Statistical supply functions for Montana wheat

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Montana State University

Abstract:
This study has intended to explore the supply responses for Montana wheat. Functions were developed for explaining five general types of relationships. Supply response functions were developed for winter wheat, spring wheat, ratio of spring wheat to winter wheat, total wheat and total grain (wheat, oats and barley).

In 1955 approximately one-third of the wheat produced in Montana was winter wheat, the remainder being spring wheat. Separate functions were derived for spring and winter wheats expressing the dependent variables (acres planted) as raw figures and as a percentage of trend.

Three functions were developed explaining the relationship between acreage of spring wheat and acreage of winter wheat. This was an attempt to explain variations in spring wheat acreage relative to winter wheat acreages. Presumably a different series of independent variables is associated with this ratio than the series associated with acreages of spring and winter wheat taken separately.

Supply response functions were developed also for total wheat acreages. In these functions an attempt was made to explain the variation in acreage winter wheat harvested plus acreage spring wheat planted. The functions derived using this dependent variable may have application in cases of agricultural adjustment where aggregate production adjustments are desirable.

One set of supply functions was derived for all grain (wheat, oats and barley). Within any given production unit wheat, oats and barley are easily substituted for one another from the standpoint of land, labor and machinery requirements. If we assume that farmers have a propensity to grow grain of some kind in some given amount, then supply functions of this nature may help to explain variations in this total acreage.

Limitations of the Study Although the multiple correlation technique has many advantages it also has some serious disadvantages which must be taken into account. Conclusions drawn from this study must necessarily be subject to the following limitations.

(1) Multiple correlation analysis is based on the assumption that the relationship between the variables is linear. This assumption is not usually valid when applied to agricultural data, therefore the linear regression coefficients do not always describe these relationships accurately.

(2) A- second limiting assumption made by this type analysis is that the effects of independent variables on the dependent variables are separate, distinct and additive. This is not a valid assumption since the effect of any simple independent Variable upon the dependent Variable is influenced by the size of the other independent variables.

(3) Multiple correlation analysis does not establish causal relationships, but merely degrees of relationship. For this reason extreme care must be taken in drawing inferences about these

relatiohships. Inferences drawn must be based on economic theory as well as statistical measures.

If the interrelationships between independent variables continue to hold in the future, then the supply functions derived may be fairly accurate guides to prediction When these interrelationships change significantly these equations will not be useful as predictive guides.

The secondary data sources used for this study were not extensive enough to cover a period of more than 18 "normal" years. This limited number of observations places an obvious limitation upon the validity of the analysis.

Summary of Results The independent variables which were most highly associated with the dependent variables used were price and yield variables. Precipitation variables in general were not closely associated with variations in the acreage planted.

Regression coefficients and partial correlation coefficients which were not significant at the 95 percent level of probability or above were considered to be not significant in this study. Coefficients which are significant at some level below 95 percent may be useful for predictive purposes when the consequence of error is less important.

Twenty-four supply response functions were derived in this study.

The multiple correlation coefficients for 11 of these equations are significant at the 99 percent level of probability. Six of the equations have multiple correlation coefficients which are significant at 95 percent and seven are significant at some level below 95 percent. One or more of the equations derived in each of the eight problems has a coefficient of multiple correlation which is significant at or above the 95 percent level of probability. The multiple correlation coefficients for all equations derived in Problems II-C, IV and V are significant at the 99 percent level. In Equation (3), Problem V, all the regression coefficients and partial correlation coefficients are significant at the 99 percent level.

Need For Further Research This study has investigated the supply response for wheat only insofar as acreage planted is concerned. Yield is the second primary factor determining total supply: therefore a complete analysis of the supply response must necessarily include a detailed analysis of factors affecting yield. Reliable knowledge about variations in yield and acre age planted is a prerequisite to an understanding of total supply response.

The application of yield information for predictive purposes will become increasingly important as weather forecasting becomes more accurate and is projected further into the future.

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PART I

INTRODUCTION

The Wheat Situation

Helen C. Farnsworth states:

> None of our leading commercial crops is in a more unbalanced demand-supply position than wheat. Never before in history has the world had to cope with such enormous surplus stocks of wheat as have existed during the past four years, mostly piled up in the four major exporting countries. The unwanted surplus of old-crop wheat must have exceeded a billion bushels in July, 1957. This huge surplus would have been larger still if North American wheat production had not been curtailed over the past four years by Government acreage and marketing restrictions and if the United States had not pursued aggressive and expensive surplus-disposal programs.1/

The burdensome wheat surpluses of recent years have been due to sharply increased production in the non-Soviet world, not to increased exports from the Soviet block, not to a decline in world wheat consumption. Soviet-block exports have been smaller and world wheat consumption considerably larger over the past five years than in any similar interwar period. Only in a few countries, primarily the United States and France, has wheat consumption sharply contracted.

The wheat crops of most countries have averaged somewhat higher in the past five years than in the interwar period. The greatest increases have come in the United States, Canada and Turkey. American wheat production in the postwar period was expanded far greater than in any other

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1/ Helen C. Farnsworth, "Wheat Under Multiple Pricing: A Case Study," Joint Economic Committee, November 1957, p. 556.

country. This accounted for more than a third of the increased postwar wheat production of the free world. American wheat producers have failed to adjust their acreage downward from a period of postwar critical world food shortage to the present period of relatively abundant food supplies.[1/]

Montana is the third largest state in the Nation with an area of over 93 million acres. Wheat is the most important single agricultural product in the state. In 1951, 1952 and 1953, over six million acres were planted to wheat. This was almost half of the 13.5 million acres of cultivated land in the state. In the period 1951-1955 Montana produced 9.1 percent of the Nation's wheat crop. Only North Dakota and Kansas produce more wheat than Montana. These three states combined produce more than one-third of the Nation's wheat.

Although some wheat is grown in every county in Montana, production is concentrated in two general areas commonly known as the spring wheat area in Eastern and Northeastern Montana and the spring and winter wheat area in North Central Montana. High protein hard red spring and hard red winter wheat are grown in these areas. During the period 1921-1938 the ratio of spring wheat planted to winter wheat planted varied from a high of 5.50 in 1929 to a low of 2.94 in 1921. In the period 1921-1955 this same ratio reached a high of 5.50 in 1929[2/] and a low of 1.25 in 1955.[3/]

1/ Ibid., pp. 556-557.

2/ Montana Department of Agriculture, Montana Agricultural Statistics, Helena, Montana, 1946, pp. 8-9.

3/ Ibid., 1956, pp. 14-16.

These ratios reflect the trend from spring wheat planting to winter wheat planting which has taken place in Montana.

Barley is the closest competing cash grain crop to wheat in the state. Price data for wheat in Montana show that the price of spring wheat has nearly always exceeded that of winter wheat by a few cents. This price differential largely reflects the premium paid for protein content. The protein premium is generally higher for spring wheat than for winter.

