To the Graduate Council:

I am submitting herewith a thesis written by Curtis R. Hancock, Jr., entitled "An Estimation of the Impact of Technology on Agricultural Output in the Southeast." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agricultural Economics.

Larry L. Bauer, Major Professor

We have read this thesis
and recommend its acceptance:

Accepted for the Council.

Vice Chancellor
Graduate Studies and Research

AN ESTIMATION OF THE IMPACT OF TECHNOLOGY ON AGRICULTURAL OUTPUT IN THE SOUTHEAST

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee

Curtis R. Hancock

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ABSTRACT

The objectives of this study were to estimate an agricultural production function for the thirteen southeastern states and to measure the timepath of the effect of technology by estimating a distributed lag function.

The procedure involved estimating a Cobb-Douglas type production function using ordinary least squares regression. The impact and timepath of public research and extension expenditures, which was used as a proxy variable for technology, was estimated using a general polynomial distributed lag technique.

The study used time series and cross sectional data from secondary sources. State data for research and extension expenditures covered the period from 1930 through 1968 while the other variables were measured from 1949 through 1968.

The general polynomial distributed lag technique did not restrict the shape of the lag distribution. Lags were varied from 0 to 20 years. Selection of the "best" lag was based on: (1) R^2, (2) the signs, magnitudes, and significance of structural parameter estimates, and (3) the reasonableness of the estimated lag distribution.

Results indicated that based on the selection criteria a lag of nine years was the optimum lag with not much difference among the lags of seven to ten years. It was hypothesized that the lag distribution would have weights that increased to a maximum and then decreased; however, the results indicated a distribution with equal weights for all years.

Results indicated that returns to investments in technology were

quite large. Even if half of the influence is attributed to private research and extension activities, there was a return of nearly 300% to public investments in research and extension.

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CHAPTER I

INTRODUCTION

The estimation of agricultural production functions has been the topic of considerable discussion and the focus of considerable research. The determination of resource productivity in agriculture provides useful information to both individuals and policymakers.

American agriculture has been characterized by tremendous increases in output. The input mix which affects the output has been in a state of change. While input levels have increased in the past twenty years, there has been an even greater change in the quality of many inputs. Hybrid seed corn has become almost universally accepted. Not only are pesticides used more widely but also the effectiveness of those used has been improved. As new technology is developed, both the input mix and the quality of the inputs will change.

During the Sixties, United States agricultural output far exceeded its demand because U.S. government programs, which set prices above equilibrium and encouraged overproduction, resulted in an economic benefit to consumers--low priced food. There were certain costs associated with this situation. The government incurred costs both in an attempt to hold production down and also in maintaining surpluses.

The Seventies brought a new situation--the surpluses have disappeared. Carryovers of feedstuffs were barely sufficient to keep the pipeline full from one marketing season to the next. Examples of this occurred with the 1972 soybean crop and the 1973 wheat crop. These occurrences were brought about by a combination of factors which are

lagged effect of the variable. The spreading of this effect over many time periods is referred to as a distributed lag. By estimating a distributed lag function on technology the manner in which the total effect is spread through time is determined.

Review of Literature

Griliches (1963, pp. 419-420) suggested that prior to estimating a production function several choices must be made as to "what will be estimated and how." He indicated that some of these were: (1) the choice of the algebraic form of the production function; (2) the choice of the variables to be included, and (3) the choice of a technique for estimating the coefficients of the production function.

Several studies have been undertaken to empirically determine the appropriate form of the production function. Griliches, Evenson, Bauer, and Mundy used the Cobb-Douglas form of the production function in their studies for the form of their estimating equation. Heady and Dillon (1961) commented that the Cobb-Douglas form has been the most popular because of its adequacy in fitting the data, computational feasibility, and its efficient use of degrees of freedom. Other forms of the production function have been used, particularly by Griliches, but his studies indicated that these forms, CES and transcendental functions, did not improve his results.

The choice of variables presents another problem. Choice is largely dictated by availability of data. Several models have been specified by other researchers. Griliches (1964) included as independent variables in his production function fertilizer (measured by weighted plant nutrients rather than expenditures), expenditures on purchased

livestock feed, and other current expenditures, land and buildings, machinery, labor, education, and research and extension expenditures. The dependent variable, output, was measured as the sum of sales, inventory change, home consumption, and government payments.

Evenson (1967) specified his model somewhat differently. He included weather as a variable. Other variables were the same ones used by Griliches but were combined differently; e.g., land, machinery, and miscellaneous expenditures were grouped together. His labor variable was quality adjusted for education. His dependent variable was the ratio of output to input.

