acreage

As already noted, soybean acreage increased rapidly throughout the study period. From slightly more than 3 million acres planted for all purposes in 1930, soybean planting increased to nearly 30 million acres in 1963. Since considerable soybean acreage was harvested for hay during the 1930's and early 1940's, acreage response was studied under two different categories: total planted acreage and acreage planted for beans (more accurately, total planted acres, minus acres for hay). However, since the statistical results were similar for the two acreage categories, only results for the latter acreage planted for beans are presented in this report. Hence, in the analysis that follows, the term acreage refers to that planted for beans (i.e. total planted acres, less acres for hay).

#### Acreage Response

Variables used in the analyses of soybean acreage are:

$X_1$: Total planted acres (acres grown alone plus half the interplanted acres) of soybeans in the current year (year t), in thousands. The total planted acreage includes acreage for soybeans cut for hay. (Because of similarity in results and to conserve space, statistical results for this variable are not presented.)

$X_2$: Total planted acres of soybeans in the previous year (year t–1), in thousands. $X_2$ is $X_1$ lagged 1 year.

$X_3$: Total acres planted for soybeans (total acres represented by $X_1$ minus soybean acreage cut for hay in the current year), in thousands. This is the variable for which statistical results are presented.

$X_4$: Total acres planted for soybeans in the previous year, in thousands. $X_4$ is $X_3$ lagged 1 year.

$X_5$: Total planted acres of oats (used for hay, pasture, soil improvement, abandoned, etc.) in the current year, in thousands.

[6]U.S. Department of Agriculture. Fluctuations in crops and weather, 1866-1948. U.S. Dept. of Agr. Stat. Bul. 101. 1951.

[7]U.S. Department of Agriculture. Agricultural statistics, 1937-63.

[8]U.S. Department of Commerce, Weather Bureau. Climatological Data, 1955-63.

$X_6$: Total planted acres of corn for all purposes (cut for hay, used for pasture, soil improvement, abandoned, etc.) in the current year, in thousands.

$X_7$: Total seeded acres of wheat for all purposes, (including acreage seeded in the preceding fall for the harvest in the given year) for the current year, in thousands.

$X_8$: Total planted acres of cotton in the current year, in thousands.

$X_9$: Price ratio of soybeans to oats for the previous crop year.

$X_{10}$: Price ratio of soybeans to corn for the previous crop year.

$X_{11}$: Price ratio of soybeans to wheat for the previous crop year.

$X_{12}$: Price ratio of soybeans to cotton for the previous crop year.

In specifying these price ratios, the higher of the two prices, (a) the market price of the crop for the previous crop year or (b) supported price (if available) for the current year, is used for each crop. Prices of soybeans, oats, corn and wheat are expressed in dollars per bushel, and the price of cotton is expressed in dollars per pound.

$X_{13}$: Yield ratio of soybeans to oats for the previous year.

$X_{14}$: Yield ratio of soybeans to corn for the previous year.

$X_{15}$: Yield ratio of soybeans to wheat for the previous year.

$X_{16}$: Yield ratio of soybeans to cotton for the previous year.

For the yield ratios, yields of soybeans, oats, corn and wheat are in bushels per acre, and yield of cotton is in pounds per acre.

$X_{17}$: Time-trend; $1930 = 1$, $1931 = 2$, . . . , etc., for all states (except Minnesota), regions and the nation. For Minnesota, the variable takes values as $1935 = 1$, $1936 = 2$, . . . , etc.[9]

$X_{18}$: Dummy variable representing the coded form of acreage allotments and feed grain programs. This variable can take a value of 0, 1, 2, or 3 for a given year depending on the presence or absence of the programs for the three competing crops (corn, wheat and cotton).

The price ratios of soybeans to competing crops are better measures of the relative profitability of soybeans as a cash crop than is the actual price of soybeans. Similarly, the yield ratios of soybeans to competing crops are better indicators of relative profitability than is the actual yield of soybeans. Hence, price and yield ratios are used as the variables to relate soybeans with other crops.

[9]1935 was the beginning of the available data series in Minnesota.

Two sets of acreage supply response functions (for variable $X_3$) are estimated for all states, regions and the nation. The first set of equations contains variable $X_4$, the lagged endogenous value of variable $X_3$. The second set of equations does not contain the lagged endogenous variable. A number of alternate regression equations and variables are used for each of these two categories: A few regressions are presented in which acreage variables corresponding to competing crops are not included. All regression equations presented contain variables representing price ratios, yield ratios, the time-trend and the dummy variable corresponding to the government programs, where these variables have statistical significance.

In presenting these regression models, any variable whose coefficient has a "wrong sign," in the economic sense, generally has been omitted. (For example, the variable representing the price ratio of soybeans to corn is expected to have a positive sign.) Also, if the coefficient of any variable is smaller than its standard error, depending on the economic importance, the variable generally is not included in the equations. Parallel equations for different measures of soybean acreage or production can be compared with reference to the variables indicated in each table. The number of equations estimated and included is not the same for all states and measures. (Some functions were discarded where the regression coefficients had the wrong sign or were of extremely low significance.) Hence, the equations in each table are numbered consecutively, rather than in parallel fashion to those of other tables.

## RESULTS FOR ACREAGE RESPONSE

The analyses of acreage planted for soybeans, with measurements in the original observations, are presented in tables 3 through 9 for the five states in the Corn Belt and for Arkansas and Minnesota. (Standard errors of the coefficients are presented in parentheses below the coefficients.) The value of $R^2$ is given for each regression equation, but the Durbin-Watson d statistic for testing the serial correlation in the residuals is computed only for a few selected regression equations of Illinois, Iowa and Indiana and is discussed in the text wherever applicable.

### Ohio

Table 3 shows regression equations for soybean acreage in Ohio. In 1963, Ohio had 6 percent of the nation's soybean acreage.

Removal of variable $X_4$ from the regression equations of table 3 lowers the value of $R^2$ considerably. Variable $X_{10}$, the soybean-corn price ratio, is significant at the 5-percent level. Generally, the regression equations in table 3 had greater values for $R^2$ when compared with the equations including acreage planted for hay, indicating that removing hay acreage from the total soybean acreage improves the predictions. The significance levels of all coefficients entering the equations increased when only acreage planted for soybeans was left in as the dependent variable.

Excluding the lagged endogenous variable, the following conclusions hold true for the soybean acreage response. First, a decrease in oat acreage for a given year is associated with an increase in soybean acreage for the same year. Second, an increase in the soybean-corn price ratio of previous year has a significant effect in increasing soybean acreage in the current year. Third, the time-trend variable, which expresses technological improvement, has a highly significant effect on soybean acreage. Finally, government programs also have a significant influence on soybean acreage.

For equation 3.1, the supply elasticities for soybean acreage with respect to the soybean-corn price ratio, calculated at the mean of the entire series, is estimated at 0.512. Hence, soybean acreage increases by about 5 percent for a 10-percent increase in the soybean-corn

Table 3. Ohio regression coefficients (with standard errors in parentheses) and $R^2$ values for total planted acres for soybeans ($X_3$), 1929 to 1963. Data used are original values of observations.

| Equation number | Constant | $X_4$ | $X_5$ | $X_9$ | $X_{10}$ | $X_{13}$ | $X_{17}$ | $X_{18}$ | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|
| 3.1 ........ | −119.03 | 0.848 | −0.160 | 78.78 | | 240.82 | 1.50 | 94.52 | 0.970 |
| | (275.95) | (0.085) | (0.143) | (50.67) | | (184.62) | (5.35) | (23.00) | |
| 3.2 ........ | −105.03 | 0.866 | −0.174 | 82.12 | | 242.08 | | 95.51 | 0.970 |
| | (266.90) | (0.044) | (0.132) | (48.43) | | (181.50) | | (22.35) | |
| 3.3 ........ | −29.75 | 0.776 | −0.167 | | 131.06 | 131.29 | 4.94 | 101.62 | 0.970 |
| | (249.81) | (0.090) | (0.143) | | (79.56) | (160.37) | (5.25) | (22.83) | |
| 3.4 ........ | −237.71 | 0.790 | | | 99.87 | 160.05 | 6.29 | 107.08 | 0.969 |
| | (175.90) | (0.090) | | | (75.40) | (159.16) | (5.15) | (22.48) | |
| 3.5 ........ | −258.20 | | −0.329 | | 375.74 | 168.89 | 43.26 | 91.95 | 0.889 |
| | (472.10) | | (0.269) | | (141.23) | (304.69) | (5.31) | (43.33) | |
| 3.6 ........ | −107.16 | | −0.353 | | 365.72 | | 42.67 | 89.83 | 0.888 |
| | (380.90) | | (0.263) | | (138.39) | | (5.14) | (42.64) | |
| 3.7 ........ | −684.01 | | | | 321.86 | 228.00 | 47.35 | 102.57 | 0.884 |
| | (320.72) | | | | (135.28) | (303.35) | (4.15) | (42.81) | |

Table 4. Indiana regression coefficients (with standard errors in parentheses) and $R^2$ values for total planted acres for soybeans ($X_3$), 1929 to 1963. Data used are original values of observations.

| Equation number | Constant | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_{10}$ | $X_{13}$ | $X_{14}$ | $X_{17}$ | $X_{18}$ | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 4.1 .... | 220.81 | 0.341 | −0.027 | −0.117 | −0.181 | 259.08 | 58.96 | 508.23 | 49.86 | 29.45 | 0.993 |
| | (445.75) | (0.154) | (0.102) | (0.061) | (0.118) | (80.02) | (143.41) | (424.28) | (11.93) | (27.67) | |
| 4.2 .... | 243.37 | 0.360 | | −0.132 | −0.182 | 244.88 | | 629.80 | 49.62 | 28.00 | 0.993 |
| | (346.02) | (0.147) | | (0.055) | (0.102) | (73.61) | | (298.61) | (11.34) | (24.40) | |
| 4.3 ... | −145.03 | 0.468 | | −0.116 | | 381.26 | | 511.16 | 41.62 | 54.11 | 0.992 |
| | (278.56) | (0.139) | | (0.056) | | (73.45) | | (302.35) | (10.82) | (20.23) | |
| 4.4 ... | −226.42 | 0.430 | | −0.097 | | 300.74 | 117.46 | 284.27 | 43.71 | 57.12 | 0.992 |
| | (291.33) | (0.145) | | (0.060) | | (76.28) | (121.09) | (382.64) | (11.04) | (20.50) | |
| 4.5 ... | −207.95 | 0.380 | | −0.081 | | 307.57 | 172.45 | | 46.84 | 55.54 | 0.992 |
| | (287.82) | (0.127) | | (0.055) | | (75.06) | (95.02) | | (10.12) | (20.22) | |
| 4.6 ... | −570.02 | 0.387 | | | | 307.40 | 193.06 | | 44.35 | 71.19 | 0.991 |
| | (149.62) | (0.129) | | | | (76.58) | (95.86) | | (10.18) | (17.50) | |
| 4.7 ... | −208.22 | | | −0.106 | | 406.86 | | 103.17 | 77.18 | 42.96 | 0.989 |
| | (325.08) | | | (0.065) | | (73.96) | | (323.88) | (2.61) | (23.35) | |
| 4.8 .... | 487.48 | | | −0.142 | −0.299 | 296.72 | | 440.31 | 77.11 | | 0.991 |
| | (256.47) | | | (0.052) | (0.085) | (67.86) | | (307.88) | (2.06) | | |
| 4.9 .... | 430.08 | | | −0.119 | −0.265 | 305.66 | 148.62 | | 76.30 | | 0.991 |
| | (261.64) | | | (0.050) | (0.077) | (68.18) | (95.27) | | (1.98) | | |
| 4.10 .. | −384.34 | | | −0.088 | | 432.58 | 164.81 | | 76.47 | 50.92 | 0.989 |
| | (319.34) | | | (0.063) | | (70.72) | (107.66) | | (2.43) | (22.85) | |
| 4.11 .. | −781.44 | | | | | 435.11 | 187.03 | | 74.41 | 67.82 | 0.989 |
| | (149.02) | | | | | (71.86) | (108.23) | | (1.96) | (19.72) | |

price ratio. (The elasticities are calculated from the coefficients of the respective equations and are not given in the tables.)

## Indiana

Table 4 contains the Indiana regression equations for soybean acreage. Indiana had 9 percent of the nation's soybean acreage in 1963.