Eighty-five percent of the crop production area in Montana is found below the 4,200 feet elevation level in a climate characterized by extreme contrasts from area to area. The major wheat producing area which lies east of the Continental Divide is subject to continental weather influences. Annual precipitation over approximately one-half of the state ranges between 13 and 16 inches. Summer temperatures range as high as 100 degrees and above while below zero temperatures may occur any time between September and May.[1/]

Dryland farms characterize the major wheat producing areas in Montana. In 1955 approximately 97 percent of the wheat planted in Montana was planted under dryland conditions. Since 1920 the size of dryland farms has increased along with acres planted per farm, while the total number of farms has decreased. In 1920 there were approximately 57 thousand farms in Montana with an average of 608 acres per farm. In 1955 there were

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1/ H. G. Bolster and H. R. Stucky, Montana's Agriculture, Montana Agricultural Extension Service, Bulletin 228, 1945, p. 3-8.

approximately 33 thousand farms in the state and the average size was 1,856 acres.[1/]

New and improved varieties of wheat have gained prominence during recent years in Montana. These new varieties must excell older varieties in factors such as yield, resistance to rust and other disease, resistance to insect damage, winter hardiness, milling qualities and protein content before they are generally acceptable. A new variety must possess a large number of these desirable qualities in order to gain wide acceptance. The most common spring wheat varieties grown are Thatcher, Ceres, Marquis and Rescue in descending order of importance. The most common winter wheat varieties grown are Yogo, Karmont and Turkey in descending order of importance. Thatcher, Ceres, Rescue, Yogo and Karmont have been increasing in importance while Marquis and Turkey are older varieties that are decreasing in importance.[2/]

The Problem and Objectives

This study is part of a project outlined under WM-13 and Montana Project MS-911, which are concerned with wheat prices and price policies in the Western Region.

The Research Project Statement lists the following:

> The demand for wheat is changing. Bread stuffs and possibly pastries constitute a declining part of the American National

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1/ Layton S. Thompson, et al, Montana Agriculture Basic Facts, Montana Agricultural Experiment Station and Extension Service, Bulletin 293, Bozeman, Montana, 1956, p. 35.

2/ Montana Federal Agricultural Statistical Service, Wheat Varieties Grown in Montana, Helena, Montana, 1950, p. 6.

diet. In some foreign lands where diets have been poor and insufficient, consumption of wheat products is increasing and will increase more as the levels of living rise in these areas.

Wheat production in America is increasing in total quantity and more markedly in production per farmer. Improved technology clear across the production board has brought this increase about. Wheat production is increasing in foreign areas likewise and for similar reasons.

This complicated situation of supply and demand changes in wheat in America and abroad has created a difficult and puzzling problem for the wheat producers of America and for the makers of public policy for dealing with such difficult problems of agricultural adjustment.

This project is proposed as a part of a regional wheat marketing project. It is designed to lay the groundwork for getting answers to problems of wheat pricing and prices as they may be related to market structures; public price and production policy, and wheat demand and supply. The subsequent project is expected to provide the basic analysis required to predict the probable effects upon wheat prices of various policies and programs that may be contemplated and of changes of supply or demand conditions affecting wheat.1/

Agricultural technology and farm labor productivity have experienced substantial advances over the past 20-30 years. The age-old problem of population pressure upon the food supply, largely in the "West", has become one of food supply pressure upon population. The fact that the problem continues to persist indicates a need for more accurate information about the nature of the supply functions for agricultural products.

This study is concerned with the derivation of a series of statistical supply functions for Montana wheat. It is hoped that such functions

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1/ Montana Agricultural Experiment Station, Research Project Statement: WM-13, Bozeman, Montana, May 15, 1953, p. 2.

will serve as a guide to policymakers in choosing between and among alternative courses of action in the field of agricultural adjustment.

Individual supply functions will be derived for spring and winter wheats as well as aggregate supply functions for all wheat and all wheat plus oats and barley.

The use of the term "supply function" in this study is not limited to the traditional price-quantity relationship, but rather to acres planted as they relate to a series of independent factors. Acres planted was chosen as the independent factor since it is presumed to be a more accurate measure of the producers intentions than production figures. Acreage and yield are the two primary determinants of production. But since yield occurrences are presumed to be more or less randomly distributed through time, some measure of acres planted was chosen as the most appropriate indicator of supply response.[1/] The intent is to analyze acreage as it relates to certain variables which significantly affect production decisions.

A study of the demand for Montana wheat was made in 1957 by Charles Yen-do Liu.[2/] The supply phase of MS-911 was designed to find sources of information and appropriate research techniques for use in a subsequent project, WM-13. One objective of WM-13 is the analysis of current and

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1/ This ignores the fact that there may be some secular trend in yield due to technological change.

2/ Charles Yen-do Liu, Price and Substitution Elasticities for Wheat Related to Price Policies for Wheat, Montana Agricultural Experiment Station, Bozeman, Montana, May 1958, p. 1-25.

past domestic and foreign supply conditions for wheat, with particular reference to the classes and qualities of wheat produced in the Western Region.

Previous Work

Except for the longstanding studies of the Food Research Institute of Stanford University, marketing research for wheat has concentrated on the problems of efficient operation of the local marketing firms (largely country elevators) and on the relations between futures trading and the price of wheat. The Food Research Institute has for 25 years carried on a comprehensive program of research into wheat which covers world supply and demand conditions, and supply and price trends and fluctuations.1/

A recent attempt has been made by Professor Wilfred Chandler of Iowa State College to estimate the supply function for New Zealand wheat.2/ The multiple regression technique was used in this study, with acres planted as the dependent variable and factors such as wheat price, fat lamb price, red clover acreage, rainfall and last year's wheat acreage as independent variables. Two levels of significance were used, one at the 95 percent level and the other at approximately the 63 percent level. One equation involving three independent variables had coefficients which were

1/ Montana Agricultural Experiment Station, op.cit., p. 2.

2/ Wilfred Chandler, "An Aggregate Supply Function for New Zealand Wheat," Journal of Farm Economics, Volume XXXIX, 1957, p. 1732.

significant at the 99 percent level. Those equations which were acceptable at the 63 percent level do not appear to be useful as a guide to prediction.

A study of the wheat supply function was conducted at Kansas State College using lagged adjusted price as the independent variable and acreage planted as the dependent variable in a simple regression model. The results of this study were not statistically significant, and the researcher in this case indicated that simple regression analysis is not an appropriate tool for determining acreage response to price.[1/]

Data Sources

Acreage, yield and price data used in this study were taken from Montana Agricultural Statistics published by the Montana Department of Agriculture, in cooperation with the Agricultural Marketing Service, United States Department of Agriculture, Helena, Montana. A composite index of prices paid by farmers (1947-49 = 100) for living and production items was used to deflate or adjust prices where applicable. This index was taken from Major Statistical Series, United States Department of Agriculture, Volume I, 1957.

Precipitation figures used in the study were taken from Climatological Data for Montana, United States Department of Commerce, Weather Bureau Annual Reports. The precipitation figures for each month of each year within an area were derived by averaging the readings from five reporting stations within the major wheat producing area.

1/ B. J. Bowlen, "The Wheat Supply Function," Journal of Farm Economics, Volume XXXVII, December 1955, p. 1177.

PART II

PROCEDURE AND ANALYSIS

Procedure

Multiple regression analysis was used in this study to establish regression equations from which predictions could be made. There are eight separate problems in the study, each using a different dependent and independent series or the same independent series and a different dependent variable. Problems Numbers IV, V,and II-C cover the time period 1921-1955. The time period 1921-1938 was used in the majority of the problems for two reasons. First adequate price and acreage data for the years prior to 1919 were not available. In the period subsequent to 1938 there were many years of unusual influences such as wars, supported prices, acreage controls and marketing quotas. The years 1919 and 1920 were eliminated on the basis of the residual influence of World War I.