Bauer (1968) specified a model that included as independent variables only labor, land, expenditures for current operating expenses excluding labor, and research and extension expenditures, and as dependent variable total farm output, i.e., the sum of farm cash marketings, government payments to farmers, value of home consumption of farmers, and net farm inventory change.

Ordinary least squares regression technique provides a simple means of estimating the production function. All of the previous researchers have used this technique in estimating the agricultural production function though it may have been a part of a simultaneous system.

The handling of one of the variables, technology, included in the models discussed here merits particular attention. There are several ways in which technology may be handled. One technique for accounting for the effect of technology is to assume that the shifting effects of technology have occurred at a relatively constant rate of change over time. With this assumption, a time or trend variable can be used as a

proxy for technology in the estimating equation. This technique is not entirely satisfactory because technology probably does not affect the production function at a constant rate. For example, technology is more readily adopted in periods of high or rising prices than in periods of low or falling prices.

Griliches (1964) introduced a variable to reflect the contribution of public expenditures for agricultural research and for the dissemination of results into the agricultural sector. The variable was measured as the sum of all relevant entries in the annual budget of the respective state agricultural experiment stations and extension services. Though Griliches did not explicitly indicate that the variable used in the study was a proxy for technology, it seems it would serve for such.

Griliches himself described this technique as crude. He realized the effect of research and extension expenditures took place over time; therefore, he defined the variable as the average of the expenditures in a given year and the sixth previous year. The results he attained indicated there was a large return on public expenditures for research and extension.

Wallace and Hoover (1966) used state and federal research and extension appropriations as a measure of technology. To take account of the lagged effect of technology, they used the geometric mean of the current and four previous years' approriations.

Evenson (1967) developed a framework for estimating the lagged effect of research and extension appropriations on production in the agricultural sector. He suggested several factors which could affect changes in productivity but indicated that most of the content of the

unexplained residual in productivity measures is made up of the contributions of public research and extension (Evenson, 1967, p. 1418).

Evenson, in his study, restricted the shape of the estimated lag distribution to either an inverted V distribution or an exponentially declining distribution. His basis for selecting the "best" distribution was to choose the distribution which maximized the coefficient of determination.

In a subsequent study by Bauer (1968), the impact and timepath of the effect of technology upon farm income was measured. Bauer used the rational distributed lag technique which was developed by Jorgenson to determine the magnitude and the timepath of technology.

In a recent study by Mundy (1972), an effort was made to estimate the lagged effect of research and extension expenditures, i.e., technology, upon aggregate farm output. The technique he used to estimate the distributed lag function was developed by Johnson (1969).

Objectives

This study specified a model for the production of agricultural output in the thirteen southeastern states. The estimation of an aggregate agricultural production function for this area is unique in that it permits observation of a somewhat more homogeneous area than the studies discussed above. The main objectives of this study were:

1. to estimate a production function for agriculture in the thirteen southeastern states;
2. and to measure the timepath of the effect of technology by estimating a distributed lag function.

Procedure

To accomplish the proposed objectives, the following steps were taken. A Cobb-Douglas production function was estimated using ordinary least squares regression technique. The effect and the timepath of technology was estimated by using a distributed lag technique developed by Tom Johnson (1969).

Justification

Examination of the aggregate agricultural production function for the Southeast is warranted for two reasons. Further study of the production function would add to the stock of knowledge in that area. Additional study of the role of technology in the production function is also necessary. Griliches (1964) commented about his work in the area:

> None of these conclusions are very firmly established, and that some may be subject to substantial bias, but the only known way of either confirming or disproving them is the slow and expensive but cumulative process of conducting additional studies of this type on different bodies of data.

Bauer (1968) suggested that it might be beneficial to compare alternative methods of estimating lag functions. He further suggested examining the lag functions determining the effect of technology in different geographic areas. This study is a step in that direction.

A second reason for the study is that the information obtained should prove to be beneficial to policymakers in making decisions in regard to appropriations of funds for research and extension (at both the macro and micro levels). Not only will it let policymakers know the approximate effect of appropriations for research and extension, but it will also let them know how long it will take for the effect to be realized.

CHAPTER II

MODEL AND PROCEDURE

The Economic Model

Ideally the specified model would include all relevant variables. But, due to various constraints imposed by lack of data and research techniques and skills, the ideal model is reduced to something less than ideal. However, some considerations of the economic model and the variables it includes should be made.

