Estimating the investment behavior of farm firms using the concept of national distributed lag functions

Billy J. Trevena

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To the Graduate Council:

I am submitting herewith a dissertation written by Billy J. Trevena entitled "Estimating the investment behavior of farm firms using the concept of national distributed lag functions." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Agricultural Economics.

Luther H. Keller, Major Professor

We have read this dissertation and recommend its acceptance:

Charles Sappington, Larry Bauer, Keith Phillips

Accepted for the Council:

Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)
April 13, 1972

To the Graduate Council:

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Major Professor

We have read this dissertation and recommend its acceptance:

Charles Hapgood
Larry J. Bauer
Keith E. Phillips

Accepted for the Council:

Vice Chancellor for Graduate Studies and Research
ESTIMATING THE INVESTMENT BEHAVIOR OF FARM FIRMS USING THE
CONCEPT OF RATIONAL DISTRIBUTED LAG FUNCTIONS

A Dissertation
Presented to
the Graduate Council of
The University of Tennessee

In Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy

by
Billy J. Trevena
June 1972
ACKNOWLEDGMENT

The author wishes to express his gratitude to everyone who helped make this study possible. He is especially indebted to the Department of Agricultural Economics for financial assistance throughout the graduate program.

To Dr. Luther H. Keller, the author expresses deep appreciation for the counsel, guidance, and encouragement he has willingly extended during the entire course of graduate study.

Appreciation is extended to the Department of Agricultural Economics Extension for the use of the Tennessee test demonstration farm records which were used in this study.

Acknowledgment is made of the assistance given by the secretarial staff of the Department of Agricultural Economics for their help in typing this manuscript.

Appreciation is expressed to Dr. Charles Sapplington, Dr. Larry Bauer, and Dr. Keith Phillips for serving on the graduate committee and reviewing this manuscript. Appreciation is also extended to Dr. T. J. Whatley and his entire staff for their guidance, instruction, and concern throughout the period of graduate study.

And finally, the author wishes to express his gratitude to his wife, Betty, and children, Billy and Lisa, for their patience, understanding, and sacrifices, both mental and material, during the graduate program.
ABSTRACT

The purpose of this study was to estimate the investment behavior function of individual farm firms using the concept of rational distributed lag functions developed by Jorgenson to estimate the time structure of the investment process. The fundamental flexible accelerator model was used to estimate the investment behavior function. The model assumed net investment to be a lagged function of all changes in desired capital. Desired capital was assumed to be proportional to net farm income and gross farm income, respectively, for the expected profits and accelerator theories of investment.

Because of the importance of the proper specification of the lag distribution in determining the time structure of the investment process, eight lag functions were imposed on the estimating equation for the expected profits and accelerator theories of investment.

In addition to the mechanism for converting changes in desired capital into changes in actual capital, nonfarm income, size of the farm firm, age of the farmer, and equity of the farmer in the farm business were added to the estimating equation in a linear fashion to establish the effect of these variables on net investment.

Observations on 180 Tennessee test demonstration farms for the four-year period, 1965-1968, were used to estimate the parameters of the lag distribution and the structural equation. The data included observations on Grade A dairy farms, farms producing manufacturing
milk, swine farms, and beef farms. A dummy variable for each of these farm classifications was added to the estimating equation to account for the effect of farm classification on the investment expenditures of the cross section of farms.

The expected profits theory of investment was rejected by this study as an explanation of the investment behavior of this group of farmers. The accelerator theory of investment appeared to be a better explanation of investment. The lag distribution relating changes in gross income to net investment involved only two periods. One distribution accounted for 83 percent of the total effect in the first year while a second accounted for 93 percent in the first period.

The estimates of the structural parameters of the accelerator model varied considerably with the lag function being estimated; however, some weak relationships were revealed. It appeared that as changes in gross income increased by $1.00, net investment increased by approximately $1.53 to $1.69 given time for the adjustment to occur. Each $1.00 increase in nonfarm income seemed to have a negative effect on net investment ranging from -$13.00 to -$11.00. Each $1.00 increase in the size of the farm business increased net investment by about $0.12. The effect of age and number of dependents of the farmer could not be determined by this study. A positive relationship was estimated between equity of the farmer in the farm business and net investment ranging from 0.08 to 0.12.