Independent variables were chosen on the basis of their hypothesized association with the dependent variables. These variables fall into four major categories; price, yield, precipitation and acreage. Price variables were expressed as a ratio between the price of spring and winter wheats for some previous period, as a weighted average price of wheat for some previous period and as the average price of barley for the previous crop year. Wheat prices were used because of their supposed influence on the acres of wheat planted. Barley prices were used because barley competes strongly with wheat as a cash grain crop in Montana. Previous wheat yields and moisture conditions were presumed to have an influence on the farmer's production plans. Acres of wheat planted the previous year was used because it was felt that number of acres planted any particular year was influenced by previous acreage planted or production patterns established.

Acreage planted (or some modification thereof) was chosen as the dependent variable. Acreage planted as a percentage of trend was used as the dependent variable in some cases in an effort to eliminate long-run trend effects from the observations. In Problem III, the acreage of winter wheat harvested plus acreage of spring wheat planted as a percentage of trend was used as the dependent variable. This was done so as to eliminate a duplication of the acreage of winter wheat which is reseeded to spring wheat in the spring. In all cases where trend was used in expressing the dependent variable, the trend equation was calculated and the observed values were divided by the calculated trend values to arrive at the percentage figure used as the dependent observation. In some cases the dependent variable was expressed in raw figures or as a ratio of raw figures. This was done in an attempt to derive a longer run supply function which was not adjusted for technological change and other factors which influence trend.

These regression problems were solved on the electronic computer at the State College of Washington, Pullman, Washington. The original data were coded and punched in accordance with Multiple Regression Library Program 60.0.014 and fed directly into Phase II of the program. Phases II and III of the program were used. In some cases it was necessary to scale variables (multiply by 1/100, 1/10, etc.) in order to get them into the form (OXX.XXXOOOO) required by the library program. Final results of analysis in which scaled data were used had to be descaled before inferences could be drawn from the results. The means, standard deviations, and simple correlation coefficients are produced from Phase II. Provision has been made in the program for the insertion of omit cards between Phase II and Phase III of the program. These cards instruct the machine to disregard certain independent variables from its calculations for Phase III. Phase III inverts the matrix and yields partial correlation coefficients and the multiple correlation coefficient. The standard errors of the regression coefficients and the t's for the regression coefficients were calculated by the use of a routine developed in the Computing Center at the State College of Washington.

Each problem was run through Phase II and Phase III of the Library Program using all of the initial independent variables listed below. Beta coefficients were also calculated for each independent variable. Subsequently certain variables were chosen for the reruns and other variables were dropped. The partial correlation coefficients, Beta coefficients, t values, and the significance levels of the b's were used in selecting the independent variables for subsequent solutions. In some cases variables which did not appear significant from a statistical point of view were retained in the rerun because of their theoretical significance. Variables were omitted from the reruns by inserting omit cards and rerunning Phase III. This rerun procedure yields a new inverse matrix, partial correlation coefficients, regression coefficients, standard errors of regression doefficients, and t values for the regression coefficients. Beta coefficients were also calculated separately for each independent variable used in the rerun. The means and standard deviations for the original variables remain unchanged by the rerun procedure.

In cases where a high degree of interserial correlation (significant at 95 percent or higher) existed between independent variables, one was omitted unless there were strong theoretical grounds for its use.

The F-Test was used to test the significance of the correlation coefficients, and the t test was used for the regression coefficients.

Analysis

PROBLEM I-A -- Acreage of Winter Wheat Planted, 1921-38, Related to Certain Price, Precipitation and Yield Variables.

Equations:

(1) $X_1 = -3,262 - 721.9\ X_2 - 1,396\ X_3 - 2,391\ X_4 - 11\ X_5 - 14\ X_6 + 23\ X_7 - 2.02\ X_8 - 17.7\ X_9 + 276.9\ X_{10}.$

$R^2 = .81198$ (Significant at 95%)

(2) $X_1 = -3,391 - 946.59\ X_3 - 3,531.41\ X_4 - 15.62\ X_5 + 23.76\ X_7 - 19.53\ X_9 + 214.71\ X_{10}.$

$R^2 = .7350$ (Significant at 95%)

(3) $X_1 = 190.01 - 14.26\ X_6 + 11.23\ X_7 - 39.64\ X_9 + 6.18\ X_{10}$

$R^2 = .3467$ (Not significant at 95%)

Dependent Variable

X_1 = Acreage of winter wheat planted in orginal figures (1921-1938).

Independent Variables

X_2 = The ratio of the price of winter wheat to the price of spring wheat for the previous year. (This variable was expressed as a decimal or as a whole number and a decimal).

X_3 = The ratio of the average price of winter wheat to the average price of spring wheat for the 2nd-4th previous years inclusive. (Expressed in the same terms as X_2).

X_4 = The ratio of the average price of winter wheat to the average price of spring wheat for the 5th-9th previous years inclusive. (Expressed in the same terms as X_2).

X_5 = Total precipitation for the three month period (July-September) prior to seeding. (This figure is an average for five weather reporting stations within the major winter wheat producing area).1/

X_6 = Total precipitation for the previous 10 month period, September-June, inclusive.2/

X_7 = Winter wheat yield per acre for the previous year.

X_8 = Spring wheat yield per acre for the previous year.

X_9 = Winter wheat average yield per acre for the three previous years.

X_{10} = Weighted average raw price for winter wheat for the 1st-3rd previous years inclusive. (First, second and third years weighted by 3, 2, and 1 respectively).

First Run

In the first equation there is a high degree of interserial correlation between variables X_3 and X_4,3/ the ratio of the price of winter wheat

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1/ Reporting station: Choteau, Geraldine, Havre, Sun River Canyon and Kinread.

2/ Ibid.

3/ Appendix A, Table I.

to the price of spring wheat for the 2nd-4th previous years and the same ratio for the 5th-9th previous years. Since the overall price trend for the price of all wheat has been an upward trend this explains why two average price ratios would have a high positive correlation coefficient. Variables X_7 and X_8, the yield of winter wheat and the yield of spring wheat for the previous year, also have a high positive correlation coefficient. This may be partially explained by the factors which affect both -- principally weather.

Three of the price variables X_2, X_3 and X_4 carry the "wrong" sign. These inverse relationships between acres planted and previous prices may be due to a number of years in which acres planted were on an upward trend because of technology while prices were tending downward due to the economic depression period.

The b values and signs associated with X_3, X_5, and X_8 are insignificant since the standard error of the b values in all cases is much greater than the b values.

Variable X_6 carries the "wrong" sign, however, neither the b value nor the partial coefficient are significant in this problem.

Variables X_7 and X_{10} are the two most significant variables in this problem, statistically. The b value and the partial r for X_{10} are both significant at the 95 percent level. The corresponding values for X_7 are significant at the 90 percent and 95 percent levels. The weighting used on X_{10} was done on the assumption that the more recent prices have a heavier influence upon the producers production decisions than do prices received several years previous. In this case the previous year's price was given a weight of three, the price two years previous was weighted by two, and the price three years previous was weighted by one.

Second Run

In the second run variables X_3, X_4, X_5, X_7, X_9, and X_{10} were used. These variables were chosen on the basis of their statistical performance in the first run, along with their theoretical significance as a criterion for judgment. Some of the variables that met the test of reasonableness and logic were used in the second run to test whether their statistical significance might be improved in a different independent series. A high degree of interserial correlation exists between some of these variables. The simple correlation coefficients between these independent variables are contained in Appendix A. Variables X_3 and X_5 do not enhance the prediction usefulness of the equation because their b's are smaller than the standard errors. The partial regression coefficients for X_4 and X_{10} are significant at the 90 percent level. The X_7 regression coefficient is significant at the 98 percent level. The partial correlation coefficient for X_7 is significant at the 95 percent level.