The values of $R^2$ for equations predicting acreage for soybeans ($X_3$) were consistently much higher than the corresponding equations predicting acreage for hay and soybeans ($X_1$). Equation 4.2 accounts for more than 99 percent of the variance of acreage for soybeans. Most of the variables are significant at the 5-percent level. The test for serial correlation in the residuals is not significant. Without the lagged endogenous variables, equation 4.8 accounts for more than 99 percent of the variance in acreage. Although the dummy variable fails to enter significantly into the equation, the linear time-trend and soybean-corn price ratios are highly significant. The test for serial correlation in the residuals is inconclusive. Equation 4.11, which does not have any acreage variables, still has a very high value for $R^2$.

The values of $R^2$ for equations in table 4, with or without the lagged endogenous variable $X_4$, differ very little. In general, the time-trend, and the soybean-corn price ratio have a significant positive effect on soybean acreage.

The estimated supply elasticities for total soybean acreage, with respect to soybean-corn price ratios, is 0.278, based on equation 4.2. Hence, Indiana soybean acreage is predicted to increase by 2.78 percent for each 10-percent rise in the soybean-corn price ratio.

## Illinois

Illinois is the leading soybean-growing state with nearly 20 percent of total 1963 planted acres. A number of equations for acreage for soybeans are presented in table 5.

The equations in table 5 are presented with and without the variable $X_4$. Including variable $X_4$, equations 5.2 and 5.6 have highest values for $R^2$. The test for autocorrelation of residuals, not highly valid in these equations, is not significant. Variables $X_4$, $X_6$, $X_7$, $X_{14}$ and $X_{17}$ are highly significant in equation 5.2. Excluding variable $X_4$, equation 5.8 still has an $R^2$ value of 0.977.

However, the test for autocorrelation of the residuals is significant at the 5-percent level. For this equation, the acreage variables are highly significant, whereas variable $X_{10}$ and $X_{14}$ are significant at only 30-and 10-percent levels, respectively.

The supply elasticity for soybean acreage with respect to the soybean-corn price ratio is 0.160 for equation 5.2. Hence, based on this equation, the soybean acreage increases by about 1.60 percent for a 10-percent rise in the soybean-corn price ratio.

## Iowa

With about 12 percent of the nation's soybean

Table 5. Illinois regression coefficients (with standard errors in parentheses) and $R^2$ values for total planted acres for soybeans ($X_3$), 1929 to 1963. Data used are original values of observations.

| Equation number | Constant | $X_4$ | $X_6$ | $X_7$ | $X_{10}$ | $X_{13}$ | $X_{14}$ | $X_{17}$ | $X_{18}$ | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 5.1 ....... | 808.46 | 0.671 | –0.211 | | 410.05 | | 1,167.80 | 52.41 | 106.38 | 0.985 |
| | (743.08) | (0.112) | (0.071) | | (164.57) | | (487.26) | (18.27) | (56.42) | |
| 5.2 ....... | 1,361.20 | 0.531 | –0.167 | –0.435 | 263.62 | | 1,417.72 | 73.89 | 97.68 | 0.988 |
| | (710.24) | (0.115) | (0.067) | (0.170) | (159.18) | | (454.31) | (18.63) | (51.49) | |
| 5.3 ....... | 1,322.99 | 0.537 | –0.142 | –0.326 | 292.47 | 452.08 | 319.31 | 49.50 | 113.50 | 0.986 |
| | (720.73) | (0.116) | (0.069) | (0.167) | (161.96) | (296.51) | (732.13) | (17.94) | (55.28) | |
| 5.4 ....... | 682.68 | 0.662 | –0.178 | | 420.24 | 550.38 | | 49.68 | 110.54 | 0.986 |
| | (730.16) | (0.109) | (0.073) | | (161.16) | (189.76) | | (17.66) | (54.03) | |
| 5.5 ....... | 763.90 | 0.653 | –0.173 | | 411.99 | 664.61 | | 36.86 | 183.89 | 0.983 |
| | (695.37) | (0.105) | (0.071) | | (157.64) | (199.64) | | (18.31) | (48.80) | |
| 5.6 ....... | –782.11 | 0.694 | | | 400.43 | 553.62 | | 66.84 | 98.01 | 0.988 |
| | (315.34) | (0.113) | | | (171.03) | (180.56) | | (18.96) | (51.81) | |
| 5.7 ....... | 1,238.58 | | –0.244 | | 701.20 | 360.07 | | 154.16 | 58.98 | 0.966 |
| | (1,057.25) | | (0.107) | | (230.36) | (286.46) | | (8.18) | (81.67) | |
| 5.8 ....... | 2,675.27 | | –0.202 | –0.802 | 280.78 | | 1,054.80 | 158.97 | | 0.977 |
| | (745.26) | | (0.077) | (0.196) | (206.52) | | (573.20) | (5.93) | | |
| 5.9 ....... | 2,672.01 | | –0.184 | –0.722 | 299.48 | | 421.63 | 156.78 | 45.23 | 0.964 |
| | (754.84) | | (0.078) | (0.188) | (210.04) | | (707.96) | (8.60) | (83.38) | |
| 5.10 ...... | 1,541.82 | | –0.272 | | 658.52 | 508.04 | | 145.26 | 160.54 | 0.959 |
| | (1,101.29) | | (0.106) | | (238.75) | (298.76) | | (7.70) | (73.40) | |
| 5.11 ...... | –958.77 | | | | 711.28 | 395.54 | | 154.29 | | 0.977 |
| | (473.80) | | | | (246.57) | (227.42) | | (5.34) | | |

acreage, Iowa is the second largest state in growing soybeans. Only oats and corn crops are considered to compete with soybeans in Iowa. Table 6 gives a number of alternate regressions for soybean acreage.

Of equations for which a d statistic was computed, equation 6.3, with a value of 0.964 for $R^2$, appears to be the best predicting equation. The d statistic, 2.27, is not significant. Variables $X_4$, $X_{10}$, $X_{17}$ and $X_{18}$ are significant at least at the 5-percent level.

The following general conclusions can be drawn from table 6. The oat acreage in Iowa mainly is being diverted to soybean acreage. Increases in the soybean-corn price ratio influence the farmers' decision toward more soybean acres. The linear trend for increases in soybean acreage, accounting especially for unquantified technical advances, is positive and significant. Acreage allotments (with the recent feed-grain program included in the variable) are quantitatively influential in diverting land to soybeans.

The supply elasticity for soybean acreage, estimated for equation 6.3 is 2.31. Hence, soybean acreage in Iowa is predicted to increase by 2.31 percent for a 10-percent increase in the soybean-corn price ratio.

### Missouri

Table 7 gives the regression equations for Missouri

**Table 6. Iowa regression coefficients (with standard errors in parentheses) and $R^2$ values for total planted acres for soybeans ($X_3$), 1929 to 1963. Data used are original values of observations.**

| Equation number | Constant | $X_4$ | $X_5$ | $X_6$ | $X_{10}$ | $X_{13}$ | $X_{14}$ | $X_{17}$ | $X_{18}$ | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 6.1 ....... | −48.46 | 0.542 | −0.064 | −0.047 | 385.33 | 286.20 | 124.57 | 38.15 | 351.44 | 0.965 |
| | (1,033.02) | (0.143) | (0.175) | (0.072) | (169.82) | (419.88) | (631.05) | (14.55) | (124.11) | |
| 6.2 ....... | −6.70 | 0.539 | −0.062 | −0.045 | 371.82 | 297.53 | | 38.34 | 347.42 | 0.965 |
| | (992.24) | (0.139) | (0.073) | (0.070) | (152.51) | (408.17) | | (14.25) | (120.14) | |
| 6.3 ....... | −522.53 | 0.545 | −0.062 | | 349.18 | 421.65 | | 36.14 | 400.46 | 0.964 |
| | (591.06) | (0.138) | (0.072) | | (146.91) | (357.06) | | (13.69) | (87.37) | |
| 6.4 ....... | −435.38 | 0.588 | | −0.045 | 386.47 | 348.75 | | 35.49 | 361.84 | 0.964 |
| | 849.66) | (0.126) | | (0.069) | (150.75) | (401.61) | | (13.78) | (118.32) | |
| 6.5 ....... | −950.78 | 0.594 | | | 363.84 | 472.78 | | 33.29 | 414.84 | 0.963 |
| | (314.71) | (0.124) | | | (145.22) | (350.38) | | (13.22) | (85.34) | |
| 6.6 ....... | −0.40 | | −0.182 | | 543.39 | 15.04 | | 86.63 | 349.86 | 0.944 |
| | (711.16) | | (0.080) | | (170.92) | (422.10) | | (6.13) | (106.68) | |
| 6.7 ....... | 9.30 | | −0.182 | | 542.94 | | | 86.67 | 349.81 | 0.944 |
| | (645.55) | | (0.079) | | (167.50) | | | (5.91) | (104.82) | |
| 6.8 ....... | −1,365.71 | | | | 659.79 | 64.98 | | 93.01 | 384.87 | 0.933 |
| | (400.91) | | | | (174.13) | (450.38) | | (5.81) | (112.78) | |

**Table 7. Missouri regression coefficients (with standard errors in parentheses) and $R^2$ values for total planted acres of soybeans ($X_3$), 1929 to 1963. Data used are original values of observations.**

| Equation number | Constant | $X_4$ | $X_5$ | $X_7$ | $X_9$ | $X_{10}$ | $X_{13}$ | $X_{17}$ | $X_{18}$ | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 7.1 ...... | −745.75 | 0.715 | −0.072 | | 171.60 | | 416.35 | 23.46 | 5.93 | 0.987 |
| | (345.79) | (0.092) | (0.060) | | (73.53) | | (163.87) | (9.03) | (33.00) | |
| 7.2 ...... | −770.12 | 0.709 | −0.070 | | 178.04 | | 407.34 | 24.43 | | 0.987 |
| | (312.58) | (0.085) | (0.059) | | (63.08) | | (153.30) | (7.12) | | |
| 7.3 ...... | −393.56 | 0.681 | −0.094 | −0.070 | 142.61 | | 276.44 | 24.75 | | 0.988 |
| | (437.25) | (0.086) | (0.062) | (0.058) | (68.94) | | (186.00) | (7.06) | | |
| 7.4 ...... | −943.69 | 0.753 | | | 175.62 | | 468.54 | 22.94 | | 0.986 |
| | (278.63) | (0.077) | | | (63.50) | | (145.50) | (7.06) | | |
| 7.5 ...... | −1,712.32 | | −0.188 | | 331.02 | 266.95 | 161.72 | 89.11 | −75.76 | 0.961 |
| | (625.85) | | (0.104) | | (127.50) | (186.76) | (285.45) | (7.48) | (54.20) | |
| 7.6 ...... | −1,445.54 | | −0.227 | | 261.42 | 276.69 | 267.65 | 82.18 | | 0.958 |
| | (686.11) | | (0.102) | | (119.36) | (189.78) | (279.86) | (5.69) | | |
| 7.7 ...... | −1,122.90 | | −0.251 | | 205.61 | 309.02 | | 82.99 | | 0.957 |
| | (502.80) | | (0.099) | | (103.97) | (186.47) | | (5.61) | | |
| 7.8 ...... | −2,306.88 | | | | 245.72 | 430.63 | 424.03 | 90.53 | | 0.951 |
| | (495.41) | | | | (126.93) | (188.14) | (288.50) | (4.54) | | |

soybean acreage.

The general conclusions from the equations given in table 7 can be summarized as follows: Dropping of variable $X_4$, the lagged endogenous variable, reduces the value of $R^2$ considerably. Among the remaining acreage variables, $X_5$ is an important one and indicates that soybean acreage increases as oat acreage decreases. Two price-ratio variables remaining in the equations for soybeans-corn and soybeans-oats are significant at 10-to 30-percent levels. The variables representing the soybean-oat yield ratio enter significantly in many of the equations. The linear time-trend coefficient is positive and highly significant in all equations presented in table 7. Hence, the major factor influencing soybean acreage in Missouri may be technological changes not systematically measured in this study. From the results, acreage allotments and feed-grain programs have contributed less to increases in soybean acreage in Missouri than in other states.

The supply elasticities with respect to the soybean-corn price ratio is 0.261 for equation 7.2.

## Arkansas

Arkansas is one of the two important soybean states outside the Corn Belt. It had 10 percent of the total planted acres for soybeans in 1963. Oats, corn and cotton are competing crops.

Table 8 gives the equations for soybean acreage. (For Arkansas, in contrast to states for which data have already been presented, the regression equations for soybean acreage were not improved over total planted acreage for soybeans and hay.) A strong positive correlation is indicated between soybean acreage and the soybean-cotton yield ratio. Also, the variable for govenment acreage-allotment programs has a positive influence on soybean acreage. When $X_4$ is not included in the equations, decreases in the acreage of oats, corn and cotton are significantly related to increases in soybean acreage. Also, the soybean-cotton price ratio is positively correlated with the soybean acreage.