A weak relationship was interpreted regarding the effect of farm classification on net investment. In general, Grade A dairy farmers
were the least likely to invest; all other variables held constant. They were followed in order of unwillingness to invest, all other variables held constant, by swine farmers, farmers producing manufacturing milk, and beef farmers.

The distributed lag theory and estimating procedure used in this study are theoretically sound, but the results of this study were not encouraging because of the instability of the structural parameter estimates between lag function specifications and the problem of obtaining an acceptable lag distribution. The evidence indicated variables other than those accounted for in this study play an important role in the investment behavior of Tennessee farmers.
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One of the mainstays of industrial economic life has long been growth and merger. Farming has seen some of this, but on a much smaller scale than in other industries. Yet, with growing farm-nonfarm interdependence, it is at least conceivable that growth in size of farm production units will be the dominant historical theme of this century. This study grew out of an interest in this growth process.

Fundamental to the study of growth of the farm firm is the interrelationship between short-run production theory and longer run investment theory which varies the firm's fixed resources. Most farm firm growth models combine an arbitrarily fixed consumption level with production theory to arrive at the flow of capital funds between production periods (11). Models using this approach assume that all income in excess of that needed for consumption in the current production period is transferred to the succeeding production period to be used as operating capital and investment capital. Investment occurs when needed to optimize the value of the objective function of the model if investment funds are available. This approach reveals very little about the investment process; it simply gives some insights into how a farm firm can grow given the resource base of the firm and a particular set of assumptions. A more realistic mechanism is needed in growth studies for transferring not only operating capital but investment capital to
future time periods. A more realistic notion concerning the investment behavior of the individual farm firm is necessary if models are to adequately describe firm growth. Once a stable investment behavior function is identified, dynamic growth models can be used to describe and predict farm firm growth.

Considerable effort has been devoted to estimating the appropriate investment behavior function for industrial corporations; however, a search of the literature revealed no estimates of such a function for individual farm firms. The purpose of this study was to investigate the nature of the investment behavior function for individual farm firms using time series and cross-sectional data on a group of Tennessee test demonstration farms.

Specifically, the purpose of this study was to estimate the investment behavior function for individual farm firms using the concept of rational distributed lag functions developed by Jorgenson (13) to estimate the time structure of the investment process. To do this, a class of rational distributed lag functions was imposed on a multiple regression model to obtain the lag distribution that best describes the time path of the investment response to changes in gross farm income and net farm income, respectively.

The rest of this chapter is devoted to background material relevant to the problem. Chapter II provides a general discussion of the theory of distributed lags. The model, source of data, and estimating procedure are discussed in Chapter III. Chapter IV presents the results of the study.
I. THEORIES OF CORPORATE INVESTMENT

Theories to explain the investment activities of industrial corporations utilize some form of the fundamental flexible accelerator model developed by Chenery (3) and Koyck (17) as the basic investment behavior model. The model assumes the firm has a desired level of capital stock, \( K_t^* \), and an actual level of capital stock, \( K_t \). Assuming that actual capital is determined by a weighted average of all past levels of desired capital, Equation (1.1) defines the level of actual capital at any point in time. The adjustment model, Equation (1.2), is obtained by taking the first difference of both sides of Equation (1.1),

\[
K_t = \sum_{j=0}^{\infty} \beta_j K_{t-j}^*
\]

\[
I_t = \sum_{j=0}^{\infty} \beta_j (K_{t-j}^* - K_{t-j-1}^*)
\]

Net investment in the current period, \( I_t \), represents the difference between actual capital stock in the current and the previous period. If \( \beta_1, \beta_2, \ldots, \beta_j, \ldots \) are all equal to zero, the entire adjustment in actual capital associated with a change in desired capital is accomplished during the current period. But if \( \beta_1, \beta_2, \ldots, \beta_j, \ldots \) are not all equal to zero, only a part of the adjustment is completed during the current period; consequently, the adjustment process will be distributed over several time periods. Koyck (17), Chenery (3),
Grunfeld (7), Nerlove (24), (25), et al., assumed the form of the distributed lag function to be that of a declining geometric progression (series) in which the proportion of total net investment in the current period is given by $\lambda$, and the proportion of total net investment in each of the succeeding periods is a constant fraction $(1-\lambda)$ of the preceding period. Using this formulation, net investment at any point in time is represented by Equation (1.3),

\[ I_t = \beta \sum_{j=0}^{\infty} \lambda(1-\lambda)^j (K_{t-j} - K_{t-j-1}) \]

where $\beta$ represents the coefficient of total net investment expenditures for the current period associated with all past changes in desired capital stock.