The conceptual model written in a general form would be:

$$Q = f\ (T, L, F, S, C, E, LA, W, D)$$

where:

Q = gross agricultural output

T = technology

L = labor

F = feed and livestock expenses

S = other production expenses

C = capital and depreciation

E = education

LA = land

W = weather

D = dummy variables for the thirteen southeastern states

Other researchers have had various notions as to how the factors of production should be identified and separated in specifying the production function. There are several other factors to be considered as well. Most researchers have estimated the production function for the entire

United States. Bauer (1968) suggested that studies of geographical areas would be appropriate.

There is another important consideration to be made regarding technology. In the specified model it is considered exogenous but, in fact, it could be considered endogenous. Not only is technology adopted more readily in periods of rising prices but its proxy research and extension expenditures are dependent largely upon each state's agricultural output. Output is dependent upon prices which are dependent upon numerous factors. The situation rapidly becomes complex and thus only a single equation model was used.

The Statistical Model

The statistical model used in this study was similar to those used by Griliches (1964) and Evenson (1967). The primary differences were in the aggregation of certain variables and in the method of handling technology, or research and extension expenditures.

The basic model was a single equation model in which gross output was related to several variables which were assumed to be exogenous. A Cobb-Douglas production function was assumed and was estimated with the following equation:

$$\text{Log } Q_{it} = \log b_o + w(s) \quad (b_1 \log T_{it}) + b_2 \log L_{it} + b_3 \log F_{it} + b_4 \log S_{it} + b_5 \log C_{it} + b_k D_{it}$$

where:

Q_{it} = gross agricultural output for each southeastern state

T_{it} = expenditures for technology by state and federal agencies in each state

L_{it} = expenditures for agricultural hired labor by farmers within each state

F_{it} = expenditures for feed and livestock by farmers within each state

S_{it} = expenditures for seed, fertilizer and lime, and miscellaneous expenses by farmers within each state

C_{it} = expenditures for capital and depreciation by farmers within each state

D_{it} = a block of thirteen dummy variables for the thirteen southeastern states with Tennessee omitted to avoid singularity

$W(s)$ = distributed lag function

and the subscripts:

i = 1-13 for the thirteen southeastern states

t = time for the years 1949 through 1968

The states considered in the study were the southeastern states--Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia. The states were selected so as to be a more or less homogeneous group. Agriculture in these states is more comparable than if all states in the United States are considered together.

The model uses both time series and cross-sectional data. It is assumed that all states have the same lag distribution and the same slope coefficients so only intercept dummies were used. The use of a smaller cross-section than used by other researchers makes this assumption more tenable.

The Variables

The Dependent Variable

The dependent variable, Q_{it} or gross agricultural output in each state in millions of dollars measured in 1968 dollars, was constructed by

summing farmer cash marketings, government payments to farmers, value of home consumption of farmers, and net farm inventory change (FIS 216 Supplement, Aug., 1970). The index of prices received by farmers for all farm products was used to convert the series to 1968 dollars (Economic Report of the President, Jan. 1969).

The Independent Variables

The independent variables were as follows:

T_{it} = technology. This variable is the sum of research and extension appropriations within each state each year (from mimeographed sheets furnished by USDA). Research appropriations are composed of federal appropriations plus state appropriations less the balance from the previous year. The values were converted to 1968 dollars by the implicit price deflator for the total gross national product (Economic Report of the President, Jan. 1969).

L_{it} = labor. This variable is the total expenditure for farm hired labor in each state in thousands of dollars (FIS 216 Supplement, Aug. 1970) converted to 1968 dollars by the index of prices paid for hired labor (Ag Prices, 1970).

F_{it} = total expenditures for feed and livestock in each state in thousands of dollars (FIS 216 Supplement, Aug., 1970) expressed in 1968 dollars using the index of prices paid for feed and livestock respectively (Ag Prices, 1970).

S_{it} = total expenditures for seed, fertilizer and lime expenses in each state in thousands of dollars (FIS 216 Supplement, Aug. 1970) expressed in 1968 dollars using the index of prices paid for seed, fertilizer, and all items in production re-

spectively (Ag Prices, 1970).

C_{it} = capital and depreciation. This variable is the farm expenditures for repair and operation of capital items and depreciation and other consumption of farm capital in each state in thousands of dollars (FIS 216 Supplement, Aug. 1970). This series is converted to 1968 dollars by the index of prices paid for all items in production (Ag Prices, 1970).

D_{it} = a block of thirteen state dummy variables. These variables are zero-one dummy variables for the thirteen southeastern states, i.e. this variable is equal to one for all observations for a particular state and zero otherwise. Tennessee was omitted to avoid singularity.