The supply elasticity, estimated at the mean values, for soybean acreage with respect to the soybean-oat price ratio is 0.741 for equation 8.2. Hence, the soybean acreage is expected to increase by 7.41 percent for a 10-percent increase in the soybean-oat ratio. Based on the same equation, the soybean acreage increases by 3.51 percent for a 10-percent increase in the soybean-cotton price ratio. These are relatively high elasticities, as would be expected in regions where emphasis is more on cash crops than on livestock production.

## Minnesota

Minnesota, with 8 percent of the nation's soybean acreage, also is an important soybean state outside the Corn Belt. Regression estimates for Minnesota are presented in table 9. Soybean-oats and soybean-wheat yield ratios generally have significant and positive coefficients in these equations. Supporting this technological effect, the linear time-trend also is significant and positive. Also, the variable for acreage allotments suggests that government programs have contributed to increases in soybean acreage in Minnesota.

**Table 8. Arkansas regression coefficients (with standard errors in parentheses) and $R^2$ values for total planted acres for soybeans ($X_3$), 1929 to 1963. Data used are original values of observations.**

| Equation number | Constant | $X_4$ | $X_5$ | $X_6$ | $X_8$ | $X_9$ | $X_{10}$ | $X_{12}$ | $X_{16}$ | $X_{17}$ | $X_{18}$ | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8.1 ........ | −79.53 | 0.898 | | −0.116 | | | 22.34 | 1.68 | 3,475.24 | 4.49 | 106.19 | 0.983 |
| | (403.72) | (0.074) | | (0.122) | | | (52.09) | (9.38) | (1,707.98) | (10.85) | (32.61) | |
| 8.2 ........ | −292.58 | 0.850 | −0.093 | −0.083 | | 46.62 | 31.07 | | 2,896.79 | 11.79 | 97.84 | 0.983 |
| | (590.62) | (0.100) | (0.198) | (0.148) | | (67.42) | (51.41) | | (1,898.73) | (14.52) | (38.13) | |
| 8.3 ........ | −41.35 | 0.901 | | −0.122 | | | 24.75 | | 3,486.49 | 3.32 | 106.92 | 0.983 |
| | (336.36) | (0.071) | | (0.116) | | | (49.40) | | (1,675.92) | (8.48) | (31.77) | |
| 8.4 ........ | 76.86 | 0.916 | | −0.142 | | | | | 3,474.86 | | 109.65 | 0.983 |
| | (159.86) | (0.064) | | (0.067) | | | | | (1,565.25) | | (28.39) | |
| 8.5 ........ | −410.21 | 0.928 | | | | | 17.27 | 3.96 | 3,814.80 | 12.02 | 92.41 | 0.982 |
| | (206.92) | (0.068) | | | | | (51.74) | (9.05) | (1,667.78) | (7.45) | (29.20) | |
| 8.6 ........ | 755.85 | | −1.240 | −0.547 | −0.421 | 303.81 | 92.02 | 23.43 | | 39.42 | 107.01 | 0.950 |
| | (1,221.57) | | (0.292) | (0.272) | (0.151) | (108.78) | (93.51) | (17.95) | | (26.02) | (63.76) | |
| 8.7 ........ | 637.84 | | −1.198 | −0.525 | −0.360 | 342.45 | 140.35 | | | 37.55 | 110.32 | 0.947 |
| | (1,230.96) | | (0.292) | (0.274) | (0.145) | (105.40) | (86.05) | | | (26.25) | (64.39) | |
| 8.8 ........ | 1,178.20 | | −1.331 | −0.601 | −0.471 | 296.26 | | 29.74 | | 33.68 | 108.20 | 0.948 |
| | (1,143.00) | | (0.278) | (0.266) | (0.142) | (108.44) | | (16.34) | | (25.34) | (63.71) | |
| 8.9 ........ | 1,344.19 | | −1.325 | −0.612 | −0.416 | 351.70 | | | | 25.89 | 114.50 | 0.941 |
| | (1,187.19) | | (0.290) | (0.277) | (0.145) | (108.44) | | | | (26.02) | (66.29) | |
| 8.10 ....... | −2,105.17 | | | | | | 232.56 | 43.03 | 4,568.38 | 97.33 | 140.13 | 0.861 |
| | (454.28) | | | | | | (135.48) | (23.60) | (4,585.02) | (11.03) | (79.74) | |

## Corn Belt Region

The major soybean growing region is the Corn Belt, with over 55 percent of the nation's acreage. Table 10 provides regression equations on planted acres for soybeans.

As for most of the individual states, decreases in the current year's planted acreage for oats, corn and wheat increase the total planted acres for soybeans for the same year. The soybean-corn price ratio is highly significant in the equations and is positively associated with soybean acreage. Also, variable $X_{14}$ is highly significant: An increase in soybean yield relative to corn yield is associated with an increase in total planted acres for soybeans. $X_{17}$, the variable representing the time-trend, again indicates soybean acreage to be growing linearly over the past 3 decades, reflecting technological innovations in general and various improvements in the soybean industry in particular.

Table 9. Minnesota regression coefficients (with standard errors in parentheses) and $R^2$ values for total planted acres for soybeans ($X^3$), 1935 to 1963. Data used are original values of observations.

| Equation number | Constant | $X_4$ | $X_7$ | $X_{11}$ | $X_{13}$ | $X_{15}$ | $X_{17}$ | $X_{18}$ | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|
| 9.1 ... | −707.61 (950.41) | 0.708 (0.130) | −0.118 (0.204) | 116.78 (399.20) | | 565.98 (220.61) | 30.08 (16.60) | 92.85 (48.86) | 0.964 |
| 9.2 ... | −599.71 (440.96) | 0.666 (0.116) | −0.124 (0.154) | | 688.56 (638.08) | 304.44 (282.92) | 32.39 (16.33) | 83.58 (45.08) | 0.965 |
| 9.3 ... | −459.93 (422.99) | 0.691 (0.113) | −0.157 (0.152) | | | 533.80 (187.38) | 29.60 (16.19) | 88.00 (45.05) | 0.964 |
| 9.4 ... | −504.88 (433.52) | 0.650 (0.115) | −0.124 (0.155) | | 1,204.40 (422.56) | | 31.79 (16.38) | 79.17 (45.04) | 0.964 |
| 9.5 ... | −1,184.71 (462.98) | 0.722 (0.125) | | 267.22 (298.07) | | 627.18 (190.68) | 34.82 (14.21) | 100.47 (46.36) | 0.963 |
| 9.6 ... | −898.06 (236.05) | 0.647 (0.112) | | | 790.37 (620.53) | 305.20 (280.72) | 40.08 (13.14) | 85.37 (44.67) | 0.964 |
| 9.7 ... | −804.32 (220.57) | 0.632 (0.112) | | | 1,307.97 (399.50) | | 39.51 (13.18) | 80.95 (44.66) | 0.963 |
| 9.8 ... | −826.08 (232.14) | 0.671 (0.112) | | | | 579.53 (182.37) | 39.20 (13.29) | 91.22 (45.00) | 0.962 |
| 9.9 ... | −1,312.96 (301.01) | | | | 1,582.37 (592.84) | | 108.43 (7.42) | 108.88 (66.35) | 0.913 |
| 9.10 .. | −1,248.95 (346.33) | | | | | 594.14 (282.28) | 112.41 (8.09) | 123.13 (69.18) | 0.905 |

Table 10. Corn Belt regression coefficients (with standard errors in parentheses) and $R^2$ values for total planted acres for soybeans ($X_3$), 1929 to 1963. Data used are original values of observations.

| Equation number | Constant | $X_4$ | $X_6$ | $X_7$ | $X_{10}$ | $X_{13}$ | $X_{14}$ | $X_{17}$ | $X_{18}$ | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 10.1 .... | 3,200.39 (2,078.95) | 0.377 (0.120) | −0.148 (0.048) | −0.335 (0.116) | 1,538.36 (470.60) | | 3,831.98 (1,428.56) | 272.73 (55.99) | 216.30 (141.39) | 9.991 |
| 10.2 .... | 750.00 (1,143.03) | 0.511 (0.125) | −0.146 (0.054) | | 1,854.16 (516.65) | | 2,360.33 (1,506.76) | 214.16 (58.32) | 354.59 (150.19) | 0.988 |
| 10.3 .... | −3,693.46 (1,493.84) | 0.507 (0.139) | | | 1,597.99 (584.16) | 853.32 (888.37) | 1,322.55 (1,892.32) | 210.46 (65.48) | 559.53 (143.58) | 0.986 |
| 10.4 .... | −2,921.99 (997.28) | 0.499 (0.137) | | | 1,422.15 (522.36) | 1,145.80 (776.43) | | 211.73 (64.86) | 531.79 (136.71) | 0.985 |
| 10.5 .... | 3,209.68 (2,395.20) | | −0.143 (0.055) | −0.476 (0.123) | 2,023.50 (512.06) | | 3,954.37 (1,645.27) | 444.55 (13.29) | 119.21 (158.94) | 0.988 |
| 10.6 .... | 4,342.15 (1,844.74) | | −0.164 (0.047) | −0.502 (0.117) | 1,917.65 (488.37) | | 3,828.12 (1,623.80) | 448.15 (12.29) | | 0.988 |
| 10.7 .... | −870.29 (2,631.13) | | −0.139 (0.068) | | 2,838.49 (571.05) | | 1,573.50 (1,886.98) | 449.07 (16.20) | 292.03 (186.66) | 0.981 |
| 10.8 .... | −4,622.75 (1,050.93) | | | | 2,497.90 (513.79) | 826.11 (920.13) | | 442.55 (16.32) | 471.81 (161.87) | 0.978 |

$X_{18}$, the dummy variable representing government programs, is positive and significant at the 5-percent level in most of the functions.

The supply elasticity for soybean acreage with respect to the soybean-corn price ratio, estimated at the mean values, is 0.270 for equation 10.1. For the Corn Belt region, soybean acreage in the current year is predicted to increase by 2.70 percent for each 10-percent increase in the soybean-corn price ratio for the previous year.

## Mississippi Delta Region

This region, second largest in production, had nearly 16 percent of the nation's soybean acreage in 1963. Table 11 includes regression equations for soybean acreage in this region. The value for the d statistic in equation 11.3 is 2.40 and indicates that the residuals are not autocorrelated. The d value for equation 11.5 is 0.91.

The general conclusions for table 11 can be summarized as follows: Among the acreage variables for the current year, $X_6$ and $X_8$, the acreages for corn and cotton enter into the equations when the lagged endogenous variable is not included. Though not significant at the 5-percent level, $X_{10}$ and $X_{12}$, the soybean-corn and the soybean-cotton price ratios, are associated positively with soybean acreage. $X_{16}$, the soybean-cotton yield ratio, is significant at the 5-percent level in the first three equations. Acreage allotments and feed grain programs for corn and cotton have significant effects in increasing soybean acreage. Cotton is the most important competing crop for soybeans in this region.

Supply elasticities with respect to the soybean-corn price ratio are somewhat higher than those for the soybean-cotton price ratio.