Although the multiple correlation coefficient in this problem is significant at the 99 percent level, predictions based on this equation may not be usefull because of the high degree of interserial correlation present.

Third Run

The third run was made using variables X_6, X_7, X_9 and X_{10}. The multiple correlation coefficient for this function is not significant at the 95 percent level. The b value and partial correlation coefficient for X_9 are significant at 95 percent. Variable X_{10} is highly insignificant since its standard error of the b far exceeds the b value. The only significant interserial correlation present in this problem is between X_7 and X_9.

PROBLEM I-B -- Acreage of Winter Wheat Planted as a Percentage of Trend (1921-38) Related to Certain Price, Yield and Precipitation Variables.

Equations:

(1) $X_1 = -2.09 - .35 X_2 - 1.57 X_3 - 1.36 X_4 - .012 X_5 - .016 X_6 + .028 X_7 - .0035 X_8 - .026 X_9 + .32 X_{10}$.

$R^2 = .7450$ (Not significant at 95%)

(2) $X_1 = -1.56 - .66 X_3 - 2.41 X_4 - .023 X_5 + .027 X_7 - .029 X_9 + .248 X_{10}$.

$R^2 = .6643$ (Significant at 95%)

(3) $X_1 = 1.52 - .016 X_6 + .0018 X_7 + .12 X_{10}$.

$R^2 = .1392$ (Not significant at 95%)

Dependent Variable

X_1 = Acreage winter wheat planted as a percentage of trend (1921-38).

Independent Variables

X_2 = The ratio of the price of winter wheat to the price of spring wheat for the previous year. (This variable was expressed as a decimal or as a whole number and a decimal).

X_3 = The ratio of the average price of winter wheat to the average price of spring wheat for the 2nd-4th previous years inclusive (expressed in the same terms as X_2).

X_4 = The ratio of the average price of winter wheat to the average price of spring wheat for the 5th-9th previous years inclusive (expressed in the same terms as X_2).

X_5 = Total precipitation for the three month period (July-September) prior to seeding. (This figure is an average for five weather reporting stations within the major winter wheat producing area).1/

X_6 = Total precipitation for the previous 10 month period, September-June, inclusive.2/

X_7 = Winter wheat yield per acre for the previous year.

X_8 = Spring wheat yield per acre for the previous year.

X_9 = Winter wheat average yield per acre for the three previous years.

X_{10} = Weighted average raw price for winter wheat for the 1st-3rd previous years inclusive. (First, second and third years weighted by 3, 2, and 1 respectively).

First Run

The statistical results pertinent to this problem may be found in Appendix B. Variables X_7 and X_{10} are the two most significant statistically. The b and the partial correlation coefficient for X_{10} are significant at the 95 percent level. The partial correlation coefficient for

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1/ Reporting station: Choteau, Geraldine, Havre, Sun River Canyon and Kinread.

2/ Ibid.

X_7 is significant at 95 percent. These two variables are also acceptable on a theoretical basis, since they both have positive b values. X_6 has a partial correlation coefficient which is significant at a level just below 95 percent.

Variables X_2 , X_3 ,X_4 , X_5 and X_8 have b values smaller than the standard error of the b. No valid inferences can be drawn from such insignificant results.

Second Run

Variables X_3, X_4, X_5, X_7, X_9 and X_{10} were used in the second run of Problem I-B. As in the first run of this problem, variables X_7 and X_{10} show the most significant results. The partial correlation and regression coefficients for these two variables are significant at 95 percent or above. The standard error of the b values for X_3 and X_5 exceeds the value of the b. The coefficients for X_4 and X_9 are not significant at 95 percent although these two variables explain a considerable portion of the total variation.

Third Run

Equation (3) was derived using variables X_6, X_7 and X_{10}. The results of all variables were highly insignificant. For this reason this equation is considered to be useless as a guide to prediction.

PROBLEM II-A -- Acreage Spring Wheat Planted (1921-38) Related to Price, Yield, Precipitation and Acreage Variables.

Equations:

(1) $X_1 = -2,633 + 5,472.9\ X_2 + 5,798.8\ X_3 - 16,584.3\ X_4 + 2.10\ X_5$

$- 43.53\ X_6 + 89.79\ X_7 + 872.2\ X_8 - 426\ X_9 + 84.10\ X_{10} - 106.56\ X_{11}.$

$R^2 = .8106$ (Not significant at 95%).

(2) $X_1 = 8,260 + 6,667.3\ X_2 + 5,236.2\ X_3 - 7,361\ X_4 + 14.34\ X_7$

$+ 70\ X_{10} - 79.79\ X_{11}.$

$R^2 = .6324$ (Significant at 95%).

(3) $X_1 = 11,874 + 5,848\ X_2 + .27\ X_5 + 25.8\ X_{10}.$

$R^2 = .4534$ (Significant at 95%).

Dependent Variable

X_1 = Acreage spring wheat planted (1921-38).

Independent Variables

X_2 = Ratio of the price of spring wheat to the price of winter wheat for the previous year.

X_3 = Same ratio as X_2 for the 2nd-4th previous years.

X_4 = Same ratio as X_2 for the 5th-9th previous years.

X_5 = Acreage winter wheat planted the previous fall.

X_6 = Precipitation the previous year from January to September.

X_7 = Precipitation prior to spring seeding, October-March.

X_8 = Price received for barley the previous year, deflated.

X_9 = Weighted average raw price for spring wheat for the 1st-3rd previous years. (Weights - 3, 2, 1).

X_{10} = Yield per acre for spring wheat the previous year.

X_{11} = Yield per acre for winter wheat the previous year.

First Run

The first equation derived in this problem involved all ten of the independent variables listed above. The partial correlation coefficients for X_2 and X_{11} are significant at the 95 percent level. The b value for X_2 is significant at the 95 percent level and the b value for X_{11} is significant at the 90 percent level. Partial correlation coefficients for X_4 and X_{10} are very high but fall short of the 95 percent level of significance. The b values for these two variables are significant at the 90 percent level.

The interserial correlation between independent variables in this problem is very high in some cases.[1/] Under these conditions it becomes very difficult to draw valid inferences about the relative importance of the variables involved.

The price variable X_3 indicates a direct relationship between price and acres planted, however, its statistical performance is not significant. X_5 indicates that there is a direct relationship between acreage winter wheat planted the previous year and acres of spring wheat planted. This reflects partially the action of producers, in areas where the option exists, to seed spring wheat on winter wheat acreage which has not survived the winter.

1/ See Appendix C, Table I.

Variables X_6, X_7, X_8, and X_9 all have standard errors of the b value which exceed the b value and are not statistically significant.

Second Run

The second equation in this problem was derived using variables X_2, X_3, X_4, X_7, X_{10} and X_{11}. The multiple correlation coefficient of .6324 is significant at the 95 percent level of probability. Variables X_2, X_{10} and X_{11} reflect the highest significance from a standpoint of statistical measures. The coefficient of partial correlation for X_2 is significant at the 95 percent level and the b value is significant at the 98 percent level. The coefficients for X_{10} and X_{11} are relatively high but they are not significant. There is a high degree of interserial correlation (.83) between X_{10} and X_{11} which is significant at the 99 percent level. The apparent effect of either one or both of these variables may be merely a reflection of the other variable. The signs attached to these two variables are reasonable and acceptable.

