AN ECONOMIC ASSESSMENT OF RESEARCH AND EXTENSION INVESTMENTS IN CORN, WHEAT, SOYBEANS, AND SORGHUM

by

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Introduction and Problem Statement

Introduction

The evaluation of public investments in agricultural research has been a topic of special interest to research administrators and policy makers concerned with productivity in agriculture. The competition from other sources for public research monies and the diminished purchasing power from recent inflation are illustrated in Figures 1.1 and 1.2. The budgets for agricultural research at the United States Department of Agriculture (USDA) and the State Agriculture Experiment Station (SAES) have increased 204 percent in current dollar terms between 1967 and 1978, but only increased a modest 23 percent (1.5 percent annually) if constant deflated dollars are considered. The combined research budget for the USDA and SAES, which was $1043 million in 1978, is a relatively small component of federal research spending, but a large portion of agricultural research relies on funds from federal sources which places agriculture in competition with large government agencies such as Department of Defense (DOD) and the Department of Energy (DOE) for limited federal research dollars. In the face of this diminished purchasing power and increased competition for public funds, research administrators are becoming more concerned with the evaluation of research programs and the allocation of research budgets.

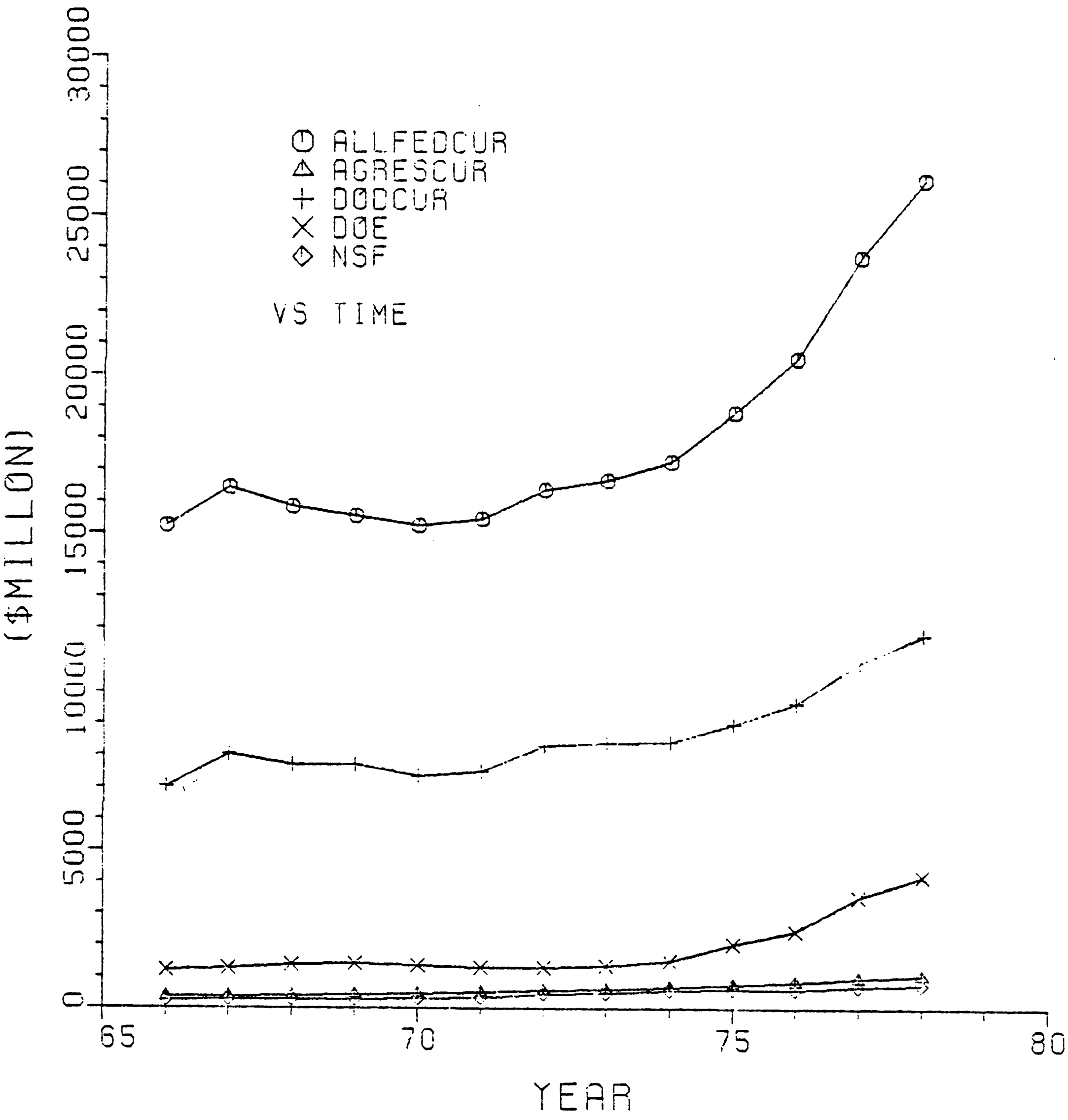


FIGURE 1.1. FEDERAL OBLIGATIONS FOR RESEARCH AND DEVELOPMENT BY DEPARTMENT OF DEFENSE, NATIONAL SCIENCE FOUNDATION, DEPARTMENT OF ENERGY, OTHER SELECTED FEDERAL AGENCIES, AND USDA AND SAES AGRICULTURAL RESEARCH IN CURRENT DOLLARS, 1966-1978.

Source: Table A-1.

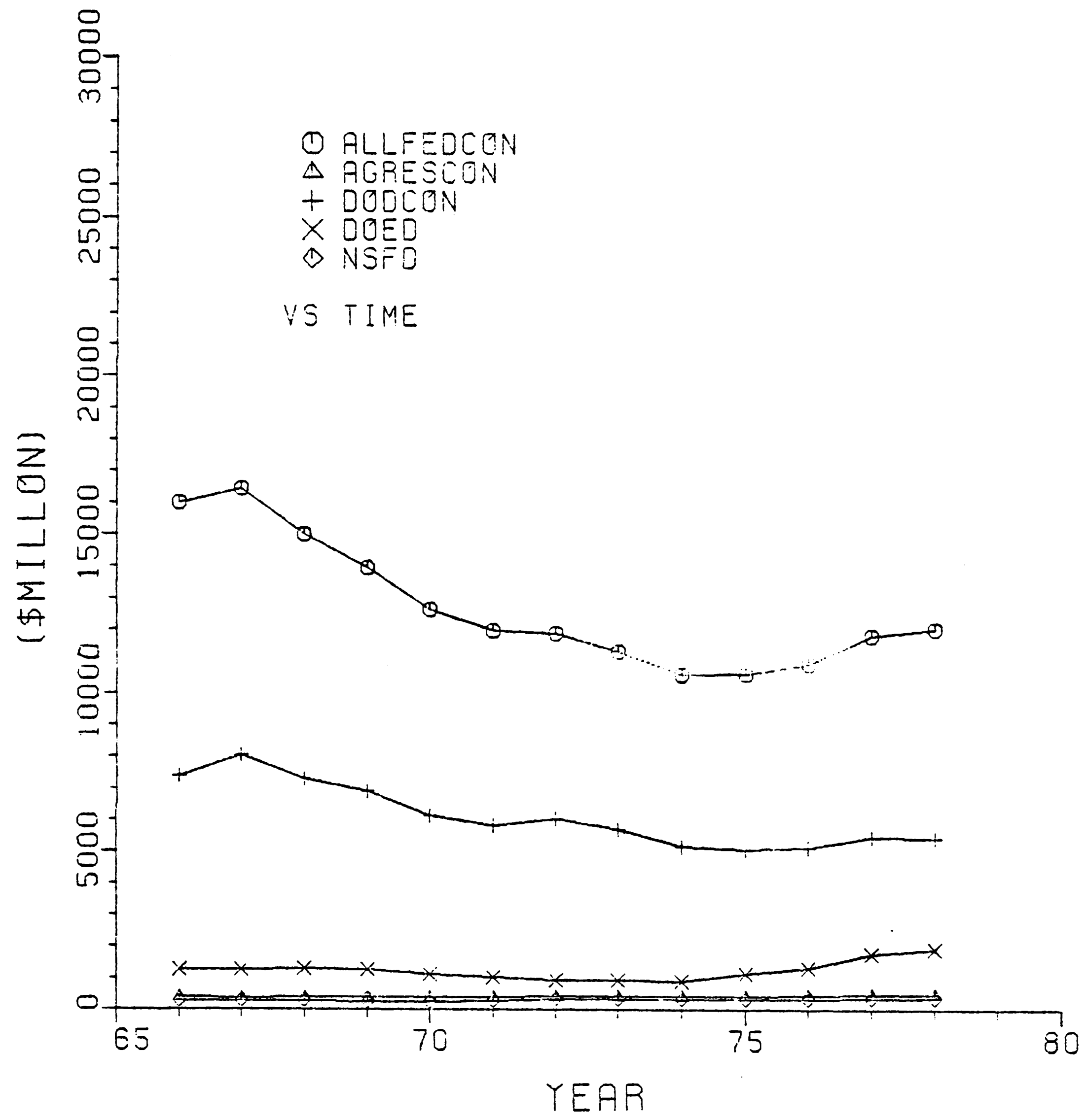


FIGURE 1.2. FEDERAL OBLIGATIONS FOR RESEARCH AND DEVELOPMENT BY DEPARTMENT OF DEFENSE, NATIONAL SCIENCE FOUNDATION, DEPARTMENT OF ENERGY, OTHER SELECTED FEDERAL AGENCIES, AND USDA AND SAES AGRICULTURAL RESEARCH IN CONSTANT DOLLARS, 1966-1978.

Source: Table A-1.

In recent years, several studies, using a variety of approaches have consistently indicated high rates of return to investments in agricultural research (Evenson, 1967, Cline, 1975, White, et al., 1978). These results have been useful in a budgetary context to demonstrate the productivity of agricultural research investments versus other uses of public funds. Although the aggregate rate of return continues to be high, a number of researchers have indicated that the rate has declined over time (Peterson, 1973, Davis, 1979, White, et al., 1980).

More recently, the emphasis of evaluation studies concerned with agricultural research have begun to shift to less aggregated levels of analysis in order to analyze the profitability of individual types of research and to address the issue of efficiency in the allocation of research funds. Two types of allocative efficiency with respect to research funding will be considered in this study. They are the efficient allocation of funds among states for selected commodities and an efficient allocation of funds among selected commodities or lines of research. Information on the rates of return available from past research investments in different commodities, or in different regions, could be used to evaluate whether research funds have been used efficiently when compared to other types of investments. The provision of this information could also help indicate where further research funds could be invested more effectively in terms of generating a higher payoff from a unit of agricultural research expenditure. A study by Bredahl and Peterson (1976) using an aggregate production function investigates the inter-commodity allocation of research expenditures by separating, or disaggregating, agricultural output into commodity groupings of cash grains, livestock, dairy and poultry as provided in the five year Census of Agriculture. Their study also estimated the marginal products of research for individual states based on a common production elasticity coefficient for all states and the average product of research in each state. In this procedure, the marginal products of research are heavily influenced by the level of agricultural output in each state and do not take account of possible regional differences in the productivity of research investment. A more accurate procedure for obtaining marginal products of research investments for interstate or interregional comparisons would be based on research production elasticities estimated for each state or regional groupings of states.

The commodity grouping approach used by Bredahl and Peterson still leaves the evaluation of agricultural research investments at a substantial level of aggregation and does not deal with several important conceptual issues associated with research evaluations individualized to smaller levels of analysis. Also, agricultural extension activities are another competing use of public funds which can interact with research investments and also have an impact on agricultural productivity. However, other than the theoretical and empirical work by Huffman (1975 and 1976) and Evenson (1978), very few evaluation studies have reported impacts from investments in agricultural extension separate from the research expenditures.

Evaluations of research investments based on state level observations confront an additional problem of accounting for the impacts of research spillovers from other states on the productivity of a particular state. The importance of interregional research spillovers, has been recognized in several other studies dealing with agricultural productivity in the U.S. and in various studies from a developmental context. Within the U.S., an aggregate study by White and Havlicek (1979) estimated that the rate of return to research in the Southern region was reduced from 70 percent to 20 percent when all outside research was considered. In another U.S. study which refined the range of feasible research spillovers, Evenson (1978) hypothesized a state's agricultural productivity is influenced by spillovers within similar geo-climatic regions and sub-regions. Because of the similarity of the research infrastructure throughout the state agricultural experiment station system, the interstate transfer and adaptation of research information is greatly facilitated. In an international context, it is the lack of this infrastructure that often hinders direct use of research from other countries. In a study of the international transfer of technology in agriculture, Evenson and Kislev (1972) found that the capacity to undertake the type of research that adapts innovations to conditions in an adopting country is a necessary precondition for successfully transfering research from one country to another. In selecting suitable agricultural technologies, geo-climatic similarities, along with economic and political considerations were again an important basis for the transferability of research. Once research innovations have been transfered and adapted, additional factors affect the ability and rate at which these innovations are adopted. In studies at the international and national level, Rogers indicates that socio-economic conditions such as farmer education and income levels, along with agricultural extension efforts are important factors affecting the diffusion rate of agricultural innovations (Solo and Rogers, 1972).

The preceding discussion has pointed out the important role of research spillovers in an international and national context. While the major problem of this study is assessing research investments in individual agricultural commodities, special considerations will also be given to the problems of evaluating the role of interregional spillovers and the role of extension expenditures as they related to changes in agricultural productivity. Extension expenditures are hypothesized to have a separate and measureable impact on productivity of individual agricultural commodities. Research and extension investments in the individual grain commodities of corn, wheat, soybeans, and sorghum will be evaluated in this study because of the importance of these commodities to the U.S. agricultural economy. The widespread cultivation of these commodities throughout the U.S. also provides a sufficient geographical dispersion to investigate patterns of research spillovers. The research spillovers are hypothesized to occur among regions based upon biological features of the individual commodities. These characteristics will be detailed in a later chapter.

Objectives of Study

The primary purpose of this study is to estimate the IRORs of research investments from in-state research sources and the IRORS of research spillovers from other states. Specifically, the impacts of: a) research investments at the state level, b) extension investments at the state level, and c) research investments by outside regions, will be estimated for individual commodities in order to anlayze the intercommodity allocation of research funding. In evaluating the impact of research and extension investments on yield levels of individual grain commodities, other factors influencing yield levels also will need to be considered. In addition to the conventional weather and land quality factors, the effects of aggregate risk behavior by producers on yield levels will also be estimated.

A second major purpose of this study is to investigate regional aspects of research and extension investments. Specific objectives of this section are to analyze separately regional differences in the impacts of in-state research and extension investments, and research investments by outside regions on yield levels of the same four commodities for several different U.S. production regions. For both the disaggregation of the analysis to smaller geographical regions and the disaggregation to individual agricultural commodities, particular attention will be given to specifying and estimating the impact of spillovers from research investments in other states and regions.

Organization of Study

A review of literature relevant to agricultural research evaluation, interregional spillovers of agricultural and industrial research, and aggregate risk analysis is presented in Chapter 2. The theoretical and empirical model and variables used in this study are presented in Chapter 3. Empirical results from the four individual commodity models and testing various forms of the research spillover variable are presented in Chapter 4. A section of the fourth chapter will present empirical results from a regional grouping of states for this analysis. A final overview with summary and conclusions of this study is presented in Chapter 5.

Chapter 2

Review of Relevant Literature

Introduction

A number of thorough literature reviews on the subject of agricultural research evaluations already exist but focus primarily on the role of allocative efficiency in the budgeting process (Norton and Davis, 1981, Sims and Gardner, 1978, Schuh and Tollini, 1979). The focus on interregional research spillovers in this study also is concerned with these budgetary issues as well as economic development implications. The literature review of this chapter will discuss briefly several of the major research evaluation articles and will concentrate then on some of the less discussed evaluation literature in the industrial and development areas that have dealt with the issues of spillovers and technological transfers, especially at a micro level. The aggregate risk analysis literature related to the analytical framework to be used in this study will be discussed as well.

Research Evaluation Methods

The high rates of return to investments in agricultural research have been obtained consistently over a variety of time periods, data bases, and evaluation techniques. A recent review of research evaluation literature by Norton and Davis (1981) develops a general classification of these evaluation techniques according to an *ex ante* or ex-post approach. Ex ante procedures have been used mainly to assess the potential of individual projects or groups of proposals and are not of primary interest in this study. The ex-post category encompasses a variety of techniques to evaluate the productivity of past research based on existing production records. These evaluations can serve as guides for future research investments but the amount of useful information depends upon the type of evaluation approach used.

The expost evaluations of agricultural research have been classified into two major groups according to the type of approach followed: (1) the consumer and producer surplus approach which in general estimates an average rate of return to research, and (2) a production function approach which includes research expenditures as a variable and from which a marginal rate of return for research is estimated. The earliest research evaluation studies utilized the consumer-producer surplus approach. In 1953 Schultz estimated a 700 percent rate of return to agricultural research by calculating the value of inputs saved in agriculture due to improved production techniques and comparing this value to the cost of the research and development (Schultz 1953). Agricultural output was estimated to be 32 percent higher in 1950 than if research had not been conducted. In another early study, Griliches used the consumer and producer surplus approach to evaluate a single commodity, hybrid corn. The estimated internal rate of return (IROR) to hybrid corn research of 37 percent was based on the loss of consumer surplus if hybrid corn were to disappear (Griliches 1958).

Subsequent evaluation efforts have built additional refinements into the basic consumer-producer surplus framework. Peterson (1967) generalized Griliches' formula to include cases between the polar extremes of perfectly elastic and perfectly inelastic supply. Schmitz and Seckler (1970) focused on the distribution of gains and losses from a technological innovation using the example of the mechanical tomato harvester. Lindner and Jarrett (1978) pointed out the importance of recognizing that level of benefits is influenced by type of shift in the supply curve (i.e. a parallel vs. a proportional shift). Additional studies have differed in the specification of supply and demand functions and the nature of the supply function shifts. The review by Norton and Davis points out that yield increasing research is characterized as shifting the supply curve horizontally and cost reducing research shifting it vertically. The consumer-producer surplus approach has also been used frequently for evaluation of individual commodities and technologies. The *ex ante* analysis by Araji provided estimates of rates of return to integrated pest management research and to individual commodities in the Western region (Araji 1978).

A second major approach for measuring returns to agricultural research utilizes an aggregate production function. The basic model used in the evaluation studies by Griliches 1964, Evenson 1967, and Peterson 1967, has been the Cobb-Douglas production function of the form:

$$(2.1) \quad Q = A \prod_{i=1}^{n} X_i^{\alpha_i} \prod_{l=1}^{m} R_i^{\beta_i} e^{\mu}$$

where

Q is output, usually aggregate output

X_i are the conventional inputs

R_i are the non-conventional inputs, in this case research and extension

α_i and β_l are the production coefficients or elasticities of the respective inputs

μ is the random error term.

In an early application of this approach, Griliches (1964) estimated an aggregate agricultural production function for the U.S. which indicated a marginal product per $1 of agricultural research investment of about $13. After adjusting for private research which is assumed to be equal to public investments, Griliches calculated an IROR to agricultural research of 53 percent. Later studies by Evenson (1967), Cline (1975) and Davis (1979) have also estimated aggregate functions for the U.S., but have turned attention to other issues such as the lag structure for research and the stability of the aggregate research production elasticity over time. Evenson argued for an "inverted V" structure centering on a mean lag of 6 - 7 years. Cline estimated a second order Almon polynomial distributed lag of 13 years, again centering on 6 - 7 years as the period of maximum returns. Davis focused attention on research productivity over time finding that the research production coefficient had declined from .069 during the 1949-59 period to .032 for the 1964-1974 period.

Although the aggregate production function has been used extensively in agricultural research evaluation studies, this approach is not without problems. The aggregate functions using value of output and value of inputs, both the dependent variable and the conventional input variables are measured in dollars for the same time period. Both the level of aggregate output and input usage are simultaneously determined within the same production period suggesting that the results from previous studies may have been subject to least squares bias.

Another problem associated with the Cobb-Douglas functional form is the assumption of a constant elasticity of substitution of one among inputs. Although a number of empirical studies using different functional forms have found this elasticity of substitution not to be equal to one (Welch 1970, Lianos 1970), while another study by Griliches (1964) has indicated an elasticity of substitution not significantly different from one. The mixed evidence on this assumption suggests that the convenience of using the Cobb-Douglas functional form may outweigh the potential problems of violating the assumption of constant elasticity of one.

A problem inherent in using a production function in any functional form to evaluate research investments is the identification of information on inputs that corresponds to the output measure. In the case of the aggregate agricultural production functions for the U.S. (Griliches 1964, Evenson 1969, Cline 1975), information on aggregate output and aggregate inputs (either in dollar value or index form) is readily available. Data availability for a production function becomes more of a problem when a less aggregated unit of analysis is chosen. Bredahl and Peterson (1976) were still able to use production functions to analyze individual commodity groupings (grains, livestock, dairy, and poultry) by using data on inputs provided for these types of farms in the Census of Agriculture which is compiled every four to five years. This farm level information is not collected between census years nor is it broken down for individual commodities. Lacking adequate commodity specific production data from secondary sources, it is not possible to use the aggregate production function approach to analyze the impacts of research investments on individual grain commodities. Information is available on prices of outputs and major inputs and various supply shift variables such as weather, land quality so that research investments on individual commodities can be analyzed in a supply response framework. The theoretical basis of the supply response model and the variables to be included are developed and presented in Chapter 3.

Aggregate Risk

Among the shift variables to be included in the supply function is a specification for the aggregate effects of price risk on yield levels. Although the literature review of this chapter is concerned primarily with development of research spillover variables in various contexts, recent work in the area of supply response models has demonstrated the importance of considering the effects of risk on producer behavior (Just 1974, Traill 1978, Ryan 1977). This section presents a review of the aggregate risk literature used with the type of supply response models proposed for this study. Most of this work has been concerned with the role of both economic and non-market forms of risk and their affects on planted acreage and are based on expected utility maximizing behavior by individual producers. The utility functions of individual producers reflect their evaluation of the probability distribution of profits. In aggregate form, producers' concerns with risk are typically represented by various measures of variability in expected yields, incomes or prices in the estimating equation. Risk averseness is indicated by a negative relationship between the measure of variability and output. Risk seeking behavior would be suggested by the opposite pattern. These relatively simple econometric models have indicated that producers have a considerable reaction to perceived changes in risk structure of individual agricultural enterprises and interactions among other agricultural enterprises. The framework provided by these authors allows direct estimation of aggregate risk behavior in supply response analysis without completely specifying the individual producers' subjective evaluation of risk.

While most of the studies of aggregate risk behavior have been concerned with producer's output or acreage response, the various studies on the influence of prices on yield levels (Houck and Gallagher, 1976, Groenewegen, 1980) imply that price risks also influence yield levels and need to be considered. At the micro level, theoretical researchers have demonstrated that producers' attitude toward risk affect their use of inputs (Sandmo 1971). Various empirical studies at an individual farm level have found that the majority of producers in the surveys have risk averse preference functions (Dillon 1977, Anderson, Dillon and Hardaker, 1976) implying that they use fewer inputs under risk than under conditions of perfect certainty, unless the inputs are risk reducing. If inputs are risk reducing more may be used under production uncertainty. The implication for yield response models is that producers' attitudes toward risk can influence yield levels. If in aggregate, producers in a particular state are risk averse with respect to income from a certain crop, yields will be lower than in the absence of risk averse behavior. In the remainder of this section, efforts to develop aggregate measures of producers' attitudes towards risk and their influence on output will be reviewed. The empirical specifications of aggregate risk for each author are also developed for testing in various commodity models.

Adaptive Risk Models

Beherman (1968) and Lin (1977) measured risk as a three year moving standard deviation of past prices. Their general model is in the form:

$$(2.2)\ Y_t = f^*(X_t^*, Z_t^*, M_t, V_t)$$

where X_t* and Z_t* represent subjective expectations in the explanatory price (X_t*) and yield (Z_t*) variables. An adaptive expectations model can be used to estimate these variables with U_t and V_t representing subjective expectations on price and yield risk which are formed by weighting past observations on expected risk. Similar to the way subjective mean expectations are formed, both price and yield risk may be represented as variances (and covariances) of past risk expectations in the following way:

$$(2.3)\quad \text{Risk}_t = \sum_{k=1}^{\infty} \gamma_k (X_{t-k} - X^*_{t-k})^2$$

where K is the number of past years in the moving average, which was for three years in both Behrman's and Lin's study, γ_K is a weighting parameter which could be weighted equally or in a declining proportion. Both Lin and Behrman modify this framework to obtain a moving average of the standard deviation of prices, gross income, or yields based on the previous three years and is computed as follows:

$$(2.4)\quad \text{Risk}_t = \sqrt{\frac{\sum_{k=1}^{t-3} (P_{t-k} - \overline{P})^2}{t-1}}$$

Previous studies have used these measures to represent producer risk with respect to gross income, yields, and any other input variables. In this study, it will be assumed that expected yield variability does not influence producer decisions so that only the influence of price risks on yield per acre through the resource allocation process for each of the individual commodities will be considered.

Adaptive Risk Model with Alternative Past Weights

Just's (1974) study of crop response in California provides a general method of evaluating supply response to changing risk based on an adaptive risk model. He develops a model which contains aggregate risk variables based on expectations and which are formed as a geometric weighting of the variances and covariances of prices and yields. Again, expressed mathematically in a general adaptive expectations model:

$$(2.2) \quad Y_t = f(X_t^*, Z_t^*)$$

where Y_t is the decision or response variable and X_t^* and Z_t^* represent subjective expectations for the explanatory price and yield variables (Just 1974). These price and yield expectations can be represented as:

$$(2.5) \quad X_t^* = \sum_{k=1}^{\infty} \alpha_k X_{t-k}$$

$$(2.6) \quad Z_t^* = \sum_{k=1}^{\infty} \beta_k Z_{t-k}$$

This adaptive expectation model can be extended to an adaptive risk model as follows:

$$(2.7) \quad Y_t = f^*(X_t^*, Z_t^*, U_t V_t, W_t)$$

where

$$(2.8) \quad U_t = \sum_{k=1}^{\infty} \gamma_k (X_{t-k} - X_{t-k}^*)^2$$

$$V_t = \sum_{k=1}^{\infty} \delta_k (Z_{t-k} - Z_{t-k}^*)^2$$

$$W_t = \sum_{k=1}^{\infty} \rho_k (X_{t-k} - X^*_{t-k}) (Z_{t-k} - Z^*_{t-k})$$

and where γ, δ, and ρ are weighting parameters which can represent declining or equi-weighted influences of past periods. Just (1974) estimated these weighting parameters rather than prespecifying them, but the weights were constrained to have geometric distributions. Other researchers adapting this procedure have prespecified a geometric declining lag structure to the adaptive risk model (Ryan 1977).

Among the specifications developed and tested in his study, Ryan (1977) included a specification of the adaptive model:

$$\text{(2.11)} \quad \text{Weighted Past Standard Deviation (PSD)} = \sqrt{\sum_{k=1}^{t=3} W_k (P_{x_{t-k}} - \bar{P}_x)^2 / _{t-1}}$$

where the weighting parameter (W_k) is prespecified to have declining geometric weights of 1/2, 1/3, 1/6 respectively over the three preceding years. In another variation, Ryan divided the geometrically declining weighted standard deviation of past prices (PSD) by the preceding three year average of past output price:

$$\text{(2.12)} \quad \text{Weighted Coefficient of Variation (WCV)} = \text{PSD} \Big/ \sum_{k=1}^{t=3} P_{x_{t-k}} / 3$$

Adaptive Risk with a Polynomial Weighted Lag of Past Risk

Another specification of an aggregate risk variable was developed by Traill (1978) and is also based on expected prices and risk as functions of past observations. The adaptive expectation model (2.1) was developed as another version of the adaptive risk model:

$$(2.13)\quad Y_t = \beta_0 + \beta_1 \sum_{i=1}^{t} \gamma P_{t-1} + \beta_2 \sum_{j=1}^{t} \delta |P^*_{t-j} - P_{t-j}| + \varepsilon_i$$

Traill defines his risk observation as a polynomial lag of the absolute differences between actual prices and expected prices where an iterative procedure is used to estimate expected price, P*. This formulation was tested on a U.S. onion supply model. Although the results were not as dramatic as those of Just, incorporating these risk variables did provide logical results and improved the overall predictive power of his equations.

Aggregate Risk Involving Interaction of Prices

Ryan (1977) also incorporated the influence of the interaction between output price and a substitute price in a specification of aggregate risk:

$$(2.14)\quad IP = \sum_{k=1}^{t} (P_{x_{t-k}} - \overline{P}_{x_t})(P_{z_{t-k}} - \overline{P}_{z_t})/t-1$$

The particular specification developed from Ryan's paper includes an interaction between the covariance of crop prices, the variability of substitute or own price, and the recent price level of these crops. The price interaction specification is designed to allow risk factors other than own price variability to be tested for potential influence on yield response levels.

Spillovers in Agricultural Research Investments

The aggregate production function has been used to study the effects of agricultural research spillovers. In an aggregate time series analysis based on national data, spillovers between states or regions are not a concern because their impacts are internalized within the unit of analysis. However, at a sub-national level, failure to account for the impacts of out-of-state or region research expenditures may bias the estimates of research productivity. The issue of interregional spillovers also may be of interest to researchers investigating the economic development impacts of interregional or international technology transfers.

From an empirical perspective, several approaches have been used in specifying and estimating the impacts of external research activities. In an aggregate study for the southern region, White and Havlicek (1979) used all research expenditures outside the 13 southern states as a source of potential research spillovers, or "borrowable research." A second study of theirs included all ten production regions of the U.S. with "borrowable research" again considered as research expenditures in all outside regions (White and Havlicek, 1981). While these results point out the importance of considering spillovers in research evaluation studies at a regional or state level, a better conceptual basis for the spillover variable is needed when dealing with individual commodities or groups of commodities.

Evenson's research (1978) investigating research and extension productivity in regions of the U.S. utilizes a model of research spillovers among states that is based on geo-climatic considerations. Evenson hypothesized that agricultural research results are most likely to generate spillovers among states within the same geo-climatic region. These geo-climatic regions which cross state boundaries are based on the soil and climatic regions and sub-regions defined in the *1957 Yearbook of Agriculture*. State agricultural research is allocated to each of the regions or subregions within a state according to the share of commodity production in each region. This procedure is followed for each of 21 agricultural commodities and then summed to create a stock of borrowable research available to producers within similar regions. Evenson then uses this spillover research variable, in addition to in-state research and extension expenditures to help explain total factor productivity for a cross section of states during the 1949-1971 time period. Among the results presented in his paper were significant impacts of this borrowable research and interactions with education, extension and basic research.

International Research Transfers

The framework of geo-climatic regions as a basis for interregional research transfers in the U.S. is based on prior research by Evenson and others on the role of international technology transfers for economic development. The important influence of local conditions, in terms of the physical, economic, and political environment has been long recognized in the international transfer of research and technology. In an article reviewing technology transfers and resource allocations, Evenson and Binswanger discuss the importance of location specificity along with adaptive and basic research activities as keys to development. They suggest three primary options, all sensitive to the locational factors available to a country for improving the productivity of a sector of its economy:

(a) The direct transfer option where a country simply screens and adopts outside techniques without prior adaptations through domestic research.

(b) A program of adaptive research where a country can screen outside technology and then modify or redesign the borrowed techniques to suit its own resource endowments.

(c) Development of a comprehensive research program in order to produce its own techniques.

The decision on the appropriate research strategy which would allow mimimun cost production is placed in an induced innovations framework. The choice of options depends on the availability of **indigenous** resources and the path allowing the most rapid and sustained growth.

A series of empirical studies reviewed by Evenson and Binswanger focused on examples in agriculture of the international technology transfer process. The studies in this volume included Evenson's investigation of the development and diffusion of sugar cane varieties and a pair of studies analyzing cereal-grain yield data for more than 70 countries over a 20 year period. Although a direct transfer approach may appear to be a suitable approach to increasing productivity, Evenson and Kislev find a number of difficulties with this approach such as high costs for screening the technology, absence of an applied research capacity to adapt particular technologies, or economic (factor scarcities) and noneconomic obstacles (climatic or physical differences).