## Lake States Region

Table 12 provides regression equations for soybean acreage in the Lake States Region. The current year's soybean acreage is mainly influenced by the previous year's acreage, the previous year's soybean-wheat price

**Table 11.** Mississippi Delta regression coefficients (with standard errors in parentheses) and $R^2$ values for total planted acres for soybeans ($X_3$), 1929 to 1963. Data used are original values of observations.

| Equation number | Constant | $X_4$ | $X_6$ | $X_8$ | $X_{10}$ | $X_{12}$ | $X_{16}$ | $X_{17}$ | $X_{18}$ | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 11.1 ..... | −562.15 (652.46) | 0.853 (0.086) | −0.037 (0.059) | | 42.13 (73.49) | 12.83 (14.07) | 6,879.62 (2,957.59) | 20.13 (16.41) | 183.47 (48.64) | 0.981 |
| 11.2 ..... | −908.05 (338.98) | 0.869 (0.080) | | | 40.19 (72.59) | 16.03 (12.96) | 7,451.21 (2,779.80) | 26.48 (12.84) | 170.63 (43.59) | 0.981 |
| 11.3 ..... | −827.86 (302.65) | 0.884 (0.075) | | | | 17.38 (12.59) | 7,542.74 (2,741.99) | 24.11 (11.95) | 170.30 (43.02) | 0.981 |
| 11.4 ..... | 568.25 (2,057.33) | | −0.280 (0.142) | −0.097 (0.118) | 255.54 (152.86) | 46.57 (31.25) | 3,967.20 (6,527.64) | 72.24 (41.65) | 297.18 (105.49) | 0.913 |
| 11.5 ..... | 1,162.85 (1,788.55) | | −0.312 (0.130) | −0.112 (0.114) | 255.76 (151.07) | 44.55 (30.71) | | 63.75 (38.78) | 278.70 (99.82) | 0.911 |
| 11.6 ..... | −2,975.06 (632.90) | | | | 295.84 (155.29) | 63.66 (27.57) | 8,648.51 (6,286.05) | 146.18 (14.62) | 256.19 (96.95) | 0.899 |

**Table 12.** Lake states regression coefficients (with standard errors in parentheses) and $R^2$ values for total planted acres for soybeans ($X_3$), 1929 to 1963. Data used are original values of observations.

| Equation number | Constant | $X_4$ | $X_5$ | $X_7$ | $X_9$ | $X_{10}$ | $X_{11}$ | $X_{13}$ | $X_{15}$ | $X_{17}$ | $X_{18}$ | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12.1 .... | −1,134.26 (760.91) | 0.769 (0.108) | | −0.128 (0.132) | | | 272.76 (158.79) | | 1,078.36 (435.29) | 28.31 (12.18) | 81.02 (53.19) | 0.966 |
| 12.2 .... | −1,437.89 (553.89) | 0.783 (0.111) | | | | 235.02 (119.14) | | | 1,001.26 (448.31) | 26.36 (12.28) | 101.12 (50.91) | 0.962 |
| 12.3 .... | −1,666.61 (523.19) | 0.788 (0.106) | | | | | 352.05 (135.69) | | 1,147.50 (428.82) | 30.18 (12.01) | 101.51 (48.70) | 0.965 |
| 12.4 .... | −1,132.09 (1,294.46) | | −0.088 (0.072) | −0.192 (0.193) | 210.62 (95.35) | | | 2,162.82 (1,058.14) | | 103.14 (8.77) | 26.89 (84.97) | 0.923 |
| 12.5 .... | −999.86 (1,205.85) | | −0.099 (0.064) | −0.209 (0.182) | 207.58 (93.33) | | | 2,223.02 (1,024.17) | | 103.60 (12.17) | | 0.922 |
| 12.6 .... | −2,735.05 (651.16) | | | | 271.06 (79.09) | | | 2,236.47 (1,025.69) | | 108.16 (7.45) | 89.52 (73.76) | 0.916 |

ratio, and the previous year's soybean-wheat yield ratio; the linear time-trend; and the presence or absence of government programs. These variables all have high positive correlations with the soybean acreage, and the best regression equations account for around 96 percent of total acreage variance. Estimated at the mean values, the supply elasticities indicate that soybean acreage increases around 4 percent for each 10-percent rise in the soybean-oat price ratio.

### All Other Regions

The remaining five census regions, "all other regions," of the United States account for only 19 percent of the nation's total planted acres for soybeans. Individually, the Appalachian, Southeast, Southern Plains, Northern Plains and Northeast account for approximately 7, 4, 1, 5 and 2 percent, respectively. These regions are relatively unimportant for individual study of soybean acreage response. Tables 13 and 14 provide, for these five regions, regression equations for soybean acreage.

Increases in the soybean-corn price ratio and the soybean-corn yield ratio especially cause expansion in bean acreage for the five regions. Government programs also are important in influencing soybean acreage.

Generally, corn and wheat compete with soybeans in the Appalachian region. The previous year's soybean-wheat price ratio is highly and positively correlated with the present year's soybean acreage. When $X_4$ is omitted from the equation for the Southeast region, the soybean-corn price ratio enters significantly into the equations. The variable representing the government programs is positive and significant at the 5-percent level in all the equations. For the Southern Plains, decreases in the acreage of oats, corn, wheat and cotton are associated with increases in soybean acreage. Changes in the soybean-corn price ratio significantly affect soybean acreage, as does change in the soybean-cotton yield ratio acreage.

### National Response Estimates

Aggregate acreage-response functions show generally the same significant explanatory variables to be important for the nation as for the individual regions and states. However, the confidence limits on prediction of the acreage-response functions are smaller for the national aggregates. The value of $R^2$ and t is almost universally larger than for parallel coefficients for regions and states.

Table 15 provides regression equations for soybean acreage. Equation 15.1 accounts for more than 99 percent of total variance in national acreage. Equa-

**Table 13. Northern Plains and Northeast regional regression coefficients (with standard errors in parentheses and $R^2$ values for total planted acres for soybeans ($X_3$), 1929 to 1963. Data used are original values of observations.**

| Equation number | Region | Constant | $X_4$ | $X_6$ | $X_7$ | $X_{10}$ | $X_{11}$ | $X_{13}$ | $X_{14}$ | $X_{17}$ | $X_{18}$ | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13.1 | Northern Plains .... | −748.72 | 0.509 | | | 144.71 | 86.20 | | 180.60 | 27.81 | 44.51 | 0.957 |
| | | (230.63) | (0.144) | | | (84.22) | (91.68) | | (96.30) | (7.76) | (23.12) | |
| 13.2 | .......... | −661.09 | 0.536 | | | 186.65 | | | 175.90 | 25.00 | 40.82 | 0.955 |
| | | (210.51) | (0.141) | | | (71.29) | | | (95.97) | (7.14) | (22.74) | |
| 13.3 | .......... | −888.86 | | | −0.008 | 235.22 | 111.41 | | 173.15 | 52.01 | 21.63 | 0.943 |
| | | (292.94) | | | (0.005) | (92.48) | (105.93) | | (111.81) | (3.62) | (29.50) | |
| 13.4 | .......... | −813.21 | | | −0.010 | 239.16 | 92.22 | | 174.74 | 52.41 | | 0.942 |
| | | (271.90) | | | (0.004) | (91.55) | (101.80) | | (110.86) | (3.55) | | |
| 13.5 | .......... | −1,216.94 | | | | 233.93 | 148.81 | | 199.82 | 52.90 | 42.89 | 0.937 |
| | | (223.98) | | | | (95.37) | (106.78) | | (114.12) | (3.69) | (27.44) | |
| 13.6 | .......... | −1,103.03 | | | | 317.39 | | | 193.17 | 50.17 | 36.13 | 0.932 |
| | | (211.90) | | | | (75.42) | | | (115.88) | (3.18) | (27.45) | |
| 13.7 | Northeast | 124.14 | 0.431 | −0.034 | −0.111 | 35.76 | | | 327.72 | 5.60 | 8.86 | 0.987 |
| | | (166.93) | (0.106) | (0.045) | (0.032) | (18.87) | | | (135.16) | (1.27) | (5.89) | |
| 13.8 | .......... | 19.60 | 0.451 | | −0.111 | 39.05 | | | 327.30 | 5.46 | 9.67 | 0.987 |
| | | (95.16) | (0.101) | | (0.032) | (18.24) | | | (134.11) | (1.25) | (5.75) | |
| 13.9 | .......... | −221.49 | 0.711 | | | 52.40 | | | 331.06 | 4.11 | 17.96 | 0.981 |
| | | (77.39) | (0.082) | | | (21.09) | | | (158.62) | (1.41) | (6.19) | |
| 13.10 | ......... | 421.18 | | −0.075 | −0.204 | 43.47 | | 123.52 | 116.25 | 10.01 | 6.28 | 0.982 |
| | | (179.21) | | (0.052) | (0.027) | (22.87) | | (66.32) | (189.88) | (0.87) | (7.03) | |
| 13.11 | ......... | 443.36 | | −0.073 | −0.204 | 39.57 | | 144.66 | | 10.10 | 8.06 | 0.981 |
| | | (169.82) | | (0.051) | (0.027) | (21.71) | | (55.97) | | (0.84) | (6.32) | |
| 13.12 | ......... | −343.27 | | | | 122.53 | | 133.19 | | 15.54 | 33.47 | 0.932 |
| | | (89.39) | | | | (34.59) | | (102.55) | | (1.00) | (10.16) | |

**Table 14.** Appalachian, Southeast and Southern Plains regional regression coefficients (with standard errors in parentheses) and $R^2$ values for total planted acres for soybeans ($X_3$), 1929 to 1963. Data used are original values of observations.

| Equation number | Region | Constant | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ | $X_{10}$ | $X_{11}$ | $X_{15}$ | $X_{16}$ | $X_{17}$ | $X_{18}$ | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 14.1 | Appalachian | −66.06 | 0.368 | −0.210 | | −0.064 | | 115.37 | 194.68 | 112.38 | | 23.49 | 46.66 | 0.983 |
| | | (405.83) | (0.134) | (0.073) | | (0.056) | | (79.73) | (104.30) | (133.16) | | (5.56) | (9.95) | |
| 14.2 | ............ | 364.34 | 0.332 | −0.258 | | −0.113 | | | 213.18 | | | 23.82 | 45.13 | 0.982 |
| | | (189.02) | (0.126) | (0.059) | | (0.043) | | | (95.23) | | | (5.43) | (9.28) | |
| 14.3 | ............ | −707.66 | 0.661 | | | | | 185.94 | 149.27 | 314.01 | | 11.88 | 48.38 | 0.977 |
| | | (228.24) | (0.099) | | | | | (71.91) | (113.22) | (115.95] | | (4.14) | (10.83) | |
| 14.4 | ............ | 314.13 | | −0.358 | | −0.120 | | 83.44 | 280.22 | | | 37.55 | 48.53 | 0.978 |
| | | (244.01) | | (0.045) | | (0.051) | | (76.18) | (101.42) | | | (2.36) | (10.06) | |
| 14.5 | ............ | 462.11 | | −0.371 | | −0.145 | | | 321.70 | | | 36.99 | 49.95 | 0.977 |
| | | (203.91) | | (0.044) | | (0.045) | | | (94.42) | | | (2.31) | (10.01) | |
| 14.6 | ............ | −1,179.82 | | | | | | 288.24 | 379.52 | 441.55 | | 37.64 | 62.09 | 0.940 |
| | | (347.29) | | | | | | (112.44) | (172.59) | (183.01) | | (2.41) | (17.02) | |
| 14.7 | Southeast .. | 314.36 | 0.749 | −0.069 | −0.022 | | | | | | | 4.51 | 26.22 | 0.988 |
| | | (127.68) | (0.101) | (0.027) | (0.011) | | | | | | | (2.21) | (8.16) | |
| 14.8 | ............ | −14.23 | 1.007 | | | | | | | | | 1.56 | 16.48 | 0.984 |
| | | (15.44) | (0.058) | | | | | | | | | (1.59) | (7.95) | |
| 14.9 | ............ | 946.10 | | −0.206 | −0.072 | | | 18.53 | | | | 16.04 | 48.26 | 0.966 |
| | | (172.93) | | (0.033) | (0.015) | | | (29.05) | | | | (3.09) | (13.78) | |
| 14. 10 | ........... | −343.86 | | | | | | 74.42 | | | | 29.32 | 23.45 | 0.838 |
| | | (171.91) | | | | | | (58.61) | | | | (7.59) | (27.92) | |
| 14.11 | Souhtern Plains ..... | 120.44 | 0.589 | −0.025 | −0.010 | −0.005 | −0.004 | 34.35 | | | 930.07 | | 3.43 | 0.949 |
| | | (76.94) | (0.094) | (0.011) | (0.003) | (0.003) | (0.002) | (9.94) | | | (347.85) | | (3.78) | |
| 14.12 | ........... | −154.23 | 0.639 | | | | | 27.76 | | | 1,091.32 | 3.40 | 4.58 | 0.938 |
| | | (28.58) | (0.088) | | | | | (9.76) | | | (296.83) | (0.92) | (3.25) | |
| 14.13 | ........... | 131.18 | | 0.043 | −0.007 | −0.013 | | 52.04 | | | 503.87 | 5.48 | | 0.877 |
| | | (151.90) | | (0.015) | (0.009) | (0.004) | | (13.19) | | | (465.78) | (2.38) | | |
| 14.14 | ........... | −266.26 | | | | | | 55.46 | | | 1,388.44 | 7.94 | 3.68 | 0.821 |
| | | (40.29) | | | | | | (15.03) | | | (491.68) | (1.13) | (5.43) | |

tion 15.1 containing variable $X_4$ and equation 15.7 not containing it, have values for the d statistic of 2.84 and 2.06, respectively. Autocorrelation is not significant at the 5-percent level in either case.