With the declining geometric lag distribution, the largest investment response to a change in desired capital occurs during the first period, and all succeeding responses decline monotonically. However, such a monotonically declining lag distribution may not best describe the observed data. The importance of the form of the lag distribution used for estimating corporate investment behavior has clearly been recognized (9), (15), and (16). By imposing Jorgenson's class of rational distributed lag functions on the data, a lag distribution that best describes the time structure of the response of net investment expenditures to changes in desired capital stock can be obtained because the lag distribution is not constrained to a particular
configuration. Jorgenson and Siebert, using time series data for a representative sample of firms selected from Fortune Directory of the 500 largest U. S. industrial corporations for 1962, indicate that in all cases a class of rational distributed log functions imposed on the data produced an estimated lag distribution superior to any of the constrained functional forms they tried in their regression analysis (16). Superiority of the estimated lag distribution was determined on the basis of minimum residual variance around the regression.

II. DEFINITIONS OF DESIRED CAPITAL

Researchers agree on the use of the fundamental flexible accelerator model as the basic adjustment model for explaining corporate investment. The area of disagreement concerns the proper specification of desired capital. The literature reveals that at least four general theories concerning the definition of desired capital has evolved.\(^\text{1}\)

The first of these theories assumes that desired capital is proportional to output, and it has become known as the "capacity utilization theory" or the "accelerator theory." It was developed by Chenery (3) and Koyck (17) and was later substantiated by Eisner (5), (6), Hickman (10), and Kuh (19).

A second theory as developed by Tinbergen (27) can be termed the "expected profits theory." It assumes desired capital is

\(^1\)See Jorgenson and Siebert (16) for a complete description of these theories.
proportional to expected profits. The question that arises with this theory concerns expected profits. How are expected profits determined? Tinbergen assumes realized profits to be a good measure of expected profits. Grunfeld (7); however, suggests that actual profits are just another measure of the value of the firm. So, he uses the market value of the firm in the securities market as a proxy variable to represent expected profits.

The "liquidity theory of investment" as used by Kuh (19) is the third theory concerning the definition of desired capital. According to this theory, investment expenditures depend on the internal funds available to the firm for investment. These funds are measured as profits after taxes plus depreciation less dividends paid (16, p. 694). It states that desired capital is proportional to the liquidity of the firm.

The fourth theory, developed by Jorgenson, is the "neoclassical theory of investment" (14), (15). It utilizes the theory of the cost and returns to capital. According to the neoclassical theory of investment, desired capital is proportional to the value of the output of the firm divided by the cost of capital.²

In this study it was possible to test only the accelerator and expected profits theories of investment because of the nature of the

²For a complete discussion of the cost of capital, see Modigliani and Miller (20), (21), (22), (23).
available data. In testing the accelerator theory, desired capital was assumed to be proportional to gross farm income, $I_g$, measured as total cash receipts plus changes in inventory of feed, supplies, and non-breeding livestock.

To test the expected profits theory, desired capital was assumed to be proportional to net farm income, $I_n$, measured as gross farm income minus total farm expenses.
Suppose a given change in an independent variable X has an effect on some dependent variable Y not only in the time period when X changes but in succeeding periods as well. The values of the parameters \( \alpha_0, \ldots \) in Equation (2.1) expresses the time shape of this relationship,

\[
y_t = \alpha_0 x_t + \alpha_1 x_{t-1} + \ldots + \alpha_j x_{t-j} + \ldots
\]

Assuming \( \sum_{t=0}^{\infty} \alpha_t = \beta \), Equation (2.1) can be expressed as:

\[
y_t = \beta (\alpha_0 x_t + \alpha_1 x_{t-1} + \ldots + \alpha_j x_{t-j} + \ldots)
\]

where \( \alpha_j \geq 0 \) and \( \sum_{j=0}^{\infty} \alpha_j = 1 \).

In this expression, \( \beta \) represents the total effect of a change in X on Y given time for the total effect to occur and \( \alpha_j \beta \) represents the partial effect of a change in X on Y defined for a change in X during the time period \( t-j \).