These technology transfer studies and the current work of Evenson, Ruttan, and others point out the importance of establishing indigenous research capacity, on a national or regional basis, to successfully benefit from interregional technology transfers. Within a dispersed agricultural system such as the U.S., the State Agricultural Experiment Stations (SAES) perform the roles of developing indigenous research and adapting transfered research to local environmental conditions. The work conducted by Evenson on geo-climatic regions in the U.S. emphasizes the importance of geo-climatic similarities as a basis for agricultural research spillovers to occur. The geo-climatic region as developed by Evenson for U.S. agriculture, after modification for individual commodities, forms the basis for the agricultural research spillover variable used in this study. A comprehensive discussion of this variable is contained in Chapter 3.

Industrial Research Spillovers

The issue of research spillovers and technological transfers has also been extensively investigated for the industrial sector (Mansfield, 1975, Griliches, 1979). In discussing the nature of spillovers, Mansfield distinguishes between vertical and horizontal technology transfers. He discusses vertical technology transfers as the transmission of information along a continuum from basic research to applied research into development and on into production. Horizontal technology transfer occurs when technology used in one place, organization, or context is transfered and used in another place, organization, or context (Mansfield, 1975). Technological transfers can involve both horizontal and vertical elements, and in general the costs and difficulties are much greater when both types of transfers are considered. These concepts of vertical and horizontal technology transfers are quite compatible with the discussions of interregional transfers and adaptations of agricultural research across geo-climatic regions as discussed by Evenson (1978).

An additional set of considerations in both industrial and agricultural settings have been regarded important in the process of technological transfer. Ruttan and Hayami distinguish several phases in their process (Hayami and Ruttan). In the early _material_ transfer phase, there is the export of a new material or product by one country to another. In the _design_ transfer stage, recipient countries are able to transfer designs, blueprints, and the ability to manufacture the new material or product. Finally, there is the capacity transfer phase which occurs when the capacity to adapt the new item to local conditions is transfered. This latter phase of creating a "knowledge generating" capacity as well as using what others have learned is more difficult and a more costly level of development to achieve.

In addition, to these distinctions among technology types, Griliches' recent review of industrial research and development (R & D) includes a discussion of industrial similarities as the basis for transfers (Griliches, 1979). In order to attempt quantification of technological transfers, Griliches uses the concept of a "technological distance" between industries as a means of identifying similarities and estimating the ease of transferability among industries (Griliches, 1979). For conceptual exposition a simple within-industry model is used:

$$(2.15) \quad Y_i = BX_i^{1-r} \; K_i^{r} \; K_a^{u}$$

where Y_i is the output of the ith firm which depends on its index of conventional inputs, X_i, its specific knowledge capital K_i, and the state of aggregate knowledge in the industry K_a. In aggregating over all industries, the function becomes:

$$(2.16) \quad \sum_{i=1}^{n} Y_i = B_i \left(\sum_{i=1}^{n} X_i \right)^{1-r} K_a^{u+r}$$

where the aggregate level of knowledge capital K_a, is the sum of all specific firm research and development capital levels.

This same formulation can be generalized to a whole array of firms and industries which "borrow" different amounts of knowledge from different sources according to their economic and technological distance from them. Aggregate knowledge in this case can be represented as:

$$(2.17) \quad K_{ai} = \sum_{i=1}^{n} W_{ij} K_j$$

where K_j is the level of knowledge available from all these sources and W_{ij} is the effective fraction of knowledge j borrowed by industry i. This W_{ij} is related to the notion of technological distance where W_{ij} becomes smaller as the "distance" increases. Various attempts to measure research borrowing stress a purchased inputs approach which utilizes "closeness" weights based on industrial purchases from each other. A second approach is to classify industrial research by industries belonging to a common Standard Industrial Classification code (SIC) as borrowable research (Griliches, 1979).

These attempts to measure closeness of industrial activities are necessary in order to develop weights for aggregating the R & D expenditures into a single measure of borrowable research. These attempts in agricultural research evaluations to identify a relevant stock of borrowable research seem to closely parallel the efforts to measure borrowable research based on similarities of geo-climatic conditions in states conducting research. In the present study, the evaluation of individual agricultural commodity research will also make use of the geo-climatic region as a basis for formulating a stock of borrowable outside research. The modifications of the geo-climatic region for use in evaluating individual agricultural commodities is discussed more fully in Chapter 3.

The concept of technological "distance" also has some degree of relevance to agricultural research and development which as an industry can benefit from "spill-ins" from other industries. Within the publicly funded agricultural research sector, the technological distance notion can be applied to the commodity groupings of a particular line of research where research on similar commodities are more likely to result in spillovers or transfers. The distinction between basic and applied research also incorporates some of the "distance" concepts. Research areas that are more basic such as pathology and genetics can produce potential breakthroughs applicable to a wide range of commodities. A testing of this technological distance concept in the form of a basic research variable is included among the various research variables to be discussed more fully in Chapter 3.

Assessment

In this chapter various approaches used to evaluate agricultural research with special focus on studies that have examined the impacts of research spillovers were discussed. Because this analysis centers on the evaluation of single agricultural commodities with special data requirements, neither the consumer-producer surplus approach nor the aggregate production function approach are appropriate for this study.

The analytical framework of the aggregate supply model to be used in this study is developed in the next chapter.

The discussion of various research spillover models used in agricultural, industrial, and developmental research evaluation provided the framework of a geo-climatic based spillover model which will be used in this study. The specification of research spillovers and other variables used in this study is also discussed in more detail in Chapter 3.

Chapter 3

Model and Variable Specification

Introduction

The aggregate production function approach which has frequently been used for analyzing aggregate agricultural research investment utilizes data on production inputs available from secondary sources. This study's objective of analyzing the impact of research investments on individual grain commodities confronts a data problem of identifying agricultural inputs used specifically in the production of each commodity. Secondary sources do not publish comprehensive input data for specific commodities and conducting a survey to collect the production information would be very time consuming and expensive. As an alternative, commodity specific research investments will be analyzed as technological shift variables within a supply response model. This chapter contains a discussion of the theoretical framework of the supply response model, which is based on the yield response model used to estimate corn yield functions by Houck and Gallagher (1976). The empirical model and a detailed specification of the variables used to estimate the empirical function are also presented in this chapter.

Theoretical Model

The supply response function to be used in analyzing the impacts on yields of investment in agricultural research is based on the following production function for each commodity:

(3.1) $G_i = f_1(I_i, L_i)$

where (G_i) is output of the ith grain commodity, (I_i) are variable inputs, (L_i) is land. Output is the product of two components, acres (L_i) and yield per acre (G_i/L_i) which are influenced by a variety of factors and the timing of producer decisions. Farmers are assumed to decide first on how much land (L_i) to plant to a particular grain (G_i), and later to decide on the level of inputs to apply. The acreage decision may be influenced by expected prices, crop rotation requirements, various agricultural policy programs, and other considerations. The yield per acre portion of total output (G_i/L_i) can also be influenced by expected prices in relation to the level of inputs applied, as well as by post-planting geo-climatic factors, such as weather and soil fertility, and by institutional factors such as those affecting technological change. Because this study is focusing on the impact of research investments on technological change in the form of increasing output per acre, special attention will be given to the yield per acre component of total output.

Although producers operate within an environment where output prices and yield levels are unknown, for purposes of exposition, the neo-classical model of profit maximization under conditions of perfect certainty will be used. The production function for the ith grain commodity (G_i) in terms of yield per acre can be expressed as:

(3.2) $(G_i/L_i) = f_2(I_i/L_i, W_i, LQ_i, T_i)$

where output per acre (G_i/L_i) is a function of inputs per acre (I_i/L_i), weather (W_i), and land quality (LQ_i), and technological change (T_i), which is represented by research and extension investments. Based on this production function, if profit maximizing behavior by producers is assumed, neo-classical production theory can be used to derive a general supply response function. With additional assumptions that the producer operates within a static environment with perfect information and all inputs are available during each production period, the individual producer's long run optimal output is determined by equality of price and long run marginal cost. The individual supply function is relevant for all prices greater than, or equal to, minimum average variable costs. According to production theory a profit maximizing producer uses additional production inputs until the value marginal product (VMP) of that input is equal to the cost of that input (PI). The profit maximizing rule for using inputs, the price of input set equal to the price of output times the marginal product of the input ($PI = PO * MP$), can also be expressed in terms of the ratio of input to output prices:

(3.3) $MP = PI_i/PO_i$

Thus, by assuming that producers are operating at profit maximizing levels, the yield per acre response function can be expressed in terms of prices and a variety of institutional and geo-climatic shifters. This general output per acre yield function can be represented as:

(3.4) $(G_i/L_i) = f_3(PO_i, PS_i, W_i, LQ_i, T_i)$

where output per acre (G_i/L_i) is a function of the price of ouptut (PO_i), the price of substitute (PS_i), weather (W_i), land quality (LQ_i) and technological change shifters which involve research and extension (T_i).

While the normative model of producer behavior is presented in terms of profit maximization, the discussion also could be made in terms of expected utility maximization where producers' utility functions reflect valuation of the mean level and variance of expected profits. A rigorous theoretical presentation of the expected utility approach has been developed and presented by Just (1974a) and Sandmo (1971). Although agricultural firms are typically competitive and face known input prices, output prices and some production factors may be uncertain. In an expected utility maximization context, resource allocations under risk would be affected by producer's perceived attitudes towards risk. If a producer is risk averse, risk acts as a friction to production and induces a lower level of resource use, unless that particular resource is risk reducing. If a producer is risk prefering, a higher level of resource is used. The expected utility maximization decision criteria was found to explain producer behavior more accurately than profit maximization in a study by Lin, Dean, and Moore (1974). They concluded that disregarding risk would lead to overestimating actual supply response. The inclusion of an aggregate risk variable in a positive supply response function helps overcome this source of bias and also reflects producer attitudes towards risk aversion, in aggregate, without prior elicitation of individual producer's subjective risk evaluations. The empirical work associated with the positive risk response estimation approach has indicated significant reaction to risk on the part of producers (Behrman, 1968, Just, 1974, Ryan, 1977). Their findings suggest the appropriateness of a positive approach to risk response estimation to our study. The specifications of risk presented in Chapter 2 are similar to the adaptive risk models of Just which incorporate the assumptions of producers' expected utility maximization and reflects attitudes toward variability of expected profits as well as mean level of expected profits. A data base composed of a cross section of major producing states over seven year time series will be used to empirically test various formulations of this theoretical model. The empirical model and the specification of individual variables that will be used to estimate the yield response functions are discussed in greater detail in the remainder of this chapter.

Empirical Models

The theoretical yield response function developed in the previous section with consideration of the role suggests the variables which will be used to empirically estimate the relationship between yield per acre and investments in research and extension. A general composite statement of the models to be separately estimated for corn, wheat, soybeans, and sorghum can be written as:

$$(3.5)\quad Y_{it} = B_1\ PO_{it-1} + B_2\ PS_{it-1} + B_3\ W_{it} + B_4\ LQ_{it} + B_5\ RK_{it} + B_6\ ISR_{it-5} + B_7\ OSR_{it-6} + B_8\ EX_{it-4}$$

where:

Y_{it}	is output per acre in state i in year t (bu/acre).
PO_{it-1}	is output price in state i in year t-1 ($/bu).
PS_{it-1}	is substitute price in state i in year t-1 ($/bu).
W_{it}	is weather in state i in year t as measued by pasture and range conditions of each crop year.
LQ_{it}	is a quality weighted land variable in state i in year t.
RK_{it}	is a measure of aggregate price risk in state in year t.
ISR_{it-5}	is a research expenditure on each individual commodity in state i in year t-5 ($million).
OSR_{it-6}	is research expenditure on each individual commodity by outside regions relevant to state i in year t-6 ($million).
EX_{it-4}	is agricultural extension expenditures relevant to these commodities in state i in year t-4 ($million).

Variable Specification and Data

While several of the variables included in the specification of the statistical model are straight forward, others require additional discussion on details of their construction. The purpose of this section is to present important aspects of the variables included in the statistical model and a more detailed discussion on the construction and data sources of these variables.

Output. Some of the rationale for using yield per harvested acre as the dependent variable in the study of the relationship between research investments and agricultural productivity change were discussed in the previous section of the theoretical model. Yield per acre has long been used as an indicator of productive efficiency in agriculture. This partial productivity measure is not used without some problems of measurement and bias. For example, yields could be increased by heavier use of inputs other than land, such as fertilizer chemicals or labor. In the case of a single agricultural commodity, it may be easier to control for these extraneous factors than when aggregate output per acre is used. Under the assumption of profit maximizing behavior, changes in price relationships could affect the usage of these inputs and subsequently affect yield levels. However, by using a quantity measure instead of value per acre, and because the partial and total factor productivity index are highly correlated, a yield per harvested acre index is assumed to be the more appropriate measure of productivity change and is used in this study.

Price of Output. Since producers make planting and input application decisions before output levels and harvest prices are known, they are responding to some form of expected price. Studies focusing on expected price formation by producers have suggested various formulations. An adaptive expectations approach (Nerlove 1958), a weighted lag of expected price declining over several years (Just 1974), and commodity futures prices (Gardner, 1977) have been discussed and used as proxies for expected price. Since the primary focus of this study is not on developing expected price estimates, a simple adaptive expectations model of expected price formed as a one year lag of prices received for each commodity will be assumed. This observation will be measured at the state level for each of the four commodities in this study. A similar construction of commodity prices for competing commodities will be used to form an expected price of substitute commodity variable.

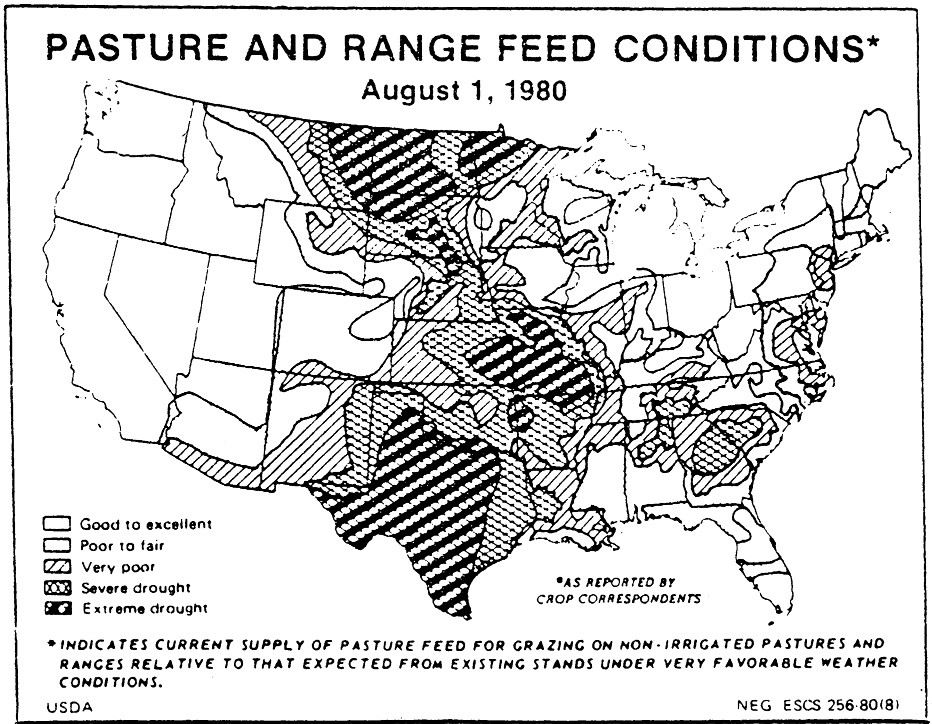
Price of Inputs. The same argument for using a one year lag of input prices as a proxy for expected prices is applicable. A more important question, however, concerns which inputs to use and how best to measure them? Since fertilizer is a major input in the production process and a major determinant in affecting the level of yields, a weighted price of fertilizer used for each crop was developed. Survey figures on levels of N - P - K per acre used by crops and by state was obtained for the 1970-1979 crop years (USDA, ESCS). The respective prices of these primary nutrients were found by calculating the pounds of amonium nitrate, super phosphate, and muriate of potash necessary to achieve the survey level of fertilizer application according to the percentage active ingredient in each. These levels of fertilizer were multiplied by the seasonal average price of each and summed over the three fertilizers to arrive at a weighted average of the price of fertilizer used on each crop in each state. This quantity weighted price of fertilizer variables will be estimated separately and in ratio form with price of output in the different commodity supply functions.

Weather. The influence of weather is a major environmental factor affecting variation in yield levels, both over time and location. To prevent serious bias in supply response estimation, these weather influences need to be taken into consideration. Historically a variety of approaches have been used. Supply response studies subsequent to 1958 made extensive use of the weather index constructed by Stallings (1958). The Stallings index basically compared yield differences in experimental test plots with a time trend. These residuals were ascribed to the influence of weather. Efforts to update this series in later years (Cline 1975) used the residual from regressing actual yields on time to arrive at an updated weather index. The problem of capturing extraneous effects in this residual index decreases the desirability of using this weather variable.

A second alternative procedure is to use climatological data such as temperature and rainfall in various formulations as a weather variable. Studies such as Morzuch and Thompson (1977) have included formulations such as temperature and rainfall deviations from normal, degree days which is a measure of the number of days during the growing season when temperatures are above a minimum needed for plant growth as well as the straight measures of temperature and rainfall. There are many problems with these types of weather variables, such as the timing and location of the climatological measurement.

The alternative adopted in this study is to use the subjective index of weather conditions reported by the statistical reporting service and published on a state basis (USDA, ESCS). This index reflects the subjective judgement of crop reporting officers in each state as to the effect of weather conditions (reflecting temperature, rainfall, humidity, etc.) on pasture and range conditions (Figure 3.1). Index values for critical months during the growing season will be tested to determine which is most appropriate. This index approach avoids problems of attempting to capture numerous and diverse weather influences and the problem of including unwanted elements in a residual variable. While this weather index is chosen as the best available measure of weather influence, it is not without problems, mainly the subjectivity involved in deriving the index values.

Land Quality. Land quality is another factor which can influence yield levels at an aggregate state level, and also within subregions of a state. If agricultural land were valued only for its use in agricultural production, some measure of price per acre of land could be used to represent this quality difference across states. However,



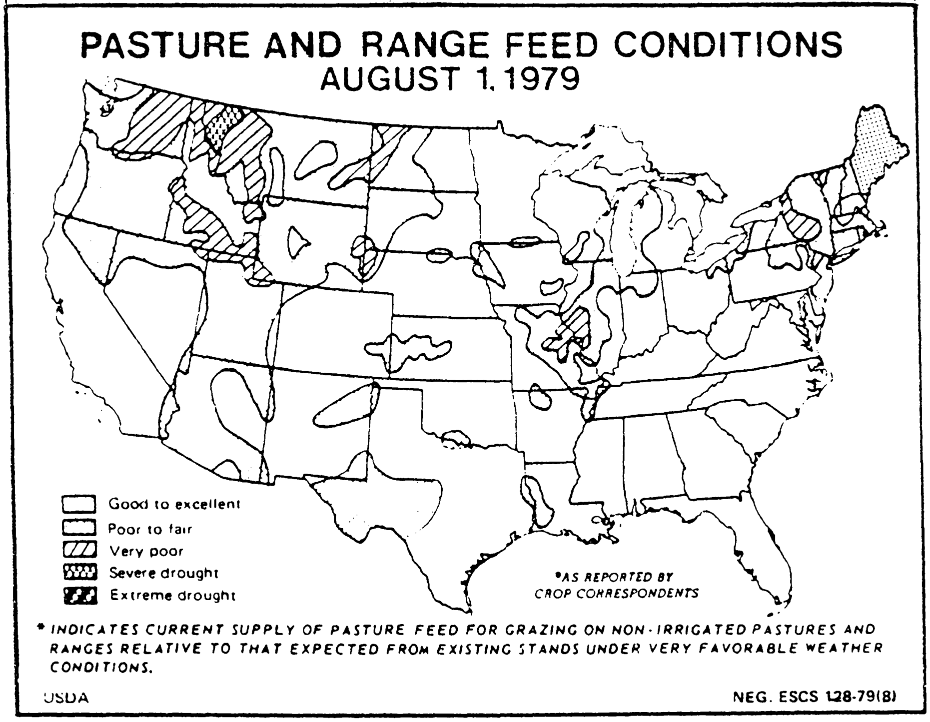
PASTURE AND RANGE FEED CONDITIONS*

August 1, 1980

*AS REPORTED BY CROP CORRESPONDENTS

* INDICATES CURRENT SUPPLY OF PASTURE FEED FOR GRAZING ON NON-IRRIGATED PASTURES AND RANGES RELATIVE TO THAT EXPECTED FROM EXISTING STANDS UNDER VERY FAVORABLE WEATHER CONDITIONS.

USDA NEG ESCS 256-80(8)



PASTURE AND RANGE FEED CONDITIONS

AUGUST 1, 1979

*AS REPORTED BY CROP CORRESPONDENTS

* INDICATES CURRENT SUPPLY OF PASTURE FEED FOR GRAZING ON NON-IRRIGATED PASTURES AND RANGES RELATIVE TO THAT EXPECTED FROM EXISTING STANDS UNDER VERY FAVORABLE WEATHER CONDITIONS.

USDA NEG. ESCS 128-79(8)

FIGURE 3.1. PASTURE AND RANGE FEED CONDITIONS, AUGUST 1.

Source: USDA, Crop Production, 1980.

as detailed by Davis (1979), several other important factors affect the value of land:

a) its value as an inflation hedge;

b) changes in price certainty over time as a result of government policies;

c) technological advances;

d) increases in urban use alternatives (Davis, 19979, p. 31).

As in Davis' study, the procedure adopted here is based on a set of land productive quality indexes developed by Hoover (Hoover 1961) and a land value measure developed by Boyne (1962). These state land values are based on land prices for the different categories of land from 1945 in order to avoid bias from technological advances from research during the period of analysis and also to minimize bias in land prices from the three other factors. Different weights for land in each state are developed for the classifications of woodland, rangeland, pasture, cropland and irrigated cropland. These different categories of land were available up to 1974 from the Davis study and were updated to be compatible with the 1973-1979 data base of this study. The result of this procedure is a measure of the constant dollar value per acre of land expressed in terms of pasture equivalents which reflect differences in land quality among states.

Aggregate Risk. The discussion of aggregate risk variables in the literature review indicated the importance of considering the impacts of risk in supply response models. Previous studies have indicated that producer's attitude toward risk can also influence output levels (Just 1974, Traill 1978, Ryan 1977). Based on their investigation, the influence of aggregate risk on yield levels will be considered in this study. Several of the risk variables presented in the literature review will be tested in the commodity models. The specification involving the variance and standard deviation of past prices:

$$(3.6) \quad \text{Risk}_1 = \sqrt{\frac{\sum_{i=1}^{t=3} (P_{x_{t-i}} - \overline{P}_{x_i})^2}{t-1}}$$

and an interaction of past prices and a substitute:

$$(3.7) \quad \text{Risk}_2 = \sum_{i=1}^{t=3} (P_{x_{t-i}} - \overline{P}_{x_i})(P_{z_{t-i}} - \overline{P}_{z_i})$$

will receive special emphasis in this examination.

<u>Research and Technical Knowledge</u>. The review of past research evaluation studies indicated considerable diversity in terms of what should be represented as research and how it is measured. The early cross sectional production function studies assumed an average lag between the research investment and its impact on output which is a weighted mean of all the lags involved. A rate of return was then estimated based on the length of the lag. Later, emphasis in the time series production function studies was on the structure of the lag between research expenditure and its impact on output. Actually there

are several types of lags that need to be considered when assessing the impact of agricultural research. There may be a lag in the time it takes to complete a particular research project after investment. If and when a project is completed, there may be another lag before a research innovation is produced. After development, there may be a lag again before the innovation is adopted by producers.

An additional issue related to the lag structure of research is the rate of depreciation in a research innovation. Some authors argue that research investments add to a "stock" of research and development capital which is subject to depreciation and obsolescence (Mansfield,1975, Griliches,1979). Studies up to now have implicitly, or explicitly assumed that the new research investments effectively measure changes in the research stock. For this to hold, the difference between the depreciation and and appreciation rate need to be negligible. Although identification of the rate of depreciation in research is important for estimating the productivity of agricultural research, very little is known about rates of research depreciation in either the public or private sector. Researchers have been able to suggest several reasons why a faster depreciation rate might occur in private industry; from a firm's perspective, once information becomes available to other firms in an industry, it loses its specificity and can be considered depreciated. Mansfield's studies suggest private research is usually short term in nature, with a lag structure that peaks somewhere between 3 and 5 years. The research then declines rapidly with little of the R & D product remaining private after ten years (Griliches,1979). However from a social point of view, because other firms may be using the research innovation, the research may not be fully depreciated if it continues to add positively to output.

This discussion points out that the flow from research investments is not necessarily equal to changes in the stock of research knowledge. However, it is quite another issue to attempt to measure the depreciation rate. Griliches argues that without prior information it seems necessary to make the assumption that the rate of change in growth of the stock of research knowledge is equal to the rate of depreciation in that stock of resarch knowledge in order to not bias the estimates of research productivity (Griliches, 1979). Estimating the rate at which research knowledge depreciates is beyond the scope of this study, and without information on the depreciation rate, we will also be making the assumption that the rate of depreciation in the stock of research knowledge is equal to the appreciation rate as measured in annual expenditures on agricultural research. Since individual grain commodities are being investigated in this study, research expenditures on corn, wheat, sorghum, and soybeans at State Agricultural Experiment Stations are used to measure the flow of research knowledge. This pool of research knowledge available for influencing productivity at the state level is influenced not only by the research efforts of a particular state, but also by research activities being done outside the states by other

SAESs, by the USDA, or by private agencies. Expenditures on extension activities are also an important part of the process that transforms this pool of available research into increases in productivity at the state level. The extension variable will be tested separately from research for its impacts on yield levels and is discussed more fully in a later section. The contribution of this outside pool of research activities to the productivity of a state is a major focus of this study. More details on the nature of these research spillovers and a method for testing their effects is presented in the discussion of that variable.

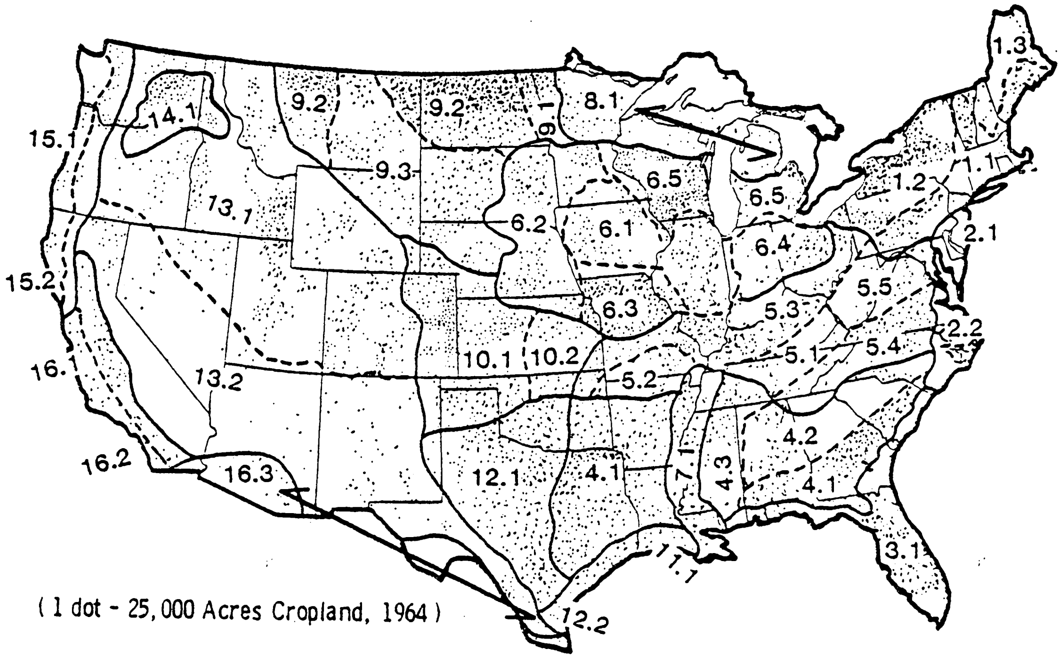
By measuring flow of research stock as the annual research expenditure on a particular commodity in a particular year, attention also needs to be given to choosing a lag structure for estimation purposes. In his unpublished dissertation, Davis compared several methods of estimating the research coefficient, testing its sensitivity to different lag structures. A consensus in the literature points towards an "inverted V" distribution centering on a mean lag of six to seven years for aggregate research and the linearly increasing and decreasing weights on research distributing benefits over a 12-13 year period. The specifications tested by Davis included this six year mean lag, a constrained second order Almon polynomial lag of 14 years, which centers on a lag of 6-7 years, a lag structure used in Griliches' original 1964 aggregate production function study ($Res_{t-1} + Res_{t-6} / 2$), and the option of simply using the same year's research expenditures. His tests showed no significant difference in the magnitude of the research coefficient from any of these specifications when estimated in an aggregate production function (Davis 1979, p. 72). This result suggests that estimates of the research coefficient will not be significantly different or unduly biased by using a less elaborate lag structure such as research investments with the same years' research or a no lag or a mean lag of n number of years for estimating the impact of research investments. This conclusion is a useful result for our current study which will be using a 5 year mean lag of research. This lag was chosen because of the constraint on the number of years for which individual commodity research data is available and because of the conceptual appeal of lagging research behind productivity impacts.

Outside Research

One of the primary issues discussed in the review of literature in Chapter 2 was the various efforts to represent the effects of research spillovers in conceptual and empirical models in a variety of applications. These discussions concluded that the geoclimatic similarities form the most reasonable basis for identifying an area of potential research spillovers. This argument forms the basis of the spillover regions used in this study's effort to estimate impacts of research investments on yield levels of corn, wheat, soybeans, and sorghum.

In his discussion of a spillover model, Evenson identified potential spillovers according to similar geoclimatic regions which are based on 16 production regions and 40 sub-regions drawn by researchers for the _1957 Yearbook of Agriculture_ (Figure 3.2). These regions and sub-regions, which extend across state boundaries, form the stock of available research to various states. The allocation of research expenditure to each region was made by alloting state research to each sub-region according to the share of commodity production in the region. This allocation was performed for all 21 commodities used in the Divisa Index on total factor productivity. This Divisa Index was used as the dependent variable in Evenson's productivity decomposition for all 48 states during the 1948-71 time period. This geo-climatically based spillover variable was found to have a significant influence on productivity level in Evenson's function.

The geoclimatic production regions used in Evenson's analysis of overall agricultural productivity, include all livestock, poultry, dairy, and the various grain commodities. The use of these geoclimatic regions as the research spillover structure for a wide range of agricultural production suggests further refinement may be necessary for evaluating individual commodities. Sundquist, Cheng, and Norton (1981) did report significant results, however, when using these regions to estimate research spillovers to wheat production in a single year, 34 state cross section. Davis also attempted to use



1. Northeast Dairy Region
2. Middle Atlantic Coastal Plain
3. Florida and Coastal Flatwoods
4. Southern Uplands
5. East-Central Uplands
6. Midland Feed Region
7. Mississippi Delta
8. Northern Lake States
9. Northern Great Plains
10. Winter Wheat and Grazing Region
11. Coastal Prairies
12. Southern Plains
13. Grazing -- Irrigated Region
14. Pacific Northwest Wheat Region
15. North Pacific Valleys
16. Dry Western Mild-Winter Region

FIGURE 3.2. U.S. AGRICULTURAL GEOCLIMATIC REGIONS AND SUBREGIONS.

Source: USDA, Yearbook of Agriculture, 1957, Washington, 1957.

these spillover regions in his cross sectional aggregate production function for the U.S., but had generally nonsignificant statistical results (Davis, 1979). When the spillover regions were refined to take account of breeding and genetic characteristics of individual commodites, Sundquist et. al., were able to identify a significant spillover effect from corn research.

In order to individualize the spillover region to the commodities being investigated in this study, spillovers are hypothesized to occur among states, or parts of states, within the same maturity zones for a particular commodity (Figures 3.3-3.5). These maturity zones reflect the photosynthesis sensitivity of three of these commodities (corn, sorghum, and soybeans) during the growing season. This means that corn and sorghum varieties are developed according to length of growing season and thus varieties newly developed in a particular region are most likely to be diffused longitudinally to other states within the same maturity zone. For soybean varieties, day length differences are the primary criterion determining soybean maturity zones. A certain portion of spillover research such as genetic parent material may also be applicable across maturity zones to other states in the form of basic research. Hence a specification of spillover research should also include some consideration of basic research applicable to all regions.