Other Statistical Considerations

Some consideration should be made as to why certain variables mentioned in the economic model were not included in the estimating equation. Ideally, land and education should be included in the production function. Education was eliminated because of a lack of data. To a certain extent, education is embodied into the farm hired wage rate which is reflected in the labor variable. Land is not included because the stock of land in the Southeast is assumed to have decreased insignificantly in the period of the study. Weather was not included because of measurement problems. The other variables were aggregated in a logical manner.

The time unit of the calendar year was chosen primarily because of the availability of data. Data prior to 1949 were unreliable for some variables other than technology. Data on the proxy variable for technology were available back to 1930 and were used in an effort to account for the lagged effect of technology.

Description of the General Polynomial Form of Distributed Lags

This study used a technique of estimating a distributed lag function which was developed by Tom Johnson (1969) and used previously by Mundy (1972). His technique allows the parameter space of the distributed lag function to be reduced.* This section will explain the technique in a general way and the following section will explain the technique as it applies to the statistical model. The general form of the lag function with, for purpose of brevity, one other independent variable, X_i, is as follows:

$$Y_t = b_i X_i + w(0)\ X_{t-0} + w(1)\ X_{t-1} + w(2)\ X_{t-2} + \ldots\ w(n)\ X_{t-(n-1)} \quad (1)$$

where the dependent variable Y is a function of the current X_i and n years of the X on which the finite lag distribution is imposed. This can be rewritten as:

$$\underset{(1x1)}{Y} = \underset{(1xk)}{X_i}\ \underset{(kx1)}{b_i} + \underset{(1xn)}{X}\ \underset{(nx1)}{w^{**}} \quad (2)$$

where k is the number of independent variables besides the lagged variable. The polynomial form allows for the reduction of parameter space, i.e. the polynomial form has fewer parameters to be estimated than this general lag structure. The lag distribution can thus be estimated without estimating n parameters. Also it is assumed that $w(s)>0$ and $\Sigma w(s) = 1$, i.e. there is no negative effect in any individual year and the total of all proportionate effect is 100% or 1.

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*This section and the following one draw heavily on Johnson (1969) and Mundy (1972).

**The following discussion will use matrix notation and matrix and vector sizes will be included beneath symbols.

The general polynomial form for generating lag weights is represented by the following equation:

$$w(s) = a_0 + a_1 s + a_2 s^2 + \ldots + a_{p-1} s^{p-1} \tag{3}$$

which is a p-1 degree polynomial containing p a's with p<n, and the lag time is s. Equation (3) can be written in matrix notation as:

$$\underset{(nx1)}{w} = \underset{(nxp)}{T} \quad \underset{(px1)}{a} \tag{4}$$

In expanded form this would be:

$$\begin{bmatrix} w(0) \\ w(1) \\ w(2) \\ . \\ . \\ . \\ w(n-1) \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & . & . & 0 \\ 1 & 1 & 1 & . & . & 1 \\ 1 & 2 & 4 & . & . & 2^{(p-1)} \\ . & . & . & & & . \\ . & . & . & & & . \\ . & . & . & & & . \\ 1 & (n-1) & (n-1)^2 & . & . & (n-1)^{(p-1)} \end{bmatrix} \begin{bmatrix} a_0 \\ a_1 \\ a_2 \\ . \\ . \\ . \\ a^{(p-1)} \end{bmatrix}$$

Replacing w in equation (2) with the right hand side of equation (4) results in the following:

$$\underset{(1x1)}{Y} = \underset{(1xk)}{X_i} \quad \underset{(kx1)}{b_i} + \underset{(1xn)\ Nxp)}{X} \quad \underset{(px1)}{T \quad a} \tag{5}$$

If we let

$$\underset{(1xn)}{X} \quad \underset{(nxp)}{T} = \underset{(1xp)}{V} \tag{6}$$

so that for each observation t, n years of data are transformed from X with the n x p matrix T where p is the number of columns in the matrix T and p minus one is the degree polynomial being considered and n is the

number of rows in the matrix T and n minus one is the length of the finite lag distribution being considered. The matrix V, then, is a vector of transformed X data where X in this study is the technology variable. After substituting V for XT in equation (5), the result is:

$$\underset{(1x1)}{Y} = \underset{(1xk)}{Xb} + \underset{(kx1)}{V}\ \underset{(1xp)}{a}\ \underset{(pxl)}{} \qquad (7)$$

the p variables V can be treated just like the other independent variables. Regressing Y on V will give least squares estimates of a's. The estimates of the a's are substituted into equation (3) to obtain the first approximation of the w's. The sum of the w's is equal to the total effect of technology and is equivalent to an estimated B value. The percentage of the effect for a single year or the lag distribution weights is obtained by dividing each w(s) by $\Sigma w(s)$.