The general conclusions for table 15 can be stated as follows: Nationally, decreases in the acreages of oats, corn, wheat and cotton are associated with increases in soybean acreage. However, the relative importance of these cash crops with respect to increases in soybean acreage depends on the set of variables included in a specific function. Generally speaking, a given decrease in acreage of oats, corn or wheat is associated with a larger increase in soybean acreage than the same reduction in cotton acreage. An increase in a given year's soybean-corn price ratio is expected to increase significantly the planted soybean acreage for the next year. Also, a positive relation exists between the soybean-corn yield ratio and soybean-planted acreage. The time-trend, reflecting unspecified technical improvements, is significant at the 1-percent level in most of the functions. The dummy variable, representing government programs, is generally significant at the 1-percent level.

The estimated national supply elasticities for soybean acreage with respect to the soybean-corn price ratios, based on regression equation 15.1, is 0.337. The soybean acreage in the nation is predicted to increase by 3.37 percent for a 10-percent increase in the soybean-corn price ratio. The elasticities are somewhat higher than for the major producing states and regions because land in the marginal regions shifts to and from soybeans more readily as prices and government programs change.

## Acreage Response Based on Logarithmic Transformations

Acreage-response functions also were estimated with all variables, except $X_{18}$, and transferred to logarithms. This dummy variable for government programs was kept in original observations since it took zero values in some years. The power functions were estimated only for three important soybean growing states (Illinois, Iowa and Indiana), two regions (the Corn Belt and Mississippi Delta) and the nation.

Statistics for the two regions and the United States only are presented in table 16 for acreage response functions. The transformation to logarithms did not improve the statistical fit for the regional response functions and for those relating to Indiana. The elasticities of soybean acreage with respect to soybean-crop price ratios generally were higher when derived from the functions with logarithmic transformations.

For national functions also (table 16), the logarithmic transformation does not improve the regression equations over those with measurement in original observations. There are two main variations between the national functions based on original observations and on logarithmic transformations. First, the oat acreage, which is negatively related to the soybean acreage in the functions based on original observations, has little or no influence in the functions based on logarithmic values. (The oat acreage variable is not shown in the national functions in table 16.) Second, the soybean-oat yield ratio does not have any positive relation with the soybean acreage in the functions based on original observations. However, the soybean-oat yield ratio does

**Table 15. United States regression coefficients (with standard errors in parentheses) and $R^2$ values for total planted acres for soybeans ($X_3$), 1929 to 1963. Data used are original values of observations.**

| Equation number | Constant | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ | $X_{10}$ | $X_{14}$ | $X_{17}$ | $X_{18}$ | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 15.1 .. | −332.52<br>(4,575.32) | 0.414<br>(0.134) | | −0.035<br>(0.037) | −0.074<br>(0.028) | | 2,679.10<br>(786.00) | 3,792.64<br>(2,144.40) | 444.22<br>(124.49) | 405.53<br>(145.12) | 0.992 |
| 15.2 .. | −609.89<br>(5,036.13) | 0.533<br>(0.115) | | −0.061<br>(0.039) | | | 2,253.06<br>(846.27) | 3,862.26<br>(2,360.82) | 246.66<br>(108.38) | 592.56<br>(138.64) | 0.990 |
| 15.3 .. | 3,515.15<br>(4,486.81) | 0.628<br>(0.119) | | −0.063<br>(0.040) | | | 1,510.54<br>(735.13) | | 222.77<br>(110.53) | 561.72<br>(141.36) | 0.989 |
| 15.4 .. | −3,807.70<br>(2,726.69) | 0.366<br>(0.124) | | | −0.081<br>(0.027) | | 2,768.16<br>(778.75) | 3,846.23<br>(2,139.25) | 513.26<br>(100.70) | 423.32<br>(143.60) | 0.992 |
| 15.5 .. | −7,129.74<br>(2,796.09) | 0.583<br>(0.114) | | | | | 2,341.05<br>(865.46) | 3,976.86<br>(2,418.55) | 339.80<br>(92.75) | 661.30<br>(134.74) | 0.989 |
| 15.6 .. | −2,560.89<br>(3.400.91) | | −0.029<br>(0.044) | | −0.127<br>(0.028) | | 3,793.35<br>(789.95) | 3,520.81<br>(2,438.66) | 796.98<br>(27.09) | 316.17<br>(158.02) | 0.990 |
| 15.7 .. | −3,479.16<br>(3,075.22) | | | | −0.129<br>(0.025) | | 3,821.12<br>(780.91) | 3,579.87<br>(2,412.56) | 802.16<br>(25.68) | 307.44<br>(155.89) | 0.989 |
| 15.8 .. | −6,254.80<br>(4,238.55) | | −0.107<br>(0.052) | | | | 4,094.72<br>(1,012.18) | 3,311.36<br>(3,135.97) | 778.73<br>(34.43) | 662.79<br>(176.13) | 0.982 |
| 15.9 .. | −4,987.25<br>(4,642.36) | | −0.110<br>(0.052) | | | −0.040<br>(0.057) | 4,263.74<br>(1,049.41) | 3,305.45<br>(3,164.72) | 753.16<br>(50.32) | 617.72<br>(188.97) | 0.982 |
| 15.10 . | −11,257.59<br>(3,670.32) | | | | | | 4,296.48<br>(1,062.77) | 3,514.15<br>(3,306.49) | 796.54<br>(35.17) | 716.79<br>(183.74) | 0.979 |

Table 16. Selected regional and United States regression coefficients (with standard errors in parentheses), $R^2$ and Durbin-Watson d values for total planted acres for soybeans ($X_3$), 1929 to 1963. Data used are logarithms of observations, except for the dummy variable ($X_{18}$).

| Equation number Region | Constant | $X_4$ | $X_6$ | $X_{10}$ | $X_{12}$ | $X_{13}$ | $X_{14}$ | $X_{16}$ | $X_{17}$ | $X_{18}$ | $R^2$ | d |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 16.1 Corn Belt ...... | 4.490 | 0.647 | –0.763 | 0.539 | | 0.348 | 0.240 | | 0.293 | 0.028 | 0.990 | 2.23 |
| | (1,419) | (0.097) | (0.322) | (0.166) | | (0.098) | (0.164) | | (0.109) | (0.011) | | |
| 16.2 ................ | 1,178 | 0.592 | | 0.534 | | 0.406 | 0.200 | | 0.354 | 0.041 | 0.988 | |
| | (0.235) | (0.102) | | (0.180) | | (0.103) | (0.176) | | (0.114) | (0.011) | | |
| 16.3 ................ | 3.429 | | –0.207 | 1.056 | | 0.403 | | | 0.991 | 0.035 | 0.973 | 1.27 |
| | (2.249) | | (0.499) | (0.171) | | (0.146) | | | (0.039) | (0.018) | | |
| 16.4 ................ | 2.497 | | | 1.045 | | 0.417 | | | 0.992 | 0.038 | 0.973 | |
| | (0.054) | | | (0.166) | | (0.140) | | | (0.038) | (0.015) | | |
| 16.5 Mississipi Delta... | 0.931 | 0.673 | –0.101 | 0.155 | 0.209 | | | 0.240 | 0.402 | 0.063 | 0.977 | 1.96 |
| | (0.648) | (0.120) | (0.120) | (0.162) | (0.207) | | | (0.148) | (0.115) | (0.018) | | |
| 16.6 ................ | 0.465 | 0.739 | | 0.189 | 0.204 | | | 0.285 | 0.374 | 0.061 | 0.977 | |
| | (0.330) | (0.091) | | (0.155) | (0.205) | | | (0.137) | (0.110) | (0.018) | | |
| 16.7 ................ | 3.896 | | –0.543 | | | | | | 0.835 | 0.096 | 0.949 | 0.99 |
| | (0.473) | | (0.116) | | | | | | (0.072) | (0.022) | | |
| 16.8 ................ | 1.700 | | | | | | | | 1.037 | 0.102 | 0.912 | |
| | (0.079) | | | | | | | | (0.074) | (0.028) | | |
| 16.9 United States .... | 3.336 | 0.766 | –0.510 | 0.548 | | 0.289 | 0.406 | | 0.135 | 0.025 | 0.993 | 2.21 |
| | (1.356) | (0.096) | (0.267) | (0.160) | | (0.154) | (0.172) | | (0.114) | (0.006) | | |
| 16.10 ................ | 0.783 | 0.758 | | 0.543 | | 0.343 | 0.271 | | 0.179 | 0.029 | 0.992 | |
| | (0.234) | (0.100) | | (0.168) | | (0.158) | (0.165) | | (0.117) | (0.006) | | |
| 16.11 ................ | 2.550 | | | 1.128 | | | | | 0.999 | 0.031 | 0.973 | 1.73 |
| | (0.052) | | | (0.168) | | | | | (0.038) | (0.010) | | |

have significant positive correlation with the soybean acreage in the functions of table 16. All other variables appear with relevant signs in the functions.

As with the previous functions, these conclusions are relevant for the equations in logarithmic form: The soybean-corn price ratio has a highly significant and positive effect on soybean acreage. The soybean-oat and soybean-corn yield ratios also are highly significant and positively associated with increases in soybean acreage. Variables for the time-trend and the government programs are significant at the 1-percent level. Acreage allotments and feed grain programs, which are intended to lower the acreages of corn, wheat and cotton, have a significant influence in increasing soybean acreage.

## PRODUCTION RESPONSE

We now present supply or response functions for soybean production. These response functions have been estimated for important soybean states and regions and for the nation. They also have been estimated with measurements in original and logarithmic form. The supply relationships estimated include soybean production lagged by 1 year, the price ratio of soybeans to competing crops, some important weather variables, a fertilizer-price index, a time-trend variable and a dummy variable for government programs. The estimates again are based on data for 1929 through 1963, except for Minnesota. The data for Minnesota cover 1935 through 1963.

### Variables Used

Variables used in the analyses of soybean production are:

$X_1$: Soybean production for the current year (year t), in thousands of bushels.

$X_2$: Soybean production for the previous year (year t – 1), in thousands of bushels.

$X_3$: Price ratio of soybeans to oats for the previous crop year.

$X_4$: Price ratio for soybeans to corn for the previous crop year.

$X_5$: Price ratio of soybeans to wheat for the previous crop year.

$X_6$: Price ratio of soybeans to cotton for the previous crop year.

In deriving these price ratios, the higher of (a) price of the crop for the previous crop year or (b) the government-support price (if available) for the current year is used for each of the four crops. The prices of soybeans, oats, corn and wheat are in dollars per bushel, and the price of cotton is in dollars per pound.

$X_7$: July precipitation, in inches for the current year.

$X_8$: Square of July precipitation for the current year.

$X_9$: August average temperature of °F. for the current year.

$X_{10}$: Square of August average temperature for the current year.

$X_{11}$: National index of average fertilizer price paid by farmers for the current year (on base year 1910 – 14 = 100).

$X_{12}$: Time-trend, 1930 = 1, 1931 = 2, . . . , for the states, (except Minnesota), regions and the nation. For Minnesota the variable takes values as 1935 = 1, 1936 = 2, . . . , etc.

$X_{13}$: Dummy variable representing the coded form of acreage allotments and feed-grain programs. This variable can take a value of 0, 1, 2 or 3 for a given year, depending on the presence or absence of the government programs for corn, wheat and cotton.

The soybean production responses are presented in two main categories. The first set of equations contains $X_2$, the lagged endogenous variable (soybean production lagged by 1 year), as an independent variable. The second set of equations does not contain $X_2$. Supply equations representing both categories are provided for the states, regions and nation. Under each category, a supply relations is presented that does not contain any weather variable and fertilizer index. A few other interesting supply relations are included in these categories.

Again, in presenting these relations, the variables whose coefficients have unexpected signs are generally omitted. For example, we expect that the soybean-corn price ratio must have a positive sign. If this price ratio has a negative coefficient, a new relation omitting this variable is estimated and presented. Functions with standard errors that are large compared with the absolute values of their coefficients are not presented. A few Durbin-Watson d statistics are computed for testing serial correlation of the residuals.