The research spillover variable for this study is formulated according to the maturity zone boundaries in a manner similar to the

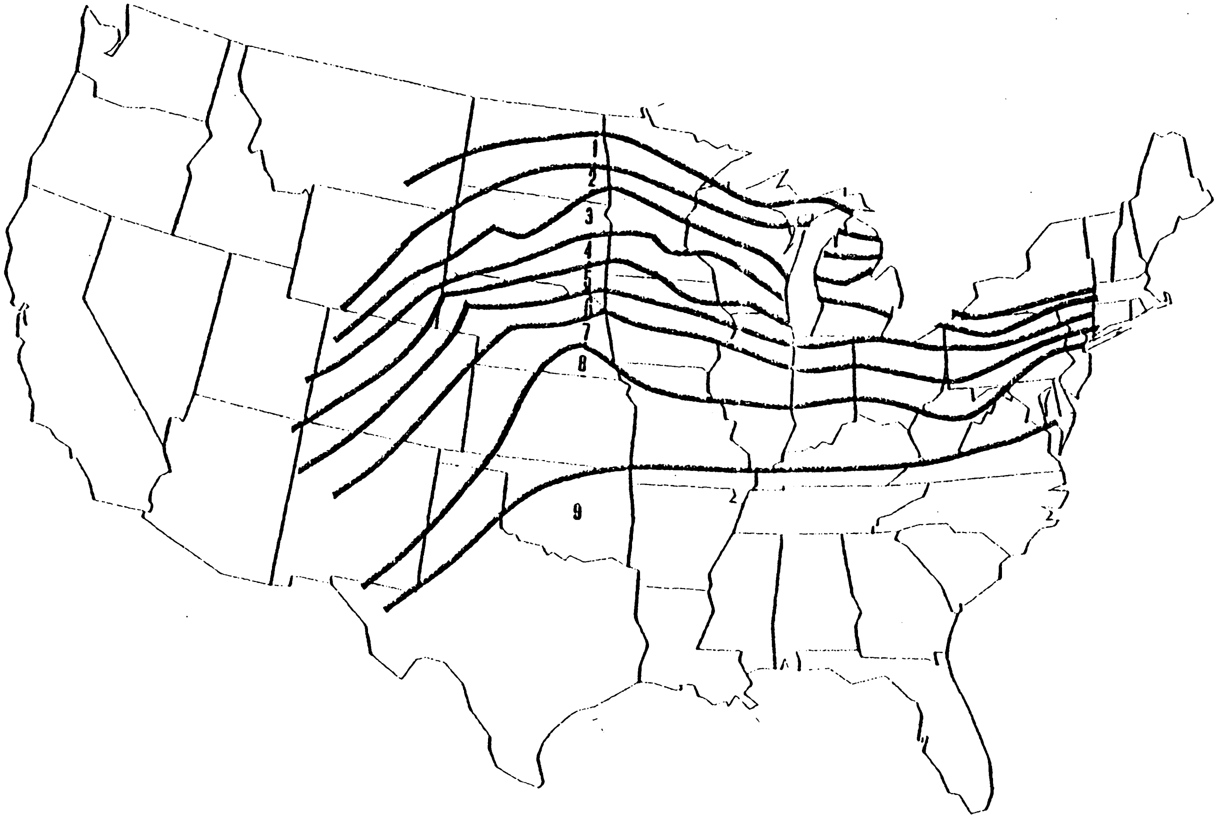


FIGURE 3.3. MATURITY ZONES FOR CORN, U.S.

Source: Jugenhemier, Robert W., <u>Corn: Improvement, Seed Production, and Uses</u>, J. Wiley and Sons, 1976.

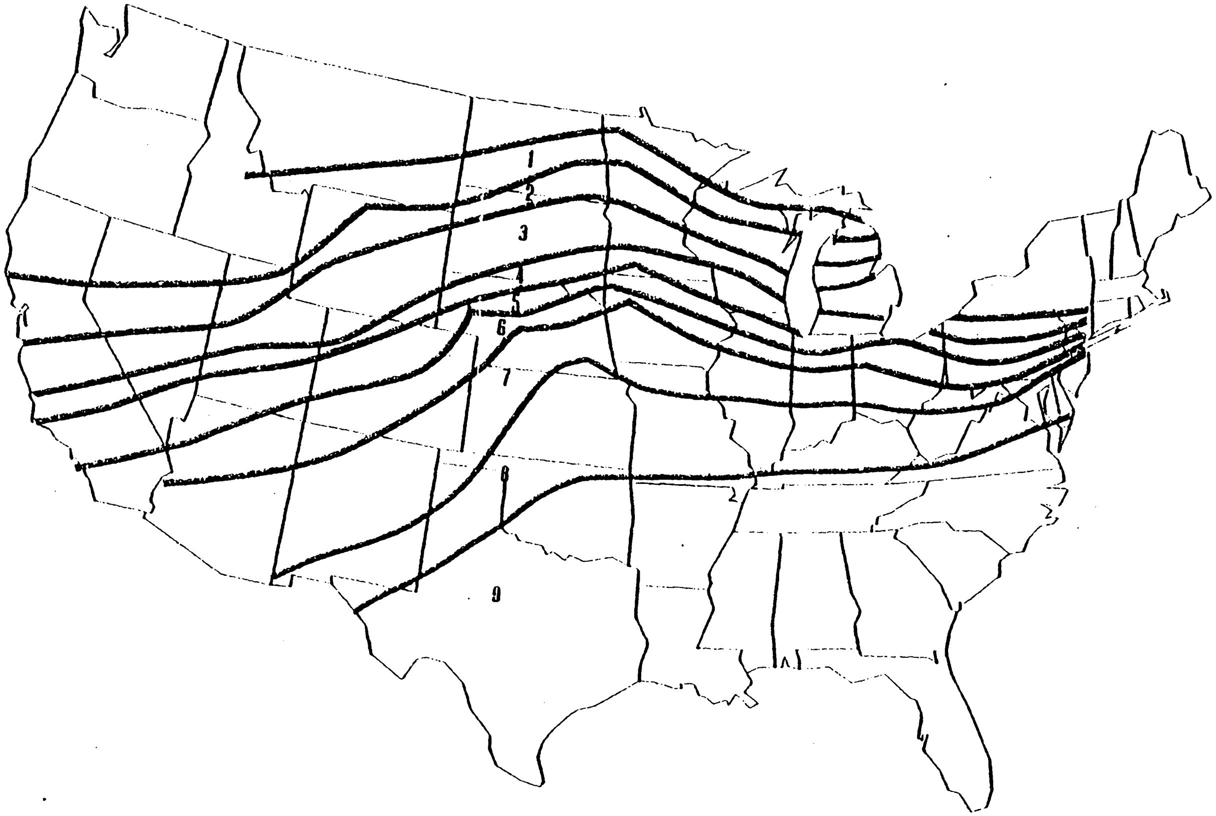


FIGURE 3.4. MATURITY ZONES FOR SORGHUM, U.S.

Source: Adapted from Jugenhemier, Robert W., Corn: Improvement, Seed Production, and Uses, J. Wiley and Sons, 1976.

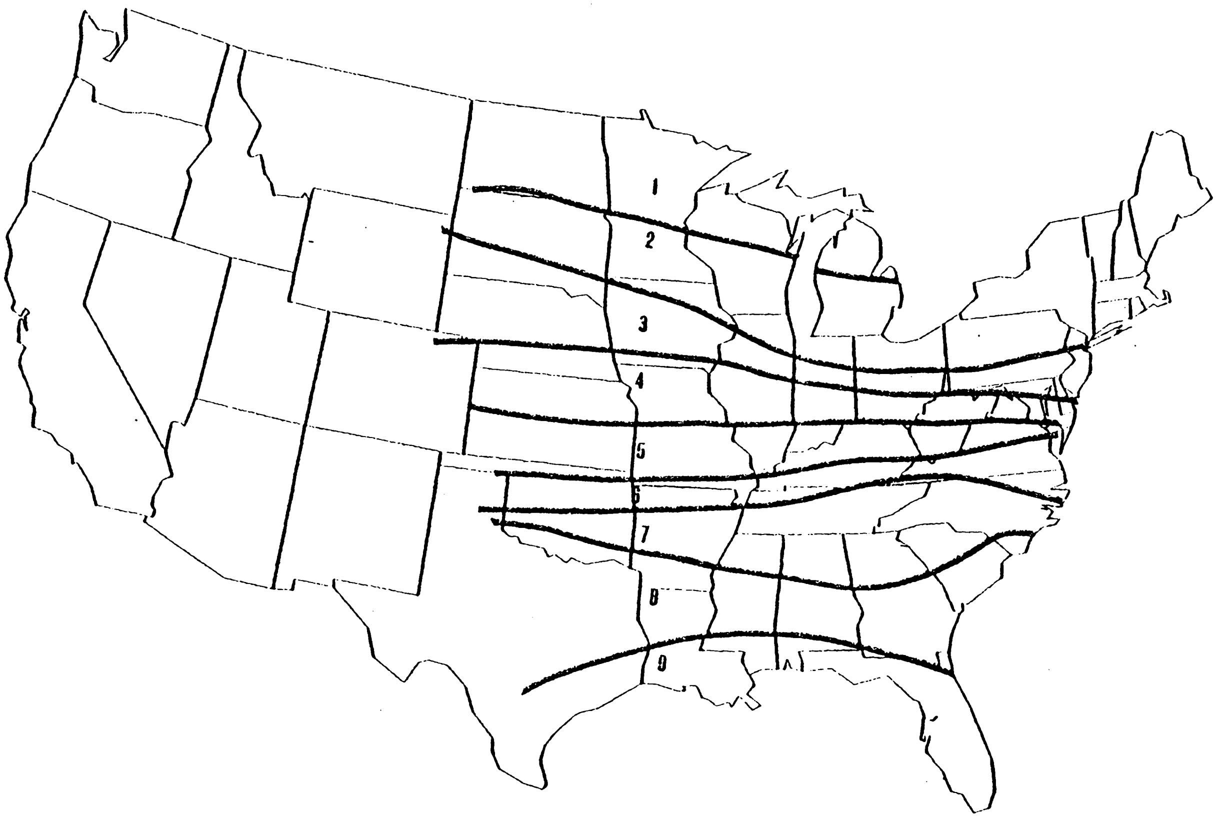


FIGURE 3.5. STANDARD SOYBEAN REGIONS, U.S.

Source: Whigham, D. Keith and Harry C. Minor, "Agronomic Characteristics and Environmental Stress," Soybean Physiology, Agronomy, and Utilization, A. Geoffrey Norman (ed.), p. 79, Academic Press, University of Michigan, 1978.

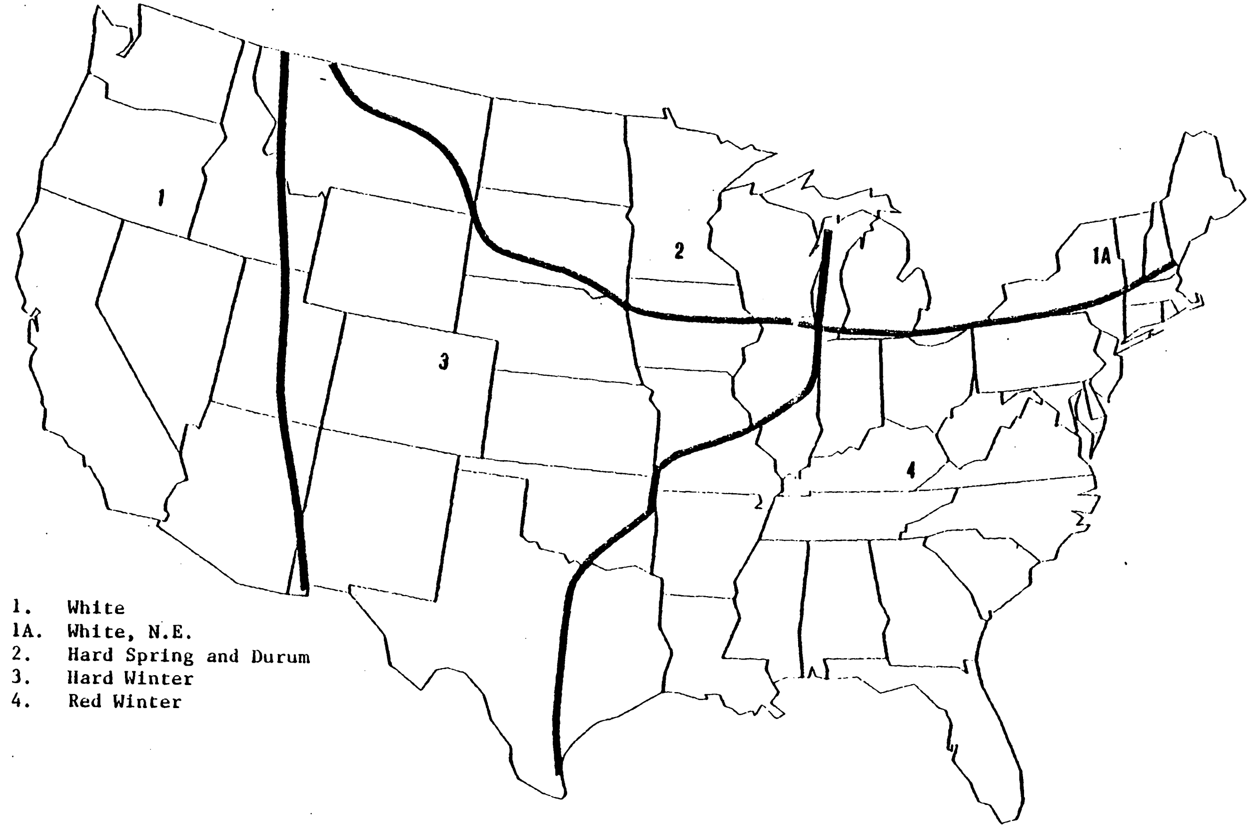


FIGURE 3.6. MAJOR WHEAT VARIETIES BY REGIONS, U.S.

Source: Quisenberry, K.S. and L.P. Retty, Wheat and Wheat Improvement, No. 13 in Agronomy, Madison, Wisconsin, 1967.

procedure used by Evenson. Since several maturity zones often cross a single state, commodity research for each state is allocated to each zone according to the proportion of production in that region. Outside research available to a state is the sum of research allocated by other states having the same maturity zones within their boundaries.

In addition to the research that is borrowed from within the same maturity zone, arguments can be made for a portion of a state's research budget on a particular commodity being applicable across zones. In a study by Evenson (1978, p. 34) shares of state research budgets were identified as basic according to involvement by departments of soil science, phytopathology, botany, zoology genetics, and plant and animal physiology. The percentages were applied to the research budgets of each state and were considered applicable to all other states. Adding this basic research component to the stock of outside research available to states from within the same maturity zone formed a second hypothesized research spillover variable.

In addition to the state research budgets, the USDA is also a participant in commodity research through its Beltsville and ARS research centers. A third formulation of potential research spillovers includes these USDA research expenditures for corn, wheat, soybeans, and sorghum as applicable to all states.

Extension

The Cooperative Extension Service (CES) does not provide a classification of extension activity by agricultural commodity as was done for research investments. However, several pieces of information are available to construct an estimate of expenditures on agricultural extension activity for crops by states. Data on total state and federal expenditures on extension are available from annual CES reports. Their annual reports also include allocation of man hours to agriculture production oriented activities along with the three other major extension program areas. Within the production oriented program area, another broad classification allocates extension effort into crop production versus livestock and farm management areas at a national level. Previous work by Evenson (1978) provides a comparable listing of crop production versus livestock and other extension efforts that is regionalized for the ten production regions of the U.S. for the 1965 crop years. Although his estimates are prior to the production periods used in this study, the national aggregate portions of extension time devoted to crop production are comparable for the two periods. Therefore, Evenson's estimates of crop production percentages, which are more specific to individual regions, are used in this study. These percentages for each state are presented in Appendix Table B-1.

Data

The data used in this study are based on individual state averages of production and price levels for the respective commodities for the crop years 1973-1979. The data on research expenditures were collected from the Cooperative Research Information Service (CRIS) for the 1967-1977 period. These data were lagged five years to account for the lagged effect of research on yields and then matched with the appropriate crop year and state of production. Data on prices and production were collected from annual issues of Agricultural Prices and Crop Production.

The number of states involved in a cross section varied among commodities. In each case, a criterion that only states which averaged more than 100,000 acres of production for the 1977-1979 crop years were considered which resulted in a cross section of 23 states for corn,[a] 25 states for wheat,[b] 24 states for soybeans,[c] and nine states for sorghum.[d] Production within the states of these cross sections included at least 92 percent of national production of each commodity.

Estimation Procedure

The cross sectional-time series data base used in this study present additional issues regarding an appropriate estimation procedure. In previous agricultural research evaluation studies, the data bases used were typically a single year cross section of the 48 states, or the major producing states (Griliches 1964, Evenson 1967, Bredahl and Peterson 1967), a pool of these cross sections for several census years (Davis, 1979, Norton, 1981), or a time series of aggregate U.S. production (Cline, 1975, White, Havlicek, and Otto, 1978). These approaches were amenable to the assumption of OLS estimation procedures which allowed estimation with little or no adjustments. However, in a pooled sample which includes a time series of continuous years and a cross section of contiguous states, it is unlikely that the behavior of the disturbances among individual states will be similar to the disturbance of a given state over time. Given this study's use of state level agricultural production and research data, the assumption of mutual independence among states becomes highly questionable because the agricultural production regions do cut across state boundaries. In order to accommodate the properties of the pooled observational units of this study, a method that takes into account cross sectionally correlated, and time-wise autoregressive behavior is used for estimation purposes (Parks, 1967). The Park's method of estimation uses a generalized least squares (GLS) procedure to estimate parameters from a pooled sample of cross sectional-time series data. This procedure first estimates a serial correlation coefficient for each state and makes an adjustment for serial correlation using this estimated coefficient. After this adjustment, a GLS procedure is used to develop and incorporate a variance-covariance matrix of the distrubances ($E\ [\varepsilon\varepsilon'] = \Omega$) into the estimation of parameters for the model. The specification of the error term is given by:

$E\ (\varepsilon^2_{it}) = J_{ii}$ which allows cross sectional heteroscedasticity

$E\ (\varepsilon_{it}\ \varepsilon_{jt}) = J_{ij}$ which allows cross sectional mutual correlation

$\varepsilon_{it} = \rho_i \varepsilon_{i\ t-1} + U_t$ which allows a first order autoregression for each cross section where ε_{it} is the error term associated with the observation in the ith state, ρ_i is the autoregressive coefficient for the ith state, and U_t is the error term associated with the autoregressive process.

Consistent estimates of the components of the variance-covariance matrix, Ω, can be obtained via the GLS procedure and then used to estimate parameters: $\hat{B} = X' \Omega^{-1}X)^{-1} (X' \Omega^{-1}Y)$, where $\hat{B}$ includes an adjustment for serial correlation for each state as well as adjustments for heterogenous variances and non-zero covariances among the states.

Summary

In this chapter the theoretical framework of the supply response model used to analyze the impact of research investments in corn, wheat, soybeans, and sorghum was developed and discussed. The empirical model, including the actual variables used to estimate the yield response relationship, and a discussion of the estimation procedure were also presented. The empirical results of the yield response models will be presented in Chapter 4.

Footnotes

[a] The corn states are Colorado, Georgia, Illinois, Indiana, Iowa, Kansas, Kentucky, Maryland, Michigan, Minnesota, Missouri, Nebraska, New York, North Carolina, North Dakota, Ohio, Pennsylvania, South Carolina, South Dakota, Tennessee, Texas, Virginia, Wisconsin.

[b] The wheat states are Arizona, Arkansas, California, Colorado, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky, Michigan, Minnesota, Missouri, Montana, Nebraska, New Mexico, North Dakota, Ohio, Oklahoma, Oregon, Pennsylvania, South Dakota, Texas, Washington, Wyoming.

[c] The soybean states are Alabama, Georgia, Illinois, Iowa, Kansas, Kentucky, Louisiana, Maryland, Michigan, Minnesota, Mississippi, Missouri, Nebraska, New Jersey, North Carolina, Ohio, Oklahoma, South Carolina, South Dakota, Tennessee, Texas, Virginia, Wisconsin.

[d] The sorghum states are Arkansas, California, Colorado, Kansas, Missouri, Nebraska, New Mexico, Oklahoma, Texas.

Chapter 4

Empirical Results

The yield response relationships discussed in the previous chapter were estimated for corn, wheat, soybeans and sorghum using the Parks' estimation procedure. This chapter deals primarily with a discussion of the estimated coefficients for the yield response relationships for the different commodities. Also, an evaluation of various elasticities and rates of return to the different research and extension investments are included. The statistical results are arranged into tables according to the type of research spillover specification being evaluated in order to facilitate an inter-commodity comparison of results.

National Models

Research Spillovers from Within the Same Maturity Zone

In this first section, functions for corn, wheat, soybeans, and sorghum included an outside research expenditure variable based on pro-rated research investments by outside states within the same maturity zone or geoclimatic region (Figs. 3.3 - 3.7). This particular specification investigates only the latitudinal spillovers and not any of the North-South spillovers involving basic research. The statistical equations estimated for each of these four commodities are:

$$(4.1)\quad YC = a_1 + B_{11}\, POC_{t-1} + B_{12}\, PSSB_{t-1} + B_{13}\, W + B_{14}\, LQ + B_{15}\, ISR_{t-5} + B_{16}\, OSR_{t-6} + B_{17}\, RISK_1$$

$$(4.2)\quad YW = a_2 + B_{21}\, POW_{t-1} + B_{22}\, PSO_{t-1} + B_{23}\, W + B_{24}\, LQ + B_{25}\, ISR_{t-5} + B_{26}\, OSR_{t-6} + B_{27}\, RISK_1 + B_{29}\, S_1 + B_{210}\, S_2$$

$$(4.3)\quad YSB = a_3 + B_{31}\, POSB_{t-1} + B_{32}\, PSC_{t-1} + B_{33}\, W + B_{34}\, LQ + B_{35}\, ISR_{t-5} + B_{36}\, OSR_{t-6} + B_{37}\, RISK_1$$

$$(4.4)\quad YSG = a_4 + B_{41}\, POSR_{t-1} + B_{42}\, PSW_{t-1} + B_{43}\, W + B_{44}\, LQ + B_{45}\, ISR_{t-5} + B_{46}\, OSR_{t-6} + B_{47}\, RISK_1$$

where

YC = Corn yield per acre (bu/ac)

YW = Wheat yield per acre (bu/ac)

YSB = Soybean yield per acre (bu/ac)

YSG = Sorghum yield per acre (bu/ac)

PO_{t-1} = Price of Output in year t-1 (\$/bu)

PS_{t-1} = Price of substitute commodity in year t-1 (\$/bu)

W = Weather as measured by the index of pasture and range conditions in August

LQ = Land quality in each state

ISR_{t-5} = Instate research expenditure on each commodity in year t-5 (\$million)

OSR_{t-6} = Outside research expenditure on each commodity measured as the sum of research conducted within similar maturity zones in year t-6 (\$million)

$RISK_1$ = Aggregate risk measured as a three year moving standard deviation of past prices.

S_1 = a regional intercept shift variable

S_2 = a second regional intercept shift variable

The wheat model (4.2) includes two zero-one intercept shift variables for states in the Southern (S1) and Western (S2) regions. These variables were included after preliminary estimation suggested that there were significant regional differences in yield response. The yield response relationship differences were hypothesized to be related to regional variations in production patterns that differed according to the four major U.S. production regions (Southern and Western regions versus the North Central region). The estimated coefficients of models (4.1) to (4.4) are presented in Table 4.1. The R^2 statistics presented for models 4.1 to 4.4 ranged from .37 for the sorghum model to .67 for the corn model. These R^2s are based on Ordinary Least Squares (OLS) estimates from the pooled cross section-time series data and can be interpreted as approximations of the explanatory power of the commodity supply models. Since OLS estimates minimize Sum of Squares Error, the models estimated using Park's method, which is a Generalized Least Squares (GLS) procedure, will have R^2 values equal to or less than the OLS results. For large samples the coefficients estimated by the Park's method are consistent, and asymptotically unbiased, efficient and normally distributed. The corn, wheat, and soybean models are based on 155 to

Table 4.1 Estimates of the Coefficients of the Yield Functions for Corn, Wheat, Soybeans, and Sorghum Using Park's Estimation Procedure.

	Corn Yield	Wheat Yield	Soybean Yield	Sorghum Yield
Intercept	-.655(3.44)	8.99(5.20)	11.57(4.39)	33.59(2.81)
Corn P_{t-1}	13.34[a/](2.85)		-3.85[a/](.805)	
Syb P_{t-1}	-2.59[a/](.963)		2.22[b/](1.09)	
Wheat P_{t-1}		7.58[b/](3.06)		-7.27[a/](1.21)
Sorgh P_{t-1}				3.8[b/](1.93)
Oat P_{t-1}		-2.34[a/](.57)		
W	.682[a/](.038)	.128[a/](.019)	.07[b/](.031)	.169[a/](.023)
LQ	1.04[a/](.102)	.109[a/](.022)	.129[a/](.024)	.225[a/](.036)
ISRes_{t-5}	7.48[a/](2.26)	4.70[a/](1.37)	3.47[a/](.701)	10.35[a/](.282)
OSRes_{t-6}	3.28[a/](.362)	1.23[a/](.141)	1.03[a/](.201)	11.87[a/](.067)
RISK 1	-25.15[a/](6.58)	-13.69[a/](5.78)	.253[ns/](2.27)	-1.15[ns/](.986)
S_1		19.52[a/](.64)		
S_2		8.38[a/](.77)		
R^2	.679	.604	.41	.375
F	46.4	31.6	15.7	4.7
States	23	25	24	9

[a/] Significant at the 1 percent level.

[b/] Significant at the 5 percent level.

[ns/] Not significant.

Numbers in parenthesis are standard errors.

165 degrees of freedom while the sorghum model has 55 degrees of freedom. With these estimator properties in mind, the estimated coefficients of the variables in models (4.1) to (4.4) were significant at either the 5 or the 1 percent level with the exception of the aggregate risk coefficient in the sorghum and soybean models. The influence of aggregate risk on yield levels, specified as a three year moving standard deviation of past prices, was used in all four models. However, a significant coefficient was obtained only for the corn and wheat models. The significant and negative coefficients for the corn and wheat models implies aggregate risk averse behavior by these producers through the input allocation process. This result also implies that a reduction in the variation in output price levels would lead to an increase in yield levels. The estimated impact of price risk is greatest for corn. At mean levels, the impact of price fluctuations on corn yields are estimated to be twice as large as the impacts on wheat yields. A ten percent reduction in corn price fluctuations would lead to an estimated 1.2 percent increase in yields. The significance of a price risk variable in models of corn and wheat is somewhat expected because these two commodities were covered by the government price support programs. However, the 1970-1978 time period included in the sample was a time of a wide grain price fluctuation following the dramatic increase in grain exports in the early 1970s. Although these commodity price support programs existed throughout the 1970-78 period of this analysis, only

1977 and 1978 had any sizeable portion of output included in the loan program (23-29 percent for wheat and 9-18 percent for corn). Apparently the wide price fluctuations of this period created enough uncertainty for corn and wheat producers that the risk mitigating effects of the target price and loan support programs were overcome.

In preliminary models, a weighted price of fertilizer variable was included in the estimated equations. Contrary to expectations, the estimated results indicated a positive and predominately significant relationship between the price of fertilizer and yields. This positive relationship is due in part to the rapid rise in the price of energy, which is a primary component of fertilizer production, during the 1973-1979 period when yield levels were also increasing. Further research identifying fertilizer usage specific to individual commodities is needed to adequately estimate the impact of fertilizer on yield levels. A time series of observations beyond the 1973-1979 period of this study could also be used to test the fertilizer-yield relationship over a longer time period.

The estimated coefficients for weather were significant and positive in all models, indicating that favorable weather during the growing season, as measured by pasture and range conditions in August, has a positive influence on yield levels. Another variable also hypothesized to be positively related to yield levels was the quality of land. The estimated coefficients for the price weighted land quality variables were also positive and significant in all four models. The results indicate corn yields have the greatest responsiveness to differences in land quality.

The yield responsiveness with respect to output and substitute prices was also estimated for each of these four commodities. As hypothesized, a positive, and significant relationship between yield and output price was estimated for each commodity. Also as expected, a negative and significant relationship was estimated for yield levels and the price of a substitute commodity. The estimated yield elasticities associated with the own price of each commodity are presented in Table 4.2. These estimated price elasticities ranged from .16 for sorghum to .46 for soybeans. These yield response elasticities along with acreage response elasticities compose total supply response elasticity. Some previous supply response studies, concerned with the role of price in the decision of how many acres to plant to a particular commodity, considered only acreage response in reporting their supply response elasticities for various commodities (Houck, et al. 1976). The yield response elasticities obtained in this study when added to the acreage response elasticities suggest a total supply response elasticity for these four commodities that are 16 to 46 percent greater than response elasticities estimated solely from acreage response models. The results reported by Houck and Gallagher indicate yield response elasticities for corn that range from .24 to .76 for states in the corn belt (Houck and Gallagher, 1976).

Table 4.2 Estimated Elasticities and Rates of Return to Research and Outside Research Investments in Corn, Wheat, Soybeans, and Sorghum.

Variable	Lag Length	Corn	Wheat	Soybeans	Sorghum
		Yield Elasticities			
Price		.366	.18	.46	.16
Inside Research		.028	.059	.043	.034
Outside Research		.144	.136	.081	.2
		Value of Additional Output per Unit of Investment			
I.S. Research		39.2	24.7	32.8	26.1
O.S. Research		16.9	6.5	9.8	23.7
	Lag Length	Internal Rate of Return (percent)			
I.S. Research	12	172.3	126.3	150.2	134.1
O.S. Research	12	76.5	48.2	53.1	93.8

Research Results and Internal Rates of Return. The results of primary interest in this study are those associated with the research variables. The estimated coefficients by outside regions were significant at the 1 percent level in all four models (4.1 to 4.4). In all models the estimated elasticities are lower for in-state research than outside research expenditures. These patterns are partially the result of the much larger pool of useable research available from outside areas. The estimated coefficients associated with the research and extension variables were also used to estimate IRORs on the investments. Estimating the IROR is a procedure which provides a standarized measure for comparing investment alternatives. Specifically it is the discount rate which makes the present value of the benefits exactly equal to the present value of the costs (Mishan, 1976). Expressed algebraically, the IROR (r) is:

$$(4.5a) \quad \Sigma \frac{B}{(1+r)^t} - 1 = 0$$

where (B) is benefits or returns to be discounted, (r) is interest rate as an annual percentage return on investment, and (n) is the number of periods over which the discounting is to take place. The aggregate production function approach to research and extension evaluation expresses the research benefits (B) in terms of its marginal product (MP). In a Cobb Douglas function, the marginal product is calculated as MP= (Q/R) where (Q) is the quantity of output and (R) is research investments in dollars. If Q is in terms of value of output, the MP is the value of marginal product of a dollar of research and extension expenditure. The supply function approach used in the current study requires a modification in order to estimate benefits. The yield response elasticity of each commodity to changes in lagged research and extension expenditures is first translated into changes in quantity of output based on mean acreage levels for the states and then valued at constant 1972 prices. These steps can be represented as:

$$(4.6)\quad \text{Benefits} = (\partial Y/\partial R * \bar{R}/\bar{Y}) * \bar{Y}/\bar{R} * \overline{Ac} * (\$/\overline{bu})$$

where (R) is dollar research expenditures, (Y) is output per acre, (Ac) is the average number of acres per state and ($/bu) is average output price per bushel in constant 1972 dollars.