The use of the general polynomial form of distributed lags was based on several reasons. First, this technique effectively reduces the parameter space which allowed the distributed lag to be included in the estimating equation without losing so many degrees of freedom. This technique also imposes no restrictions on the shape or timepath of the lag distribution as Evenson's "inverted V" lag distribution did. Other techniques either imposed restrictions on the lag distribution or presented analytical problems which were beyond the scope of this thesis. This method also can be incorporated into ordinary least squares technique of estimation.

Estimation Technique

The agricultural production function was specified previously in this chapter as:

$$Q_{it} = f(L_{it}, F_{it}, S_{it}, C_{it}, D_{mit}, T_{it}) \qquad (8)$$

Variables excluding state dummy variables were changed to the log form with the following equation resulting:

$$\text{Log } Q_{it} = \log b_0 + b_2 \log L_{it} + b_3 \log F_{it} + b_4 \log S_{it} + b_5 \log C_{it} + \sum_{m=6}^{17} b_m D_{mit} + \sum_{s=0}^{m-1} w(s) \log T_{i,t-s} \quad (9)$$

Assuming p equals 3, a second degree polynomial, and n equals 5, a four year lag, then the production function would be:

$$\text{Log } Q_{it} = b_0 + \sum_{i=2}^{5} b_i \log X_{it} + \sum_{m=6}^{17} b_m D_{mit} + \sum_{s=0}^{n-1} w(s) \text{ Log } T_{i,t-s} \quad (10)$$

where the w's are the lag weights, s is the lag time, n-1 is the number of lag weights, i is ith state of the thirteen southeastern states, and t is the year. Using a second degree polynomial and a four year lag, equation (10) becomes:

$$\text{Log } Q_{it} = \log b_0 + \sum_{i=2}^{5} b \log X_{it} + \sum_{m=6}^{17} b_m D_{mit} + w(0)\, X_t + w(1)\, X_{t-1} + w(2)\, X_{t-2} + w(3)\, X_{t-3} + w(4)\, X_{t-4} \quad (11)$$

where:

$$w(0) = a_0$$

$$w(1) = a_0 + a_1 + a_2$$

$$w(2) = a_0 + 2a_1 + 4a_2$$

$$w(3) = a_0 + 3a_1 + 9a_2$$

$$w(4) = a_0 + 4a_1 + 16a_2$$

which can be rewritten in matrix notation, with only V a included for simplicity, as:

$$Y = [X_t \; X_{t-1} \; X_{t-2} \; X_{t-3} \; X_{t-4}] \begin{bmatrix} 1 & 0 & 0 \\ 1 & 1 & 1 \\ 1 & 2 & 4 \\ 1 & 3 & 9 \\ 1 & 4 & 16 \end{bmatrix} \begin{bmatrix} a_0 \\ a_1 \\ a_2 \end{bmatrix} \tag{12}$$

This is the relationship expressed in equation (5):

$$Y = XTa$$

By using ordinary least squares estimation technique to regress the dependent variable, Q_{it}, on the dependent variables estimates of the structural parameters, $\hat{b}_i$'s and $\hat{a}_i$'s were obtained. In this study, lag distributions were estimated with polynomials of degree zero to five and with length of lag distributions from zero to nineteen years.

Criteria for Selection of the Degree of the General Polynomial and Length of Lag

There were three major criteria for choosing the degree of the polynomial and the number of years in the estimated lag distribution: (1) The coefficient of determination or R^2. Obviously, a higher R^2 explains a greater portion of the variation in the dependent variable. (2) The signs, magnitudes, and the significance of the structural parameter estimates. There are several other studies with which comparisons can be made. (3) The reasonableness of the estimated lag distributions. If estimates of the lag parameters, the a_i's, give negative w(s) when multiplied by the transformation matrix, T, then the lag function yielding those weights must be disregarded.

There is some amount of searching in this process. Alternate lages using twenty, fifteen, ten, five, and one years of research and extension expenditures were made. For each of these lags, runs were

made for each degree polynomial from zero to fifth degree. This meant that initially thirty estimations of the aggregate agricultural production function had to be made. By utilizing the above criteria, it was ascertained which of the above lags appeared to be the "best"; then intermediate years were examined.