### State Supply Functions

The supply functions for soybean production are presented in table 17 for the states of the Corn Belt, Arkansas and Minnesota. In all states studied, $X_2$, soybean production lagged by 1 year, is positively related to soybean output for the given year. However, omitting $X_2$ does not reduce the value of $R^2$ importantly for the functions of Ohio, Indiana, Illinois and Iowa, but it does for Missouri, Arkansas and Minnesota. For Ohio, Indiana, Illinois and Iowa, an increase in soybean output for a given year is associated with an increase in soybean-corn price ratio for the previous year. For Missouri and Arkansas, the soybean-oat and soybean-corn price ratios are positively related to soybean production. The supply functions for Minnesota soybean production do not contain any price ratio. July rainfall is positively associated with an increase in soybean production in all the states except Minnesota. A decrease

**Table 17. State regression coefficients (with standard errors in parentheses) and $R^2$ values for soybean production ($X_1$), 1929 to 1963. Data used are original values of observations.**

| Equation number | State | Constant | $X_2$ | $X_4$ | $X_7$ | $X_{11}$ | $X_{12}$ | $X_{13}$ | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|
| 17.1 | Ohio ... | –10,714.22 | 0.432 | 6,244.16 | 933.78 | –52.27 | 763.34 | 1,892.46 | 0.977 |
| | | (4,359.92) | (0.130) | (2,198.77) | (377.89) | (50.99) | (257.37) | (563.28) | |
| 17.2 | ......... | –13,280.58 | 0.503 | 4,953.80 | 979.75 | | 550.07 | 2,093.81 | 0.976 |
| | | (3,572.83) | (0.110) | (1,804.50) | (375.56) | | (151.66) | (528.41) | |
| 17.3 | ......... | –10,416.55 | 0.474 | 5,031.09 | | | 600.96 | 2,508.28 | 0.970 |
| | | (3,724.70) | (0.120) | (1,976.58) | | | (164.76) | (552.09) | |
| 17.4 | ......... | –11,705.77 | | 11,017.86 | 750.16 | –142.06 | 1,531.71 | 1,763.32 | 0.967 |
| | | (5,063.32) | | (1,931.20) | (435.12) | (50.25) | (129.05) | (654.13) | |
| 17.5 | ......... | –22,057.77 | | 9,110.67 | 809.64 | | 1,203.58 | 2,446.04 | 0.958 |
| | | (3,895.75) | | (2,015.92) | (484.18) | | (62.86) | (677.25) | |
| 17.6 | ......... | –19,248.76 | | 8,976.98 | | | 1,214.89 | 2,775.19 | 0.954 |
| | | (3,618.66) | | (2,073.76) | | | (64.33) | (677.13) | |
| 17.7 | Indiana . | –17,627.09 | 0.488 | 6,915.11 | 1,234.84 | | 1,031.07 | 918.24 | 0.985 |
| | | (5,172.52) | (0.127) | (2,661.12) | (521.07) | | (277.89) | (676.88) | |
| 17.8 | ......... | –12,864.64 | 0.533 | 5,941.59 | | | 1,005.73 | 1,393.26 | 0.982 |
| | | (5,131.44) | (0.135) | (2,830.71) | | | (298.97) | (696.06) | |
| 17.9 | ......... | –30,567.80 | | 11,960.19 | 1,532.22 | | 2,059.37 | 771.12 | 0.977 |
| | | (4,754.14) | | (2,805.96) | (625.14) | | (87.80) | (819.91) | |
| 17.10 | ........ | –26,036.40 | | 11,314.29 | | | 2,147.37 | 1,356.72 | 0.973 |
| | | (4,731.37) | | (3,017.72) | | | (86.55) | (847.26) | |
| 18.1 | Illinois . | –11,069.10 | 0.351 | 14,532.14 | 4,169.64 | –241.99 | 3,014.64 | 1,760.17 | 0.981 |
| | | (12,554.11) | (0.147) | (5,995.80) | (1,113.51) | (143.99) | (836.13) | (1,801.38) | |
| 18.2 | ......... | –25,636.40 | 0.444 | 10,030.77 | 3,756.21 | | 2,100.98 | 3,224.23 | 0.979 |
| | | (9,373.34) | (0.141) | (5,536.86) | (1,120.94) | | (655.70) | (1,627.46) | |
| 18.3 | ......... | –14,703.66 | 0.408 | 7,523.09 | | | 2,531.35 | 4,581.76 | 0.970 |
| | | (10,219.86) | (0.163) | (6,380.50) | | | (747.84) | (1,833.22) | |
| 18.4 | ......... | –12,093.02 | | 21,322.14 | 4,206.88 | –371 52 | 4,850.58 | 922.13 | 0.977 |
| | | (13,559.34) | | (5,703.98) | (1,203.26) | (144.14) | (354.32) | (1,909.42) | |
| 18.5 | ......... | –9,737.06 | | 21,538.62 | 4,394.48 | –402.95 | 4,941.84 | | 0.976 |
| | | (12,482.68) | | (5,610.57) | (1,123.66) | (126.90) | (295.73) | | |
| 18.6 | ......... | –38,646.33 | | 16,491.35 | 3,494.81 | | 4,087.42 | 3,143.88 | 0.971 |
| | | (9,635.69) | | (5,888.09) | (1,278.98) | | (212.71) | (1,862.17) | |
| 18.7 | ......... | –27,456.36 | | 13,660.92 | | | 4,338.32 | 4,415.89 | 0.964 |
| | | (9,604.68) | | (6,386.18) | | | (211.28) | (1,986.25) | |
| 18.8 | Iowa .... | –18,089.98 | 0.313 | 16,960.09 | 1,498.03 | –251.96 | 2,278.36 | 6,419.63 | 0.949 |
| | | (12,845.94) | (0.179) | (5,891.11) | (1,199.28) | (155.42) | (704.23) | (3,498.68) | |
| 18.9 | ......... | –30,915.10 | 0.456 | 11,663.41 | 1,367.48 | | 1,357.39 | 8,654.01 | 0.944 |
| | | (10,410.95) | (0.160) | (5,042.57) | (1,230.87) | | (428.10) | (3,307.93) | |
| 18.10 | ........ | –26,850.28 | 0.506 | 11,539.03 | | | 1,281.11 | 10,332.91 | 0.941 |
| | | (9,786.12) | (0.154) | (5,061.63) | | | (424.26) | (2,954.43) | |
| 18.11 | ........ | –20,663.62 | | 22,958.86 | 2,084.60 | –386.26 | 3,360.48 | 4,510.93 | 0.943 |
| | | (13,224.08) | | (4,966.40) | (1,193.29) | (140.08) | (349.99) | (3,455.06) | |
| 18.12 | ........ | –49,034.82 | | 17,778.62 | 2,363.02 | | 2,495.90 | 7,271.89 | 0.927 |
| | | (9,204.41) | | (5,093.93) | (1,317.43) | | (172.30) | (3,652.38) | |
| 18.13 | ........ | –45,159.67 | | 18,815.06 | | | 2,589.05 | 10,139.82 | 0.919 |
| | | (9,272.00) | | (5,244.74) | | | (170.25) | (3,402.97) | |

**Table 17. Cont'd.**

| Equation number State | Constant | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_7$ | $X_{11}$ | $X_{12}$ | $X_{13}$ | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 19.1 Missouri . . . | −20,555.99 | 0.763 | 1,695.58 | 3,672.24 | | 1,931.65 | | 453.11 | 436.06 | 0.979 |
| | (9,484.77) | (0.100) | (2,098.66) | (3,386.99) | | (390.62) | | (227.13) | (875.16) | |
| 19.2 . . . . . . . . . . . . | −22,705.13 | 0.749 | 2,305.72 | 3,582.93 | | 1,940.19 | | 506.68 | | 0.979 |
| | (8,333.53) | (0.095) | (1,681.44) | (3,336.72) | | (384.99) | | (197.39) | | |
| 19.3 . . . . . . . . . . . . | −13,178.72 | 0.767 | 2,632.13 | | | | | 610.10 | | 0.959 |
| | (8,367.84) | (0.108) | (2,175.18) | | | | | (222.28) | | |
| 19.4 . . . . . . . . . . . . | −66,410.98 | | 5,339.81 | 16,066.92 | | 2,099.48 | | 2,055.66 | −1,448.48 | 0.933 |
| | (12,780.87) | | (3,562.10) | (5,178.88) | | (679.83) | | (149.67) | (1,463.39) | |
| 19.5 . . . . . . . . . . . . | −61,710.45 | | 3,380.28 | 17,215.90 | | 2,079.82 | | 1,969.16 | | 0.931 |
| | (11,861.69) | | (2,960.26) | (5,045.35) | | (679.30) | | (121.47) | | |
| 19.6 . . . . . . . . . . . . | −52,298.65 | | 3,796.63 | 13,539.23 | | | | 2,118.00 | | 0.909 |
| | (12,957.08) | | (3,344.48) | (5,542.24) | | | | (125.90) | | |
| 19.7 Arkansas . . . | −13,611.34 | 0.807 | 2,444.91 | | | 409.50 | | 416.25 | 1,304.21 | 0.958 |
| | (6,741.61) | (0.088) | (1,609.44) | | | (493.68) | | (190.36) | (878.62) | |
| 19.8 . . . . . . . . . . . . | −12,712.51 | 0.812 | 2,583.04 | | | | | 428.15 | 1,259.85 | 0.957 |
| | (6,618.08) | (0.087) | (1,592.17) | | | | | (188.80) | (872.26) | |
| 19.9 . . . . . . . . . . . . | −46,259.08 | | 10,073.29 | 7,132.01 | | 1,107.89 | −257.61 | 2,614.96 | | 0.884 |
| | (13,493.83) | | (2,275.54) | (2,615.95) | | (855.80) | (111.27) | (286.55) | | |
| 19.10 . . . . . . . . . . . | −68,393.43 | | 9,442.78 | 7,023.57 | | 1,322.63 | | 2,050.40 | | 0.862 |
| | (10,213.65) | | (2,423.08) | (2,805.28) | | (912.48) | | (161.42) | | |
| 19.11 . . . . . . . . . . . | −64,409.29 | | 10,200.99 | 5,928.88 | | | | 2,090.58 | | 0.852 |
| | (10,015.73) | | (2,408.97) | (2,750.84) | | | | (161.91) | | |
| 19.12 Minnesota 1935-1963 . | −4,689.76 | 0.628 | | | 969.32 | −697.21 | | 925.78 | 1,488.76 | 0.943 |
| | (9,035.25) | (0.165) | | | (7,771.23) | (984.19) | | (368.80) | (1,200.46) | |
| 19.13 . . . . . . . . . . . | −5,392.00 | 0.624 | | | | | | 885.61 | 1,510.26 | 0.941 |
| | (2,894.72) | (0.139) | | | | | | (320.17) | (1,152.73) | |
| 19.14 . . . . . . . . . . . | −14,085.49 | | | | | | | 2,212.21 | 2,753.08 | 0.894 |
| | (2,845.95) | | | | | | | (165.36) | (1,476.86) | |

in fertilizer price is significantly related to an increase in soybean production in Ohio, Illinos, Iowa and Arkansas. In all states considered, the linear time-trend is significant at least at the 5-percent level for most of the functions. The presence of acreage allotments and feed-grain programs for competing crops has a positive influence on soybean production in all states except Missouri.

Generally, the regression models account for 85 to 90 percent of the total variation in soybean production. Figs. 1 and 2 compare actual and predicted soybean production, with predictions based on equations 18.5 and 18.11 for Illinois and Iowa, respectively.

Supply elasticities for soybean output with respect to the soybean-corn price ratio show that, when the selected regressions do not contain the lagged soybean output variable, the corresponding elasticities are very high for Missouri, Iowa and Ohio. They are lowest for Illinois. These supply elasticities are greater than unity for Missouri and Iowa. The elasticities with respect to the soybean-oat price ratio are very high for Arkansas and Missouri. In general, the supply elasticities for soybean production are higher than those for soybean acreage. This difference probably arises because of the inclusion of the fertilizer variable in equations for production.

### Supply Response for Regions

Supply functions for the main regions are presented in table 18. Fig. 3 compares actual and predicted soybean production for the Corn Belt. Many of the functions have $R^2$ values greater than 0.95, and most equations have significant explanatory variables.

The models having the variable of lagged soybean production for all eight soybean-growing regions indicate that the output for a given year is strongly influenced in the positive direction by the soybean output of the previous year. Removing $X_2$, the lagged endogenous variable, from the relations, however, does not lower the value of $R^2$ importantly for the Corn Belt region, although it does for all other regions. Among price ratios, only the price ratio of soybean to corn influences regional soybean production, with the exception of the Mississippi Delta region. In the Mississippi Delta region, increases in both the soybean-corn price ratio and the soybean-oat price ratio are related to increases in soybean output.