Since there is a lag between the expenditure of funds and the realization of returns, the research benefits need to be distributed over some time period. Various procedures used to distribute the research benefits including the method used in this study have been summarized in a paper by Davis (1979). Based on evidence presented in previous research evaluation studies, research benefits were assumed to be distributed over time in an "inverted V" pattern (Evenson, 1967, Cline, 1975, White, et al., 1978). The benefits are represented as the shaded area in Figure 4.1. Functional forms for lagged research expenditures such as a second order Almon polynomial which allow endpoints to be constrained or the "inverted V" distribution have been estimated in these aggregate research evaluation studies which indicate significant impacts to research over a 12 to 14 year period

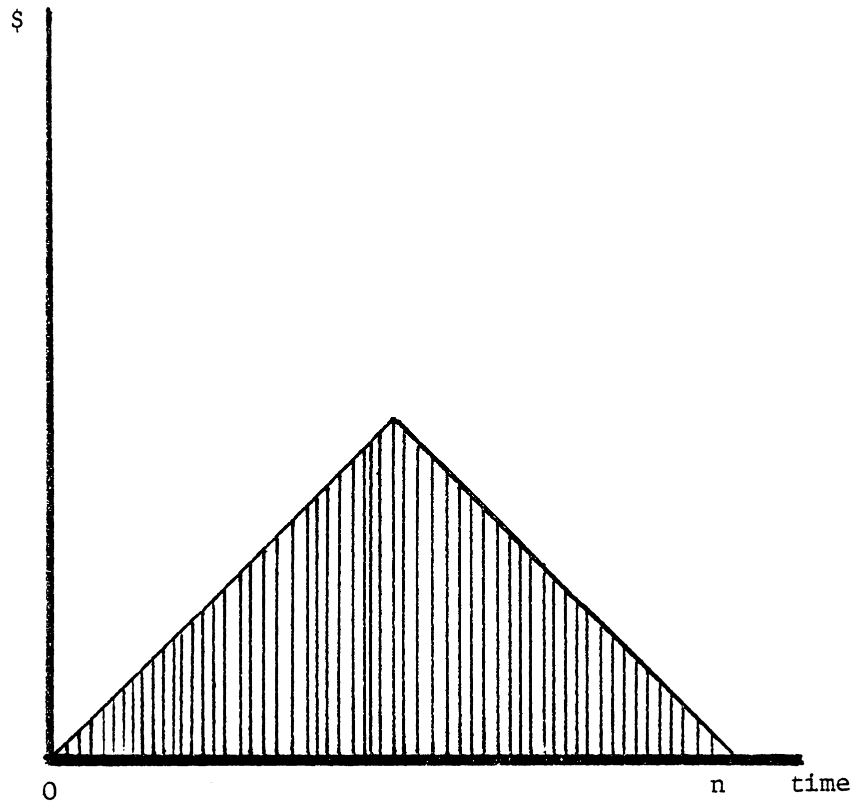


FIGURE 4.1. DISTRIBUTION OF RESEARCH AND EXTENSION BENEFITS OVER TIME ACCORDING TO AN INVERTED V PATTERN.

centering on the sixth and seventh year. The increasing pattern of benefits up to the sixth year and the subsequent decreasing pattern until year 12 indicated for aggregate research expenditures was assumed to also hold for grain research.

Based on the "inverted V" distribution of benefits, the formula for calculating the IROR in our study is:

$$(4.5b) \quad B\left[\sum_{i=1}^{n} \frac{w_i}{(1+r)^i}\right] - 1 = 0$$

where n is the total number of years over which past research has an impact on output, and w_i is the weight for period i. The weights (w_i) are calculated according to the following procedure:

$$(4.5c) \quad w_i = \frac{2i-1}{2(n/2)^2} \text{ for } i = 1 \text{ to } n/2, \text{ and}$$

$$(4.5d) \quad w_i = \frac{2n-(2i-1)}{2(n/2)^2} \text{ for } i = n/2 + 1 \text{ to } n.$$

This is the same procedure that was used by Bredahl to estimate IRORs in his study (Bredahl, 1975). Although private research activities undoubtedly contribute to the productivity of these grain commodities, private research investment data are not available for inclusion in any of the supply functions. In the statistical model the effects of the excluded private research variable are included in the residual. The GLS procedure used in this study also adjusts for systematic first order auto-correlation in the time series and cross sectional correlation among states so that the individual coefficients are estimated in a consistent and unbiased fashion.

The estimated IRORs for in-state expenditures on research ranged from 126.3 percent for wheat to 172.3 percent for corn. In this first set of results, the estimated IRORs for research expenditures by outside states ranged from 48.2 percent for wheat to 93.8 percent for sorghum. The relatively higher IROR on outside research for sorghum is perhaps the result of sorghum production in the U.S. being centered in a smaller, more homogeneous region where research results are more easily transferred among states.

Research Spillovers with Basic Research Included

In the first set of models (4.1 - 4.4), potential research spillovers were identified as occuring among states within the same geo-climatic region or maturity zone. In addition to this concept of research spillovers, physical scientists acknowledge that a certain amount of the research done within each region is basic and applicable over all regions in which a particular crop is produced. Evenson identified basic research according to the academic discipline performing the research (phytopathology, soil science, botany, zoology, genetics, and plant and animal physiology) and basic research was calculated as percentage of total agricultural research for each of the ten U.S. production regions (Evenson, 1978, p. 181). The average basic research percentages found by Evenson were applied to the levels of state research expenditures for the four individual grain commodities of this study. This basic research component from all states was considered part of the stock of outside borrowable research for each state and then included with the research spillovers occuring from investments within the state's own maturity zone region. The response equations are:

$$(4.7)\quad YC = a_7 + B_{71}\ POC_{t-1} - B_{72}\ PSSB_{t-1} + B_{73}\ W + B_{74}\ LQ + B_{75}\ ISR_{t-5} + B_{76}\ OSR_{t-6} + B_{77}\ EXT_{t-4} + B_{78}\ RISK_1$$

$$(4.8)\quad YW = a_8 + B_{81}\ POW_{t-1} + B_{82}\ W + B_{83}\ LQ + B_{84}\ ISR_{t-5} + B_{85}\ OSR_{t-6} + B_{86}\ EXT_{t-4} + B_{87}\ RISK_1 + B_{88}\ S_1 + B_{89}\ S_2$$

$$(4.9)\quad YSB = a_9 + B_{91}\ POSB_{t-1} + B_{92}\ PSC_{t-1} + B_{93}\ W + B_{94}\ LQ + B_{95}\ ISR_{t-5} + B_{96}\ OSR_{t-6} + B_{97}\ EXT_{t-4} + B_{98}\ RISK_2$$

$$(4.10)\quad YSG = a_{10} + B_{101}\ POSG_{t-1} + B_{102}\ PSW_{t-1} + B_{103}\ W + B_{104}\ LQ + B_{105}\ ISR_{t-5} + B_{106}\ OSR_{t-6} + B_{107}\ EXT_{t-4} + B_{108}\ RISK_2$$

where:

EXT_{t-4} = extension expenditures on each commodity per state ($million).

$RISK_2$ = an aggregate risk variable specified as the covariance of output and substitute prices based on a three year moving average.

and the remaining variables are defined the same as in models (4.1) to (4.4).

The estimated coefficients of models (4.7) to (4.10) are presented in Table 4.3 and are again based on a cross section of the primary producing states (23 corn states, 25 wheat states, 24 soybean states, and 9 sorghum states).[a/] The estimated coefficients for the

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[a/] See footnotes at end of Chapter 3.

Table 4.3 Estimates of the Coefficients of the Yield Functions for Corn, Wheat, Soybeans, and Sorghum With Outside Research as Same Maturity Zone Plus Basic Research Using Park's Estimation Procedure.

	Corn Yield	Wheat Yield	Soybean Yield	Sorghum Yield
Intercept	-2.95(3.60)	8.36(3.58)	8.76(2.67)	30.8(3.07)
Corn P_{t-1}	10.96[a](3.81)		-.66[ns](.41)	
Syb P_{t-1}	-2.64[b](1.24)		1.23[a](.373)	
Wht P_{t-1}		3.05[c](1.68)		-6.89[a](3.5)
Sorgh P_{t-1}				1.57[c](.96)
W	.649[a](.046)	.135[a](.030)	.043[a](.027)	.145[a](.041)
LQ	1.01[a](.117)	.082[a](.006)	.061[a](.015)	.182[a](.058)
ISRes$_{t-5}$	7.98[a](2.32)	2.41[c](1.31)	4.60[a](.475)	7.17[a](2.35)
OSRes$_{t-6}$	4.29[a](.472)	.885[a](.161)	1.23[a](.162)	12.96[a](.829)
Ext$_{t-4}$	2.43[b](1.02)	2.00[b](.839)	1.46[ns](1.41)	3.52[a](.975)
RISK 1	-20.51[b](7.92)	-3.28[b](1.42)		
RISK 2			2.97[a](.502)	-1.17[ns](1.40)
S_1		19.36[a](.929)		
S_2		7.84[a](.493)		
R^2	.682	.578	.612	.438
F	40.9	25.11	31.42	5.09
States	23	25	24	9

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[a] Significant at 1 percent level.

[b] Significant at 5 percent level.

[c] Significant at 10 percent level.

[ns] Not significant.

Numbers in parenthesis are standard errors.

weather and land quality variables were very similar in significance level and in magnitude to the results obtained in models (4.1) to (4.4). The price elasticities based on models (4.7) to (4.10) are presented in Table 4.4. The estimated price elasticities are similar to those estimated for models 4.1 to 4.4, ranging from .06 for sorghum to .301 for corn. The estimated elasticity of .06 for sorghum after including an additional basic research component and an extension variable is a reduction from the .162 estimate from model (4.4).

The results of the estimated coefficients for the aggregate risk variables were also similar to the results from models 4.1 - 4.4. Aggregate risk specified as a three year moving standard deviation of past prices was significant in only the corn and wheat models, with the price fluctuations again having the greatest impact on corn yields. A second specification of aggregate risk involving an interaction between output price and substitute price over a moving three year average was tested in the soybean and sorghum models. The estimated coefficient of the price interaction risk variable was not significant for the sorghum model, but was significant at the 1 percent level for the soybean model. The significant risk coefficient in the soybean model does not give a clear cut picture of aggregate risk averse or risk preferring behavior by soybean producers since large price fluctuations in one commodity can be dampened by smaller fluctuations in the second commodity. The positive coefficient does suggest that similar movements in prices of corn and soybeans have a positive impact on soybean yields.

Table 4.4 Estimated Elasticities and Rates of Return to Research, Outside Research, and Extension Investments in Corn, Wheat, Soybeans, and Sorghum.

		Corn	Wheat	Soybeans	Sorghum
Variable		Yield Elasticities			
Price		.301	.14	.27	.061
Inside Research		.031	.03	.057	.020
Outside Research		.181	.121	.246	.285
Extension		.028	.077	n.s.	.095
		Value of Additional Output per Unit of Investment			
I.S. Research		41.0	14.0	40.1	18.1
O.S. Research		17.8	5.1	12.0	34.6
Extension		11.4	10.5	n.s.	8.87
	Lag Length	Internal Rate of Return (percent)			
I.S. Research	12	177.7	81.0	176.4	101.2
O.S. Research	12	96.2	27.2	62.6	116.0
Extension	12	63.1	62.7	n.s.	47.0
	8	95.6	90.1	n.s.	79.5

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n.s. Not significant.

The inclusion of basic research expenditures by all states as a component of outside spillover research caused no major change in the magnitude of estimated impacts of research investments on yield levels. All coefficients for in-state and outside research expenditures were significant at the 1 percent level except for the wheat model where the coefficient on in-state expenditures was significant at the 10 percent level. The estimated IROR associated with the in-state research investments in these four commodities ranged from 81 percent for wheat to 177.7 percent for corn. No clearly discernable pattern of change was apparent when comparing the estimated IRORs based on models 4.7-4.10 with the estimated IRORs based on models 4.1-4.4. The estimated IRORs for corn and soybean research expenditures were higher and the estimated IRORs for wheat and sorghum research expenditures were less than the estimated IRORs based on mdoels 4.1-4.4. The estimated IRORs associated with outside research investments were higher for the corn, soybeans, and sorghum models (4.7, 4.9, 4.10) when basic research expenditures were included as outside research than in models 4.1, 4.3, and 4.4 where only research expenditures by states within the same maturity zone were considered. The estimated IROR for wheat research expenditures were lower in model 4.8 when basic research expenditures were included than in model 4.2. The highest estimated IROR for outside research investments was again associated with the sorghum model.

The models in this section also included a test of the impact of agricultural extension expenditures on yield levels of corn, wheat, soybeans, and sorghum. The estimated coefficient for extension expenditures were significant at the 5 percent level in all but the soybean model (4.9). Assuming a comparable 12 year "inverted V" distributed lag for benefits, the estimated IRORs from agricultural extension investments, presented in Table 4.4, range from 47 for sorghum to 95.6 percent for corn with no estimate provided for the soybean model. These estimated IRORs for extension investments were comparable to the IRORs for outside corn and sorghum research investments, but greater than both in-state and outside research investments for wheat. The magnitude of the extension coefficient is surprising especially in relation to the wheat research coefficients. The higher estimated coefficient for extension expenditures in the wheat model is partially the result of more pervasive wheat production patterns with less production centered in the southern states where the highest levels of state agricultural extension expenditures occur. The nonsignificance of the extension coefficient in the soybean model is also difficult to explain. The extension variable is a composite of expenditures for agricultural extension activities related to all cash grain commodities to that portion related to soybean production may not be refined sufficiently. Further efforts could be directed toward refining a measure of extension effort that is related specifically to each crop.

Research Spillovers With Basic and USDA Research Included

A third type of interstate research spillover variable was formulated to include research expenditures by USDA on these four commodities. The USDA research component is primarily Agricultural Research Service (ARS) sponsored activities at Beltsville and other regional ARS centers. The corn, wheat, soybean and sorghum research expenditures by USDA are added to the sum of basic research investments and the spillovers generated by research investments from within the same geoclimatic region. The statistical models which included this third specification of outside research can be written as:

$$(4.11)\ YC = a_{11} + B_{111}\ POC_{t-1} - B_{112}\ PSB_{t-1} + B_{113}\ W + B_{114\$u.}\ LQ + B_{115}\ ISR_{t-5} + B_{116}\ OSR_{t-6} + B_{117}\ EXT_{t-4} + B_{118}\ RISK_1$$

$$(4.12)\ YW = a_{12} + B_{121}\ POW_{t-1} + B_{122}\ W + B_{123}\ LQ + B_{124}\ ISR_{t-5} + B_{125}\ OSR_{t-6} + B_{126}\ EXT + B_{127}\ RISK_1 + B_{128}\ S_1 + B_{129}\ S_2$$

$$(4.13)\ YSB = a_{13} + B_{131}\ POSB_{t-1} - B_{132}\ PSC_{t-1} + B_{133}\ W + B_{134}\ LQ + B_{135}\ ISR_{t-5} + B_{136}\ OSR_{t-6} + B_{137}\ EXT_{t-4} + B_{138}\ RISK_2$$

$$(4.14)\ YSG = a_{14} + B_{142}\ POSG_{t-1} - B_{141}\ PSW_{t-1} + B_{143}\ W + B_{144}\ LQ + B_{145}\ ISR_{t-5} + B_{146}\ OSR_{t-6} + B_{147}\ EXT_{t-4} + B_{148}\ RISK_2$$

where all variables are as defined in 4.1 to 4.4 and 4.7 to 4.10.

The empirical results for models 4.11-4.14 are presented in Table 4.5 with estimated elasticities and IRORs in Table 4.6. The statistical results for the weather and land quality variables were again very similar to the results estimated in models 4.1 to 4.4 and

Table 4.5 Estimates of the Coefficients of the Yield Functions for Corn, Wheat, Soybeans, and Sorghum With Outside Research as Similar Maturity Zone Plus Basic and U.S.D.A. Research Using Park's Estimation Procedure.

	Corn Yield	Wheat Yield	Soybean Yield	Sorghum Yield
Intercept	-18.17(6.65)	6.34(5.70)	8.11(2.38)	10.14(2.31)
Corn P_{t-1}	11.06[a](2.45)		-.82[c](.457)	
Syb P_{t-1}	-3.24[a](.716)		1.14[a](.302)	
Wheat P_{t-1}		.752[d](.481)		-4.57[a](.914)
Oat P_{t-1}				
Sorgh P_{t-1}				.67[ns](1.17)
W	.477[a](.063)	.125[a](.035)	.041[c](.021)	.212[a](.021)
LQ	.85[a](.078)	.072[a](.011)	.093[a](.011)	.224[a](.064)
$ISRes_{t-5}$	7.23[b](3.09)	2.91[b](1.24)	4.45[a](.247)	8.74[a](1.60)
$OSRes_{t-6}$	4.16[a](.212)	.788[a](.154)	.921[a](.099)	10.50[a](.46)
Ext_{t-4}	3.09[a](.07)	2.28[a](.778)	.298[d](.22)	3.79[a](.43)
RISK 1	-15.06[b](7.59)	-1.02[b](.504)		
RISK 2			2.84[a](.246)	2.75[a](1.04)
S_1		19.98[a](.696)		
S_2		7.60[a](.479)		
R^2	.682	.581	.493	.446
F	40.7	22.8	19.3	5.1
States	23	25	24	9

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[a] Significant at 1 percent level.

[b] Significant at 5 percent level.

[c] Significant at 10 percent level.

[d] Significant at 15 percent level.

[ns] Not significant.

Numbers in parenthesis are standard errors.

4.6 to 4.10. All coefficients were significant at the 1 percent level, for models 4.11 to 4.14 except for weather in the soybean model. With the inclusion of an additional variable in the models to estimate the impact of agricultural extension expenditures, the percentage of variation in yield levels explained by the hypothesized variables increased slightly as is expected. However, the coefficient for price of oats in the wheat model (4.12) was no longer significant after including additional outside basic research expenditures and the extension expenditures. This model was re-estimated with the price of wheat deflated by the prices received for all other commodities to take account of all possible substitutes in production.

The estimated coefficients for the aggregate risk variable in models 4.11-4.14 were also similar to earlier results. The coefficient for aggregate risk, specified as a three year moving standard deviation of past prices, was significant in only the corn and wheat models. This result reinforces the results in the earlier set of models which implied risk averse behavior in aggregate by corn and wheat producers. A second specification of risk was formulated as a three year moving average of the interaction of output price and substitute price and was included in a second estimation of the soybean and sorghum models. The results of this specification, presented in Table 4.6, indicate a positive and significant relationship between this interaction of prices and yield levels of soybeans and sorghum. The sign of the coefficient on past price

Table 4.6 Estimated Elasticities and Rates of Return to Research, Outside Research and Extension Investments in Corn, Wheat, Soybeans, and Sorghum.

		Corn	Wheat	Soybeans	Sorghum
Variable		Yield Elasticities			
Price		.303	.041	.249	.088
Inside Research		.028	.036	.056	.028
Outside Research		.51	.346	.33	.482
Extension		.035	.088	n.s.	.102
		Value of Additional Output per Unit of Investment			
I.S. Research		37.6	15.1	34.8	22.0
O.S. Research		20.8	4.3	9.1	33.5
Extension		14.5	12.02	n.s.	9.55
	Lag Length	Internal Rate of Return (percent)			
I.S. Research	12	162.4	80.6	156.7	112.7
O.S. Research	12	107.9	20.1	43.2	133.5
Extension	12	58.2	48.7	n.s.	42.1
	8	87.3	73.1	n.s.	63.2

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n.s. Not significant.

interaction variables indicates yields are positively influenced by similar movements in the price of output and a production substitute. Larger diverse fluctuations in prices of output and a substitute commodity are associated with lower yield levels. Conversely, higher yields are associated with smaller price fluctuations of output and substitute prices which move in the same direction.

The commodity price coefficients and the associated price elasticities presented in Table 4.6 are very similar to the results for models 4.7-4.10. The estimated price elasticities from models 4.11-4.14 range from .18 for wheat to .30 for corn with the sorghum price coefficient not being significant in the sorghum model. The significant interaction between sorghum and wheat prices in a three year moving average of price covariances is apparently picking up the influence of sorghum price on sorghum yields. In other sorghum models which did not include a price risk term, the lagged sorghum price was significantly related to sorghum yields.

The coefficients of the research and extension variables tested in these four models (4.11-4.14) also changed very little with the inclusion of USDA research expenditures on corn, wheat, soybeans, and sorghum as part of outside research. These sets of coefficients are all significant at either the 5 or 1 percent level with the exception again being the extension coefficient in the soybean model. The estimated IRORs for in-state research investments ranged from 80.6 percent for wheat to 162.4 percent for corn which are very similar in magnitude to the IRORs to research investments which were presented in Table 4.4. The results in Table 4.6 are based on outside research on these four commodities formulated as the sum of research expenditures within the same maturity zone plus basic research expenditures by all states and USDA research expenditures. The estimated IRORs based on this third specification of outside research investments ranged from 20.1 percent for wheat to 133.5 percent for sorghum. The magnitude of these IRORs are also very similar to the results obtained from models 4.7-4.10. The estimated IROR on outside sorghum research investment was again the highest among the four commodities studied. The estimated IROR for outside research investments is also higher than the IROR for in-state research investments, suggesting that the outside research activities on sorghum is more readily useable by the sorghum producing states.

The estimated impacts of extension expenditures on yield levels presented in Table 4.6 were also similar to the results based on models 4.7-4.10. With the exception of the nonsignificant result in the soybean model, the estimated IRORs on investments in agricultural extension ranged from 42.1 percent for sorghum to 87.3 percent for corn. The IRORs for extension investments are comparable in magnitude to the estimated IRORs for outside expenditures for the case of corn and sorghum research. The magnitude of the estimated IROR for extension investments for wheat, which is much larger than the IROR for outside research investments, is partially the result of the larger pool of outside research provided by the pervasive production patterns for wheat.

Assessment. The statistical results presented in Tables 4.1, 4.3, and 4.5 provided estimates of the impacts of investments in in-state research, outside research, and agricultural extension on yield levels of corn, wheat, soybeans, and sorghum. The three sets of results were organized according to three different specifications of outside research which progressively increased the stock of available outside research. Presentation of three different, but related, sets of models allows comparison of the stability of the various estimates obtained. The estimated price elasticities for the different commodities ranged fropm .30 to .37 for corn; .25 to .46 for soybeans; .04 to .18 for wheat; and .06 to .16 for sorghum. The estimated IRORs for in-state research investments ranged from 162.4 to 177.7 percent for corn, 150.2 to 176.4 percent for soybeans, 80.6 to 126.3 percent for wheat, and 101 to 134 percent for sorghum. The estimated IRORs for investment in agricultural research by outside regions ranged from 76.5 to 108 percent for corn, 43.2 to 53 percent for soybeans, 20 to 48 percent for wheat, and 94 to 116 percent for sorghum. Estimates of the IRORs on extension expenditures were presented in Table 4.4 and 4.6 with no estimate provided for extension expenditures for soybeans because of the nonsignificant coefficient. The estimated IRORs for investments in agricultural extension ranged from 58.2 to 63.1 percent for corn, 48.7 to 62.7 percent for wheat, and 42 to 47 percent for sorghum. The level of these estimated IRORs are affected by the 12 year "inverted V" distribution of benefits. If a shorter 8 year duration of impacts for extension investments is assumed and benefits are again distributed in an "inverted V" pattern, the estimated IRORs on extension investments ranged from 87.3 to 95.6 percent for corn, 73 to 90 percent for wheat, and 63 to 79.5 percent for sorghum. A longer time distribution of benefits would create a larger stock of useable knowledge and would cause a reduction in the estimated IRORs to investment in these commodities. The impacts of a shorter time period for discounting is noticeable in the higher rate of return when yield increasing benefits from extension investments are spread over 8 rather than 12 years.

The pattern emerging from these three sets of results indicate that corn research investments have the highest rate of return and that investments in wheat research have the lowest rate of return. While the estimated 80 to 126 percent IRORs for wheat research are lower than the three other commodities, these rates reflect a very profitable rate of return. However, the higher rates of return to corn and soybean research suggest that state grain research investments could be more profitably invested in these two commodities.

The attempts to measure the impacts of outside research on yield per acre for corn, wheat, soybeans, and sorghum indicate that these spillovers have a significant effect on yield per acre for these four commodities. The estimated IRORs are 25 to 60 percent less than the IRORs for in-state research investments. In a later section the ratio of these IRORs for outside research investments to the IRORs for in-state research investments will be compared to the ratio of federal funds to state funds to test whether states are being compensated for the spillovers from their research expenditures.

The highest rate of return for investments to outside research occurs for sorghum. Sorghum production is confined to a smaller, more homogeneous region than the other three commodities so that outcomes of sorghum research may be more readily adaptable for use by other states within the spillover region. These IRORs from outside research investments indicate a viable avenue being used by individual states to increase yield per acre productivity.

Regional Results

The wheat models presented in the previous sections utilized zero-one variables to allow for differences in intercepts to account for effects of regional location differences (South and West vs. Mid West) on yield levels. The significance of these results suggest that there may be regional differences in production patterns and productivity for other commodities as well. The cross sectional time series model used in this study is easily adaptable to using various regional combination of states for the same 1973-79 production period. The states used in this regional study were classified according to the four major geographic regions used by USDA (Northeast, Southern, North Central, and Western). Corn and soybean production are primarily confined to the North Central and Southern regions and these are the only two regions where corn and soybean yield responses are analyzed separately. The same two regions and the West are analyzed separately for wheat. Sorghum yield response to research investment was originally analyzed for only nine states in a relatively homogeneous region in the Southern and Northern Plains states. Therefore, a separate regional analysis is not performed for sorghum.

The statistical model used to estimate the yield relationships on a regional basis are from the models specified in (4.7) to (4.9). The statistical model to estimate corn yield relationships in the North Central and Southern regions is:

$$(4.15)\ YC = a_{15} + B_{151}\ POC_{t-1} + B_{152}\ PSSB_{t-1} + B_{153}\ W + B_{154}\ LQ + B_{155}\ ISR_{t-5} + B_{156}\ OSR_{t-6} + B_{157}\ EXT_{t-4} + B_{158}\ RISK_1$$

where the variables are defined as in model (4.7). The statistical model used to estimate soybean yield relationship for the North Central and Southern region is:

$$(4.16)\ YSB = a_{16} + B_{161}\ POSB_{t-1} + B_{162}\ PSC_{t-1} + B_{163}\ W + B_{164}\ LQ + B_{165}\ ISR_{t-5} + B_{166}\ OSR_{t-4} + B_{167}\ EXT_{t-4} + B_{168}\ RISK_2 + B_{169}\ S_1$$

where

S_1 = an intercept shifter for a group of states in the southern region, (Mid-Atlantic vs. all other Southern states), and the remaining variables are as defined in model (4.9).

The statistical model used to estimate the wheat yield relationships for the North Central, Southern and Western regions is:

$$(4.17)\ YW = a_{17} + B_{171}\ POW_{t-1} + B_{172}\ PSO_{t-1} + B_{173}\ W + B_{174}\ LQ + B_{175}\ ISR_{t-5} + B_{176}\ OSR_{t-6} + B_{177}\ EXT_{t-4} + B_{178}\ RISK_1 + B_{179}\ S_1$$

where

S_1 = an intercept shifter for a group of states in the Western (Pacific vs. Mountain States) and North Central regions (North Plains vs. all other states),

the remaining variables are defined as in model (4.8).

The estimated coefficients for models (4.15) to (4.17) are presented in Tables 4.7, 4.8, and 4.9. Based on similar models, a greater percentage of variation was explained in the corn and soybean functions for states of the North Central region than when national data was used. This result is not too surprising given the concentration of U.S. corn and soybean production in this region and the relative homogeneity of growing conditions.

Corn and soybean yield functions specified in models (4.15) and (4.16) were also estimated from a cross section of data from states in the Southern region. In contrast to results from the North Central models, a smaller percentage of variation was explained and fewer coefficients were significant in the yield functions estimated for the Southern region. Within the Southern region, the soybean model in particular presented problems. Corn, wheat, and sorghum were

Table 4.7 Estimates of the Coefficients of the Yield Functions for Corn in the North Central and Southern Regions With Outside and Basic Research Using Park's Estimation Procedure.

	North Central	South
Intercept	-17.78(5.80)	-14.55(6.65)
Corn P_{t-1}	22.25[a](1.69)	24.49[a](1.89)
Syb P_{t-1}	-1.5[a](.326)	-8.18[a](.469)
W	.825[a](.027)	.694[a](.042)
LQ	.560[a](.080)	1.24[a](.120)
ISRes_{t-5}	16.32[a](.704)	22.47[a](7.31)
OSRes_{t-6}	.945[b](.428)	8.35[a](.41)
Ext_{t-4}	11.62[a](1.14)	-.59[ns](.77)
RISK 1	-67.97[a](1.9)	-26.73[a](3.97)
R^2	.781	.780
F	34.0	20.9
States	12	8

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[a] Significant at 1 percent level.

[b] Significant at 5 percent level.

[c] Significant at 10 percent level.

[ns] Not significant.

Numbers in parenthesis are standard errors.

Table 4.8 Estimates of the Coefficients of Yield Functions for Soybeans in the North Central and Southern Region Using Park's Estimation Procedure.

	North Central	South
Intercept	10.89(3.54)	5.409(1.76)
Syb P_{t-1}	2.83[a/](.31)	.472[a/](.297)
Corn P_{t-1}	-3.99[a/](.692)	
W	.63[b/](.027)	.129[a/](.014)
LQ	-.07[ns/](.073)	.293[a/](.051)
$ISRes_{t-5}$		2.52[ns/](1.89)
$OSRes_{t-6}$	1.09[a/](.222)	1.03[a/](.087)
Ext_{t-4}	1.37[ns/](1.17)	.621[b/](.277)
RISK 2	-6.32[a/](.95)	
S_1		-.309[ns/](.24)
R^2	.681	.510
F	24.9	8.18
States	11	9

[a/] Significant at 1 percent level.

[b/] Significant at 5 percent level.

[c/] Significant at 10 percent level.

[ns/] Not significant.

Numbers in parenthesis are standard errors.

Table 4.9 Estimates of the Coefficients of the Yield Functions for Wheat in the Western, Southern, and North Central Regions Using Park's Estimation Procedure.

	West	South	North Central
Intercept	-14.85(6.82)	-7.64(2.64)	8.67(2.36)
Wheat P_{t-1}	4.41[a](1.24)	6.39[a](.99)	.123[ns](.53)
Oats P_{t-1}	-5.8[a](1.24)		
W	.156[a](.045)	.271[a](.05)	.133[a](.015)
LQ	.466[a](.104)	.09[a](.031)	.224[a](.05)
$ISRes_{t-5}$	10.19[a](3.69)	10.89[a](3.22)	6.86[a](1.62)
$OSRes_{t-6}$	1.15[c](.631)	4.16[a](.991)	.490[b](.185)
Ext_{t-4}	3.43[b](1.65)	.435[b](.215)	1.01[ns](1.36)
RISK	-3.84[c](2.26)	-6.97[a](.892)	
N_1	17.91[a](1.32)	-20.57[a](2.41)	12.06[a](1.51)
N_2			12.12[a](1.53)
R^2	.704	.537	.609
F	15.8	7.8	13.8
States	10	9	10

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[a] Significant at 1 percent level.

[b] Significant at 5 percent level.

[c] Significant at 10 percent level.

[ns] Not significant.

Numbers in parenthesis are standard errors.

considered substitutes in the production of soybeans and their prices were tested for impacts on soybean yield levels. However, none of these price coefficients were found to be significant at the .05 level in any of the estimated soybean yield functions. In the model presented in Table 4.8, lagged soybean prices deflated by all prices received were included to take account of the influence of economic substitutes on soybean price. The coefficient for in-state research expenditures by these southern states also was not significant.

A comparison of estimated price elasticities for corn and soybean yields are presented in Table 4.10. The estimated corn price elasticities of .57 in the North Central and .76 in the South are somewhat larger than the elasticities based on national data in models (4.1), (4.7), and (4.11). The estimated price elasticities for soybean yields of .38 in the North Central, and .07 in the Southern region are similar to the estimated elasticities from the national data.

The regional yield response functions for wheat (Model 4.17) involved a three way comparison of the Southern, North Central, and Western regions. The estimated equation for wheat yields in the Southern region again accounted for the lowest percentage of explained variation in yield per acre. The equations estimated for the North Central states also caused problems in that the wheat price and extension expenditure coefficients were not significant. The price of various substitute commodities were tested in the regional wheat

Table 4.10 Estimated Elasticities and Rates of Return to Corn and Soybean Research and Extension in the North Central and Southern Regions.