The standard errors of the b values for X_3 and X_4 are very high and their partial correlation coefficients are low. The standard error of the b value for X_7 exceeds the b value, consequently this variable is not useful.

Third Run

The third equation was derived using variables X_2, X_5 and X_{10}. X_2 and X_{10} were chosen on the basis of their performance in the second run. X_{11} was deleted because of its high correlation with X_{10}. In this problem the interserial correlation between X_2 and X_5 and X_2 and X_{10} is significant. The partial correlation coefficient for X_2 is significant at the 95 percent level. The b value for X_2 is significant at the 98 percent level. The standard error of the b for X_5 exceeds the b value. The multiple correlation coefficient of .4534 is significant at the 95 percent level of probability.

PROBLEM II-B -- Acreage Spring Wheat Planted as a Percentage of Trend (1921-38) Related to Price, Precipitation, Acreage and Yield Variables.

Equations:

(1) $X_1 = -236.77 + 128.43\ X_2 + 126.9\ X_3 - 593.2\ X_4 + .06\ X_5$

$- 1.15\ X_6 + 2.41\ X_7 + 19.61\ X_8 - 7.68\ X_9 + 2.30\ X_{10} - 2.95\ X_{11}.$

$R^2 = .8387$ (Significant at 95%)

(2) $X_1 = -273.57 + 162.19\ X_2 + 82.16\ X_3 - 310.73\ X_4 + .27\ X_7$

$+ 2.00\ X_{10} - 2.21\ X_{11}.$

$R^2 = .5614$ (Significant at 99%)

(3) $X_1 = 332.81 + 90.7\ X_2 + 1.22\ X_{10}.$

$R^2 = .2167$ (Not significant at 95%)

Dependent Variable

X_1 = Acreage spring wheat planted as a percentage of trend (1921-38).

Independent Variables

X_2 = Ratio of the price of spring wheat to the price of winter wheat for the previous year.

X_3 = Same ratio as in X_2 for the 2nd-4th previous years.

X_4 = Same ratio as in X_2 for the 5th-9th previous years.

X_5 = Acreage winter wheat seeded the previous fall.

X_6 = Precipitation the previous year, January-September.

X_7 = Precipitation prior to spring seeding, October-March.

X_8 = Price of barley the previous year deflated.

X_9 = Weighted average raw price for spring wheat for the 1st-3rd previous years. (Weights = 3, 2, 1).

X_{10} = Yield per acre for spring wheat the previous year.

X_{11} = Yield per acre for winter wheat the previous year.

First Run

The first equation derived made use of the same 10 variable independent series used in Problem II-A. The Beta coefficients and partial correlation coefficients for the individual variables retained the same relative magnitudes they had in Problem II-A. The b values and partial correlation coefficients for variables X_2, X_4, X_5, X_{10} and X_{11} were all significant at the 95 percent level except for the b value for X_5 which was significant at the 90 percent level. This indicates the effect of using acres planted as a percentage of trend instead of acres planted in original figures as a dependent variable.

Variable X_3 had a low partial correlation coefficient and a very high standard error of the b. The standard errors of the b's for X_6, X_7, X_8 and X_9 are all greater than their corresponding b values. As a result the statistical performance of these variables is highly insignificant.

The partial correlation coefficients in this problem have undoubtedly been distorted by the high degree of interserial correlation present.

Second Run

The second equation in this problem was derived using variables X_2, X_3, X_4, X_7, X_{10} and X_{11}. The variables which appear to explain the greatest part of the total variation are X_2, X_4, X_{10} and X_{11}. The partial correlation coefficient and the b value for X_2 are significant at the 95 percent level. The serial correlation between X_2 and X_4 and between X_{10} and X_{11} is significant at the 99 percent level.

Variables X_3 and X_7 are less significant in this equation than they were in Equation (1). Each has a standard error of the b which exceeds the b value.

Third Run

Equation (3) was derived using variables X_2 and X_{10}. X_4 and X_{11} were deleted because of their high interserial correlations with X_2 and X_{10} respectively. The interserial correlation between X_2 and X_{10} is significant at the 95 percent level. The partial correlation and regression coefficients for X_2 and X_{10} are not significant at the 95 percent level. The multiple correlation coefficient is not significant at a high level of significance.

PROBLEM II-C -- Acreage Spring Wheat Planted as a Percentage of Trend (1921-55) Related to Price, Precipitation, Acreage and Yield Variables.

Equations:

(1) $$X_1 = 70.78 + 217\ X_2 - 16.66\ X_3 - 226\ X_4 + .007\ X_5 - 2.09\ X_6 + 1.06\ X_7 - 1.92\ X_8 + 11.63\ X_9 + 2.67\ X_{10} + 2.37\ X_{11}.$$

$R^2 = .5881$ (Significant at 99%)

(2) $X_1 = 46.23 + 192.88\ X_2 - 72.16\ X_3 - 223.78\ X_4 - 1.76\ X_6$
$+ 1.88\ X_{10} - 1.21\ X_{11}.$

$R^2 = .4737$ (Significant at 99%)

(3) $X_1 = 110.71 + 190.3\ X_2 - 67.2\ X_3 - 250.4\ X_4 + .17\ X_{10}.$

$R^2 = .3879$ (Significant at 99%)

Dependent Variable

X_1 = Acreage spring wheat planted as a percentage of trend (1921-55).

Independent Variable

X_2 = Ratio of the price of spring wheat to the price of winter wheat for the previous year.

X_3 = Same ratio as X_2 for 2nd-4th previous years.

X_4 = Same ratio as X_2 for 5th-9th previous years.

X_5 = Acreage winter wheat seeded the previous fall.

X_6 = Precipitation the previous year, January-September.

X_7 = Precipitation prior to spring seeding, October-March.

X_8 = Price of barley the previous year deflated.

X_9 = Weighted average raw price for spring wheat for the 1st-3rd previous years. (Weights = 3, 2, 1).

X_{10} = Yield per acre for spring wheat the previous year.

X_{11} = Yield per acre for winter wheat the previous year.

First Run

This problem uses the same identical variables as Problem II-B. The time series has been increased from 1921-1938 to 1921-1955. Although this longer series includes periods of acreage control and price support, it was used in an attempt to approximate the character of traditional relationships under these conditions.

In this problem as in the two previous problems the coefficients for X_2 and X_{10} are significant at the 95 percent level. The statistical performance of these two variables is considerably higher than any other variables involved. These results are undoubtedly distorted by the high interserial correlation between the two variables.

Variables X_4, X_6, and X_{11} carry the same sign they had in the two previous problems. Their coefficients are not significant at the 95 percent level.

The standard errors of the b values for X_3, X_5, X_7, X_8 and X_9 are greater than the b values.

<u>Second Run</u>

Equation (2) was derived using independent variables X_2, X_3, X_4, X_5, X_{10} and X_{11}. A high degree of interserial correlation exists within this independent series.

The coefficients for variables X_2 and X_4 are all significant at or above the 95 percent level. The interserial correlation between these two variables is not significant. These two variables have retained the same signs they had in the two previous problems.

The coefficients for variables X_3, X_6, X_{10} and X_{11} are not significant.

Third Run

Equation (3) was derived using variables X_2, X_3, X_4 and X_{10}. The only significant interserial correlation present in this independent series is between X_2 and X_{10}. The regression and correlation coefficients for X_2 are significant at the 95 percent level. These coefficients for X_4 are significant at the 99 percent level. The multiple correlation coefficient of .3879 is also significant at the 99 percent level. Variable X_{10} is highly insignificant in this function since its standard error of b far exceeds the b value.