The analyses for all regions, except the Lake States and Southern Plains, indicate that an increase over the normal July rainfall increases soybean production. Except for the Corn Belt, the variable for the fertilizer price index also enters into the equations when $X_2$, the soybean production lagged by 1 year, is excluded. In the Corn Belt region, both $X_2$ (lagged output) and $X_{11}$ (fertilizer price index) enter into the same equation with the expected signs. A fall in the fertilizer price is predicted to increase soybean production.

The supply elasticities for soybean production with respect to the soybean-corn price ratio are highest for the Mississippi Delta region. Elasticities with respect to

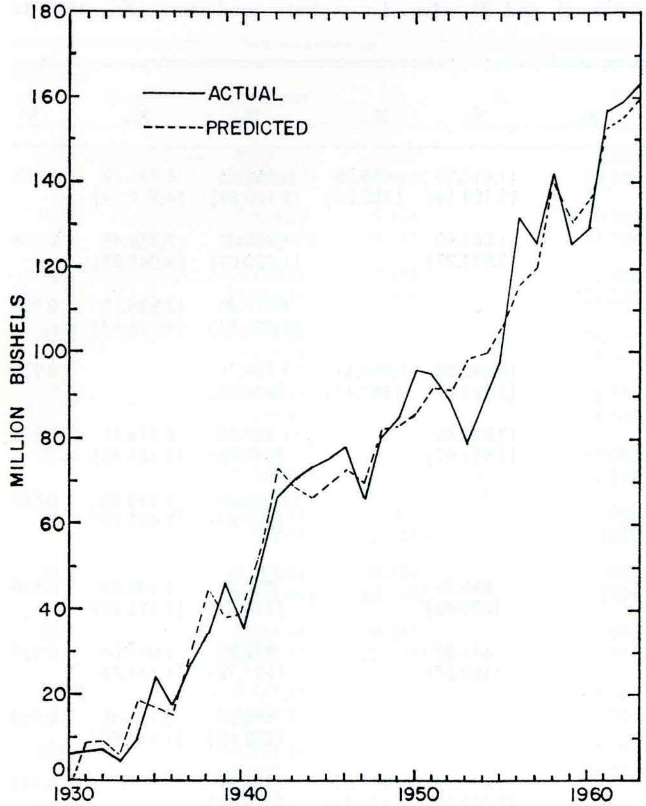


Fig. 1. Soybean production in Illinois: actual observations and predicted values from equation 18.5.

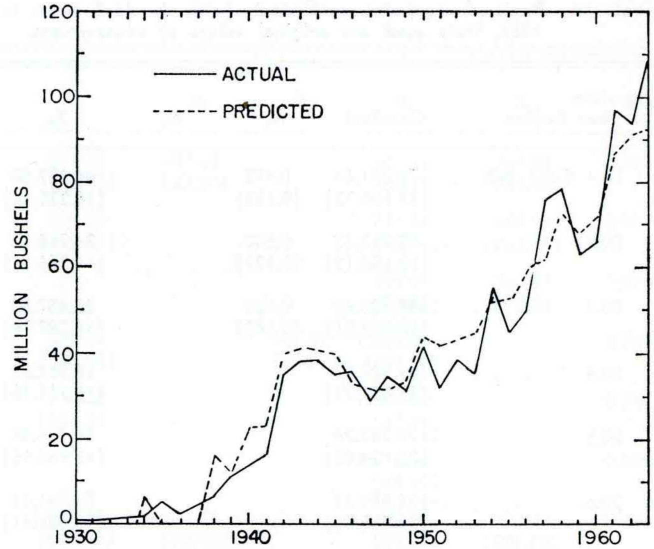


Fig. 2. Soybean production in Iowa: actual observations and predicted values from equation 18.11.

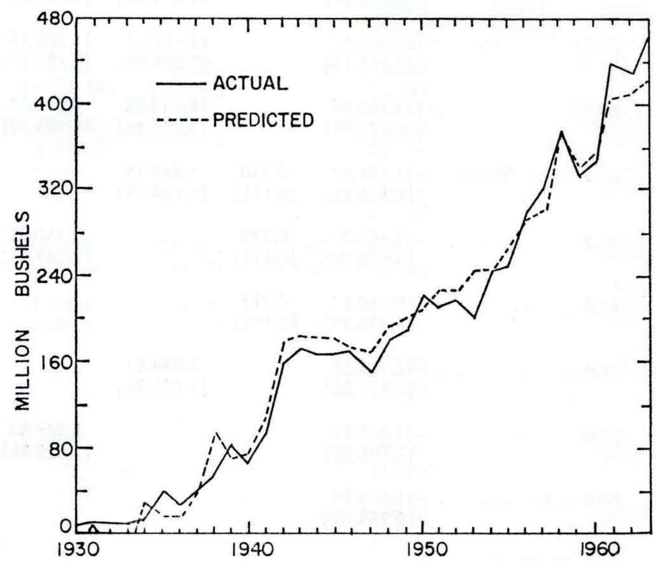


Fig. 3. (above) Soybean production in the Corn Belt: actual observations and predicted values from equation 23.4.

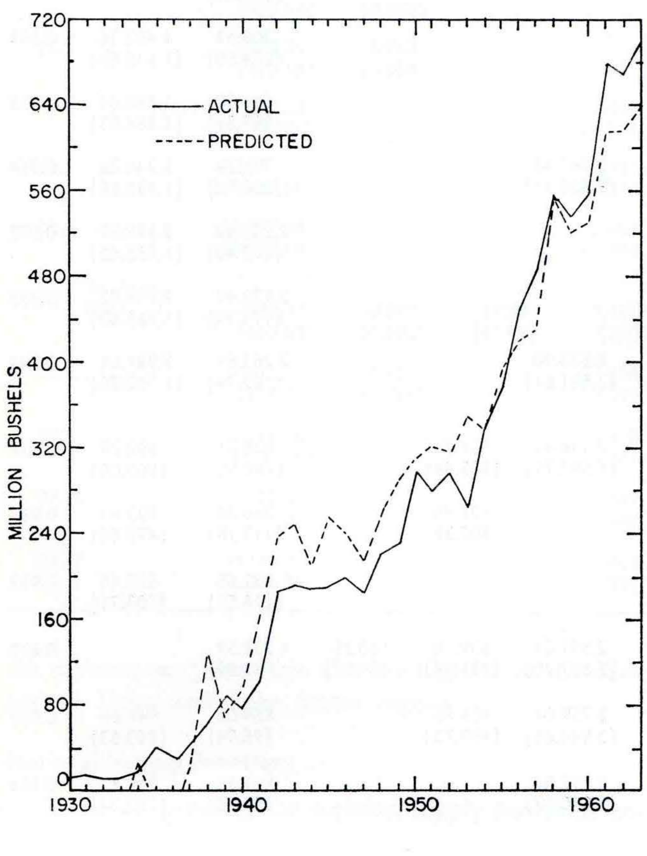


Fig. 4. (left) Soybean production in the United States: actual observations and predicted values from equation 24.8.

**Table 18. Regional regression coefficients (with standard errors in parentheses) and $R^2$ values for soybean production ($X_1$), 1929 to 1963. Data used are original values of observations.**

| Equation number | Region | Constant | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_7$ | $X_{11}$ | $X_{12}$ | $X_{13}$ | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 20.1 | Corn Belt.... | –78,351.64 | 0.472 | | 44,157.60 | | 11,814.95 | –436.78 | 6,659.56 | 6,751.68 | 0.985 |
| | | (33,101.73) | (0.133) | | (16,225.14) | | (3,109.14) | (360.20) | (2,100.89) | (4,551.19) | |
| 20.2 | ............ | –99,913.32 | 0.540 | | 34,718.10 | | 11,063.40 | | 4,885.02 | 9,358.45 | 0.984 |
| | | (28,155.12) | (0.121) | | (14,356.11) | | (3,072.27) | | (1,520.07) | (4,045.25) | |
| 20.3 | ............ | –58,203.62 | 0.589 | | 25,457.60 | | | | 4,911.84 | 13,826.18 | 0.977 |
| | | (30,502.21) | (0.143) | | (16,787.74) | | | | (1,806.74) | (4,576.47) | |
| 20.4 | ............ | –101,328.52 | | | 78,957.23 | | 14,445.80 | –1,064.61 | 13,764.71 | | 0.978 |
| | | (35,571.71) | | | (15,201.16) | | (3,387.07) | (347.41) | (830.76) | | |
| 20.5 | ............ | –178,747.26 | | | 66,705.45 | | 12,578.50 | | 11,385.50 | 8,214.15 | 0.973 |
| | | (28,124.82) | | | (15,966.56) | | (3,921.97) | | (546.16) | (5,185.33) | |
| 20.6 | ............ | –138,859.17 | | | 59,341.43 | | | | 12,086.09 | 13,238.84 | 0.963 |
| | | (28,866.78) | | | (18,081.41) | | | | (672.83) | (5,656.50) | |
| 20.7 | Mississippi Delta ....... | –32,693.83 | 0.776 | 4,582.79 | 1,839.98 | | 866.35 | | 894.01 | 1,942.28 | 0.970 |
| | | (14,694.71) | (0.099) | (2,450.41) | (2,290.95) | | (639.46) | | (370.73) | (1,155.99) | |
| 20.8 | ............ | –24,787.76 | 0.817 | 4,194.83 | | | 671.87 | | 712.25 | 2,044.04 | 0.969 |
| | | (10,840.93) | (0.084) | (2,387.05) | | | (588.07) | | (291.78) | (1,141.72) | |
| 20.9 | ............ | –21,425.27 | 0.822 | 4,237.13 | | | | | 686.24 | 2,141.45 | 0.968 |
| | | (10,488.51) | (0.085) | (2,399.28) | | | | | (292.42) | (1,144.50) | |
| 20.10 | ........... | –98,095.83 | | 17,267.21 | 11,047.93 | | 1,641.27 | –273.87 | 4,145.47 | | 0.912 |
| | | (20,630.39) | | (3,074.60) | (3,291.58) | | (1,063.05) | (146.24) | (374.47) | | |
| 20.11 | ........... | –125,508.17 | | 17,182.11 | 11,103.18 | | 2,060.50 | | 3,580.95 | | 0.901 |
| | | (15,153.18) | | (3,204.39) | (3,430.77) | | (1,083.20) | | (231.58) | | |
| 20.12 | ........... | –113,165.99 | | 18,036.05 | 9,091.63 | | | | 3,504.48 | | 0.889 |
| | | (14,278.97) | | (3,308.36) | (3,403.19) | | | | (237.81) | | |
| 21.1 | Lake States.. | –11,181.91 | 0.710 | 1,419.19 | | | | | 708.53 | 1,452.36 | 0.953 |
| | | (6,365.26) | (0.118) | (1,184.15) | | | | | (274.50) | (1,118.95) | |
| 21.2 | ............. | –9,455.21 | 0.730 | | 2,160.92 | | | | 646.00 | 1,688.64 | 0.953 |
| | | (5,642.78) | (0.111) | | (2,063.84) | | | | (257.51) | (1,154.53) | |
| 21.3 | ............. | –10,850.11 | 0.722 | | | 3,347.48 | | | 701.14 | 1,746.38 | 0.954 |
| | | (5,436.29) | (0.108) | | | (2,420.11) | | | (260.93) | (1,135.25) | |
| 21.4 | ............. | –36,148.66 | | 4,594.51 | | | | | 2,250.58 | 2,178.57 | 0.892 |
| | | (7,373.60) | | (1,598.35) | | | | | (172.40) | (1,666.62) | |
| 21.5 | ............. | –31,266.10 | | | 6,847.88 | | | | 2,173.49 | 2,998.92 | 0.882 |
| | | (7,096.20) | | | (3,008.98) | | | | (173.79) | (1,766.40) | |
| 21.6 | ............. | –31,615.74 | | | | 8,533.20 | | | 2,253.84 | 2,981.51 | 0.884 |
| | | (6,959.09) | | | | (3,581.61) | | | (182.74) | (1,750.70) | |
| 21.7 | Northern Plains ....... | –6,863.26 | 0.775 | | | 2,148.40 | 403.70 | | 235.71 | 898.09 | 0.937 |
| | | (3,552.30) | (0.117) | | | (1,587.79) | (305.44) | | (120.95) | (502.05) | |
| 21.8 | ............. | –6,683.13 | 0.759 | | 1,803.27 | | 427.45 | | 216.24 | 823.43 | 0.937 |
| | | (3,656.08) | (0.126) | | (1,433.35) | | (307.32) | | (115.28) | (495.89) | |
| 21.9 | ............. | –5,480.36 | 0.764 | | 1,679.15 | | | | 232.65 | 809.15 | 0.932 |
| | | (3,609.15) | (0.128) | | (1,453.44) | | | | (116.51) | (503.71) | |
| 21.10 | ............ | –12,771.75 | | | 6,258.66 | 2,591.04 | 639.10 | –140.35 | 1,232.59 | | 0.879 |
| | | (5,451.78) | | | (2,359.22) | (2,687.70) | (431.88) | (54.87) | (152.89) | | |
| 21.11 | ............ | –22,741.85 | | | 4,807.05 | 2,759.01 | 455.66 | | 884.02 | 948.64 | 0.859 |
| | | (4,657.99) | | | (2,485.41) | (2,944.86) | (459.73) | | (95.94) | (753.63) | |
| 21.12 | ............ | –21,648.13 | | | 4,624.47 | 2,897.83 | | | 907.98 | 939.85 | 0.854 |
| | | (4,524.02) | | | (2,477.82) | (2,940.63) | | | (92.82) | (753.34) | |