Variable		Corn		Soybeans	
		North Central	South	North Central	South
		Yield Elasticities			
Price		.572	.76	.382	.072
Inside Research		.086	.049	.105	n.s.
Outside Research		.044	.036	.082	.151
Extension		.009	n.s.	n.s.	.025
		Value of Output to a Unit of Investment			
I.S. Research		67.5	20.9	54.4	n.s.
O.S. Research		8.2	1.9	5.3	6.9
Extension		8.46	n.s.	n.s.	3.31
	Lag Length	Internal Rate of Return (percent)			
I.S. Research	12	291.4	87.1	233.7	n.s.
O.S. Research	12	48.6	10.4	31.2	42.3
Extension	12	49.3	n.s.	n.s.	19.8
	8	73.9	n.s.	n.s.	29.7

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n.s. Not significant.

models with the oats price found to be significantly related to wheat yields in the Western region. Corn and sorghum prices also were tested in the North Central and Southern regions, but were not found to have a significant effect on wheat yields for states in these two regions. Lagged wheat prices deflated by prices received for farm products was used to account for the influence of economic substitutes in wheat production in the Southern and North Central regions. The different results for wheat production in the North Central and Southern states as compared to the national and Western regional models suggest different patterns of production practices which may be more invariant to changing economic stimuli. Rainfall is also generally more plentiful and less variable in these two regions as compared to the West which would reduce fluctuations in yield levels leaving less variation to be explained by the price variables. Within the three main wheat regions, the influence of various geoclimatic regions remain strong and again were represented by zero-one intercept shift variables.

The research and extension coefficients for the regional corn, soybeans, and wheat models (4.15 to 4.17) were all significant at either the one or the five percent level with the exception of extension expenditures for corn in the South and extension expenditures for corn and wheat in the North Central region. In models comparing identical specifications of an outside research expenditure variable, the results indicate higher rates of return to in-state corn and soybean research investments in the North Central region than in the South. This outcome is influenced in part by the procedure used to calculate the value of increased output resulting from the research investments. The increased yields were applied to a greater number of acres per state in the North Central region resulting in a greater total quantity of output per unit of research investment. A comparison of yield elasticity with respect to inside research investments for the two regions is not directly weighted by the greater number of acres per state. These yield elasticities also show a similar pattern of corn and soybean yields being more responsive to research investments in the North Central region than in the Southern region.

The estimated impacts of spillovers from outside research investments consisting of basic research expenditures and research expenditures from the same geo-climatic region, indicate higher rates of return for outside corn research expenditures in the Northern region than the outside research investments in the Southern region. Expenditures on soybean research by outside regions provide a higher estimated rate of return in the Southern region. A similar pattern of higher responsiveness to outside research investments is present for the Southern region when the comparison is based on yield elasticities. In the regional wheat models (4.17), the estimated coefficients for both in-state and spillover research are significant at the .05 level in all three regions. A comparison of estimated

IRORs among regions presented in Table 4.11 indicates that the lowest estimated IROR for in-state expenditures on wheat research occurs in the Southern region (78.8 percent) and the highest in the North Central region (148.1 percent). The magnitude of these IRORs again were influenced by the greater number of wheat acres per state in the North Central region which includes Kansas, Nebraska and the Dakotas. The estimated elasticities for in-state expenditures on research follow the same pattern of being the highest for the North Central region and lowest for the Southern region. The effect of outside wheat research investments and activities exhibited the opposite pattern with the highest estimated IROR occuring in the South and lowest in the Western region.

Efforts to estimate a regional model for corn, soybeans, and wheat (Models 4.15, 4.16, 4.17) produced mixed results for the extension coefficients. The coefficients of extension expenditures were not significant in the North Central wheat and soybean models, and also nonsignificant in the corn model for the Southern region.

The greater number of corn and soybean acres per state in the North Central region also influenced the estimated IRORs for investments in agricultural extension. The estimated IRORs are larger in the North Central region, but the yield elasticities with respect to extension expenditures indicate greater responsiveness to extension expenditures in the South. In the regional wheat models (4.17), the estimated IRORs on extension investments which were available for two

Table 4.11 Estimated Elasticities and Rates of Return to Research Investments in Wheat in the Western, Southern, and North Central Regions.

Variable	Lag Length	Western	Southern	North Central
		Yield Elasticities		
Price		.348	.308	n.s.
Inside Research		.063	.042	.082
Outside Research		.118	.352	.037
Extension		.07	.018	n.s.
		Value of Output to a Unit of Investment		
I.S. Research		18.3	17.5	34.0
O.S. Research		4.2	13.0	4.9
Extension		12.52	1.38	n.s.
		Internal Rate of Return (percent)		
I.S. Research	12	82.1	78.8	148.1
O.S. Research	12	25.1	62.3	28.4
Extension	12	63.9	8.8	n.s.
	8	95.8	13.2	n.s.

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n.s. Not significant.

of the regions, ranged from 9.0 percent in the South to 64.0 percent in the Western region under an assumed 12 year distribution of benefits and 13.2 to 96 percent when an 8 year distribution is assumed.

Assessment and Implications

The supply response model has been used in this study to evaluate publicly funded research and extension investments for corn, wheat, soybeans, and sorghum. The supply response approach was used to estimate yield per acre relationships at the national level and for regional groupings of states. The impressive rates of return from expenditures on corn, wheat, soybeans, and sorghum research indicate that these investments are a profitable use of public funds. The higher rates of return found for corn and soybean research spending suggest that further funds could be more profitably invested in corn and soybean research than in wheat and sorghum.

In addition to the impact on yields of research investments at the state level, expenditures on research by other outside states and agencies have been shown to have an impact on yield at the state level. Outside research was organized and specified as a different research investment variable according to:

(a) research expenditures by states within similar maturity zones or geo-climatic regions,

(b) investments in basic research by all outside states plus the similar geo-climatic based research investments, and

(c) USDA sponsored research at regional centers plus the basic research and the similar geo-climatic region research investments.

These three formulations of an outside research variable were included in separate yield response functions and were found to have significant impacts on yield levels. The estimated IROR to individual states of these outside research expenditures are lower than the IRORs from in-state commodity research investments which are partially the result of the larger stock of research investments available to states from outside sources.

The presence of spillovers from research expenditures by outside states indicates that the benefits of research activities are not confined to the state conducting the research and suggests that some sort or compensation to states is appropriate. The federal share of funding to state Agricultural Experiment Stations is a recognition that some of each states' research creates benefits that are national in scope. Since a state's research expenditure creates benefits for other states as well as for the originating state, a ratio of the estimated benefits from outside research to the benefits from in-state research can be compared to the ratio of federal to state research funding as a measure of whether the federal share of funding is in line with to the level of interstate spillovers being produced. Based on CRIS records of commodity research expenditures according to sources of funding, the ratio of federal funds to funds from state sources ranged from .22 to .59 for these four commodities during the 1967-1977 period (Table 4.12). The ratio of IRORs for outside research investments to the IROR for in-state investments on corn, wheat, and soyben research ranged from .26 for wheat to .45 for corn with the ratio nearly equal to 1.0 for sorghum. The levels of these ratios for corn, wheat, and soybean research indicate that the level of federal funding to states for these three commodities is comparable to the level of spillover benefits being created by state investments in corn, wheat, and soybean research. The higher ratio of IRORs for sorghum research suggest that a larger share of the state level sorghum research spills over and that increasing the share of federal funding for sorghum research through increased federal spending could be used to compensate states for this spillover.

This study also included an evaluation of agricultural extension investments separate from the impacts of research investments. In this evaluation only expenditures on extension activities related to the cash grain commodities are included because extension activities for one of these commodities is expected to be generally applicable to the other commodities, and also because a finer breakdown of these expenditures is not available. Although agricultural production oriented extension activities can have additional social impacts, the evaluation of extension expenditures in this study is concerned with impacts on increases in grain yields. Assuming the same 12 year lagged distribution used to allocate benefits of research investments,

Table 4.12 Ratio of Research Expenditures from Federal Sources to Expenditures From Non-Federal Sources for Corn, Sorghum, Wheat and Soybeans, 1966-1977.

Year	Corn	Sorghum	Wheat	Soybean
1977	.374	.22	.311	.426
1976	.367	.221	.274	.376
1975	.440	.219	.312	.359
1974	.432	.246	.332	.375
1973	.46	.250	.374	.413
1972	.446	.269	.346	.413
1971	.398	.271	.332	.460
1970	.456	.238	.350	.455
1969	.470	.271	.366	.487
1968	.497	.283	.372	.470
1967	.582	.358	.451	.502
1966	.591	.377	.470	.508

Source: CRIS, Inventory of Agricultural Research, Annual Reports, 1966-77.

the estimated IROR for state investments in agricultural extension activities range from 42 percent for sorghum to 63 percent for corn with nonsignificant results obtained for the soybeans model. When the extension related benefits are assumed to be distributed over an 8 year pattern, also in an "inverted V" distribution, the estimated IRORs on extension investments range from 63 percent for sorghum to 95 percent for corn. With the exception of the estimated IROR for investments in extension activities related to wheat production, the rates of return on agricultural extension expenditures for individual commodities are less than the IROR for in-state research investments. However, it is important to recognize that the rates of return estimated for research and extension are sensitive to the type and length of lag assumed. Although many previous research evaluation studies have made conceptual arguments for inclusion of extension as a necessary and complementary component to successful research investments, very little empirical work has been done to investigate lag structures for extension. Because of multicollinearity and estimation difficulties, research evaluation studies typically have combined extension expenditures with research expenditures and estimated a single coefficient for the combined impacts (Evenson, 1967, Cline, 1975, White, et al., 1978, Davis, 1979). In one of the few studies separately evaluating research and extension expenditures, Evenson (1978) estimated an IROR of 110 percent for aggregate agricultural extension investments in combination with farm management and applied engineering research.

Evenson's study also measured the impact of extension investments in terms of its impacts on agricultural production. He also assumed a geometrically declining weights for the lag structure for the inmpacts of extension related expenditures. According to this pattern, 50 percent of the impacts are realized in the first year after expenditure, 25 percent in the second year, 12.5 percent in the third year, and so on until the impacts are neglible. The distribution of a larger share of total impacts in the earlier years yields a higher IROR after discounting when compared to an "inverted V" distribution spread over a comparable number of years. The range of IRORs estimated for extension investments under different assumptions of the lag length and structure emphasize the sensitivity of the IROR measure and the caution that needs to be used in comparing extension expenditures with other types of public investments.

Overall, these results indicate that extension investments, along with research investment are significant in affecting yield levels for corn, wheat, and soybeans. However, the rate of return to state investments for agricultural extension is not as great as for research investments in these individual commodities under the assumptions that were made concerning lag length and distribution of benefits. Given the lack of information on these patterns for extension investments, it is difficult to draw any policy implication for prefering research over extension investments.

Although relatively more is known about the structure and distribution of benefits from research investments, information is lacking in several areas which are critical to obtaining precise estimates of rates of return on research expenditures. For example, little is known about the role of private research and its interaction and effects on publicly funded research. Without large scale cooperation from private agribusiness firms on their specific research areas, further investigation and understanding of the impacts on private agricultural research is unlikely. Another conceptual issue that research evaluations have been unable to deal adequately with is a correct valuation of the technical change benefits from research investments. The most correct procedure for assessing the social value of a research investment would be to analyze economic conditions with and without the research investment. Since we are unable to develop a properly controlled environment of the United States without the various research innovations, research evaluations, including the present one, are forced to conduct a "before and after" type of analysis of the impacts of research investments. Since many economic changes may have evolved without the particular research investments being evaluated, from a wider social perspective, the "before and after" approach may be biasing upwards the estimated IRORs to research and extension investments. Another factor affecting the valuation of research benefits and the estimated rates of return are the influence of the various commodity programs on the prices used for valuation, and the influence of research on prices. To the extent that commodity programs have increased prices, the estimated IRORs may be biased upwards. Further research could investigate the magnitude of bias caused by not using a "with and without" analysis and the price impacts of commodity research.

In addition to the inter-commodity comparison of differences in rates of return to research and extension investments, the cross sectional-time series data base used in this study also enabled a regional comparison of these research and extension rates of return for corn, wheat, and soybeans. The estimated regional models indicate that there are regional differences in (a) the type of economic substitutes in production that were found, (b) the significance levels of various coefficients, and (c) the percentage of variation in yield levels explained by similar models in different regions. For corn and soybeans, the models estimated for states in the North Central region had the largest percentage of variation explained and the highest estimated IROR for research and extension investments in these commodities. The highest estimated IROR for wheat research investments also occurs in the North Central region. The location of these high estimated IRORs in the North Central region are consistent with the concentration of U.S. production of these commodities in the Mid West and the highest level of per state research investments in corn, soybeans, and wheat. The pattern of IROR results and the record of research investments for the North Central region indicates a high degree of relative economic efficiency has been achieved in an interregional allocation of state research investments for these commodities.

The interregional pattern of results for investments in agricultural extension activities for these grain commodities indictes a higher rate of return for regions with the largest number of acres in production of each grain. However, the highest average of extension expenditure per state is in the Southern region which is not the top producer of any of these commodities. This high average for extension investments and IRORs in the Southern region contrasts with the relative economic efficiency observed for state research investments. However, there apparently are many arguments other than economic efficiency for states making investments in extension or research. The significance level of the extension expenditure coefficient indicates that extension investments do have an impact on yield levels and to a degree can be used to substitute for research expenditures. The extension expenditure also could be used to more effectively reach special groups such as small or low income farmers than is possible with state level research activities. An investigation of this possibility on a regional basis is a topic for future research.

The state level extension expenditure also can interact with research spillovers from outside states. These outside research expenditures also can possibly substitute for resarch expenditures at the state level. Based on the formulation of research spillovers used in this study, the largest stock of "borrowable" outside research is available to states in the North Central region where corn, soybean, and wheat production are concentrated. The highest estimated IROR for outside corn research investments is in the North Central region. Otherwise, the highest IROR to outside research for wheat and soybeans occurs in the Southern region which suggests that even though much of the outside research spillover within the same maturity zone, outside research is being utilized more effectively within the Southern region.

Chapter 5

Summary and Conclusions

The major purpose of this study was to assess returns to research investments in individual agricultural commodities. In conducting this assessment, a number of related research evaluation issues were considered. These issues included estimating the impacts on yield levels of extension investments, inter-regional research spillovers, and aggregate risk behavior by producers. The structure and main results of the analysis are presented below in a chapter by chapter summary.

Summary

In the first chapter, the major research problem of an efficient allocation of publicly funded research investments was presented in the general context of research evaluation. Advantages of conducting an evaluation of research investments for individual agricultural commodities in separate regions such as guides for future regional and commodity research funding allocations and the major problems that are likely to be encountered in such an evaluation such as limited production input data and research spillover issues were discussed. The need to consider extension investments separately from research investments and the need to analyze the impacts of interregional research spillovers at a state level of analysis were the major conclusions of the first chapter.

In Chapter 2, the review of literature focused on studies concerned with evaluation of research and extension investments made at a sub-national level. Special attention was also given to literature in the agricultural, development, and industrial research areas which were concerned with various types of spillovers. The concept of horizontal transfers in the form of interregional research spillovers within similar geo-climatic regions was developed out of these studies and formed the basis of the variable used to identify research spillovers among individual agricultural commodities. The review of evaluation methods in Chapter 2 ruled out the aggregate production function approach because of limited production input data. A supply response model which utilizes more accessible data on prices and other supply shifters was developed as a workable alternative. The role of risk in an aggregate supply response model was also considered in a special section of this chapter.

In Chapter 3, the theoretical basis of the supply response model as an appropriate framework of analysis was developed. Based on the theoretical model, the general empirical model and variables were then presented and discussed. Chapter 3 also contained a discussion of data sources for the study and the special time series-cross sectional algorithm used to estimate the coefficients of the models presented.

The results of estimating yield relationships for corn, wheat, soybeans, and sorghum were presented in Chapter 4. The presentation of statistical results was organized into two sections according to observations drawn from a national group of states and a regional grouping of states. The prices of output and a substitute commodity, weather, land quality differences, aggregate risk, instate and outside research investments, and extension investments were significant variables explaining yield per acre of corn, wheat, soybeans and sorghum. Estimated IRORs on instate research investments ranged from 81 percent for wheat to 177 percent for corn. Estimated IRORs for outside research investments ranged from 21 percent for wheat to 133 percent for sorghum. The estimated IRORs for extension investments ranged from 42 percent for sorghum to 96 percent for corn. The estimated IRORs in the various U.S. production regions were of a comparable magnitude for the respective research and extension investments.

Conclusions

The discussion of the major conclusions of this study are drawn directly from the results presented in Chapter 4. The major objective of this study was to assess research investments on individual agricultural commodities. Related to this objective, the major conclusion of this study is that research investments do have a significant and measurable impact on productivity of individual commodities. The cross commodity comparison of research productivity provided by this framework indicated that corn and soybean research investments had the highest estimated IRORs. While investments for all commodities have estimated IRORs that are higher than the 35-60 percent level estimated for agriculture in aggregate (Davis, 1979, Peterson and Fritzharris, 1977), the results suggest there is a relative underallocation of agricultural research funds for corn and soybean research.

The results also indicate that the impacts of research are not confined to the state making the investment. Other studies have acknowledged the occurrence of interregional spillover at a sub-national level and have attempted to account for them in either an unstructured fashion of all outside research (White and Havlicek, 1981) or in a pattern based on geo-climatic similarities (Evenson, 1978; Davis, 1979). The spillover regions developed for the individual commodities of this study were based on research being usable for states within the same maturity region. The results indicate that research spillovers, based on a pattern of maturity zones plus basic research shares from other states are very significant in explaining yield for photosensitive crops like corn, sorghum, and soybeans. Research spillovers for wheat patterned on climatic and variety similarities plus basic research expenditures by other states were significant in explaining variation in wheat yields. Spillover regions for other commodities could also be defined by using a similar procedure of focusing on characteristics of individual commodities to identify the location of similar varieties and research activities.

The significance of outside research expenditures in contributing to productivity in other states suggest some sort of compensation to states may be worth considering. A comparison of the existing record of federal funding share at state agricultural experiment stations to the estimated level of benefits attributable to outside research investments indicated that the federal "compensation" for interregional spillovers was comparable to the generated benefits during the pre-1974 period. The estimated share of research benefits generated by outside research expenditures is greater than the share of federal funding in the more recent years which suggests that more federal funding for state agricultural research may be appropriate. In addition to federal funding, more interstate funding of projects where spillovers are most likely could be used as a means to compensate for some of the research spillovers.

The role of private research activities was not considered in this study. Agricultural research expenditure data by private firms for individual commodities are not available and an arbitrary adjustment to the rates of return or the research coefficient in order to account for private research has not been made in this study. Such an adjustment is not desirable since any systematic bias from a first order auto-correlation and cross sectional correlation disturbance have been accounted for in Generalized Least Squares Parks estimation procedure and the remaining random disturbances from the unspecified term are captured in the residual.

In addition to the two components of research investments, the statistical models estimated in this study provided information about the contribution of extension investments to productivity increases. With the exception of soybeans, extension expenditures were found to have a significant impact on grain yields. The estimated IRORs were based on an "inverted V" distribution of benefits over a 12 and 8 year pattern. Using these assumed distributions, the IROR on investment was less for extension than for research, although still highly profitable. Despite the fact that conceptual arguments for separating extension expenditure from research which have often been made in past studies (Davis, 1979, Cline, 1975, Evenson, 1967), estimation difficulties such as multicollinearity problems have usually required either adding extension with research expenditures, and estimating a common coefficient, or assuming that extension impacts are comparable to research when calculating IRORs. The results from this study show that the latter procedure appears to bias upwards the impact of extension investments. The IRORs for corn and sorghum research expenditures have been estimated to be 75 to 100 percent larger than the return on extension investments. The estimated IROR for wheat research expenditures are within the same range as the return on extension investment. Both comparisons are made on the basis of an "inverted V" distribution of 8 and 12 years for extension and 12 years for research. These mixed results do not provide a clear signal to policy makers on a choice of allocating scarce public funds between research and extension.

The comparison of estimated IRORs for an 8 year versus a 12 year distribution of benefits with IRORs calculated from a geometrically declining lag by Evenson (1978) demonstrate the sensitivity of the IROR measure to the underlying lag assumptions. Under a certain set of assumptions, the estimated IRORs for extension expenditures could be made comparable to the IRORs for research investments. Decisions regarding the allocation of public funds between extension and research also need to consider criteria other than the yield increasing potential of these funds. Goals such as promotion of a reliable food supply system, reasonably priced food for consumers, and improved economic well-being for certain groups are frequently mentioned as the rationale for government food and agricultural programs. The ability of research and extension programs to contribute toward these goals are arguments that should be considered in the allocation of public funds. The overall results do indicate that under conservative assumptions, the present allocation of funds between research and extension has produced high rates of return for both research and extension investments.

Regional Results

The cross sectional-time series nature of the data in this study enabled a regional comparison of the research and extension results. The higher estimated IRORs in the North Central region where corn, soybean, and wheat research and production is located, suggests a relative degree of allocative efficiency has been achieved in the regional distribution of research funds.

The highest estimated IRORs for corn extension investments occurs in the North Central region and the highest IROR for wheat extension investment occurs in the Western region. However, the largest per state average extension expenditure occurs in the Southern region. The significant coefficient estimated for extension expenditures in the regional models indicate that extension investments can be used to positively influence yields. Whereas the research activities are more concerned with achieving general technical advances, extension activities, which are more concerned with disseminating these advances, can be used to direct new technical advances toward assisting certain audiences. If large extension resources are devoted toward clientele who do not have sufficient production resources, advances in welfare may not show up in the yield per acre measure which is being used to evaluate extension investments in this study.

The regional results also indicate that research conducted by outside states and regions can be used to increase yield levels of particular states. The higher IRORs for outside wheat and soybean research investments in the Southern region suggest that these states are more effectively utilizing this source of increasing yield. Alternatively, since the majority of research is assumed to be transferred latitudinally within a geographical region, the higher IRORs in the South suggest that the research being done in the South is more easily transferable among states within similar maturity zones and geo-climatic regions.

The analysis of research and extension in individual agricultural commodities focused on benefits created by increasing yields at the farm levels. However, producers benefit primarily by being early adopters of the new technologies. Various studies (White et. al. , 1978; Lindner and Jarrett, 1978) indicate that in the long run, consumers are the primary beneficiaries of research and extension investments in the form of lower food prices. However, under certain conditions such as when barriers of entry to a certain type of agriculture exist, the quasi-rents would persist and be captured by producers. We would still conclude that consumers are the primary beneficiaries of the substantial rates of return from research and extension investments in corn, wheat, soybeans, and sorghum.

The results of this study also have several interesting implications for the general use of a supply response model for yield analysis. In either acreage or yield response models, the impact of technical change has generally been represented by a linear time trend. The investment in agricultural research for agricultural commodities has been used in this study as the source of that technical change. The significant results for the research investments coefficients suggest that research expenditures can be used as a more appropriate measure of technical change in various commodity supply models. The results obtained from evaluating research investment for several grain commodities suggest that a supply response framework might be used to evaluate investments in other research areas such as individual types of livestock or dairy categories.

The supply response model used in this study also considered the effects of aggregate risk on yield response. Aggregate risk, measured as a three year moving standard deviation of past prices, was found to have a significant negative impact on yield levels of corn and wheat which implies risk averse behavior by these producers. The risk averse response by corn and wheat producers during the 1973-1979 sample period suggests yields can be increased by reducing price fluctuations in these commodities.

In sum, research investments by states and outside regions were found to have significant effects on yield levels of corn, wheat, soybeans, and sorghum. With the exception of soybeans, extension investments were also found to have a significant effect on yield levels of individual grain commodities. Regional differences in rates of return on investments were also investigated with higher IRORs found for states in the North Central region than in the Southern region. Further research efforts could be directed toward exploring reasons for these regional differences such as socio-economic and political differences in regions. Additional research could also concentrate on identifying lag structure for the various research and extension investments and possible regional differences in these structures. A final suggested research topic related to this study is to extend the evaluation of agricultural research investments to other individual commodity categories such as changes of livestock.

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APPENDIX TABLES

TABLE A-1. RESEARCH AND DEVELOPMENT EXPENDITURES BY GOVERNMENT AGENCIES (DOD, HEW, USDA+SAES, DOE, NASA, NSF, OTHER SELECTED AGENCIES AND TOTAL FEDERAL RESEARCH) IN CURRENT AND CONSTANT DOLLARS 1966-1978.

($1000)

YEAR	DOE R+D EXPENDITURE CUR $	DOE R+D EXPENDITURE CONST $	NASA R+D EXPENDITURE CUR $	NASA R+D EXPENDITURE CONST $	NSF R+D EXPENDITURE CUR $	NSF R+D EXPENDITURE CONST $	OTHER R+D EXPENDITURE CUR $	OTHER R+D EXPENDITURE CONST $
1966	1212	1271.77	5050	5299.06	244	256.034	541	567.68
1967	1257	1257.00	4867	4867.00	262	262.000	694	694.00
1968	1369	1296.40	4429	4194.13	284	268.939	625	591.86
1969	1406	1260.99	3963	3554.26	274	245.740	744	667.26
1970	1346	1117.01	3800	3153.53	289	239.834	1043	865.56
1971	1303	1009.30	3258	2523.63	337	261.038	1357	1051.12
1972	1298	942.63	3157	2292.67	455	330.428	1169	848.95
1973	1363	925.95	3061	2079.48	480	326.087	1288	875.00
1974	1489	912.94	3002	1840.59	556	340.895	1278	783.57
1975	2047	1153.24	3064	1726.20	595	335.211	1486	837.18
1976	2464	1308.55	3447	1830.59	609	323.420	1541	818.37
1977	3536	1761.83	3703	1845.04	697	347.285	1695	844.54
1978	4196	1930.97	3876	1783.71	754	346.986	2005	922.69

YEAR	DOD R+D EXPENDITURE CUR $	DOD R+D EXPENDITURE CONST $	HEW R+D EXPENDITURE CUR $	HEW R+D EXPENDITURE CONST $	USDA+SAES R+D EXPENDITURE CUR $	USDA+SAES R+D EXPENDITURE CONST $	TOTAL FED R+D EXPENDITURE CUR $	TOTAL FED R+D EXPENDITURE CONST $
1966	7024	7370.41	1014	1064.01	359	375.970	15247	15999.0
1967	8049	8049.00	1147	1147.00	373	373.000	16441	16441.0
1968	7709	7300.19	1252	1185.61	402	380.527	15827	14987.7
1969	7696	6902.24	1297	1163.23	423	379.513	15543	13939.9
1970	7360	6107.88	1221	1013.28	459	380.911	15236	12644.0
1971	7509	5816.42	1476	1143.30	497	385.212	15437	11957.4
1972	8318	6040.67	1751	1271.60	571	414.851	16377	11893.2
1973	8404	5709.24	1838	1248.64	615	417.764	16670	11324.7
1974	8420	5162.48	2290	1404.05	671	411.276	17275	10591.7
1975	9012	5077.18	2363	1331.27	756	425.723	18832	10609.6
1976	9655	5127.46	2546	1352.10	830	440.601	20565	10921.4
1977	10963	5462.38	2787	1388.64	949	473.001	23725	11821.1
1978	11825	5441.79	3132	1441.33	1043	480.022	26169	12042.8

SOURCE: NSF, SCIENCE INDICATORS 1979, "TABLE 4-2 RESEARCH AND DEVELOPMENT EXPENDITURES BY U.S. GOVERNMENT DEPARTMENTS, 1966-1978."

TABLE B-1. BASIC RESEARCH AND CROP PRODUCTION SHARES FOR GRAINS.

STATE	B.RES	CROPSH
ALA	0.090	0.448
ARK	0.126	0.400
ARZ	0.135	0.589
CAL	0.146	0.502
COL	0.135	0.589
DEL	0.146	0.380
FLO	0.090	0.448
GEO	0.090	0.448
IDA	0.135	0.589
ILL	0.172	0.277
IND	0.172	0.277
IOW	0.172	0.277
KAN	0.110	0.339
KEN	0.131	0.357
LOU	0.126	0.400
MAR	0.146	0.380
MAS	0.126	0.380
MIC	0.154	0.283
MIN	0.154	0.283
MIS	0.126	0.400
MON	0.135	0.589
MOS	0.172	0.277
NCA	0.131	0.357
NDK	0.110	0.339
NEB	0.110	0.339
NEV	0.135	0.000
NHA	0.146	0.380
NJE	0.110	0.380
NME	0.135	0.589
NYK	0.147	0.380
OHI	0.172	0.277
OKL	0.143	0.312
ORE	0.146	0.502
PEN	0.147	0.380
SCA	0.090	0.448
SDK	0.110	0.339
TEN	0.131	0.357
TEX	0.143	0.312
UTA	0.135	0.589
VER	0.146	0.380
VIR	0.131	0.357
WAS	0.146	0.502
WVA	0.131	0.357
WIS	0.154	0.283
WYO	0.135	0.589

TABLE B-2. WEIGHTS FOR CORN SPILLOVER REGIONS.

STATE	REG1	REG2	REG3	REG4	REG5	REG6	REG7	REG8	REG9
COL	0.0000	0.0164	0.0348	0.1563	0.1952	0.4967	0.1006	0.0000	0.0000
GEO	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
ILL	0.0000	0.0000	0.0000	0.0088	0.0567	0.1374	0.6224	0.1748	0.0000
IND	0.0000	0.0000	0.0000	0.0000	0.0720	0.2362	0.4891	0.2028	0.0000
IOW	0.0000	0.0000	0.0000	0.0578	0.2825	0.3644	0.3013	0.0000	0.0000
KAN	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.6384	0.3616	0.0000
KEN	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.8922	0.1078
MAR	0.0000	0.0000	0.0000	0.0000	0.0000	0.0045	0.0341	0.9614	0.0000
MIC	0.0043	0.0105	0.0597	0.5510	0.3746	0.0000	0.0000	0.0000	0.0000
MIN	0.0024	0.0366	0.2560	0.4499	0.2548	0.0000	0.0000	0.0000	0.0000
MOS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.4498	0.5384	0.0418
NEB	0.0000	0.0000	0.0000	0.0096	0.0768	0.1476	0.6882	0.0779	0.0000
NYK	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000
NCA	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
NDK	0.0168	0.1387	0.7812	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
OHI	0.0000	0.0000	0.0000	0.0000	0.0764	0.3419	0.5589	0.0229	0.0000
PEN	0.0000	0.0000	0.0000	0.0577	0.1338	0.2269	0.2916	0.2899	0.0000
SCA	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
SDK	0.0000	0.0133	0.1996	0.1298	0.4560	0.2013	0.0000	0.0000	0.0000
TEN	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
TEX	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.7590	0.0552	0.1858
VIR	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.3270	0.6730
WIS	0.0009	0.0997	0.3609	0.3623	0.1763	0.0000	0.0000	0.0000	0.0000

TABLE B-3. WEIGHTS FOR WHEAT SPILLOVER REGIONS.

STATE	REG1	REG2	REG3	REG4	REG1A
ALA	0.00	0.00	0.00	1.00	0.0
ARK	0.00	0.00	0.00	1.00	0.0
ARZ	0.85	0.00	0.15	0.00	0.0
CAL	1.00	0.00	0.00	0.00	0.0
COL	0.00	0.00	1.00	0.00	0.0
CON	0.00	0.00	0.00	1.00	0.0
DEL	0.00	0.00	0.00	1.00	0.0
FLO	0.00	0.00	0.00	1.00	0.0
GEO	0.00	0.00	0.00	1.00	0.0
IDA	0.70	0.00	0.30	0.00	0.0
ILL	0.00	0.00	0.00	0.60	0.0
IND	0.00	0.00	0.00	1.00	0.0
IOW	0.00	0.20	0.80	0.00	0.0
KAN	0.00	0.00	1.00	0.00	0.0
KEN	0.00	0.00	0.00	1.00	0.0
LOU	0.00	0.00	0.00	1.00	0.0
MAR	0.00	0.00	0.00	1.00	0.0
MAS	0.00	0.00	0.00	0.00	1.0
MIC	0.00	0.00	0.00	0.10	0.9
MIN	0.00	1.00	0.00	0.00	0.0
MIS	0.00	0.00	0.00	1.00	0.0
MON	0.10	0.50	0.40	0.00	0.0
MOS	0.00	0.00	0.80	0.20	0.0
NCA	0.00	0.00	0.00	1.00	0.0
NDK	0.00	1.00	0.00	0.00	0.0
NEB	0.00	0.00	1.00	0.00	0.0
NEV	1.00	0.00	0.00	0.00	0.0
NHA	0.00	0.00	0.00	0.00	1.0
NJE	0.00	0.00	0.00	1.00	0.0
NME	0.00	0.00	1.00	0.00	0.0
NYK	0.00	0.00	0.00	0.10	0.9
OHI	0.00	0.00	0.00	1.00	0.0
OKL	0.00	0.00	0.95	0.05	0.0
ORE	1.00	0.00	0.00	0.00	0.0
PEN	0.00	0.00	0.00	1.00	0.0
SCA	0.00	0.00	0.00	1.00	0.0
SDK	0.00	0.75	0.00	0.25	0.0
TEN	0.00	0.00	0.00	1.00	0.0
TEX	0.00	0.00	0.80	0.20	0.0
UTA	0.70	0.00	0.30	0.00	0.0
VER	0.00	0.00	0.00	0.00	1.0
VIR	0.00	0.00	0.00	1.00	0.0
WAS	1.00	0.00	0.00	0.00	0.0
WVA	0.00	0.00	0.00	1.00	0.0
WIS	0.00	1.00	0.00	0.00	0.0
WYO	0.00	0.00	1.00	0.00	0.0

TABLE B-4. WEIGHTS FOR SOYBEAN SPILLOVER REGIONS.