PROBLEM III -- Acreage Winter Wheat Harvested Plus Acreage Spring Wheat Seeded (1921-38) Related to Price and Precipitation Variables.

Equations:

(1) $X_1 = 52.27 - 117.35\ X_2 + 61.38\ X_3 - 12.90\ X_4 + 92.85\ X_5$
$- 17.92\ X_6 + 1.33\ X_7 - .59\ X_8 + 83.62\ X_9$

$R^2 = .6571$ (Significant at 95%)

(2) $X_1 = 53.99 - 93.51\ X_2 - 57.4\ X_3 - 11.32\ X_4 + 91.62\ X_5$
$- 20.60\ X_6 + 71.39\ X_9.$

$R^2 = .6048$ (Not significant at 95%)

(3) $X_1 = 113.03 - 27.14\ X_3 - 22.4\ X_6 + 27.5\ X_9.$

$R^2 = .4284$ (Significant at 95%)

Dependent Variable

X_1 = Acreage winter wheat harvested plus acreage spring wheat seeded as a percentage of trend (1921-38).

Independent Variables

X_2 = Average price all wheat previous year, deflated.

X_3 = Same as X_2 for 2nd-4th previous years.

X_4 = Same as X_2 for 5th-10th previous years.

X_5 = Price of barley previous year deflated.

X_6 = Ratio of index of prices received for wheat the previous year to the index of prices received for livestock and livestock products the previous year (1947-49 = 100).

X_7 = Precipitation in inches, September-March.

X_8 = Total precipitation for previous year.

X_9 = Weighted average price for wheat 1st-3rd previous years. (Weights = 3, 2, 1).

First Run

Equation (1) was derived using the full independent series. This problem was designed to yield a supply function for all wheat. Acres harvested was used for winter wheat to avoid duplicating the winter wheat acreage which is reseeded to spring wheat in the spring.

Variable X_3 is the only one whose coefficients are significant at the 95 percent level. This problem reflects an inverse relationship between all wheat price variables and acres planted as a percent of trend, with the exception of X_9 which shows a direct relationship.

Variable X_5 has a positive b value which in this case is a "wrong" sign. The coefficients are not significant, consequently it is not possible to draw valid inferences about the variable.

Variables X_7 and X_8 are not useful in this problem since the standard errors of the b's exceed the b values.

Second Run

Equation (2) was derived using variables X_2, X_3, X_4, X_5, X_6 and X_9. Variables having a standard error of the b which exceeded the b value in the first run were deleted from the second run.

The coefficients for X_3 and X_6 are significant at the 95 percent level, as indicated in Appendix F. The coefficients for X_9 are significant slightly below the 95 percent level. In this equation as in Equation (1) there is a direct relationship between X_9 and X_1 and an inverse relationship between the other wheat price variables and X_1. A direct relationship is indicated between X_5 and X_1 where an inverse relationship could be expected to exist, however, the coefficients for X_5 are not significant.

There is a high degree of interserial correlation among the independent variables used in this equation. This has undoubtedly distorted the partial correlation coefficients upward.

Third Run

Equation (3) was derived using independent variables X_3, X_6 and X_9. The only significant interserial correlation present in this problem is between X_3 and X_9 as indicated in Appendix F, Table I. The b values for X_6 and X_9 are significant at the 98 percent level and the b value for X_3 is significant at approximately 90 percent. The partial correlation coefficients for X_6 and X_9 are significant at the 95 percent level. The multiple correlation coefficient of .4284 is significant at the 95 percent level.

PROBLEM IV -- Acreage Spring Wheat Planted Plus Winter Wheat Harvested Plus Barley and Oats Planted as A Percentage of Trend (1921-55), Related to Price and Precipitation Variables.

Equations:

(1) $X_1 = 127.75 + 3.89\ X_2 + 13.44\ X_3 + 12.24\ X_4 - 7.17\ X_5$

$- .44\ X_6 + .81\ X_7 - .65\ X_8.$

$R^2 = .4847$ (Significant at 99%)

(2) $X_1 = 138.91 + 4.82\ X_2 + 12.80\ X_3 + 10.44\ X_4 - 7.34\ X_5$

$R^2 = .4220$ (Significant at 99%)

(3) $X_1 = 133.04 + 14.12\ X_3 + 9.66\ X_4 - 4.99\ X_5.$

$R^2 = .3971$ (Significant at 99%)

Dependent Variable

X_1 = Acreage spring wheat planted plus winter wheat harvested plus barley and oats planted as a percentage of trend (1921-55).

Independent Variables

X_2 = Weighted average price for wheat, oats and barley the previous year, deflated. (Weights = acres planted, respectively).

X_3 = Same as X_2 for 2nd-4th previous years.

X_4 = Same as X_2 for 5th-10th previous years.

X_5 = Ratio of the index of prices received for wheat, oats and barley to the index of prices received for livestock and livestock products the previous year, deflated.

X_6 = Precipitation the previous year, January-September. (A combined average for the spring and winter wheat areas).

X_7 = Precipitation prior to spring seeding, October-March.

X_8 = Total precipitation the previous year. (An average for the spring and winter wheat areas).

First Run

This problem was designed to establish an aggregate supply function for grain. Wheat, oats and barley are considered to be the principal grain crops which compete for production resources.

Equation (1) was derived using the entire independent series. The statistical measures relating to this problem may be found in Appendix G.

The coefficients for X_3 are significant at the 99 percent level. The partial correlation coefficient for X_4 is significant at 95 percent and the regression coefficient is significant at the 98 percent level. The interserial correlation between X_3 and X_4 is insignificant. These two variables indicate a positive relationship between historical price averages and acreage of grain planted. The remaining five variables used in this problem have highly insignificant results.

Second Run

Variables X_2, X_3, X_4 and X_5 were used to derive Equation (2). The partial correlation coefficient and regression coefficient for X_3 are significant at the 99 percent and 98 percent levels respectively. The coefficients for X_4 are both significant at the 95 percent level.

The only interserial correlation present in this problem exists between X_2 and X_5; significant at the 99 percent level.

The statistical performance of X_2 has fallen while that of X_5 has risen in this independent series. The results of both are still insignificant.

Equation (2) indicates that for any given year (1921-55) a one cent change, in the deflated weighted average price for all wheat, oats and barley for the 2nd-4th previous years, will be accompanied by a 12.8 percent direct change in the combined acreage of these grains planted as a percentage of trend. Similarly a one cent change in X_4 will be accompanied by a 10.44 percent change in X_1.

Third Run

Equation (3) was derived using variables X_3, X_4, and X_5. These three variables have no significant interserial correlation. The partial correlation and regression coefficients for X_3 are significant at the 99 percent level. The partial correlation and regression coefficients for X_4 are significant at the 95 percent level. X_5 has a standard of the b which is almost as big as the b, and a very small partial correlation coefficient. The multiple correlation coefficient is significant at the 99 percent level.

PROBLEM V -- Ratio of the Acreage of Spring Wheat Planted to Acreage Winter Wheat Planted (1921-55) Related to Price, Precipitation and Yield Variables.