**Table 18 Cont'd.**

| Equation number | Region | Constant | $X_2$ | $X_3$ | $X_4$ | $X_7$ | $X_8$ | $X_{11}$ | $X_{12}$ | $X_{13}$ | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 22.1 | Appalachian. | −8,091.74 | 0.853 | | 2,564.68 | 818.12 | −57.56 | | 205.12 | 359.88 | 0.978 |
| | | (4,442.37) | (0.084) | | (2,185.36) | (345.02) | (33.20) | | (88.81) | (284.50) | |
| 22.2 | .......... | −9,664.62 | 0.834 | | 3,666.17 | 459.63 | | | 227.58 | 208.94 | 0.976 |
| | | (4,501.80) | (0.087) | | (2,164.55) | (285.91) | | | (90.95) | (280.38) | |
| 22.3 | .......... | −4,176.81 | 0.846 | | 2,401.27 | | | | 199.01 | 364.37 | 0.974 |
| | | (3,626.91) | (0.089) | | (2,070.82) | | | | (91.61) | (270.28) | |
| 22.4 | .......... | −24,261.06 | | | 16,019.67 | 385.32 | | −97.51 | 1,222.89 | | 0.904 |
| | | (10,013.38) | | | (3,440.43) | (587.46) | | (65.21) | (147.00) | | |
| 22.5 | .......... | −37,971.44 | | | 15,734.14 | 747.62 | | | 1,026.60 | | 0.897 |
| | | (7,139.21) | | | (3,505.15) | (537.34) | | | (67.49) | | |
| 22.6 | .......... | −28,327.77 | | | 14,053.79 | | | | 1,016.54 | | 0.890 |
| | | (5,386.80) | | | (3,339.81) | | | | (68.10) | | |
| 22.7 | Northeast .. | −5,347.36 | 0.781 | | 945.87 | 1,237.45 | −103.31 | | 82.30 | 307.39 | 0.949 |
| | | (1,768.49) | (0.108) | | (699.62) | (507.87) | (52.45) | | (39.55) | (201.13) | |
| 22.8 | .......... | −3,328.96 | 0.734 | | 943.80 | 255.95 | | | 92.64 | 278.69 | 0.942 |
| | | (1,513.66) | (0.110) | | (734.71) | (103.06) | | | (41.16) | (210.67) | |
| 22.9 | .......... | −2,053.14 | 0.707 | | 814.20 | | | | 100.49 | 252.86 | 0.929 |
| | | (1,545.47) | (0.119) | | (795.47) | | | | (44.55) | (228.39) | |
| 22.10 | .......... | −5,427.36 | | | 3,652.44 | 135.08 | | −39.53 | 425.57 | 313.53 | 0.860 |
| | | (3,049.55) | | | (1,064.45) | (163.94) | | (28.67) | (75.85) | (364.45) | |
| 22.11 | .......... | −8,602.84 | | | 3,195.02 | 189.11 | | | 330.39 | 552.46 | 0.851 |
| | | (2,030.17) | | | (1,027.05) | (161.65) | | | (31.94) | (325.58) | |
| 22.12 | .......... | −7,507.18 | | | 3,036.90 | | | | 329.75 | 525.72 | 0.844 |
| | | (1,812.27) | | | (1,024.35) | | | | (32.13) | (326.77) | |
| 23.1 | Southeast .. | −3,933.56 | 0.984 | | | 1,074.17 | −81.10 | | 66.23 | | 0.971 |
| | | (3,553.31) | (0.059) | | | (1,222.43) | (106.62) | | (32.64) | | |
| 23.2 | .......... | −1,325.55 | 0.989 | | | 151.32 | | | 59.29 | | 0.971 |
| | | (925.66) | (0.058) | | | (148.05) | | | (31.11) | | |
| 23.3 | .......... | −488.71 | 0.983 | | | | | | 61.32 | | 0.970 |
| | | (432.12) | (0.058) | | | | | | (31.07) | | |
| 23.4 | .......... | −11,820.18 | | | 1,447.83 | 2,614.81 | −246.83 | −37.42 | 636.92 | | 0.725 |
| | | (15,721.86) | | | (1,674.27) | (3,879.56) | (336.18) | (64.62) | (125.43) | | |
| 23.5 | .......... | −17,977.11 | | | 1,987.51 | 2,896.83 | −261.12 | | 582.32 | | 0.721 |
| | | (11,448.88) | | | (1,374.94) | (3,804.51) | (331.41) | | (81.77) | | |
| 23.6 | .......... | −10,293.44 | | | 2,064.55 | | | | 570.93 | | 0.715 |
| | | (3,999.14) | | | (1,341.33) | | | | (78.54) | | |
| 23.7 | Southern Plains ...... | −942.33 | 0.899 | 59.39 | 1,133.99 | | | | 37.49 | | 0.914 |
| | | (653.63) | (0.085) | (97.99) | (230.82) | | | | (17.93) | | |
| 23.8 | .......... | −818.72 | 0.901 | | 208.42 | | | | 34.94 | | 0.940 |
| | | (614.41) | (0.084) | | (193.36) | | | | (17.25) | | |
| 23.9 | .......... | −2,784.78 | | | 1,415.58 | | | −24.84 | 247.01 | −153.58 | 0.735 |
| | | (1,787.41) | | | (344.53) | | | (15.02) | (42.80) | (137.50) | |
| 23.10 | .......... | −3,302.84 | | | 1,349.78 | | | −17.57 | 217.51 | | 0.724 |
| | | (1,733.29) | | | (340.85) | | | (13.59) | (33.81) | | |
| 23.11 | .......... | −4,136.71 | | | 1,421.22 | | | | 184.20 | | 0.709 |
| | | (1,006.36) | | | (339.96) | | | | (22.13) | | |

the soybean-oat price ratio also are highest for the Mississippi Delta and Lake States regions.

### National Supply Functions

Table 19 provides the soybean supply functions derived for the United States. In equation 24.3, containing $X_2$ and $X_4$, the soybean-corn price ratio is significant at the 20-percent level, and all other variables are significant at the 5-percent level. However, the variable representing the fertilizer index does not enter into these functions. This equation accounts for more than 95 percent of the variance in production over the period. Its Durbin-Watson d statistic is 2.56, denoting lack of autocorrelation.

Omitting variable $X_2$, the soybean production lagged by 1 year, a number of alternative supply relations are provided in table 19. Equation 24.8 is perhaps the best among these for prediction. It accounts for 95 percent of variation in national production and all its coefficients are highly significant. Fig. 4 shows actual observations and predicted values based on equation 24.8. The predicted values overestimate for the years from 1940 to 1953 and underestimate for the years from 1956 to 1963.

In summary for the nation, the soybean-oat price ratio has but little quantitative influence on soybean production. The soybean-corn price ratio is more strongly associated with changes in soybean output. The intra-year effects of weather are indicated since above-average July rainfall increases soybean production. When $X_2$ is not included in the functions, the fertilizer price index has a negative effect on soybean output. In most of the relations presented, the variable representing government programs is statistically significant. Acreage allotments and feed-grain programs quantitatively cause an increase in soybean output because land is diverted to soybeans from competing crops.

The supply elasticities with respect to soybean-corn price ratio are estimated as 0.217 and 0.867 for equations 24.3 and 24.8, respectively. Based on equation 24.8, the United States soybean output increases by nearly 8.67 percent for a 10-percent increase in the soybean-corn price ratio.

### Supply Relations Using Logarithmic Values

For an alternative form of soybean supply functions, all variables except $X_{18}$ were again converted to logarithms for the states of Illinois, Iowa and Indiana, for the Corn Belt and Mississippi Delta and for the nation. Tables 20 and 21 include selected soybean response or supply functions.

The soybean output response functions in logarithmic transformation are generally better (only for Iowa) when compared with the functions fitted to the original values. The fertilizer index variable, which generally appears in the functions based on original observations, fails to enter into the functions based on logarithmic values. However, other variables appear in both cases at about equally significant levels.

The supply elasticities with respect to soybean-corn price ratio are highest for those functions where the lagged soybean output is not included. The supply elasticity, based on equation 26.8, for soybean production is 1.528 for the nation, denoting a 15.28-percent increase in soybean output with a 10-percent increase in the soybean-corn price ratio.

The supply elasticities for the logarithmic transformations again are generally higher than those estimated at the mean values for the equations based on the original values of observations. The supply elasticities for soybean production are much higher than the corresponding supply elasticities for soybean acreage.

**Table 19. United States regression coefficients (with standard errors in parentheses) and $R^2$ values for soybean production ($X_1$), 1929 to 1963. Data used are original values of observations.**

| Equation number | Constant | $X_2$ | $X_3$ | $X_4$ | $X_7$ | $X_{11}$ | $X_{12}$ | $X_{13}$ | $R^2$ |
|---|---|---|---|---|---|---|---|---|---|
| 24.1 .... | −141,074.14 | 0.758 | 5,890.00 | 26,536.20 | 16,686.57 | | 4,384.19 | 9,144.09 | 0.984 |
| | (53,700.96) | (0.095) | (14,122.40) | (27,368.89) | (6,609.40) | | (1,836.40) | (4,451.61) | |
| 24.2 .... | −61,427.62 | 0.810 | 9,648.98 | 5,322.10 | | | 3,874.50 | 12,185.50 | 0.981 |
| | (47,441.24) | (0.102) | (15,330.74) | (28,434.20) | | | (2,022.19) | (4,678.26) | |
| 24.3 .... | −134,588.85 | 0.755 | | 33,460.00 | 16,975.25 | | 4,403.71 | 9,595.20 | 0.984 |
| | (50,636.07) | (0.094) | | (21,434.59) | (6,474.52) | | (1,835.02) | (4,253.72) | |
| 24.4 .... | −48,391.70 | 0.807 | | 16,180.10 | | | 3,892.16 | 13,020.71 | 0.981 |
| | (42,235.90) | (0.100) | | (22,366.99) | | | (2,000.90) | (4,439.29) | |
| 24.5 .... | −267,364.38 | | 11,169.95 | 121,456.39 | 29,220.35 | −1,703.70 | 22,214.92 | 2,067.58 | 0.954 |
| | (97,571.29) | | (25,492.77) | (43,730.69) | (11,186.75) | (972.78) | (2,502.42) | (8,851.64) | |
| 24.6 .... | −255,868.64 | | 3,800.71 | 85,989.31 | | | 19,069.41 | 15,136.50 | 0.938 |
| | (72,203.29) | | (27,184.48) | (47,164.28) | | | (1,186.87) | (8,278.92) | |
| 24.7 .... | −262,033.05 | | | 132,349.35 | 29,568.25 | −1,579.09 | 21,873.15 | 3,409.13 | 0.953 |
| | (95,403.13) | | | (35,453.96) | (10,996.41) | (916.77) | (2,343.21) | (8,184.56) | |
| 24.8 .... | −252,994.20 | | | 133,888.10 | 31,027.42 | −1,745.78 | 22,407.09 | | 0.953 |
| | (91,569.28) | | | (34,754.95) | (10,273.91) | (812.98) | (1,933.33) | | |
| 24.9 .... | −371,011.41 | | | 110,788.43 | 27,957.19 | | 18,292.77 | 9,562.81 | 0.948 |
| | (73,787.31) | | | (34,277.11) | (11,322.03) | | (1,117.67) | (7,609.28) | |
| 24.10 ... | −250,431.29 | | | 90,155.43 | | | 19,053.66 | 15,461.86 | 0.938 |
| | (59,832.34) | | | (35,956.49) | | | (1,162.05) | (7,814.24) | |