STATE	REG1	REG2	REG3	REG4	REG5	REG6	REG7	REG8	REG9
ALA	0.000	0.000	0.000	0.000	0.000	0.000	0.426	0.171	0.403
ARZ	0.000	0.000	0.000	0.000	0.000	0.362	0.559	0.079	0.000
DEL	0.000	0.000	0.000	0.181	0.819	0.000	0.000	0.000	0.000
GEO	0.000	0.000	0.000	0.000	0.000	0.000	0.571	0.429	0.000
ILL	0.000	0.129	0.353	0.255	0.263	0.000	0.000	0.000	0.000
IND	0.000	0.292	0.566	0.036	0.106	0.000	0.000	0.000	0.000
IOW	0.000	0.331	0.478	0.191	0.000	0.000	0.000	0.000	0.000
KAN	0.000	0.000	0.000	0.208	0.792	0.000	0.000	0.000	0.000
KEN	0.000	0.000	0.000	0.000	0.542	0.458	0.000	0.000	0.000
LOU	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.434	0.566
MAR	0.000	0.000	0.000	0.141	0.859	0.000	0.000	0.000	0.000
MIC	0.041	0.959	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MIN	0.054	0.946	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MIS	0.000	0.000	0.000	0.000	0.000	0.000	0.667	0.330	0.000
MOS	0.000	0.000	0.000	0.405	0.224	0.371	0.000	0.000	0.000
NCA	0.000	0.000	0.000	0.000	0.000	0.606	0.394	0.000	0.000
NEB	0.000	0.000	0.273	0.727	0.000	0.000	0.000	0.000	0.000
NJE	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000
OHI	0.000	0.624	0.336	0.040	0.000	0.000	0.000	0.000	0.000
OKL	0.000	0.000	0.000	0.000	0.232	0.490	0.244	0.034	0.000
SCA	0.000	0.000	0.000	0.000	0.000	0.000	0.516	0.484	0.000
SDK	0.000	0.296	0.694	0.000	0.000	0.000	0.000	0.000	0.000
TEN	0.000	0.000	0.000	0.000	0.000	0.775	0.225	0.000	0.000
TEX	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.814	0.185
VIR	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000
WIS	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

TABLE B-5. WEIGHTS FOR SORGHUM SPILLOVER REGIONS.

STATE	REG1	REG2	REG3	REG4	REG5	REG6	REG7	REG8	REG9
ALA	0	0	0	0.0000	0.0000	0.0000	0.00000	0.0000	1.0000
ARK	0	0	0	0.0000	0.0000	0.0000	0.00700	0.4880	0.5035
ARZ	0	0	0	0.0000	0.0000	0.0000	0.00000	0.0000	1.0000
CAL	0	0	0	0.0000	0.1506	0.3657	0.26420	0.2194	0.0000
COL	0	0	0	0.0153	0.0212	0.2804	0.68300	0.0000	0.0000
GEO	0	0	0	0.0000	0.0000	0.0000	0.00000	0.0000	1.0000
ILL	0	0	0	0.0006	0.0090	0.0960	0.18660	0.7080	0.0000
IND	0	0	0	0.0000	0.0778	0.0574	0.45820	0.4065	0.0000
IOW	0	0	0	0.0025	0.0818	0.1598	0.75570	0.0000	0.0000
KAN	0	0	0	0.0000	0.0000	0.0084	0.03804	0.9536	0.0000
KEN	0	0	0	0.0000	0.0000	0.0000	0.00000	0.3515	0.6485
LOU	0	0	0	0.0000	0.0000	0.0000	0.00000	0.0000	1.0000
MIS	0	0	0	0.0000	0.0000	0.0000	0.00000	0.0000	1.0000
MOS	0	0	0	0.0000	0.0000	0.0000	0.09100	0.8980	0.0109
NEB	0	0	0	0.0000	0.0011	0.0629	0.32280	0.6130	0.0000
NME	0	0	0	0.0000	0.0000	0.0000	0.41900	0.3213	0.2595
NCA	0	0	0	0.0000	0.0000	0.0000	0.00000	0.0000	1.0000
OKL	0	0	0	0.0000	0.0000	0.0000	0.00000	0.5714	0.4285
SCA	0	0	0	0.0000	0.0000	0.0000	0.00000	0.0000	1.0000
TEN	0	0	0	0.0000	0.0000	0.0000	0.00000	0.0000	1.0000
TEX	0	0	0	0.0000	0.0000	0.0000	0.09100	0.8980	0.0109
VIR	0	0	0	0.0000	0.0000	0.0000	0.00000	0.9670	0.0330

TABLE C-1. CROSS SECTIONAL-TIME SERIES DATA FOR CORN, 1973-1979.

YEAR	STATE	CRNYD bu.	CRNLOP $/bu	SYBLOP $/bu	JUNWT	AUGWT	LAND	ISRES $	OSRES $	BAS RES $	EXTEN $1000	RISK1
79	COL	127	2.10	6.35	86	88	25139	50799	6054772	330652	1297.88	0.150000
79	GEO	65	2.45	6.40	87	82	6053	291887	819968	1151114	2628.67	0.317543
79	ILL	128	2.15	6.65	90	89	25788	751948	6160326	175481	1326.63	0.115470
79	IND	112	2.15	6.75	91	96	14101	633891	5335181	324936	1123.00	0.125831
79	IOW	127	2.00	6.60	91	89	23713	1163399	4375849	384419	1229.73	0.144338
79	KAN	117	2.25	6.60	88	88	22473	521367	3430309	641811	1416.26	0.173205
79	KEN	102	2.35	6.70	90	96	5589	201140	2105645	943364	1426.43	0.028868
79	MAR	99	2.25	6.50	92	92	10286	52856	4944108	464695	889.16	0.250000
79	MIC	95	2.10	6.70	88	89	8212	230345	2040261	936657	1176.31	0.125831
79	MIN	100	1.90	6.55	82	92	12516	548870	1814466	936628	1184.42	0.259808
79	MOS	103	2.15	6.70	90	84	10139	884133	4246212	518554	1096.06	0.202073
79	NEB	115	2.05	6.50	85	87	22713	711948	6291978	175476	1029.96	0.152753
79	NYK	85	2.35	6.25	92	72	7656	409263	617383	1129477	2675.64	0.175594
79	NCA	76	2.35	6.75	93	82	6214	372577	745715	1151114	2552.31	0.125831
79	NDK	76	2.00	6.45	79	72	14468	54169	327862	1225503	509.51	0.264575
79	OHI	115	2.15	6.75	90	97	11712	567378	5412409	324935	1363.34	0.152753
79	PEN	95	2.45	6.30	93	85	6194	281828	6662370	175464	1517.40	0.076376
79	SCA	80	2.25	6.80	91	76	7800	133743	957516	1225503	1456.15	0.251661
79	SDK	74	1.80	6.50	78	88	17374	131351	3307174	760025	515.39	0.332916
79	TEN	83	2.30	6.50	94	93	5971	183173	894126	1151114	1459.59	0.251661
79	TEX	105	2.40	6.25	83	85	22824	80790	4882883	513992	3052.66	0.115470
79	VIR	83	2.35	6.80	97	93	7279	197396	2104940	943364	2134.48	0.225462
79	WIS	103	2.00	6.70	87	91	8220	231697	2062154	936657	1365.09	0.230940

TABLE C-1. CROSS SECTIONAL-TIME SECTIONAL DATA FOR CORN, 1973-1979 (CONT.).

YEAR	STATE	CRNYD bu.	CRNLOP $/bu	SYBLOP $/bu	JUNWT	AUGWT	LAND	ISRES $	OSRES $	BAS RES $	EXTEN $1000	RISK1
78	COL	110	1.95	5.25	79	61	24753	39063	5757535	325128	1166.31	0.325320
78	GEO	50	1.90	5.95	83	78	5875	253515	787409	1134178	2451.22	0.388373
78	ILL	111	2.15	5.90	90	73	25218	774750	5805687	195287	1238.10	0.175594
78	IND	108	2.00	5.50	90	84	13723	604834	4916620	346118	1021.06	0.202073
78	IOW	117	2.00	5.80	90	82	23156	1321902	4093557	382203	1184.43	0.202073
78	KAN	102	1.95	5.35	90	59	22250	451990	3260694	677008	1297.41	0.251661
78	KEN	85	2.30	6.20	88	89	5430	197309	2053004	948614	1366.62	0.132288
78	MAR	97	2.00	5.50	86	85	10079	53002	4487479	495088	879.47	0.321455
78	MIC	81	1.95	5.60	92	75	7984	289782	2080935	921591	1351.91	0.180278
78	MIN	104	1.90	5.60	89	87	12210	515760	1811898	921562	1104.32	0.275379
78	MOS	87	2.00	5.65	90	75	9939	688904	3914077	537084	1230.50	0.264575
78	NEB	113	1.95	5.50	89	80	22349	643111	6016795	195281	912.71	0.229129
78	NYK	79	2.20	5.10	85	74	7477	377694	630862	1126824	2587.13	0.180278
78	NCA	76	2.20	5.95	85	74	5983	327769	644321	1134178	2456.16	0.225462
78	NDK	79	1.90	5.40	90	87	14250	68502	369531	1220923	469.02	0.288675
78	OHI	105	1.95	5.65	87	84	11399	527614	5158135	346117	1258.55	0.229129
78	PEN	95	2.35	5.50	89	82	6042	272810	6345119	195270	1436.84	0.086603
78	SCA	55	1.95	5.90	85	80	7555	115968	867983	1134178	1321.64	0.360555
78	SDK	67	1.85	5.40	91	89	16969	133832	3207351	740212	549.69	0.317543
78	TEN	66	2.10	5.85	89	81	5772	179358	769667	1134178	1357.22	0.304138
78	TEX	100	2.20	5.35	55	44	22431	72901	4512802	533529	2810.25	0.225462
78	VIR	82	2.10	5.80	93	94	7071	198014	1941931	948614	2213.92	0.292973
78	WIS	98	2.00	5.35	92	90	8050	267891	2004949	921590	1232.73	0.264575

TABLE C-1. CROSS SECTIONAL-TIME SECTIONAL DATA FOR CORN, 1973-1979 (CONT.).

YEAR	STATE	CRNYD bu.	CRNLOP $/bu	SYBLOP $/bu	JUNWT	AUGWT	LAND	ISRES $	OSRES $	BAS RES $	EXTEN $1000	RISK1
77	COL	116	2.25	6.60	69	72	24367	25190	5160305	297705	1118.19	0.350000
77	GEO	24	2.45	6.95	53	55	5697	165379	780297	1080112	2475.18	0.360555
77	ILL	105	2.35	7.60	80	87	24648	746359	5362624	176574	1302.89	0.340343
77	IND	102	2.25	6.95	83	90	13345	648744	4530311	326193	926.26	0.396863
77	IOW	86	2.25	7.75	80	76	22599	1232105	3812665	363152	1046.48	0.284312
77	KAN	96	2.25	7.45	90	90	22027	383991	3036369	635120	1302.37	0.360555
77	KEN	90	2.35	7.10	81	92	5271	118850	2012526	894793	1341.41	0.332916
77	MAR	72	2.50	6.75	65	74	9872	170612	4199890	469238	764.51	0.407226
77	MIC	85	2.20	7.80	61	74	7756	266995	1702174	838559	1328.98	0.350000
77	MIN	100	2.35	7.70	77	71	11904	536220	1708684	838530	990.72	0.246644
77	MOS	76	2.40	7.25	81	78	9739	663491	3796726	522661	1241.05	0.350000
77	NEB	99	2.25	7.45	89	89	21985	535272	5493347	176567	840.13	0.284312
77	NYK	80	2.55	6.50	89	78	7298	355830	489610	1046375	2496.62	0.292973
77	NCA	51	2.45	7.00	74	61	5752	308467	648391	1080112	2407.07	0.360555
77	NDK	73	2.40	8.00	44	49	14032	90100	260054	1130604	416.26	0.317543
77	OHI	105	2.25	7.40	77	88	11086	407253	4746193	326188	1204.16	0.396863
77	PEN	92	2.50	6.60	79	85	5890	207022	5757813	176558	1387.35	0.288675
77	SCA	36	2.45	7.25	62	52	7310	84805	873119	1080112	1373.10	0.360555
77	SDK	59	2.40	7.35	68	71	16564	149755	2783604	673261	460.12	0.288675
77	TEN	65	2.60	6.60	80	76	5573	183121	759012	1080112	1330.10	0.419325
77	TEX	98	2.40	6.10	84	58	22038	84671	4325260	519237	2430.96	0.409268
77	VIR	55	2.55	7.10	67	54	6863	229923	1946970	894793	1893.09	0.350000
77	WIS	104	2.40	7.10	75	79	7880	342974	1708791	838560	1114.19	0.292973

TABLE C-1. CROSS SECTIONAL-TIME SECTIONAL DATA FOR CORN, 1973-1979 (CONT.).

YEAR	STATE	CRNYD bu.	CRNLOP $/bu	SYBLOP $/bu	JUNWT	AUGWT	LAND	ISRES $	OSRES $	BAS RES $	EXTEN $1000	RISK1
76	COL	102	2.60	4.25	71	65	23981	31927	4681220	288806	1030.53	0.217945
76	GEO	62	2.65	4.55	84	72	5519	182242	663637	974139	2378.47	0.340343
76	ILL	107	2.50	4.70	83	61	24078	656748	4862853	160259	1206.83	0.304138
76	IND	110	2.40	4.70	75	78	12967	613559	4132178	292416	878.05	0.361709
76	IOW	91	2.40	4.55	88	56	22042	1036605	3506023	337040	969.13	0.246644
76	KAN	96	2.45	4.50	86	49	21804	408743	2766329	564821	1185.40	0.304138
76	KEN	102	2.55	4.65	74	83	5112	113962	1814724	798415	1289.91	0.292973
76	MAR	92	2.60	4.65	74	77	9665	173403	3913425	413669	737.11	0.425245
76	MIC	69	2.30	4.50	86	55	7528	284264	1484070	789223	1252.83	0.304138
76	MIN	59	2.40	4.60	47	26	11598	277865	1464821	789206	911.63	0.305505
76	MOS	61	2.50	4.55	82	45	9539	593131	3596400	451727	1139.94	0.353601
76	NEB	85	2.40	4.50	80	48	21621	526038	4958248	160253	763.32	0.284312
76	NYK	76	2.45	4.25	91	88	7119	385897	418342	958135	2404.60	0.284312
76	NCA	80	2.65	4.60	74	64	5521	314148	619040	974139	2322.53	0.427200
76	NDK	40	2.40	4.45	70	48	13814	85692	237170	1042044	397.55	0.409268
76	OHI	103	2.40	4.65	72	85	10773	397699	4302235	292413	1139.94	0.332916
76	PEN	90	2.50	4.40	83	84	5738	261651	5230874	160243	1311.76	0.275379
76	SCA	74	2.65	4.50	81	67	7064	89420	793367	974139	1181.58	0.381881
76	SDK	31	2.40	4.40	51	31	16159	127464	2445245	638555	431.73	0.381881
76	TEN	79	2.65	4.50	80	69	5374	203527	700929	974139	1252.49	0.404145
76	TEX	120	2.65	4.20	79	65	21645	82392	3980138	448666	2379.14	0.350000
76	VIR	78	2.65	4.50	67	46	6655	179517	1730903	798415	1700.24	0.431084
76	WIS	68	2.50	4.50	78	37	7710	277647	1429387	789223	1031.65	0.292973

TABLE C-1. CROSS SECTIONAL-TIME SECTIONAL DATA FOR CORN, 1973-1979 (CONT.).

YEAR	STATE	CRNYD bu.	CRNLOP $/bu	SYBLOP $/bu	JUNWT	AUGWT	LAND	ISRES $	OSRES $	BAS RES $	EXTEN $1000	RISK1
75	COL	93	2.95	6.65	63	74	23595	26252	4838792	258211	1028.11	0.687895
75	GEO	55	3.15	6.90	86	79	5341	203222	647237	879910	2274.95	0.783603
75	ILL	116	3.00	6.60	93	81	23509	591953	4968064	143972	1284.82	0.710657
75	IND	98	3.00	7.00	93	82	12589	607628	4174430	252005	931.46	0.721133
75	IOW	90	2.80	6.35	90	63	21484	888512	3516449	302246	1012.70	0.579511
75	KAN	84	2.95	6.60	84	68	21580	438650	2954021	498382	1175.94	0.721318
75	KEN	77	3.00	6.95	96	78	4953	107134	1799790	722543	1342.00	0.642106
75	MAR	91	3.25	7.00	95	84	9457	150227	3943765	358405	845.75	0.855589
75	MIC	80	2.85	6.40	94	81	7301	217796	1627276	725146	1317.59	0.687895
75	MIN	70	2.80	6.35	92	56	11292	237138	1566125	725132	939.35	0.650641
75	MOS	63	3.05	6.75	87	47	9340	461590	3614892	397555	1218.98	0.814616
75	NEB	85	2.80	6.50	74	64	21257	496567	5136463	143968	790.55	0.636894
75	NYK	85	3.00	7.00	89	76	6939	296656	373322	875087	2578.11	0.660328
75	NCA	67	3.15	6.90	92	73	5290	247819	662318	879910	2357.70	0.835045
75	NDK	51	2.95	6.35	86	80	13596	78473	209485	939040	400.89	0.790021
75	OHI	92	3.00	6.70	90	84	10459	437588	4456102	252002	1137.49	0.721318
75	PEN	82	3.00	7.00	94	80	5585	224013	5455480	143959	1399.94	0.606218
75	SCA	63	3.15	6.55	84	70	6819	73493	785371	879910	1200.28	0.836441
75	SDK	37	2.90	6.40	79	62	15753	112248	2559787	585581	442.45	0.765049
75	TEN	60	3.35	6.90	93	78	5176	165930	699075	879910	1354.90	0.849137
75	TEX	103	3.20	6.65	84	77	21252	91700	3934289	395173	2435.50	0.841804
75	VIR	86	3.20	6.65	95	83	6447	190955	1721901	722543	1722.37	0.855005
75	WIS	83	2.95	6.40	92	58	7540	272474	1581899	725147	1092.47	0.737360

TABLE C-1. CROSS SECTIONAL-TIME SECTIONAL DATA FOR CORN, 1973-1979 (CONT.).

YEAR	STATE	CRNYD bu.	CRNLCP $/bu	SYBLOP $/bu	JUNWT	AUGWT	LAND	ISRES $	OSRES $	BAS RES $	EXTEN $1000	RISK1
74	COL	101	2.55	5.40	64	57	23595	31246	4488443	260029	956.99	0.696372
74	GEO	56	2.50	5.65	83	85	5341	219518	600046	913244	2113.26	0.675599
74	ILL	83	2.45	5.75	94	73	23509	664419	4665006	139872	1102.25	0.687895
74	IND	71	2.35	5.70	95	66	12589	671995	3829851	257970	1011.15	0.673573
74	IOW	80	2.35	5.65	92	78	21464	1053658	3234302	301073	936.50	0.655515
74	KAN	76	2.40	5.65	87	62	21580	255969	2677302	520953	1095.13	0.554828
74	KEN	85	2.45	5.60	92	92	4953	123085	1662593	753119	1235.45	0.661236
74	MAR	84	2.45	5.40	93	66	9457	194929	3599047	369308	774.82	0.638148
74	MIC	61	2.35	5.70	89	69	7301	163163	1533434	745745	1190.06	0.670025
74	MIN	61	2.20	5.70	85	76	11292	224398	1458806	745732	893.46	0.598080
74	MOS	55	2.39	5.60	92	65	9340	448402	3267392	420973	1166.94	0.670149
74	NEB	68	2.25	5.45	84	51	21257	496037	4724114	139866	735.21	0.576541
74	NYK	80	2.60	5.20	89	77	6939	412735	397080	897440	2456.35	0.708543
74	NCA	74	2.30	5.60	93	89	5290	204437	611637	913244	2213.56	0.587991
74	NDK	49	2.15	5.50	84	70	13596	93001	231821	974542	386.51	0.587055
74	OHI	73	2.45	5.65	92	71	10459	390352	4043031	257965	1073.71	0.703160
74	PEN	81	2.55	5.35	92	77	5585	177087	4975712	139858	1316.67	0.629153
74	SCA	58	2.40	5.65	86	82	6819	81384	716758	913244	1097.80	0.623886
74	SDK	33	2.15	5.55	84	53	15753	156382	2432310	594489	399.81	0.565803
74	TEN	61	2.65	5.50	93	82	5176	167680	639968	913244	1271.52	0.740968
74	TEX	92	2.55	5.30	68	62	21252	142456	3589481	418659	2253.51	0.650718
74	VIR	76	2.35	5.50	94	89	6447	200975	1555687	753119	1571.29	0.586174
74	WIS	68	2.40	5.60	92	73	7540	208535	1462476	745746	986.57	0.662898

TABLE C-1. CROSS SECTIONAL-TIME SECTIONAL DATA FOR CORN, 1973-1979 (CONT.).

YEAR	STATE	CRNYD bu.	CRNLOP $/bu	SYBLOP $/bu	JUNWT	AUGWT	LAND	ISRES $	OSRES $	BAS RES $	EXTEN $1000	RISK1
73	COL	102	1.61	4.23	91	82	23209	32320	4902607	238090	1020.09	0.215019
73	GEO	48	1.59	4.31	85	84	5163	193685	763345	845716	2304.19	0.242693
73	ILL	103	1.59	4.47	92	83	22940	502719	5033266	135544	1228.74	0.250599
73	IND	102	1.56	4.25	92	92	12211	630035	4205517	242305	1084.55	0.278388
73	IOW	107	1.65	4.74	92	87	20926	962550	3431462	282880	965.60	0.309892
73	KAN	100	1.52	4.10	92	80	21356	237795	2916116	490499	1234.78	0.200083
73	KEN	85	1.72	4.06	97	91	4794	96285	1939476	699365	1280.97	0.300056
73	MAR	85	1.54	4.04	90	80	9249	181030	3940925	349214	830.25	0.170098
73	MIC	79	1.49	4.60	92	84	7074	175562	1734970	681706	1285.67	0.232594
73	MIN	93	1.50	4.58	89	84	10986	250284	1495754	681692	947.86	0.248797
73	MOS	88	1.43	4.28	89	73	9140	428578	3736512	398828	1204.13	0.182483
73	NEB	94	1.53	4.47	89	77	20893	443617	5216153	135540	802.28	0.213854
73	NYK	77	1.71	3.50	80	76	6760	310747	459569	832840	2592.74	0.255147
73	NCA	82	1.48	4.13	93	88	5059	182094	713791	845716	2383.89	0.207926
73	NDK	56	1.37	4.25	74	57	13378	95544	266294	894717	415.81	0.186815
73	OHI	79	1.57	4.32	94	90	10145	416875	4750657	242302	1179.21	0.256320
73	PEN	78	1.80	3.60	93	83	5432	192082	5477722	135532	1422.20	0.251064
73	SCA	55	1.48	4.19	86	84	6574	76973	822597	845716	1150.08	0.191398
73	SDK	54	1.37	4.24	82	57	15347	138503	2600177	540839	460.29	0.160000
73	TEN	66	1.66	4.07	93	80	4978	153763	812934	845716	1284.49	0.240208
73	TEX	95	1.53	4.12	83	76	20859	119347	3978559	396616	2252.40	0.095394
73	VIR	84	1.49	4.03	97	95	6239	203190	1838465	699365	1495.35	0.153080
73	WIS	83	1.49	4.45	88	71	7370	246513	1701709	681708	1035.33	0.194251

TABLE C-2. CROSS SECTIONAL-TIME SERIES DATA FOR WHEAT, 1973-1979.

YR	STATE	WHTYD bu	WHTLOP $/bu	OATLOP $/bu	JUNWT	AUGWT	LAND	ISRES $	OSRES $	BAS RES $	EXTEN $1000	RISK1
79	ALA	26.0	3.00	1.40	85	88	5045	39665	1593362	1175136	1795.96	0.614410
79	ARZ	76.3	2.93	.	93	77	54217	109639	6262696	577511	668.33	0.686950
79	ARK	35.0	2.95	1.45	91	90	17320	95777	1537250	1175136	1260.82	0.585947
79	CAL	70.5	3.25	1.60	91	88	63640	358626	2012449	1087100	3329.50	0.457056
79	COL	26.6	2.75	1.20	86	88	25139	208127	3793133	915988	1118.19	0.320208
79	GEO	35.0	2.95	1.30	87	82	6053	103439	1529588	1175136	2475.18	0.435890
79	IDA	50.4	3.08	1.45	97	72	33314	643029	5729307	577511	706.53	0.318172
79	ILL	43.0	3.05	1.25	90	89	25788	80401	1597249	1150371	809.01	0.548483
79	IND	47.0	3.00	1.55	91	96	14101	338854	1294173	1175136	926.26	0.461880
79	IOW	37.0	2.65	1.20	91	89	23713	14301	6100068	659752	1046.48	0.453689
79	KAN	38.0	2.85	1.40	88	88	22473	1512172	2489088	915988	1302.37	0.368556
79	KEN	38.0	3.15	1.95	90	96	5589	37521	1595506	1175136	1341.41	0.614410
79	LOU	28.0	3.05	.	80	87	15371	49402	1583625	1175136	1423.08	0.633114
79	MAR	37.0	3.00	1.50	92	92	10286	43876	1589151	1175136	764.51	0.557494
79	MIC	43.0	3.35	1.25	88	89	8212	253846	1697294	1126774	1328.98	0.676387
79	MIN	35.1	2.85	1.10	82	92	12516	284552	1828557	1169342	990.72	0.214554
79	MIS	32.0	2.95	.	88	91	9570	36357	1596670	1175136	1496.49	0.614410
79	MOS	44.0	2.95	1.15	90	84	10139	357875	5272833	666162	1241.05	0.490748
79	MON	22.7	2.76	1.15	83	69	26559	568084	7917360	321275	639.12	0.190000
79	NEB	34.0	2.70	1.20	85	87	22713	428889	3572372	915988	840.13	0.275379
79	NJE	36.0	3.00	1.45	93	86	15433	52002	1581025	1175136	787.49	0.462277
79	NME	22.0	2.85	.	87	88	40424	43436	6328900	577511	610.87	0.615332
79	NYK	41.0	3.40	1.40	92	72	7656	99612	1851527	1126774	2496.62	0.725144
79	NCA	36.0	2.85	1.25	93	82	6214	84601	1548426	1175136	2407.07	0.425245
79	NDK	26.3	2.75	1.00	79	72	14468	1272382	840727	1169342	416.26	0.185023
79	OHI	48.0	3.20	1.35	90	97	11712	262065	1370962	1175136	1204.16	0.540833
79	OKL	38.0	3.00	1.45	88	87	13429	584443	5049845	665547	902.44	0.390512
79	ORE	46.0	3.45	1.40	92	75	27350	477894	1893181	1087100	1169.14	0.416333
79	PEN	31.0	3.30	1.45	93	85	6194	17544	1615483	1175136	1387.35	0.458258
79	SCA	35.0	3.00	1.20	91	76	7800	40162	1592865	1175136	1373.10	0.522015
79	SDK	21.4	2.76	1.05	78	88	17374	169466	3561418	920578	460.12	0.211266
79	TEN	34.0	2.85	1.75	94	93	5971	40459	1592568	1175136	1330.10	0.416333
79	TEX	30.0	2.95	1.30	83	85	22824	538182	5096106	665547	2430.96	0.472582
79	UTA	26.7	2.99	1.60	88	75	34759	120887	6251449	577511	503.98	0.282902
79	VIR	35.0	3.05	1.50	97	93	7279	87613	1545415	1175136	1893.09	0.519615
79	WAS	39.6	3.40	1.60	82	70	35450	834548	1536527	1087100	1032.97	0.388373
79	WIS	40.0	2.80	1.10	87	91	8220	33058	2080051	1169342	1114.19	0.479201
79	WYO	22.1	2.75	1.35	82	79	36130	52117	3949144	915988	369.75	0.320468

TABLE C-2. CROSS SECTIONAL-TIME SERIES DATA FOR WHEAT, 1973-1979 (CONT.).

YR	STATE	WHTYD bu	WHTLOP $/bu	OATLOP $/bu	JUNWT	AUGWT	LAND	ISRES $	OSRES $	BAS RES $	EXTEN $1000	RISK1
78	ALA	26.0	2.05	1.35	87	81	4883	32739	1627542	1068564	1637.62	0.604840
78	ARZ	70.0	2.60	.	100	67	54232	81315	5433715	587755	600.80	0.663050
78	ARK	37.0	2.05	1.10	91	54	16951	106845	1553435	1068564	1183.33	0.568620
78	CAL	64.1	2.72	1.45	100	92	63575	404631	1694832	1020892	3230.70	0.457640
78	COL	23.4	2.11	0.95	79	61	24753	146815	3268751	889039	1030.53	0.585260
78	GEO	32.0	2.25	1.45	83	78	5875	142033	1518248	1068564	2378.47	0.425250
78	IDA	57.7	2.55	1.30	97	85	32663	372960	5142069	587755	605.74	0.520000
78	ILL	38.0	2.10	1.10	90	73	25218	99787	1615875	1037827	749.37	0.579510
78	IND	39.0	2.20	1.60	90	84	13723	375912	1284368	1068564	878.05	0.529150
78	IOW	31.0	2.10	1.10	90	82	23156	18721	5518145	632739	969.13	0.687390
78	KAN	30.0	2.15	1.10	90	59	22250	1218559	2197007	889039	1185.40	0.626500
78	KEN	35.0	2.00	1.75	88	89	5430	29114	1631166	1068564	1289.91	0.563470
78	LOU	36.0	2.10	1.45	78	70	14824	37130	1623151	1068564	1288.72	0.617120
78	MAR	37.0	2.10	1.50	86	85	10079	55401	1604879	1068564	737.11	0.536780
78	MIC	40.0	2.00	1.35	92	75	7984	266315	1721392	1018754	1252.83	0.600000
78	MIN	33.6	2.50	1.05	89	87	12210	284537	1836763	1065876	911.63	0.234310
78	MIS	31.0	2.00	1.35	86	75	9162	50641	1609640	1068564	1399.39	0.583810
78	MOS	34.0	2.10	1.20	90	75	9939	213060	4860656	635793	1139.94	0.522020
78	MON	30.2	2.38	1.30	95	97	26325	523385	7112944	331455	594.19	0.622170
78	NEB	32.0	2.20	0.95	89	80	22349	461285	2954281	889039	763.32	0.579510
78	NJE	36.0	2.15	1.40	89	86	15086	14044	1646237	1068564	743.80	0.430160
78	NME	19.0	2.10	.	70	70	40028	17049	5497981	587755	596.30	0.797580
78	NYK	35.0	1.95	1.65	85	74	7477	97493	1890215	1018754	2404.60	0.520420
78	NCA	33.0	2.20	1.55	85	74	5983	83718	1576563	1068564	2322.53	0.416330
78	NDK	29.8	2.44	0.95	90	87	14250	1260253	861047	1065876	397.55	0.924175
78	OHI	39.0	2.15	1.50	87	84	11399	227613	1432667	1068564	1139.94	0.561991
78	OKL	27.0	2.30	1.45	86	53	13215	523395	4552451	635427	873.07	0.529937
78	ORE	42.4	2.65	1.15	99	97	27018	469868	1629596	1020892	1132.94	0.614410
78	PEN	33.0	2.40	1.60	89	82	6042	38977	1621304	1068564	1311.76	0.332916
78	SCA	33.0	2.15	1.40	85	80	7555	33578	1626702	1068564	1181.58	0.480451
78	SDK	21.4	2.51	1.10	91	89	16969	236115	3524214	814601	431.73	0.773822
78	TEN	35.0	2.25	1.70	89	81	5772	42777	1617503	1068564	1252.49	0.425245
78	TEX	20.0	2.25	1.30	55	44	22431	273616	4802230	635427	2379.14	0.567891
78	UTA	29.8	2.44	1.40	92	68	34100	124337	5390692	587755	465.86	0.542863
78	VIR	35.0	2.15	1.45	93	94	7071	62195	1598085	1068564	1700.24	0.493288
78	WAS	46.0	2.65	1.30	94	92	34737	748846	1350618	1020892	992.91	0.642910
78	WIS	34.7	1.97	1.10	92	90	8050	30198	2091101	1065876	1031.65	0.649333
78	WYO	25.9	2.11	1.25	96	92	35650	50844	3364722	889039	355.49	0.789958

TABLE C-2. CROSS SECTIONAL-TIME SERIES DATA FOR WHEAT, 1973-1979 (CONT.).