CHAPTER III

RESULTS OF ESTIMATION

The Estimated Lag Distribution

Based on the criterion of reasonableness of the lag weights, all polynomials were eliminated because of negative weights except that of the zero degree. The number of years lag given a zero degree polynomial was chosen on the basis of R^2 (Table 1). A lag of nine years (current year and the eight previous years) had the highest R^2 and the t value for the estimated parameter of the transformed research and extension variable was the greatest. However, due to the small differences among the R^2's and the t values of the estimated parameter of the transformed research and extension variable, it appeared that a lag period of seven to ten years was appropriate. For the purpose of discussion, a nine year lag was used. The main difference between a lag of ten, nine, eight, or seven years was that ten percent, eleven percent, twelve percent, and fourteen percent of the effect would be felt each year of the respective lags. This lag period is similar to that of Evenson's (1967) which was six to seven years. The estimated coefficient ($\hat{b}_1$) is obtained summing the nine individual w's, which in the case of a zero degree polynomial are, of course, all equal.

The estimate of a_0 was .0065 so:

w(0) = .0065	w(5) = .0065
w(1) = .0065	w(6) = .0065
w(2) = .0065	w(7) = .0065
w(3) = .0065	w(8) = .0065
w(4) = .0065	w(9) = .0065

Table 1. Observations on zero degree polynomial lag distributions

Years of R & E expenditures	R^2	S_e	t value for a
20	.98243499	.02745610	.72305296
15	.98242231	.02746601	.46185210
10	.98254728	.02736820	1.39559130
9	.98257070	.02734983	1.50846030
8	.98256058	.2735776	1.46074758
7	.98256227	.02735644	1.46878650
6	.98250428	.02740189	1.16111600
5	.98246438	.02743312	.89133647
1	.98251650	.02739232	1.23214758

The sum of this series is .05861 which is the estimated total coefficient for the technology variable for a nine year lag. A one percent change in technology will result in a .05 percent change in farm output. But the total effect is spread over nine years at the rate of

$$\frac{w(s)}{\Sigma w(s)} = \frac{.0065}{.05861} = .111$$

or 11.1 percent of the total effect of technology takes place each year. The configuration of the lag distribution is shown in Figure 1.

Other studies, such as Bauer's, have indicated that longer lags existed for research and extension expenditures. Because Bauer considered the entire United States and the states involved in this study are more homogeneous, it would be expected that the lag would be shorter. There is a greater degree of homogeneity because production practices in this specific area are more similar than those of the entire United States.

Structural Parameters

Estimates of the structural parameters are shown in Table 2. The dummy variable for Tennessee is left out to prevent singularity. The production function for Tennessee would include the structural variables with all of the dummy variables excluded. The t-values for the dummy variables are used to determine if output of a particular state is significantly different from Tennessee. The t-values are used to test the hypothesis that $b_i > 0$ for the structural variables and that $b_i \neq 0$ for the dummy variables.

Of the structural variables, labor, feed and livestock, and seed, fertilizer, and lime were significant at the one percent level. The parameter "a" used to generate the lag distribution on technology was