Equations:

(1) $X_1 = 43.61 - .14\ X_2 - .091\ X_3 + 33.09\ X_4 + .19\ X_5 + 34.01\ X_6 + 4.42\ X_7 - 29.44\ X_8.$

$R^2 = .6048$ (Significant at 99%)

(2) $X_1 = 67.61 - .16\ X_2 + 14.39\ X_4 + 3.45\ X_6 + 5.02\ X_7.$

$R^2 = .5633$ (Significant at 99%)

(3) $X_1 = 68.13 + 14.26\ X_4 + 3.15\ X_6 + 4.89\ X_7.$

$R^2 = .5317$ (Significant at 99%)

Dependent Variable

X_1 = Ratio of acreage spring wheat planted to acreage winter wheat planted (1921-55).

Independent Variables

X_2 = Fall moisture for winter wheat area, July-September.

X_3 = Spring moisture for winter wheat area plus spring wheat area, February-April.

X_4 = Ratio of the price of spring wheat to the price of winter wheat for the previous year.

X_5 = Ratio of the average price for spring wheat to the average price for winter wheat for the 2nd-4th previous years.

X_6 = Ratio of the yield for spring wheat to the yield for winter wheat for the previous year.

X_7 = Ratio of the average yield for spring wheat to the average yield for winter wheat for the 2nd-4th previous years.

X_8 = Ratio of the value per acre for spring wheat to the value per acre for winter wheat for the previous year.

First Run

Equation (1) was derived using variables X_1 through X_8. This problem was designed in an attempt to explain the variance in the relative acreage of spring and winter wheat planted. Observations were chosen from the period 1921-1955 primarily to learn how traditional relationships might have been affected by acreage controls and administered prices. The interserial correlation in this problem is very low as Appendix H will indicate.

Variables X_4 and X_7 are the only variables having significant coefficients. The partial correlation coefficient for X_4 is significant at 95 percent and the regression coefficient is significant at 98 percent. The partial correlation coefficient and the regression coefficient for X_7 are both significant at the 99 percent level.

Equation (1) indicates that a one unit change in X_4 will be associated with a 33.09 units change in X_1. A one unit change in X_7 will be associated with a 5.42 units change in X_1. There is a direct relationship between each of these variables and the dependent variable.

The remainder of the variables used in this problem did not have coefficients that were significant.

Second Run

Equation (2) was derived using independent variables X_2, X_4, X_6 and X_7. There is no significant interserial correlation among variables of this independent series.

The partial correlation coefficients and regression coefficients for X_4, X_6 and X_7 are all significant at the 99 percent level. The coefficients for X_2 are not significant. A one unit change in X_4, X_6 or X_7 will be associated with 14.39 unit, 3.45 unit and 5.02 unit changes in X_1 respectively. Equation (2) indicates that changes in the price ratio have a greater effect on the ratio of acres planted than do changes in the yield ratio. The independent series used in this problem is associated with 65 percent of the total variation in the ratio of the acreage spring wheat planted to the acreage winter wheat planted for the period 1921-1955.

Third Run

Equation (3) was derived using X_4, X_6 and X_7 as the independent series. This independent series has no significant interserial correlation. The partial correlation coefficients and the b values for all three variables used in this equation are significant at the 99 percent level of significance. The multiple correlation coefficient is also significant at the 99 percent level.

PART III

SUMMARY AND CONCLUSIONS

Discussion

This study has intended to explore the supply responses for Montana wheat. Functions were developed for explaining five general types of relationships. Supply response functions were developed for winter wheat, spring wheat, ratio of spring wheat to winter wheat, total wheat and total grain (wheat, oats and barley).

In 1955 approximately one-third of the wheat produced in Montana was winter wheat, the remainder being spring wheat. Separate functions were derived for spring and winter wheats expressing the dependent variables (acres planted) as raw figures and as a percentage of trend.

Three functions were developed explaining the relationship between acreage of spring wheat and acreage of winter wheat. This was an attempt to explain variations in spring wheat acreage relative to winter wheat acreages. Presumably a different series of independent variables is associated with this ratio than the series associated with acreages of spring and winter wheat taken separately.

Supply response functions were developed also for total wheat acreages. In these functions an attempt was made to explain the variation in acreage winter wheat harvested plus acreage spring wheat planted. The functions derived using this dependent variable may have application in cases of agricultural adjustment where aggregate production adjustments are desirable.

One set of supply functions was derived for all grain (wheat, oats and barley). Within any given production unit wheat, oats and barley are easily substituted for one another from the standpoint of land, labor and machinery requirements. If we assume that farmers have a propensity to grow grain of some kind in some given amount, then supply functions of this nature may help to explain variations in this total acreage.

Limitations of the Study

Although the multiple correlation technique has many advantages it also has some serious disadvantages which must be taken into account. Conclusions drawn from this study must necessarily be subject to the following limitations.

(1) Multiple correlation analysis is based on the assumption that the relationship between the variables is linear. This assumption is not usually valid when applied to agricultural data, therefore the linear regression coefficients do not always describe these relationships accurately.

(2) A second limiting assumption made by this type analysis is that the effects of independent variables on the dependent variables are separate, distinct and additive. This is not a valid assumption since the effect of any simple independent variable upon the dependent variable is influenced by the size of the other independent variables.

(3) Multiple correlation analysis does not establish causal relationships, but merely degrees of relationship. For this reason extreme care must be taken in drawing inferences about these relationships. Inferences drawn must be based on economic theory as well as statistical measures.

If the interrelationships between independent variables continue to hold in the future, then the supply functions derived may be fairly accurate guides to prediction. When these interrelationships change significantly these equations will not be useful as predictive guides.

The secondary data sources used for this study were not extensive enough to cover a period of more than 18 "normal" years. This limited number of observations places an obvious limitation upon the validity of the analysis.

Summary of Results

The independent variables which were most highly associated with the dependent variables used were price and yield variables. Precipitation variables in general were not closely associated with variations in the acreage planted.

Regression coefficients and partial correlation coefficients which were not significant at the 95 percent level of probability or above were considered to be not significant in this study. Coefficients which are significant at some level below 95 percent may be useful for predictive purposes when the consequence of error is less important.

Twenty-four supply response functions were derived in this study. The multiple correlation coefficients for 11 of these equations are significant at the 99 percent level of probability. Six of the equations have multiple correlation coefficients which are significant at 95 percent and seven are significant at some level below 95 percent. One or more of the equations derived in each of the eight problems has a coefficient of multiple correlation which is significant at or above the 95 percent level of probability. The multiple correlation coefficients for all equations derived in Problems II-C, IV and V are significant at the 99 percent level. In Equation (3), Problem V, all the regression coefficients and partial correlation coefficients are significant at the 99 percent level.

Need For Further Research

This study has investigated the supply response for wheat only insofar as acreage planted is concerned. Yield is the second primary factor determining total supply: therefore a complete analysis of the supply response must necessarily include a detailed analysis of factors affecting yield. Reliable knowledge about variations in yield and acreage planted is a prerequisite to an understanding of total supply response.

The application of yield information for predictive purposes will become increasingly important as weather forecasting becomes more accurate and is projected further into the future.

Policy Implications

The equations presented in Part II may have a twofold usefulness insofar as they are significant. First they may be a guide to the prediction of future events, and secondly they may be a useful guide to policymakers whose job it is to influence what happens in the future. These regression equations may be interpreted directly by saying that a one unit change in any particular independent variable will be associated with a change in the dependent variable equal to the b value for that independent variable. This interpretation should be made only after the limitations of the analysis are considered and certain value judgments made about the relative importance of the variables involved. The most valid equations for purposes of prediction are those with a very low level of interserial correlation and highly significant coefficients of regression, partial correlation and multiple correlation.