YR	STATE	WHTYD bu	WHTLOP $/bu	OATLOP $/bu	JUNWT	AUGWT	LAND	ISRES $	OSRES $	BAS RES $	EXTEN $1000	RISK1
77	ALA	28.0	3.20	1.80	63	63	4721	25426	1287293	918110	1744.57	0.35473
77	ARZ	72.0	3.92	.	60	73	54247	43945	4872791	476779	617.39	0.45967
77	ARK	39.0	3.15	1.65	72	72	16582	78424	1234295	918110	1129.97	0.37749
77	CAL	64.5	3.63	1.90	41	39	63510	290381	1418649	876423	3102.99	0.25942
77	COL	22.2	2.45	1.45	69	72	24367	129662	3078043	722116	1028.11	0.67885
77	GEO	33.0	3.05	1.45	53	55	5697	124095	1188624	918110	2274.95	0.20207
77	IDA	42.6	2.51	1.45	60	69	32012	305751	4610985	476779	624.90	0.71143
77	ILL	43.0	3.05	1.55	80	87	24648	103852	1266505	886121	797.79	0.43589
77	IND	45.0	3.00	1.60	83	90	13345	243083	1069636	918110	931.46	0.50083
77	IOW	37.0	3.00	1.55	80	76	22599	18761	4810736	528368	1012.70	0.55302
77	KAN	28.5	2.70	1.55	90	90	22027	1318599	1889106	722116	1175.94	0.60277
77	KEN	37.0	2.95	1.80	81	92	5271	14825	1297894	918110	1342.00	0.41932
77	LOU	34.0	3.30	1.65	69	80	14277	47150	1265569	918110	1373.11	0.50744
77	MAR	36.0	3.12	1.65	65	74	9872	40124	1272595	918110	845.75	0.35796
77	MIC	40.0	2.60	1.55	61	74	7756	268349	1368605	868757	1317.59	0.60000
77	MIN	39.6	2.89	1.55	77	71	11904	133386	1488406	928012	939.35	0.85750
77	MIS	34.0	3.15	1.65	73	71	8754	29289	1283430	918110	1457.39	0.20817
77	MOS	39.0	2.95	1.65	81	78	9739	212014	4306291	518831	1218.98	0.40723
77	MON	25.9	2.57	1.45	68	60	26091	472760	6065767	283031	619.27	0.76961
77	NEB	35.0	2.65	1.50	89	89	21985	487540	2720165	722116	790.55	0.57951
77	NJE	31.0	2.89	1.60	79	87	14739	17066	1295653	918110	821.28	0.49366
77	NME	21.5	3.32	.	77	81	39632	12827	4903909	476779	631.08	0.34176
77	NYK	39.0	2.70	1.65	89	78	7298	91912	1545042	868757	2578.11	0.46458
77	NCA	30.0	3.00	1.55	74	61	5752	80003	1232716	918110	2357.70	0.25166
77	NDK	24.8	2.77	1.35	44	49	14032	1007742	614050	928012	400.89	1.06604
77	OHI	47.0	2.90	1.55	77	88	11086	186354	1126365	918110	1137.49	0.56199
77	OKL	27.0	2.95	1.70	91	80	13001	483900	4036525	518466	880.12	0.45092
77	ORE	38.7	2.85	1.60	64	58	26686	440515	1268515	876423	1125.46	0.69342
77	PEN	33.0	3.00	1.60	79	85	5890	39585	1273134	918110	1399.94	0.39051
77	SCA	29.0	3.10	1.80	62	52	7310	20073	1292646	918110	1200.28	0.32532
77	SDK	23.9	2.93	1.55	68	71	16564	161292	2758703	725959	442.45	0.72196
77	TEN	36.0	3.05	1.80	80	76	5573	31304	1281415	918110	1354.90	0.28431
77	TEX	25.0	3.15	1.65	84	58	22038	279904	4240521	518466	2435.50	0.34034
77	UTA	23.1	2.60	1.75	52	61	33441	113579	4803157	476779	484.77	0.69159
77	VIR	31.0	3.05	1.60	67	54	6863	61002	1251717	918110	1722.37	0.15275
77	WAS	33.9	2.85	1.60	61	55	34024	598049	1110981	876423	954.63	0.70059
77	WIS	41.0	2.80	1.50	75	79	7880	28029	1593763	928012	1092.47	0.54775
77	WYO	20.0	2.40	1.55	82	75	35170	55790	3151915	722116	362.20	0.81682

TABLE C-2. CROSS SECTIONAL-TIME SERIES DATA FOR WHEAT, 1973-1979 (CONT.).

YR	STATE	WHTYD bu	WHTLOP $/bu	OATLOP $/bu	JUNWT	AUGWT	LAND	ISRES $	OSRES $	BAS RES $	EXTEN $1000	RISK1
76	ALA	27.0	2.95	1.70	83	68	4559	23171	1093496	824258	1623.86	0.492440
76	ARZ	75.0	3.15	.	77	64	54262	43422	4201192	438387	577.41	0.304140
76	ARK	39.0	2.85	1.45	80	56	16213	63159	1053509	824258	1070.41	0.482180
76	CAL	63.5	3.26	1.90	46	47	63445	229287	1181295	792413	2890.22	0.304140
76	COL	21.8	3.25	1.85	71	65	23981	115625	2718406	641262	956.99	0.304140
76	GEO	31.0	2.90	1.55	84	72	5519	110409	1006259	824258	2113.26	0.327870
76	IDA	47.8	3.43	1.55	90	87	31361	185544	4059070	438387	594.03	0.450330
76	ILL	39.0	3.15	1.40	83	61	24078	79297	1081380	799833	684.43	0.472580
76	IND	36.0	3.20	1.50	75	78	12967	187927	928740	824258	1011.15	0.520420
76	IOW	35.0	3.45	1.45	88	56	22042	20643	4363028	451008	936.50	0.507440
76	KAN	30.0	3.40	1.60	86	49	21804	1130407	1703624	641262	1095.13	0.251660
76	KEN	31.0	3.00	1.60	74	83	5112	12057	1104611	824258	1235.45	0.419320
76	LOU	33.0	2.95	1.50	78	66	13730	30970	1085697	824258	1321.76	0.680690
76	MAR	38.0	2.90	1.55	74	77	9665	34930	1081738	824258	774.82	0.435890
76	MIC	38.0	3.20	1.40	86	55	7528	320253	1150974	770121	1190.06	0.503322
76	MIN	32.2	2.92	1.45	47	26	11598	238220	1311419	805034	893.46	0.778610
76	MIS	29.0	2.75	1.55	78	54	8356	30130	1086537	824258	1356.15	0.189297
76	MOS	33.0	3.05	1.60	82	45	9539	199209	3749497	470575	1166.94	0.464579
76	MON	30.9	3.54	1.45	87	84	25857	448138	5346115	248133	588.61	0.306649
76	NEB	32.0	3.35	1.45	80	48	21621	443278	2390753	641262	735.21	0.229129
76	NJE	42.0	2.90	1.55	82	67	14392	20995	1095672	824258	772.14	0.453689
76	NME	26.0	3.60	.	66	65	39236	11467	4233147	438387	610.08	0.351188
76	NYK	38.0	2.95	1.40	91	88	7119	73702	1397524	770121	2456.35	0.529937
76	NCA	29.0	2.80	1.40	74	64	5521	85860	1030807	824258	2213.56	0.321455
76	NDK	24.7	4.18	1.30	70	48	13814	880427	669213	805034	386.51	0.340196
76	OHI	40.0	3.25	1.45	72	85	10773	168650	948017	824258	1073.71	0.375278
76	OKL	24.0	3.35	1.65	86	56	12787	411444	3539254	470233	841.91	0.256580
76	ORE	45.2	3.80	1.70	87	92	26354	412483	998099	792413	1080.66	0.450925
76	PEN	30.0	2.95	1.50	83	84	5738	9101	1107566	824258	1316.67	0.360555
76	SCA	26.0	2.75	1.45	81	67	7064	17247	1099421	824258	1097.80	0.390512
76	SDK	13.2	4.01	1.40	51	31	16159	112768	2543390	635121	399.81	0.206640
76	TEN	37.0	2.90	1.70	80	69	5374	28790	1087877	824258	1271.52	0.368556
76	TEX	22.0	3.30	1.50	79	65	21645	260175	3690523	470233	2253.51	0.360555
76	UTA	24.7	3.45	1.75	83	67	32782	97549	4147064	438387	456.15	0.286880
76	VIR	32.0	2.95	1.40	67	46	6655	53575	1063092	824258	1571.29	0.229129
76	WAS	45.0	3.85	1.65	89	90	33311	489715	920867	792413	913.04	0.480451
76	WIS	34.8	3.25	1.35	78	37	7710	33189	1516450	805034	986.57	0.346458
76	WYO	24.1	3.60	1.70	91	84	34690	62932	2771099	641262	340.20	0.257941

TABLE C-2. CROSS SECTIONAL-TIME SERIES DATA FOR WHEAT, 1973-1979 (CONT.).

YR	STATE	WHTYD bu	WHTLOP $/bu	OATLOP $/bu	JUNWT	AUGWT	LAND	ISRES $	OSRES $	BAS RES $	EXTEN $1000	RISK1
75	ALA	24.0	3.65	1.50	85	87	4398	12508	1029603	814540	1724.49	1.15052
75	ARZ	71.0	3.10	.	75	59	54276	49335	4231837	421102	605.14	0.74198
75	ARK	32.0	3.60	1.40	89	85	15843	52166	989944	814540	1132.31	1.14308
75	CAL	62.2	3.76	1.90	85	82	61822	305202	1110217	775147	3298.32	1.01096
75	COL	22.5	3.80	1.90	63	74	23595	108815	2756938	624222	1020.09	1.15786
75	GEO	27.0	3.30	1.45	86	79	5341	46775	995335	814540	2304.19	0.98744
75	IDA	44.5	3.91	1.75	77	91	30710	233971	4047201	421102	679.75	1.28741
75	ILL	39.0	3.85	1.50	93	81	23509	63188	1013991	795077	762.97	1.20708
75	IND	43.0	3.95	1.60	93	82	12589	245471	796639	814540	1084.55	1.29549
75	IOW	34.0	4.10	1.45	90	63	21484	16939	4339065	440970	965.60	1.30082
75	KAN	29.0	3.90	1.55	84	68	21580	960681	1905072	624222	1234.78	1.20449
75	KEN	34.0	3.70	1.60	96	78	4953	9477	1032633	814540	1280.97	1.13474
75	LOU	16.0	3.95	1.30	83	86	13183	33139	1008972	814540	1486.32	1.27012
75	MAR	34.0	3.60	1.45	95	84	9457	32123	1009987	814540	830.25	1.12434
75	MIC	38.0	3.80	1.60	94	81	7301	301415	1108704	758544	1285.67	1.36001
75	MIN	30.8	4.39	1.45	92	56	11292	229111	1261140	795015	947.86	1.33867
75	MIS	24.0	3.05	1.35	87	88	7959	34697	1007413	814540	1436.99	0.89768
75	MOS	33.0	3.70	1.65	87	47	9340	159565	3746702	460770	1204.13	1.14308
75	MON	31.3	4.09	1.55	85	99	25623	432991	5338432	237849	611.86	1.26456
75	NEB	32.0	3.80	1.50	74	64	21257	727806	2137947	624222	802.28	1.11289
75	NJE	36.0	3.75	1.60	93	90	14045	1530	1040581	814540	831.14	1.17347
75	NME	26.0	4.00	.	75	74	38840	17309	4263863	421102	663.94	1.21763
75	NYK	39.0	3.60	1.65	89	76	6939	107484	1302636	758544	2592.74	1.31434
75	NCA	31.0	3.30	1.40	92	73	5290	73382	968728	814540	2383.89	1.00426
75	NDK	25.9	4.86	1.40	86	80	13596	840119	650132	795015	415.81	1.62448
75	OHI	42.0	4.00	1.60	90	84	10459	175460	866650	814540	1179.21	1.28582
75	OKL	24.0	3.85	1.55	92	88	12573	399147	3508716	460495	886.84	1.15362
75	ORE	47.3	4.20	1.85	79	88	26022	325749	1089670	775147	1202.28	1.40801
75	PEN	33.0	3.65	1.65	94	80	5585	7144	1034966	814540	1422.20	1.09134
75	SCA	27.0	3.40	1.45	84	70	6819	16859	1025251	814540	1150.08	1.03116
75	SDK	21.1	4.30	1.45	79	62	15753	107394	2415302	632351	460.29	1.33717
75	TEN	31.0	3.45	1.55	93	78	5176	30955	1011155	814540	1284.49	1.02574
75	TEX	23.0	3.80	1.45	84	77	21252	233946	3673917	460495	2252.40	1.14595
75	UTA	25.4	3.97	1.90	71	87	32123	100924	4180248	421102	473.01	1.25599
75	VIR	31.0	3.25	1.30	95	83	6447	45181	996929	814540	1495.35	0.94236
75	WAS	47.4	4.20	1.75	83	88	32598	463519	951901	775147	1066.83	1.45162
75	WIS	30.3	3.89	1.45	92	58	7540	38448	1451803	795015	1035.33	1.30270
75	WYO	24.9	3.96	1.80	81	76	34210	49748	2816005	624222	373.94	1.38164

TABLE C-2. CROSS SECTIONAL-TIME SERIES DATA FOR WHEAT, 1973-1979 (CONT.).

YR	STATE	WHTYD bu	WHTLOP $/bu	OATLOP $/bu	JUNWT	AUGWT	LAND	ISRES $	OSRES $	BAS RES $	EXTEN $1000	RISK1
74	ALA	23.0	2.70	1.10	85	81	4398	19850	1032753	785484	1474.82	0.74144
74	ARZ	66.0	2.60	.	55	63	15843	37404	3894914	436370	513.36	0.53519
74	ARK	26.0	2.70	1.08	93	77	15676	48190	1004414	785484	1006.94	0.75871
74	CAL	52.0	3.21	1.40	91	83	61822	257498	1103502	759021	2893.57	0.86731
74	COL	25.5	3.75	1.40	64	57	23595	83419	2487899	631715	881.50	1.33839
74	GEO	23.0	2.65	1.20	83	85	5341	40072	1012531	785484	2021.61	0.71766
74	IDA	43.0	4.33	1.40	83	69	30710	249142	3683176	436370	580.16	1.58935
74	ILL	30.0	2.95	1.05	94	73	23509	70720	1021133	763701	652.85	0.87203
74	IND	36.0	2.95	1.10	95	66	12589	263195	789409	785484	830.15	0.91820
74	IOW	30.0	3.10	1.05	92	78	21464	17439	4043641	447217	893.72	0.96837
74	KAN	27.5	3.60	1.10	87	62	21580	1004233	1567085	631715	1088.82	1.22572
74	KEN	31.5	2.95	1.10	92	92	4953	16565	1036038	785484	1100.30	0.85448
74	LOU	20.0	2.65	1.05	86	79	13183	23468	1029135	785484	1200.25	0.68391
74	MAR	36.0	2.80	1.15	93	66	9457	26592	1026011	785484	679.15	0.79775
74	MIC	40.0	4.20	1.20	89	69	7301	354259	1108249	722997	1110.07	1.56468
74	MIN	28.9	4.10	1.05	85	76	11292	277818	1211943	769868	783.58	1.44010
74	MIS	24.0	2.70	1.10	88	79	7959	24637	1027966	785484	1154.62	0.73993
74	MOS	29.0	2.80	1.20	92	65	9340	176972	3445180	463138	1082.36	0.79681
74	MON	24.7	4.05	1.15	83	81	25623	362940	5059139	251872	537.26	1.40094
74	NEB	34.0	3.50	1.05	84	51	21257	381438	2189881	631715	705.82	1.18710
74	NJE	41.0	3.05	1.40	89	81	14045	9	1052594	785484	695.55	0.92975
74	NME	18.0	3.30	.	50	65	38840	11059	3921259	436370	588.83	1.03697
74	NYK	40.0	4.00	1.40	89	77	6939	101191	1361317	722997	2235.73	1.47564
74	NCA	36.0	2.70	1.05	93	89	5290	66684	985919	785484	2095.31	0.75295
74	NDK	20.4	4.54	1.05	84	70	13596	837579	652183	769868	375.85	1.72372
74	OHI	42.0	3.60	1.15	92	71	10459	202783	849820	785484	1009.81	1.22985
74	OKL	21.0	3.50	1.10	85	70	12573	414689	3209233	462833	759.93	1.12878
74	ORE	43.8	4.70	1.45	88	85	26022	355119	1005880	759021	1080.50	1.74058
74	PEN	36.0	3.15	1.25	92	77	5585	3595	1049008	785484	1155.83	0.94193
74	SCA	25.0	2.70	1.15	86	82	6819	14921	1037682	785484	961.61	0.74586
74	SDK	18.4	3.90	1.00	84	53	15753	98696	2434786	601963	398.58	1.37394
74	TEN	29.0	2.75	1.20	93	82	5176	27411	1025192	785484	1099.02	0.74809
74	TEX	16.0	3.10	1.08	68	62	21252	262877	3361045	462833	1885.51	0.92251
74	UTA	27.1	3.92	1.75	76	57	32123	83792	3848526	436370	418.59	1.36075
74	VIR	37.0	2.80	1.05	94	89	6447	43071	1009533	785484	1377.69	0.79103
74	WAS	39.1	4.80	1.40	93	87	32598	442848	918151	759021	955.07	1.80308
74	WIS	36.6	3.80	1.10	92	73	7540	46224	1443537	769868	937.99	1.36398
74	WYO	24.7	4.10	1.30	80	69	34210	54134	2517185	631715	345.33	1.58447

TABLE C-2. CROSS SECTIONAL-TIME SERIES DATA FOR WHEAT, 1973-1979 (CONT.).

YR	STATE	WHTYD bu	WHTLOP $/bu	OATLOP $/bu	JUNWT	AUGWT	LAND	ISRES $	OSRES $	BAS RES $	EXTEN $1000	RISK1
73	ALA	23.0	1.36	0.84	90	83	4236	15001	1017814	738595	3873.76	0.11015
73	ARZ	70.0	1.64	.	98	78	54291	25053	3712496	411060	1269.76	0.15695
73	ARK	28.0	1.33	0.72	88	73	15474	48377	984438	738595	2556.25	0.11015
73	CAL	54.0	1.80	0.93	89	83	60199	245773	1152074	704295	7279.62	0.18520
73	COL	24.5	1.77	0.87	91	82	23209	85529	2254174	611795	2254.17	0.33201
73	GEO	27.0	1.36	0.85	85	84	5163	44874	987941	738595	4794.66	0.08544
73	IDA	45.0	1.92	0.87	81	74	30059	263069	3474481	411060	1651.56	0.32716
73	ILL	30.0	1.46	0.74	92	83	22940	94712	990668	709422	1643.15	0.08327
73	IND	35.0	1.38	0.79	92	92	12211	205867	826948	738595	2396.46	0.04000
73	IOW	32.0	1.52	0.75	92	87	20926	5385	3615638	450246	2491.63	0.13748
73	KAN	37.0	1.68	0.82	92	80	21356	869625	1470078	611795	3001.36	0.23072
73	KEN	33.0	1.47	0.80	97	91	4794	15632	1017183	738595	2758.88	0.09238
73	LOU	22.0	1.41	0.77	80	82	12636	36305	996510	738595	3186.82	0.12503
73	MAR	34.0	1.38	0.81	90	80	9249	15723	1017092	738595	1606.97	0.08000
73	MIC	35.0	1.67	0.84	92	84	7074	288968	1106795	683421	2765.50	0.17578
73	MIN	38.9	1.94	0.70	89	84	10986	257493	1023826	743482	1920.36	0.28746
73	MIS	27.0	1.35	0.77	89	83	7562	19241	1013574	738595	3041.00	0.11676
73	MOS	30.0	1.43	0.85	89	73	9140	170805	3200006	445654	2796.62	0.09292
73	MON	23.9	1.88	0.71	75	61	25389	389423	4629446	249511	1442.66	0.30050
73	NEB	35.0	1.74	0.77	89	77	20893	402791	1936912	611795	1820.93	0.29462
73	NJE	36.0	1.46	0.92	91	80	13698	6526	1026290	738595	1706.90	0.05033
73	NME	29.5	1.63	.	95	76	38444	8895	3728655	411060	1515.13	0.14933
73	NYK	36.0	1.55	0.98	80	76	6760	114308	1281456	683421	5365.00	0.11269
73	NCA	35.0	1.34	0.75	93	88	5059	62655	970160	738595	4918.57	0.07234
73	NDK	27.5	1.90	0.61	74	57	13378	620833	660486	743482	969.31	0.31225
73	OHI	32.0	1.60	0.82	94	90	10145	210923	821893	738595	2514.38	0.12662
73	OKL	30.0	1.70	0.86	90	81	12359	355437	3017082	445360	2009.50	0.19296
73	ORE	35.8	2.05	0.96	77	68	25690	266919	1130927	704295	2927.76	0.35275
73	PEN	28.0	1.56	0.90	93	83	5432	1078	1031737	738595	2845.02	0.07024
73	SCA	25.0	1.37	0.80	86	84	6574	52841	979974	738595	2121.64	0.07024
73	SDK	25.6	1.81	0.66	82	57	15347	98826	2206414	578025	1080.38	0.25942
73	TEN	31.0	1.43	0.90	93	80	4978	25489	1007326	738595	2703.94	0.07095
73	TEX	29.0	1.56	0.85	83	76	20859	264512	3108007	445360	4566.52	0.13051
73	UTA	24.9	1.77	1.05	93	93	31464	78286	3659264	411060	1081.32	0.21362
73	VIR	37.0	1.44	0.81	97	95	6239	28555	1004260	738595	3622.43	0.04726
73	WAS	32.8	2.04	0.91	74	54	31885	580607	817240	704295	2579.79	0.34530
73	WIS	33.0	1.59	0.80	88	71	7370	58935	1222384	743482	2428.14	0.15373
73	WYO	23.1	1.64	0.83	85	85	33730	53418	2286285	611795	931.22	0.28042

TABLE C-3. CROSS SECTIONAL TIME SERIES DATA FOR SOYBEANS, 1973-1979.

YEAR	STATE	SYBYD bu	SYBLOP $/bu	CRNLOP $/bu	JWT	AWT	LAND	ISRES $	OSRES $	BAS RES $	EXTEN $1000	RISK1
79	ALA	25.0	6.70	2.30	85	88	5045	616406	3315743	1313264	1795.96	0.67268
79	GEO	28.0	6.40	2.45	87	82	6053	651954	2436784	1404064	2475.18	0.50083
79	ILL	38.5	6.65	2.15	90	89	25788	1016261	4960730	6703519	1302.89	0.85196
79	IND	36.0	6.75	2.15	91	96	14101	685805	5160387	6703519	926.26	0.78581
79	IOW	38.0	6.60	2.00	91	89	23713	1009735	3673214	6886191	1046.48	0.98022
79	KAN	26.5	6.60	2.25	88	88	22473	389273	1939851	7348881	1302.37	1.05633
79	KEN	32.5	6.70	2.35	90	96	5589	431124	2185312	7243260	1341.41	0.45092
79	LOU	28.0	6.60	2.40	80	87	15371	886130	1244982	4949451	1423.08	0.54848
79	MAR	30.0	6.50	2.25	92	92	10286	207347	2021363	7348881	569.36	0.66144
79	MIC	29.5	6.70	2.10	88	89	8212	118391	1853396	7354207	1328.98	1.10000
79	MIN	32.0	6.55	1.90	82	92	12516	614677	1495883	7354207	990.72	1.05159
79	MIS	29.0	6.70	2.65	88	91	9570	849087	2325839	1403743	1496.49	0.27839
79	MOS	31.5	6.70	2.15	90	84	10139	558854	3127033	7056586	1241.05	0.81292
79	NEB	34.0	6.50	2.05	85	87	22713	459465	2277986	7244352	840.13	0.97511
79	NJE	30.0	6.85	2.30	93	86	15433	46893	1131051	7531553	787.49	0.99289
79	NCA	23.5	6.75	2.35	93	82	6214	831496	2382073	3789745	2407.07	0.54848
79	OHI	36.0	6.75	2.15	90	97	11712	973236	3931143	6886191	1204.16	0.88459
79	OKL	23.0	6.35	2.40	88	87	13429	58265	5554349	929097	902.44	0.71821
79	SCA	24.0	6.80	2.25	91	76	7800	676953	2593373	1404064	1373.10	0.68739
79	SDK	33.0	6.50	1.80	78	88	17374	74324	3562734	7072783	460.12	0.97767
79	TEN	27.0	6.50	2.30	94	93	5971	359512	2846036	3789745	1330.10	0.40723
79	TEX	26.0	6.25	2.40	83	85	22824	198362	3214447	4657156	2430.96	0.48218
79	VIR	28.5	6.80	2.35	97	93	7279	434469	1051551	7425932	1893.09	0.68069
79	WIS	34.0	6.70	2.00	87	91	8220	193331	1839819	7360066	1114.19	0.91697

TABLE C-3. CROSS SECTIONAL-TIME SERIES DATA FOR SOYBEANS, 1973-1979 (CONT.).

YEAR	STATE	SYBYD bu	SYBLOP $/bu	CRNLOP $/bu	JWT	AWT	LAND	ISRES $	OSRES $	BAS RES $	EXTEN $1000	RISK1
78	ALA	22.0	5.75	2.10	87	81	4883	434461	2322642	1111231	1637.62	1.20139
78	GEO	17.5	5.95	1.90	83	78	5875	675595	1744247	1185901	2378.47	1.20554
78	ILL	33.0	5.90	2.15	90	73	25218	853025	4390285	6636866	1206.83	1.45717
78	IND	34.0	5.50	2.00	90	84	13723	653368	4365205	6636866	878.05	1.14054
78	IOW	38.0	5.80	2.00	90	82	23156	1067960	3167551	6787415	969.13	1.61271
78	KAN	18.0	5.35	1.95	90	59	22250	274529	1602666	7230929	1185.40	1.51850
78	KEN	30.0	6.20	2.30	88	89	5430	295405	1886463	7207230	1289.91	1.23929
78	LOU	25.0	5.80	2.00	78	70	14824	754439	809515	4740848	1288.72	1.07510
78	MAR	32.0	5.50	2.00	86	85	10079	193017	1723259	7230929	548.95	1.05633
78	MIC	24.0	5.60	1.95	92	75	7984	173690	1627793	7217446	1252.83	1.68028
78	MIN	35.0	5.60	1.90	89	87	12210	531203	1342912	7217446	911.63	1.58219
78	MIS	21.5	6.35	2.00	86	75	9162	788907	1638404	1185603	1399.39	1.17296
78	MOS	28.5	5.65	2.00	90	75	9939	495482	2518091	7038697	1139.94	1.35769
78	NEB	34.0	5.50	1.95	89	80	22349	471908	1917313	7114466	763.32	1.50028
78	NJE	30.0	5.55	2.05	89	86	15086	10747	971022	7381478	743.80	1.54461
78	NCA	24.0	5.95	2.20	85	74	5983	776846	1726820	3728162	2322.53	1.20312
78	OHI	33.0	5.65	1.95	87	84	11399	810030	3321164	6787415	1139.94	1.39194
78	OKL	17.0	5.25	2.15	86	53	13215	38747	4183251	843120	873.07	1.17934
78	SCA	22.0	5.90	1.95	85	80	7555	519006	1817608	1185901	1181.58	1.37508
78	SDK	30.5	5.40	1.85	91	89	16969	37011	3052859	6955907	431.73	1.50028
78	TEN	23.5	5.85	2.10	89	81	5772	312883	2137588	3728162	1252.49	1.06419
78	TEX	26.0	5.35	2.20	55	44	22431	193108	2450204	4548615	2379.14	0.95699
78	VIR	28.0	5.80	2.10	93	94	7071	356584	938266	7357779	1700.24	1.30000
78	WIS	32.0	5.35	2.00	92	90	8050	151460	1561698	7222960	1031.65	1.32571

TABLE C-3. CROSS SECTIONAL-TIME SERIES DATA FOR SOYBEANS, 1973-1979 (CONT.).

YEAR	STATE	SYBYD bu	SYBLOP $/bu	CRNLOP $/bu	JWT	AWT	LAND	ISRES $	OSRES $	BAS RES $	EXTEN $1000	RISK1
77	ALA	21.0	7.05	2.5	63	63	4721	311605	2095917	941718	1744.57	1.38564
77	GEO	20.0	6.95	2.4	53	55	5697	418324	1518959	996973	2274.95	1.37143
77	ILL	38.0	7.60	2.3	80	87	24648	560445	3340736	4191042	1284.82	1.47309
77	IND	37.0	6.95	2.2	83	90	13345	585525	3402544	4191042	931.46	1.31371
77	IOW	35.5	7.75	2.2	80	76	22599	896182	2455081	4313311	1012.70	1.60416
77	KAN	28.5	7.45	2.2	90	90	22027	264760	1287625	4699501	1175.94	1.51850
77	KEN	31.0	7.10	2.3	81	92	5271	174975	1500575	4681621	1342.00	1.37326
77	LOU	23.5	6.85	2.7	69	80	14277	575706	712289	3209442	1373.11	1.35370
77	MAR	27.0	6.75	2.5	65	74	9872	144167	1447819	4699501	629.86	1.29067
77	MIC	30.0	7.80	2.2	61	74	7756	146891	1256122	4674990	1317.59	1.65630
77	MIN	35.5	7.70	2.3	77	71	11904	431772	814301	4674990	939.35	1.55430
77	MIS	21.5	6.90	2.6	73	71	8754	525744	1424843	996774	1457.39	1.29904
77	MOS	32.0	7.25	2.4	81	78	9739	523777	2011702	4537441	1218.98	1.43643
77	NEB	36.0	7.45	2.2	89	89	21985	401075	1556613	4599752	790.55	1.50582
77	NJE	24.0	7.50	2.5	79	87	14739	9407	797127	4821769	821.28	1.58929
77	NCA	22.0	7.00	2.4	74	61	5752	696648	1425454	2536166	2357.70	1.35769
77	OHI	35.5	7.40	2.2	77	88	11086	742569	2805053	4313311	1137.49	1.42916
77	OKL	23.0	6.60	2.3	91	80	13001	40758	3462818	712644	880.12	1.37143
77	SCA	20.5	7.25	2.4	62	52	7310	344963	1625249	996973	1200.28	1.42916
77	SDK	30.5	7.35	2.4	68	71	16564	30753	2291989	4457457	442.45	1.50582
77	TEN	23.5	6.60	2.6	80	76	5573	285880	1706097	2536166	1354.90	1.30767
77	TEX	26.5	6.10	2.4	84	58	22038	109459	2101965	3047382	2435.50	1.28550
77	VIR	19.0	7.10	2.5	67	54	6863	236175	666512	4803889	1722.37	1.38954
77	WIS	35.0	7.10	2.4	75	79	7880	183648	1216868	4679508	1092.47	1.34536

TABLE C-3. CROSS SECTIONAL-TIME SERIES DATA FOR SOYBEANS, 1973-1979 (CONT.).