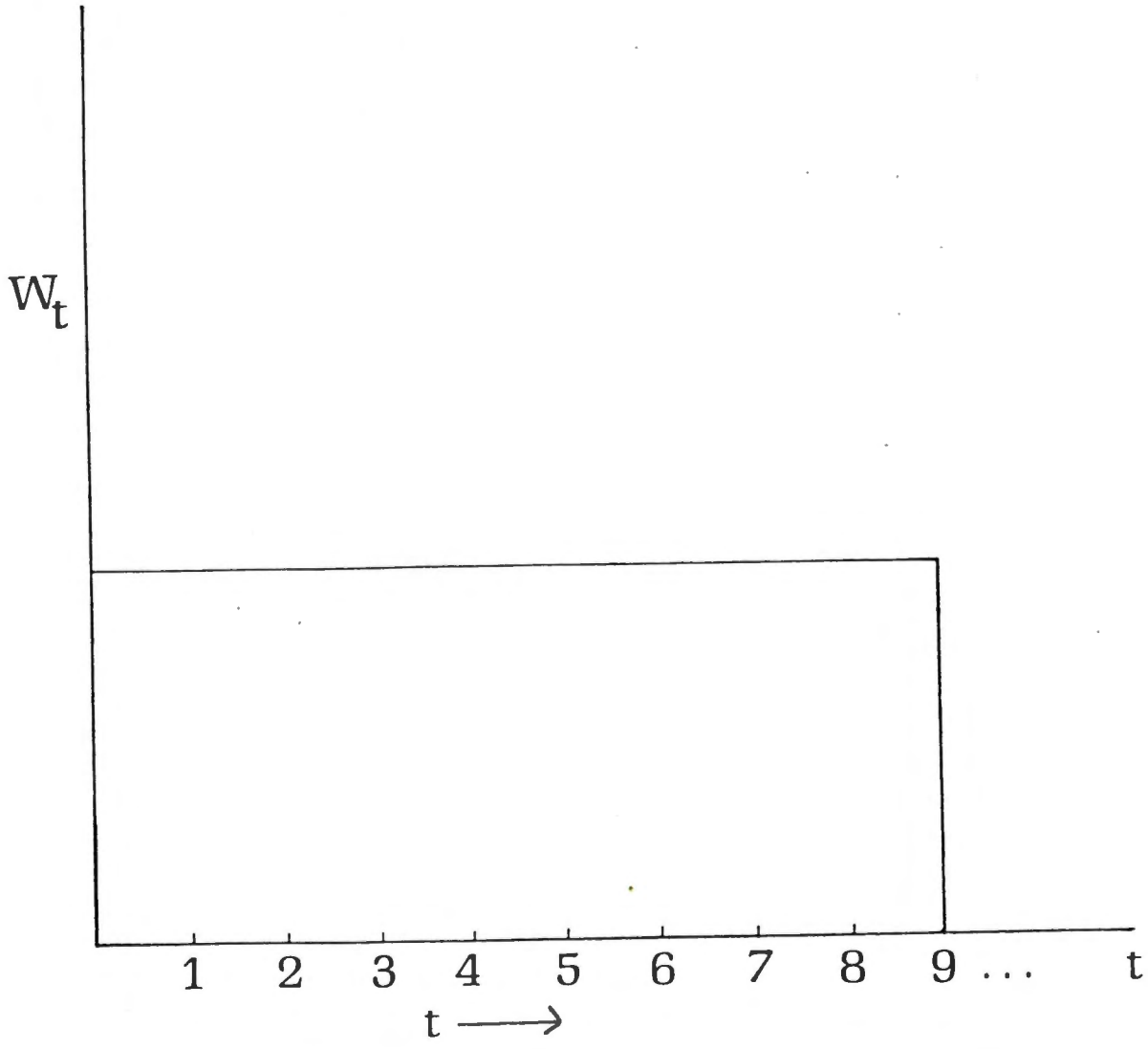


Figure 1. Lag distribution of the effect of technology on farm output, Southeastern U.S.

Table 2. Ordinary least squares estimates of the structural parameters and their t-value for the production function specified with zero-degree lag polynomials and nine back years of technology

Variable	Estimated coefficient	(t-value)	Level of significance* (Percent)
Constant term	-2.20303		
Labor	.17102	(6.639)	1
Feed and livestock	.21128	(9.424)	1
Seed, fertilizer, and lime	.53687	(13.169)	1
Capital and depreciation	.02182	(.419)	N.S.
Technology	.05861	(1.508)	10
State Dummies			
X_6 - Alabama	-.05129	-3.750	1
X_7 - Arkansas	-.03254	-2.549	5
X_8 - Florida	-.07511	-3.660	1
X_9 - Georgia	-.06392	-4.887	1
X_{10} - Kentucky	.04800	5.450	1
X_{11} - Louisiana	-02621	-1.651	10
X_{12} - Mississippi	-02668	-2.363	5
X_{13} - North Carolina	.04132	2.570	5
X_{14} - Oklahoma	.04196	1.390	N.S.
X_{15} - South Carolina	-.03888	-2.976	1
X_{16} - Texas	-.03205	-0.816	N.S.
X_{17} - Virginia	-.07535	-7.239	1

*The tests for significance for the structural variables were one-tailed tests while those for the dummy variables were two-tailed.

significant at the ten percent level while the coefficient for capital and depreciation was not significant.

The size of the coefficient of technology does not seem great. But for a ten percent increase in research and extension expenditures there will be a .586 percent increase in gross output. Examination of the data at the geometric mean of the data series indicates that an increase in research and extension expenditures of $800,000 would generate an increase in gross output of over $4,500,000. The rate of return is over five dollars for every dollar invested in research and extension activities. Even if half of the return is attributed to private research as Evenson suggests, there is nearly a 300 percent return.

The sum of the coefficients, labor, feed and livestock, seed, fertilizer, lime and miscellaneous, capital and depreciation, and technology, is .9996. This implies essentially constant returns to scale. Constant returns to scale occur when a small proportionate increase in all inputs gives rise to a proportionate increase in output. The sum of the coefficients is very similar to that of Bauer's while it is somewhat lower than the sums attained by Evenson and Griliches.