Some of the variables used such as yield and precipitation do not lend themselves to administrative control and are useful only for explanatory and predictive purposes. Absolute prices and price ratios are subjust to administrative control and may therfore be useful in influencing future acreages.

Price and yield for some previous period are the two independent variables which are associated most highly with acreage planted in all cases where these two variables are used. This indicates that for purposes of administrative control, using these derived supply functions, price manipulation will be most effective in influencing acres planted.

APPENDIX

TABLE I. PROBLEM I-A -- SIMPLE CORRELATION COEFFICIENTS.

Variable	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
X_1	1.00	-.52[a]	-.50[a]	-.60[b]	-.34	-.22	-.09	-.31	-.48[a]	-.43
X_2		1.00	.71[b]	.69[b]	.17	.05	.34	.52[a]	.39	.49[a]
X_3			1.00	.83[b]	.40	.031	.34	.47[a]	.31	.67[b]
X_4				1.00	.40	.14	.59[b]	.71[b]	.55[a]	.48[a]
X_5					1.00	.19	.24	.33	.10	.12
X_6						1.00	-.13	.12	-.034	.21
X_7							1.00	.83[b]	.59[b]	.085
X_8								1.00	.62[b]	.25
X_9									1.00	.017
X_{10}										1.00

a/ Significant at 95% level.

b/ Significant at 99% level.

TABLE II. PROBLEM I-A -- FIRST RUN.

Variable	Mean	Std. Dev.	β	r[a]	t	b	Sb	Signf. b	Signf. r
X_1	873.22	135.2							
X_2	.94	.05	-.27	-.33	-1.00	-721.9	718	N.S.	N.S.
X_3	.96	.03	-.31	-.29	-.86	-1,396	1,621	N.S.	N.S.
X_4	.98	.03	-.53	-.41	-1.29	-2,391	1,846	N.S.	N.S.
X_5	3.74	1.06	-.09	-.16	-.45	-11	24.37	N.S.	N.S.
X_6	10.18	2.31	-.24	-.44	-1.40	-14	10.1	80%	N.S.
X_7	13.92	3.58	.61	.60	2.12	23	10.9	90%	95%
X_8	11.33	4.20	-.06	-.064	-.18	-2.02	11	N.S.	N.S.
X_9	13.85	2.27	-.30	-.43	-1.34	-17.7	13	N.S.	N.S.
X_{10}	.93	.31	.64	.67	2.55	276.9	108	95%	95%

R^2 = .81198 (Significant at 95%)

a/ Partial Correlation Coefficient.

APPENDIX A (CONT'D)

TABLE III. PROBLEM I-A -- SECOND RUN.

Variable	r[a]	b	Sb	t	Signf. b	β	Signf. r
X_3	-.198	- 946.59	1,412.62	- .670	N.S.	-.21	N.S.
X_4	.531	-3,531.41	1,700.28	2.076	90%	-.78	N.S.
X_5	-.202	- 15.62	22.85	- .683	N.S.	-.12	N.S.
X_7	.659	23.76	8.17	2.906	98%	.63	95%
X_9	-.415	- 19.53	12.90	-1.514	80%	-.33	N.S.
X_{10}	.539	214.71	100.99	2.125	90%	.49	N.S.

R^2 = .7350 (Significant at 99%)

a/ Partial Correlation Coefficient.

APPENDIX A (CONT'D)

TABLE IV. PROBLEM I-A -- THIRD RUN.

Variable	r[a]	b	Sb	t	Signf. b	β	Signf. r
X_6	-.28	-14.26	13.43	-1.06	N.S.	-.24	N.S.
X_7	.28	11.23	10.52	1.07	N.S.	.30	N.S.
X_9	-.55	-39.64	16.55	-2.39	95%	-.67	95%
X_{10}	.016	6.18	101.46	.061	N.S.	.014	N.S.

R^2 = .34668 (Not significant at 95%)

a/ Partial Correlation Coefficient.

X_1 = Acreage winter wheat planted (1921-38).

X_2 = Ratio of the price of winter wheat to the price of spring wheat for the previous year.

X_3 = Same ratio as X_2 for 2nd-4th previous years.

X_4 = Same ratio as X_2 for 5th-9th previous years.

X_5 = Precipitation prior to seeding, July-September.

X_6 = Precipitation previous, September-June.

X_7 = Yield per acre winter wheat for previous year.

X_8 = Yield per acre spring wheat for previous year.

X_9 = Average yield for winter wheat for the three previous years.

X_{10} = Weighted average raw price for winter wheat for the 1st-3rd previous years. (3, 2, and 1 were used to weight prices for the 1st, 2nd, and 3rd years respectively).

APPENDIX B

TABLE I. PROBLEM I-B -- SIMPLE CORRELATION COEFFICIENTS.

Variable	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
X_1	1.00	-.24	-.21	-.32	-.27	-.24	.069	-.12	-.45	.24
X_2		1.00	.71b/	.69b/	.17	-.085	.34	.52a/	.39	.49a/
X_3			1.00	.83b/	.40	-.025	.34	.47a/	.31	.67b/
X_4				1.00	.40	.090	.59b/	.71b/	.55a/	.48a/
X_5					1.00	.17	.24	.33	.10	.12
X_6						1.00	.004	.10	.026	.15
X_7							1.00	.83b/	.59b/	.085
X_8								1.00	.62b/	.25
X_9									1.00	.017
X_{10}										1.00

a/ Significant at 95% level.

b/ Significant at 99% level.

TABLE II. PROBLEM I-B -- FIRST RUN.

Variable	Mean	Std. Dev.	β	r[a]	t	b	Sb	Signf. b	Signf. r
X_1	1.00	.14							
X_2	.94	.04	-.10	-.15	- .42	- .35	.84	N.S.	N.S.
X_3	.96	.04	-.45	-.28	- .83	-1.57	1.88	N.S.	N.S.
X_4	.98	.03	-.07	-.22	- .64	-1.36	2.13	N.S.	N.S.
X_5	3.74	1.06	-.09	-.15	- .43	- .012	.028	N.S.	N.S.
X_6	10.07	2.42	-.28	-.46	-1.49	- .016	.011	80%	N.S.
X_7	13.92	3.58	.72	.61	2.16	.028	.013	90%	95%
X_8	11.33	4.20	-.11	-.095	- .27	- .0035	.012	N.S.	N.S.
X_9	13.85	2.27	-.42	-.52	-1.70	- .026	.015	80%	N.S.
X_{10}	.93	.31	.71	.67	2.53	.32	.13	95%	95%

R^2 = .74501 (Not significant at 95% level).

a/ Partial Correlation Coefficient.

APPENDIX B (CONT'D)

TABLE III. PROBLEM I-B -- SECOND RUN.

Variable	r[a]	b	Sb	t	Signf. b	β	Signf. r
X_3	-.125	- .66	1.59	- .417	N.S.	-.19	N.S.
X_4	-.355	-2.41	1.91	-1.26	80%	-.52	N.S.
X_5	-.256	- .023	.026	- .88	N.S.	-.17	N.S.
X_7	.668	.027	.0092	2.98	98%	.69	95%
X_9	-.525	- .029	.0145	-2.05	90%	-.47	N.S.
X_{10}	.549	.248	.114	2.18	95%	.55	95%

R^2 = .6643 (Significant at 95%)

a/ Partial Correlation Coefficient.