YEAR	STATE	SYBYD bu	SYBLOP $/bu	CRNLOP $/bu	JWT	AWT	LAND	ISRES $	OSRES $	BAS RES $	EXTEN $1000	RISK1
76	ALA	24.0	4.65	2.7	83	68	4559	289096	1613725	728763	1623.86	1.21689
76	GEO	23.5	4.55	2.6	84	72	5519	385659	1221380	785369	2113.26	1.17580
76	ILL	33.0	4.70	2.5	83	61	24078	552815	3210296	3828960	1102.25	0.95175
76	IND	34.0	4.70	2.4	75	78	12967	491007	3173311	3828960	1011.15	1.15326
76	IOW	31.0	4.55	2.4	88	56	22042	711501	2352806	3929412	936.50	0.90738
76	KAN	15.0	4.50	2.4	86	49	21804	262888	1118469	4212608	1095.13	1.05159
76	KEN	27.0	4.65	2.5	74	83	5112	87216	1282806	4214487	1235.45	1.15578
76	LOU	28.0	4.70	3.0	78	66	13730	614816	536567	2807926	1321.76	1.25831
76	MAR	25.0	4.65	2.6	74	77	9665	102694	1242464	4212608	577.03	1.20035
76	MIC	20.5	4.50	2.3	86	55	7528	56616	1274734	4220306	1190.06	0.96090
76	MIN	22.0	4.60	2.4	47	26	11598	498437	871251	4220306	893.46	0.88459
76	MIS	22.0	4.65	2.8	78	54	8356	481219	1059514	785187	1356.15	1.12953
76	MOS	20.0	4.55	2.5	82	45	9539	399634	1756546	4093586	1166.94	1.10038
76	NEB	20.0	4.50	2.4	80	48	21621	326468	1516611	4138564	735.21	1.00042
76	NJE	24.0	4.45	2.5	82	67	14392	26418	666481	4313060	772.14	1.15036
76	NCA	22.0	4.60	2.6	74	64	5521	493277	1148324	2235776	2213.56	1.15326
76	OHI	33.0	4.65	2.4	72	85	10773	361529	2554559	3929412	1073.71	1.02510
76	OKL	22.0	4.25	2.6	86	56	12787	29592	2804325	565895	841.91	1.20035
76	SCA	18.0	4.50	2.6	81	67	7064	279370	1245318	785369	1097.80	1.02754
76	SDK	17.0	4.40	2.4	51	31	16159	51565	2310645	4050256	399.81	1.00374
76	TEN	22.5	4.50	2.6	80	69	5374	212634	1341791	2235776	1271.52	1.20554
76	TEX	26.0	4.20	2.6	79	65	21645	85962	1696814	2688904	2253.51	1.22712
76	VIR	20.5	4.50	2.6	67	46	6655	194310	524884	4314939	1571.29	1.07587
76	WIS	22.0	4.50	2.5	78	37	7710	66633	1228892	4224808	986.57	0.95394

TABLE C-3. CROSS SECTIONAL-TIME SERIES DATA FOR SOYBEANS, 1973-1979 (CONT.).

YEAR	STATE	SYBYD bu	SYBLOP $/bu	CRNLOP $/bu	JWT	AWT	LAND	ISRES $	OSRES $	BAS RES $	EXTEN $1000	RISK1
75	ALA	24.5	7.05	3.3	85	87	4398	243768	1465502	684513	1724.49	1.62050
75	GEO	25.5	6.90	3.1	86	79	5341	239494	1227750	731126	2304.19	1.29526
75	ILL	36.0	6.60	3.0	93	81	23509	489869	3144487	2446420	1228.74	1.07221
75	IND	33.5	7.00	3.0	93	82	12589	526854	3152801	2446420	1084.55	1.37568
75	IOW	34.0	6.35	2.8	90	63	21484	688643	2359316	2537746	965.60	0.80728
75	KAN	21.0	6.60	2.9	84	68	21580	235245	1170335	2834261	1234.78	1.26194
75	KEN	27.0	6.95	3.0	96	78	4953	83300	1229386	2840518	1280.97	1.44604
75	LOU	24.5	7.20	3.3	83	86	13183	508868	596808	1993642	1486.32	1.66257
75	MAR	28.0	7.00	3.2	95	84	9457	111250	1243724	2834261	618.31	1.48162
75	MIC	26.0	6.40	2.8	94	81	7301	46035	1227043	2812872	1285.67	0.90738
75	MIN	26.5	6.35	2.8	92	56	11292	449518	823437	2812872	947.86	0.89534
75	MIS	22.5	6.90	3.4	87	88	7959	402567	1069074	730974	1436.99	1.35537
75	MOS	26.0	6.75	3.0	87	47	9340	304558	1671302	2736827	1204.13	1.23597
75	NEB	27.0	6.50	2.8	74	64	21257	230231	1504050	2750123	802.28	1.01520
75	NJE	26.0	6.75	3.0	93	90	14045	28517	684606	2925587	831.14	1.44665
75	NCA	23.5	6.90	3.1	92	73	5290	371124	1140250	1622714	2383.89	1.38587
75	OHI	33.0	6.70	3.0	90	84	10459	486890	2496959	2537746	1179.21	1.19274
75	OKL	23.0	6.65	3.3	92	88	12573	22654	2675296	542366	886.84	1.21022
75	SCA	22.0	6.55	3.1	84	70	6819	215555	1212168	731126	1150.08	1.19102
75	SDK	25.0	6.40	2.9	79	62	15753	36168	2246938	2641397	460.29	1.08813
75	TEN	25.0	6.90	3.3	93	78	5176	177657	1239157	1622714	1284.49	1.41503
75	TEX	25.0	6.65	3.2	84	77	21252	56011	1723056	1896207	2252.40	1.26595
75	VIR	25.0	6.65	3.2	95	83	6447	182506	454681	2931843	1495.35	1.31325
75	WIS	25.5	6.40	2.9	92	58	7540	65716	1227568	2816901	1035.33	0.98022

TABLE C-3. CROSS SECTIONAL-TIME SERIES DATA FOR SOYBEANS, 1973-1979 (CONT.).

YEAR	STATE	SYBYD bu	SYBLOP $/bu	CRNLOP $/bu	JWT	AWT	LAND	ISRES $	OSRES $	BAS RES $	EXTEN $1000	RISK1
74	ALA	23.0	5.50	2.5	85	81	4398	439095	1160988	669872	1474.82	1.31051
74	GEO	25.5	5.65	2.5	83	85	5341	177962	916587	726557	2021.61	1.39536
74	ILL	24.0	5.75	2.4	94	73	23509	513930	2789232	1891804	1051.38	1.33031
74	IND	25.0	5.70	2.3	95	66	12589	505615	2838525	1891804	830.15	1.36588
74	IOW	28.0	5.65	2.3	92	78	21464	639587	2090482	1984230	893.72	1.30852
74	KAN	19.5	5.65	2.4	87	62	21580	200709	1108629	2269598	1088.82	1.33605
74	KEN	24.0	5.60	2.4	92	92	4953	70338	1091169	2286560	1100.30	1.32610
74	LOU	25.0	5.70	2.3	86	79	13183	548397	443776	1657784	1200.25	1.36405
74	MAR	28.5	5.40	2.4	93	66	9457	127320	1207249	2269598	505.79	1.26619
74	MIC	21.0	5.70	2.3	89	69	7301	49772	1035087	2258805	1110.07	1.33135
74	MIN	21.0	5.70	2.2	85	76	11292	453377	691595	2258805	783.58	1.31458
74	MIS	18.5	5.60	2.5	88	79	7959	337650	856266	726429	1154.62	1.28220
74	MOS	21.5	5.60	2.3	92	65	9340	339953	1536331	2180381	1082.36	1.29508
74	NEB	23.5	5.45	2.2	84	51	21257	244562	1295903	2189542	705.82	1.23844
74	NJE	29.0	5.55	2.5	89	81	14045	26925	665371	2362023	695.55	1.38623
74	NCA	21.5	5.60	2.3	93	89	5290	259352	967232	1391073	2095.31	1.36148
74	OHI	25.0	5.65	2.4	92	71	10459	501944	2262723	1984230	1009.81	1.28526
74	OKL	23.0	5.40	2.5	85	70	12573	30140	2245028	544915	759.93	1.28671
74	SCA	18.5	5.65	2.4	86	82	6819	193544	919108	726557	961.61	1.34179
74	SDK	20.0	5.55	2.1	84	53	15753	40843	1918003	2090364	398.58	1.25540
74	TEN	21.0	5.50	2.6	93	82	5176	160445	990225	1391073	1099.02	1.31183
74	TEX	30.0	5.30	2.5	68	62	21252	62360	1350576	1568568	1885.51	1.17500
74	VIR	23.5	5.50	2.3	94	89	6447	185530	425586	2378986	1377.69	1.26112
74	WIS	20.0	5.60	2.4	92	73	7540	22723	1032505	2262890	937.99	1.27704

TABLE C-3. CROSS SECTIONAL-TIME SERIES DATA FOR SOYBEANS, 1973-1979 (CONT.).

YEAR	STATE	SYBYD bu	SYBLOP $/bu	CRNLOP $/bu	JWT	AWT	LAND	ISRES $	OSRES $	BAS RES $	EXTEN $1000	RISK1
73	ALA	21.0	3.81	1.5	90	83	4236	274806	1077407	586143	3873.76	0.54501
73	GEO	21.0	4.31	1.5	85	84	5163	187849	890457	624011	4794.66	0.81242
73	ILL	31.5	4.47	1.5	92	83	22940	455498	2963961	1914743	2646.23	0.85687
73	IND	31.5	4.25	1.5	92	92	12211	406205	3017667	1914743	2396.46	0.77597
73	IOW	34.0	4.74	1.6	92	87	20926	556923	2120659	1996696	2491.63	1.04386
73	KAN	22.0	4.10	1.5	92	80	21356	186553	1061588	2235095	3001.36	0.72390
73	KEN	25.5	4.06	1.7	97	91	4794	67026	1068320	2258326	2758.88	0.66910
73	LOU	22.0	3.88	1.4	80	82	12636	378972	452047	1608258	3186.82	0.54286
73	MAR	31.0	4.04	1.5	90	80	9249	87933	1180280	2235095	1196.77	0.66701
73	MIC	24.0	4.60	1.4	92	84	7074	50591	1177778	2241108	2765.50	0.96127
73	MIN	29.0	4.58	1.5	89	84	10986	394082	724610	2241108	1920.36	0.96075
73	MIS	22.0	4.19	1.5	89	83	7562	248917	832446	623917	3041.00	0.70117
73	MOS	27.0	4.28	1.4	89	73	9140	319722	1574851	2156654	2796.62	0.78691
73	NEB	30.0	4.47	1.5	89	77	20893	289180	1361246	2170710	1820.93	0.92110
73	NJE	21.0	3.87	1.7	91	80	13698	32486	643273	2317047	1706.90	0.62067
73	NCA	24.0	4.13	1.4	93	88	5059	206685	890998	1318163	4918.57	0.71598
73	OHI	25.0	4.32	1.5	94	90	10145	384683	2489816	1996696	2514.38	0.79431
73	OKL	23.0	4.23	1.4	90	81	12359	17604	2163157	463617	2009.50	0.85822
73	SCA	19.0	4.19	1.4	86	84	6574	185328	886628	624011	2121.64	0.72856
73	SDK	24.0	4.24	1.3	82	57	15347	31864	2116311	2098333	1080.38	0.80133
73	TEN	23.5	4.07	1.6	93	80	4978	183692	942766	1318163	2703.94	0.71445
73	TEX	20.0	4.12	1.5	83	76	20859	33043	1212988	1529817	4566.52	0.79211
73	VIR	27.0	4.03	1.4	97	95	6239	135285	367605	2340278	3622.43	0.62482
73	WIS	25.0	4.45	1.4	88	71	7370	29818	1165076	2244705	2428.14	0.91477

TABLE C-4. CROSS SECTIONAL-TIME SERIES DATA FOR SORGHUM, 1973-1979.

YR	STATE	SOR YLD bu	SOR LOP $/bu	WHT LOP $/bu	JUN WT	AUG WT	LAND	ISRES $	OSRES $	BAS RES $	EXTEN $1000	RISK1	RISK2
79	ARZ	71	2.63	2.93	93	77	54217	61036	2000097	14877	260.97	0.254231	1.10320
79	ARK	62	1.76	2.95	91	90	17320	68096	382136	265439	1388.70	0.263502	0.93550
79	CAL	75	2.46	3.25	91	88	63640	53050	1619704	64630	4102.87	0.115036	1.04317
79	COL	38	1.76	2.75	86	88	25139	31644	375534	260595	1297.88	0.102632	0.83980
79	GEO	39	1.82	2.95	87	82	6053	139465	351061	265439	896.78	0.181475	0.87000
79	ILL	68	1.79	3.05	90	89	25788	5987	1677051	64540	558.75	0.155242	0.98800
79	IND	55	1.79	3.00	91	96	14101	49479	1659366	64630	425.54	0.107858	1.03500
79	IOW	70	1.79	2.65	91	89	23713	57969	342937	260593	425.28	0.115902	0.59892
79	KAN	69	1.88	2.85	88	88	22473	580047	1162637	67468	1416.26	0.156205	0.94133
79	KEN	68	1.82	3.15	90	96	5589	5604	1712726	69384	714.00	0.155242	1.00600
79	LOU	38	2.02	3.05	80	87	15371	63715	372427	265439	577.84	0.310483	1.11867
79	MIS	44	2.16	2.95	88	91	9570	115596	349080	265439	738.27	0.266646	1.25592
79	MOS	82	1.79	2.95	90	84	10139	51886	1970427	14889	1096.06	0.243379	1.02850
79	NEB	79	1.76	2.70	85	87	22713	478527	1248392	64614	1029.96	0.125300	0.90750
79	NME	52	2.21	2.85	87	88	40424	45435	1972948	14888	672.28	0.165630	1.28442
79	NCA	53	1.93	2.85	93	82	6214	15190	421752	265439	1000.74	0.201080	0.98725
79	OKL	45	2.02	3.00	88	87	13429	130302	1541102	69382	1029.99	0.138924	1.01308
79	SCA	38	1.96	3.00	91	76	7800	9428	430513	265439	667.12	0.110000	0.94867
79	TEN	51	2.21	2.85	94	93	5971	11534	425841	265439	739.15	0.315013	1.03992
79	TEX	54	2.10	2.95	83	85	22824	435065	1669411	14883	3052.66	0.144222	1.16167

TABLE C-4. CROSS SECTIONAL-TIME SERIES DATA FOR SORGHUM, 1973-1979 (CONT.).

YR	STATE	SOR YLD bu	SOR LOP $/bu	WHT LOP $/bu	JUN WT	AUG WT	LAND	ISRES $	OSRES $	BAS RES $	EXTEN $1000	RISK1	RISK2
78	ARZ	78	2.13	2.60	100	67	54232	28581	1820968	14225	259.14	0.391535	0.07205
78	ARK	60	1.62	2.05	91	54	16951	54739	259087	288797	1325.29	0.309892	0.12683
78	CAL	71	2.35	2.72	100	92	63575	62228	1584233	54161	3644.34	0.240069	0.05220
78	COL	31	1.62	2.11	79	61	24753	26819	351013	274698	1166.31	0.360555	0.02327
78	GEO	29	2.04	2.25	83	78	5875	85814	283995	288797	879.70	0.170880	-0.00100
78	ILL	68	1.62	2.10	90	73	25218	5437	1615531	54081	521.65	0.243379	0.07600
78	IND	65	1.62	2.20	90	84	13723	22563	1603102	54162	413.39	0.256970	0.04933
78	IOW	75	1.65	2.10	90	82	23156	59425	307560	274696	410.38	0.281484	0.05258
78	KAN	52	1.62	2.15	90	59	22250	502187	1126633	56838	1297.41	0.326037	0.05550
78	KEN	62	1.65	2.00	88	89	5430	4287	1562559	68179	695.10	0.256970	0.07700
78	LOU	34	1.68	2.10	78	70	14824	64448	277569	288797	571.17	0.509346	0.18950
78	MIS	38	1.65	2.00	86	75	9162	87795	265560	288797	723.79	0.327159	0.15150
78	MOS	80	1.48	2.10	90	75	9939	58215	1811288	14230	1230.50	0.384361	0.11192
78	NEB	75	1.65	2.20	89	80	22349	433621	1201878	54147	912.71	0.311929	0.02675
78	NME	46	1.88	2.10	70	70	40028	55699	1798398	14229	635.36	0.295691	0.06892
78	NCA	52	1.82	2.20	85	74	5983	15123	304111	288797	978.69	0.287112	0.07092
78	OKL	36	1.79	2.30	86	53	13215	175928	1411465	68177	1066.24	0.280535	0.05375
78	SCA	32	1.85	2.15	85	80	7555	6362	309136	288797	656.04	0.266271	0.05225
78	TEN	51	1.68	2.25	89	81	5772	11034	304935	288797	722.67	0.341955	0.12867
78	TEX	49	1.90	2.25	55	44	22431	359261	1487739	14226	2810.25	0.241109	0.06800

TABLE C-4. CROSS SECTIONAL-TIME SERIES DATA FOR SORGHUM, 1973-1979 (CONT.).

YR	STATE	SOR YLD bu	SOR LOP $/bu	WHT LOP $/bu	JUN WT	AUG WT	LAND	ISRES $	OSRES $	BAS RES $	EXTEN $1000	RISK1	RISK2
77	ARZ	80	2.46	3.92	60	73	54247	42886	1798596	11517	668.33	0.490540	0.08635
77	ARK	52	2.13	3.15	72	72	16582	55820	226957	229273	1260.82	0.373230	0.16567
77	CAL	73	2.58	3.63	41	39	63510	36458	1560097	40142	3329.50	0.442380	0.06267
77	COL	31	1.82	2.45	69	72	24367	15954	365429	211135	1118.19	0.422530	0.21100
77	GEO	28	2.18	3.05	53	55	5697	30912	277231	229273	2475.18	0.316440	0.05050
77	ILL	64	1.93	3.05	80	87	24648	5551	1606846	40084	1302.89	0.461120	0.13592
77	IND	78	1.82	3.00	83	90	13345	17587	1592074	40143	926.26	0.468080	0.12200
77	IOW	74	1.88	3.00	80	76	22599	59418	324855	211133	1046.48	0.423200	0.18525
77	KAN	60	1.90	2.70	90	90	22027	481467	1091030	42152	1302.37	0.395260	0.20425
77	KEN	57	1.96	2.95	81	92	5271	6465	1532824	58222	1341.41	0.251660	0.13575
77	LOU	33	2.30	3.30	69	80	14277	37338	261944	229273	1423.08	0.390000	0.24433
77	MIS	32	2.04	3.15	73	71	8754	49347	284296	229273	1496.49	0.430040	0.13867
77	MOS	73	1.96	2.95	81	78	9739	52506	1812267	11525	1241.05	0.395140	0.19300
77	NEB	71	1.90	2.65	89	89	21985	418893	1155731	40129	840.13	0.380040	0.18075
77	NME	48	2.07	3.32	77	81	39632	65404	1781856	11523	610.87	0.467010	0.20183
77	NCA	37	2.21	3.00	74	61	5752	10796	295700	229273	2407.07	0.270620	0.10233
77	OKL	38	2.04	2.95	91	80	13001	157575	1397194	58220	902.44	0.414050	0.14575
77	SCA	16	2.07	3.10	62	52	7310	5771	294920	229273	1373.10	0.295127	0.06975
77	TEN	51	2.24	3.05	80	76	5573	9972	298825	229273	1330.10	0.244336	0.14033
77	TEX	48	2.18	3.15	84	58	22038	376088	1496864	11520	2430.96	0.316439	0.13100

TABLE C-4. CROSS SECTIONAL-TIME SERIES DATA FOR SORGH-1979 (CONT.).

YR	STATE	SOR YLD bu	SOR LOP $/bu	WHT LOP $/bu	JUN WT	AUG WT	LAND	ISRES $	OSRES $	BAS RES $	EXTEN $1000	RISK1	RISK2
76	ARZ	73.0	2.91	3.15	77	64	54262	38434	12920	600.80	0.32140	-0.19610	
76	ARK	50.0	2.18	2.85	80	56	16213	79407	228669	1183.33	0.40447	0.12525	
76	CAL	71.0	2.83	3.26	46	47	63445	51693	38732	3230.70	0.34385	0.05405	
76	COL	28.0	2.32	3.25	71	65	23981	14757	206829	1030.53	0.19630	0.28683	
76	GEO	43.0	2.38	2.90	84	72	5519	29133	228669	2378.47	0.36638	0.04883	
76	ILL	59.0	2.10	3.15	83	61	24078	5305	38679	1206.83	0.43936	0.20050	
76	IND	67.0	2.13	3.20	75	78	12967	19713	38733	878.05	0.35218	0.23225	
76	IOW	65.0	2.21	3.45	88	56	22042	55340	206827	969.13	0.34210	0.23400	
76	KAN	43.0	2.27	3.40	86	49	21804	506027	41051	1185.40	0.30370	0.23617	
76	KEN	60.0	2.16	3.00	74	83	5112	5508	60518	1289.91	0.29006	0.09917	
76	LOU	35.0	2.69	2.95	78	66	13730	44420	228669	1288.72	0.35076	0.12675	
76	MIS	37.0	2.30	2.75	78	54	8356	22068	228669	1399.39	0.39323	-0.00233	
76	MOS	60.0	2.24	3.05	82	45	9539	24708	12928	1139.94	0.30746	0.15633	
76	NEB	57.0	2.27	3.35	80	48	21621	456145	38718	763.32	0.31342	0.21808	
76	NME	60.0	2.46	3.60	66	65	39236	55127	12926	596.30	0.30348	0.15960	
76	NCA	51.0	2.38	2.80	74	64	5521	10664	228669	2322.53	0.33531	0.05083	
76	OKL	30.0	2.35	3.35	86	56	12787	141151	60516	873.07	0.33081	0.18617	
76	SCA	34.0	2.38	2.75	81	67	7064	11444	228669	1181.58	0.38436	0.04175	
76	TEN	52.0	2.30	2.90	80	69	5374	7539	228669	1252.49	0.36529	0.06425	
76	TEX	50.5	2.38	3.30	79	65	21645	340142	12923	2379.14	0.35233	0.10717	

TABLE C-4. CROSS SECTIONAL-TIME SERIES DATA FOR SORGH-1979 (CONT.).

YR	STATE	SOR YLD BU	SOR LOP $/BU	WHT LOP $/BU	JUN WT	AUG WT	LAND	ISRES $	OSRES $	BAS RES $	EXTEN $1000	RISK1	RISK2
75	ARZ	68	3.44	3.10	75	59	54276	43773	10338	617.39	0.87506	0.04850
75	ARK	49	2.80	3.60	89	85	15843	58554	218096	1129.97	0.80542	0.19500
75	CAL	72	3.44	3.76	85	82	61822	27825	35566	3102.99	0.85874	0.10375
75	COL	26	2.66	3.80	63	74	23595	22293	200959	1028.11	0.60186	0.03400
75	GEO	36	2.80	3.30	86	79	5341	30970	218096	2274.95	0.80102	0.12000
75	ILL	68	2.80	3.85	93	81	23509	6236	35497	1284.82	0.80002	0.20683
75	IND	64	2.74	3.95	93	82	12589	23001	35566	931.46	0.72279	0.17792
75	IOW	62	2.72	4.10	90	63	21484	51676	200958	1012.70	0.71084	0.17175
75	KAN	42	2.69	3.90	84	68	21580	590939	37356	1175.94	0.65092	0.05883
75	KEN	65	2.46	3.70	96	78	4953	4946	52634	1342.00	0.59506	0.10983
75	LOU	33	3.08	3.95	83	86	13183	39350	218096	1373.11	1.00406	0.23217
75	MIS	35	2.88	3.05	87	88	7959	19520	218096	1457.39	0.82100	0.07417
75	MOS	54	2.74	3.70	87	47	9340	18252	10347	1218.98	0.74191	0.14067
75	NEB	55	2.66	3.80	74	64	21257	354488	35554	790.55	0.64516	0.05450
75	NME	50	3.00	4.00	75	74	38840	65021	10345	631.08	0.78996	0.09400
75	NCA	51	2.74	3.30	92	73	5290	9031	218096	2357.70	0.75659	0.10217
75	OKL	38	2.86	3.85	92	88	12573	146430	52632	880.12	0.72753	0.07592
75	SCA	35	2.66	3.40	84	70	6819	10842	218096	1200.28	0.74009	0.12300
75	TEN	48	2.69	3.45	93	78	5176	4079	218096	1354.90	0.75514	0.12942
75	TEX	52	2.80	3.80	84	77	21252	333272	10342	2435.50	0.73021	0.12600

TABLE C-4. CROSS SECTIONAL-TIME SERIES DATA FOR SORGHUM, 1973-1979 (CONT.).

YR	STATE	SOR YLD bu	SOR LOP $/bu	WHT LOP $/bu	JUN WT	AUG WT	LAND	ISRES $	OSRES $	BAS RES $	EXTEN $1000	RISK1	RISK2
74	ARZ	81	2.86	2.60	55	63	15843	65950	1228707	12027	577.41	0.799083	0.64927
74	ARK	48	2.04	2.70	93	77	15676	42299	196620	182794	1070.41	0.546474	0.91720
74	CAL	72	2.86	3.21	91	83	61822	61227	1083275	32152	2890.22	0.774231	0.86608
74	COL	29	2.32	3.75	64	57	23595	31903	265152	164201	956.99	0.653784	0.67258
74	GEO	35	2.07	2.65	83	85	5341	25665	190924	182794	2113.26	0.632376	0.78347
74	ILL	47	1.99	2.95	94	73	23509	5908	1120666	32066	1102.25	0.546839	0.95502
74	IND	55	2.13	2.95	95	66	12589	0	1119761	214825	1011.15	0.623084	0.93565
74	IOW	46	2.07	3.10	92	78	21464	49119	231088	164199	936.50	0.594671	0.92170
74	KAN	40	2.10	3.60	87	62	21580	289312	819051	34354	1095.13	0.580259	0.73770
74	KEN	66	1.88	2.95	92	92	4953	3516	1054088	50658	1235.45	0.508626	0.66525
74	LOU	40	2.38	2.65	86	79	13183	8757	226881	182794	1321.76	0.785897	1.25440
74	MIS	32	2.13	2.70	88	79	7959	23215	216658	182794	1356.15	0.622923	0.70867
74	MOS	51	2.18	2.80	92	65	9340	8742	1282296	12040	1166.94	0.646297	0.84793
74	NEB	33	2.04	3.50	84	51	21257	325975	859901	32142	735.21	0.558957	0.67043
74	NME	50	2.49	3.30	50	65	38840	47573	1244339	12039	610.08	0.731049	0.96122
74	NCA	52	2.07	2.70	93	89	5290	16157	212555	182794	2213.56	0.555608	0.75067
74	OKL	38	2.24	3.50	85	70	12573	146878	914096	50656	841.91	0.606053	0.80475
74	SCA	38	1.90	2.70	86	82	6819	13282	220056	182794	1097.80	0.483873	0.74900
74	TEN	59	1.96	2.75	93	82	5176	2181	227385	182794	1271.52	0.587055	0.76513
74	TEX	52	2.10	3.10	68	62	21252	351500	1022383	12035	2253.51	0.506491	0.82180

TABLE C-4. CROSS SECTIONAL-TIME SERIES DATA FOR SORGHUM, 1973-1979 (CONT.).

YR	STATE	SOR YLD bu	SOR LOP $/bu	WHT LOP $/bu	JUN WT	AUG WT	LAND	ISRES $	OSRES $	BAS RES $	EXTEN $1000	RISK1	RISK2
73	ARZ	72	1.72	1.64	98	78	54291	58456	1434869	10883	605.14	0.208167	0.40617
73	ARK	45	1.19	1.33	88	73	15474	32830	270803	160856	1132.31	0.087369	0.40318
73	CAL	70	1.75	1.80	89	83	60199	43296	1252058	28729	3298.32	0.198578	0.66398
73	COL	35	1.49	1.77	91	82	23209	31679	253781	142698	1020.09	0.240208	0.86585
73	GEO	35	1.20	1.36	85	84	5163	38527	260366	160856	2304.19	0.249800	0.42500
73	ILL	61	1.20	1.46	92	83	22940	6553	1259172	28635	1228.74	0.133167	0.46567
73	IND	71	1.30	1.38	92	92	12211	6806	1251386	28729	1084.55	0.196723	0.54715
73	IOW	73	1.30	1.52	92	87	20926	65753	221150	142696	965.60	0.202978	0.55797
73	KAN	56	1.39	1.68	92	80	21356	294052	951147	30850	1234.78	0.221886	0.69060
73	KEN	68	1.27	1.47	97	91	4794	5755	1283363	46793	1280.97	0.213620	0.39960
73	LOU	33	1.10	1.41	80	82	12636	2570	307890	160856	1486.32	0.083865	0.52847
73	MIS	35	1.24	1.35	89	83	7562	12792	281341	160856	1436.99	0.191572	0.43250
73	MOS	70	1.27	1.43	89	73	9140	4780	1515725	10895	1204.13	0.172434	0.49850
73	NEB	68	1.37	1.74	89	77	20893	266719	1055257	28720	802.28	0.223681	0.65130
73	NME	54	1.45	1.63	95	76	38444	42745	1455709	10893	663.94	0.191398	0.75015
73	NCA	58	1.23	1.34	93	88	5059	16896	286658	160856	2383.89	0.171561	0.40320
73	OKL	44	1.41	1.70	90	81	12359	145761	1116123	46791	886.84	0.181751	0.67440
73	SCA	37	1.18	1.37	86	84	6574	9395	296363	160856	1150.08	0.210079	0.34860
73	TEN	51	1.18	1.43	93	80	4978	2065	308334	160856	1284.49	0.219621	0.41193
73	TEX	60	1.34	1.56	83	76	20859	264718	1112311	10891	2252.40	0.118462	0.46273

An Economic Evaluation of Research and Extension Expenditures on Corn, Wheat, Soybeans, and Sorghum

by

Daniel Otto

(ABSTRACT)

The evaluation of public investments in agricultural research has been a topic of special interest to research administrators and others concerned with productivity in agriculture. Tighter research budgets and diminished purchasing power due to inflation have increased concern about research budget allocations. Earlier research evaluation studies have indicated high rates of return to overall agricultural investments. This study is concerned with the evaluation of research investments made at an individual agricultural commodity level. The primary objectives of this study are:

(a) to estimate the marginal product and internal rates of return to research investments in corn, wheat, soybeans, and sorghum.

(b) to estimate separately the internal rate of return to extension investments in these commodities.

(c) to estimate the effect of spillovers from research investments in these commodities by other outside states.

(d) to estimate the impact of these research and extension investments in grain commodities for individual geographical production regions in the U.S.

The theoretical framework of a supply response model with inclusion of a variable to account for aggregate risk by producers was developed as the basis for analyzing research and extension investments in corn, wheat, soybeans, and sorghum. Individual commodity models focusing on the relationship of yield per acre to output prices, land quality differences, weather, aggregate risk, and investments in research and extension were specified. Data were collected for these variables for a cross section of the major producing states of each commodity for the 1973-1979 crop years. The Park's model, a generalized least squares procedure which includes adjustments for first order autocorrelation within each state and cross sectional correlation among states, was used to estimate coefficients of individual commodity models.

Empirical results for the individual commodity models indicate that the prices of output and a substitute commodity, weather, land quality differences, aggregate risk, in-state and outside research investments, and extension investments were significant variables explaining yield per acre of corn, wheat, soybeans, and sorghum. The estimated internal rates of return on research investments indicate very favorable rates of return to both in-state and outside investments in agricultural research. The returns to in-state research investments ranged from 81 percent for wheat to 177 for corn and the returns to outside research investments ranged from 21 percent for wheat to 133 percent for sorghum. The rates of return to outside research expenditures indicate that the benefits of research investments are not confined solely to the state making the investment. The significance of these spillovers suggest that the contribution of federal funds to state research programs is appropriate as a means of compensating states for the externalities. The contributions of extension investment to productivity increases of these grain commodities were estimated separately from the contributions of investments in agricultural research. Based on assumptions of 8 and 12 year "inverted V" distributions of benefits from increased yield per acre, the estimated IRORs for extension investments ranged from 42 percent for sorghum to 96 percent for corn. The estimated IRORs for research and extension investments in the various U.S. production regions were comparable to the rates estimated for the U.S. in total. While the IROR to research investments were higher than for extension investments, these rates are highly sensitive to assumptions made concerning the length and structure of the lag between expenditures and impacts. The measure of benefits based solely on yield increases also may not be appropriate for all types of research and extension expenditures.

Aggregate risk based on past variations in prices has a significant impact on corn and wheat yields. The significant negative coefficients imply risk averse behavior by corn and wheat producers in the aggregate. Increases in price variability have a depressing effect on yield. The models developed in this study enable price elasticities for grain yields to be estimated. Elasticities estimated at mean levels, using expected nominal prices, ranged from .06 for sorghum to .30 for corn. These elasticities indicate total supply response is 6 to 30 percent greater than estimates based solely on acreage response.