Marginal products were calculated for each of the exogeneous variables and are included in Table 3. The formula for calculating the marginal products was as follows:

$$MP_{xi} = b_i \frac{\hat{Y}}{\bar{X}_i}$$

where X_i was taken at its geometric mean and $\hat{Y}$ was calculated with all inputs held at their geometric mean. The geometric means of the exogenous variables are included in Table 4. The expected value of Y was calculated to be $767,800,000. The marginal product indicates the

Table 3. Marginal products of the specified factors of production

Variable	Marginal Product
Labor	1.478
Feed and livestock	1.672
Seed, fertilizer, lime, and miscellaneous	3.834
Capital and depreciation	.105
Technology	5.770

Table 4. Geometric means of the specified factors of production

Variable	Geometric Mean
Labor	$ 88,840,000
Feed and livestock	$ 97,030,000
Seed, fertilizer, lime, and miscellaneous	$107,500,000
Capital and depreciation	$159,100,000
Technology	$ 7,790,000

change in output resulting from a unit increment in a variable input. If the amount of labor was increased by $1,000, there would be an increase in output of $1,478. The magnitude of the marginal product of capital and depreciation relative to the other marginal products indicates that investments in capital items would be less profitable than in others.

The magnitude of the coefficient of research and extension is comparable to that of Griliches. The coefficients of technology of Bauer and Evenson were considerably higher. It must be pointed out that the aggregation of variables differed from study to study. These differences made comparisons of coefficients attained from various studies impractical.

CHAPTER IV

SUMMARY AND CONCLUSIONS

Summary

Agricultural output has been and likely will continue to be in a state of change. Basic to the changes in output has been tremendous change in agricultural inputs. The objectives of this study were to estimate the aggregate agricultural production function and to measure the impact and timepath of technology upon gross farm output for the Southeast.

The basic model used was a Cobb-Douglas production function which included a distributed lag function. The distributed lag function was included to allow for the effects of research and extension expenditures, a proxy variable for technology. The method of estimation of the production function was ordinary least squares regression with an incorporated distributed lag function on the technology variable. Several computer runs were made which allowed the length of the lag function to vary between zero and nineteen years. Also the degree of the polynomial form used for the lag distribution could vary from a zero to a fifth degree polynomial. The criteria used to select the model which best fit the data were: (1) the coefficient of determination, R^2, (2) the reasonableness of the estimated structural paramenter, and (3) the reasonableness of the estimated lag distributions.

The data covered the period 1949 to 1968, with the exception of research and extension expenditures for which it was necessary to go back through 1930 in order to estimate the distributed lag function. All structural variables were expressed in logarithms. The study used both

cross-sectional and time series data. Dummy variables were used to separate out the cross-sectional effects.

The final results indicated a nine year lag period based upon the previously mentioned criteria, but there was little difference among the lags of seven, eight, nine, or ten years. The lag distribution chosen was a zero degree polynomial form because all other forms generated negative weights which violated the third criterion.

The signs of the estimates of the structural parameters were consistent with theory. The magnitude of the estimates was not easily compared to other studies because of differences in aggregation. Though the magnitude of the coefficient for the technology variable was apparently not great, in reality technology had a significant impact upon gross output--over a 500 percent return on the investment. All structural variables except technology and capital and depreciation were significant at the one percent level with technology significant at the ten percent level and capital and depreciation insignificant.

Conclusions

Examination of the aggregate agricultural production function led to several observations. Technology should be included in the function. Other structural variables affected output as expected except for capital and depreciation.

Efforts to estimate the lagged effect of technology on output were only partially successful. Use of the general polynomial without restrictions on the signs of the weights which were obtained from the estimated a_i's allowed too much freedom and violated the assumption that there could be no negative effect on any time period.*

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*Mundy's study (1972) experienced this same difficulty.

A subsequent study by Mundy, Sappinton, and Bauer* in which the general polynomial was imposed upon a known lag distribution resulted in a perfect fit of the known data. However, when random error was introduced upon the independent variable, the generated a_i's produced negative weights when multiplied by the transformation matrix. Quadratic programming possibly could be applied to the analysis and restrict the weights to positive values.

Future studies might explore this area as a means of incorporating a lag distribution into the agricultural production function. Though objectives were only partially reached, there was benefit from the study in that economic knowledge was furthered in an area where relatively little analysis has been undertaken.

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*Unpublished work at U.T., 1973.

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VITA

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