If the parameters of Equation (2.2) are unknown, they must be estimated to find the effect of X on Y and the time path of that effect. But, Equation (2.2) is an infinite series and can be estimated only with a very large number of lagged values of X. Therefore, some type
of reduction technique is necessary to perform the estimation task. Koyck (17) developed such a technique for the declining geometric distribution which allows the estimation of the parameters with only one lagged variable. Jorgenson (13) has developed a reduction technique for estimating the parameters of any lag distribution. His class of rational distributed lag functions is sufficiently general to include the simple geometric distribution and other more complicated distributions as well.

I. RATIONAL DISTRIBUTED LAG FUNCTIONS

Using the general notation of the distributed lag operator $L$ (8, p. 21), where:

\[
L X_t = X_{t-1} \\
L^2 X_t = X_{t-2} \\
\vdots \\
L^j X_t = X_{t-j}
\]

Equation (2.2) can be shortened to Equation (2.3),

\[
(2.3) \quad Y_t = \beta \left( p_0 + p_1 L + p_2 L^2 + \ldots + p_j L^j + \ldots \right) X_t
\]

The part inside the parentheses represents an infinite power series or infinite polynomial in $L$ written in the open form. Denoting this polynomial as $P(L)$, Equation (2.3) can be represented by
Equation (2.4). By the assumptions of Equation (2.2), \( P(L) \) is a convergent series and can be viewed as a rational generating function

\[
Y_t = \beta P(L) X_t
\]

for the \( P's \) (8). Hence, \( P(L) \) can be expressed in the closed form, i.e., \( P(L) \) can be factored into a ratio of two finite polynomials in \( L \) as shown in Equation (2.5),

\[
P(L) = \frac{U(L)}{V(L)} = \frac{U_0 + U_1 L + U_2 L^2 + \ldots + U_i L^i}{V_0 - V_1 L - V_2 L^2 - \ldots - V_i L^i}.
\]

By normalizing \( U(L) \) and \( V(L) \) and dividing through by \( V(L) \), Equation (2.4) becomes Equation (2.6)

\[
Y_t = V_1 Y_{t-1} + V_2 Y_{t-2} + \ldots + V_i Y_{t-i} + \beta X_t + \beta U_1 X_{t-1}
\]

\[+ \beta U_2 X_{t-2} + \ldots + \beta U_j X_{t-j}\]

which represents a class of distributed lag functions from which it is possible to estimate the parameters of the lag function which describes best the data on which this class of lag functions is imposed. For this sequence to be an acceptable distributed lag function (nonnegative and convergent) it is sufficient for both sequences defined by \( U(L) \) and \( V(L) \) to be convergent and nonnegative" (8, p. 23). This requires that

\[3\]To normalize these polynomials means to set \( U_0 \) and \( V_0 \) equal to one.
the roots of the auxiliary difference equation defined by $V(L)$ be real and positive but less than one. As pointed out by Jorgenson, they do not have to be equal, and for this discussion will be assumed to be unequal.

As an example of a lag distribution written in open form, consider Equation (2.7),

$$Y_t = \beta [\lambda X_t + \lambda(1-\lambda) X_{t-1} + \lambda(1-\lambda)^2 X_{t-2} + \lambda(1-\lambda)^3 X_{t-3} + \ldots]$$

where: $0 \leq \lambda \leq 1$

which is the simple geometric distribution of Equation (1.3). To

Suppose $P(L) = \frac{1}{V(L)} = \frac{1}{V_0 + V_1 L + V_2 L^2 + \ldots + V_i L^i}$, substituting into Equation (2.4) and dividing through by $V(L)$ yields:

$$Y_t - V_1 Y_{t-1} - V_2 Y_{t-2} - \ldots - V_i Y_{t-i} = \beta X_t.$$ 

By setting the right-hand side of this equation equal to zero, we get the auxiliary equation of the $i$th ordered difference equation defined by $V(L)$. The general solution of this auxiliary equation yields:

$$Y_t = C_1 \lambda_1^t + C_2 \lambda_2^t + \ldots + C_i \lambda_i^t$$

where $C_1, C_2, C_3, \ldots C_i$ are constant terms defined by the initial conditions, and $\lambda_1, \lambda_2, \lambda_3, \ldots \lambda_i$ are the unequal roots of this $i$th ordered difference equation.

Jorgenson chose to call this form of the class of distributed lag functions the general pascal distribution because the roots of the auxiliary difference equations do not have to be equal as in the pascal distributions (2, p. 139).
estimate the effect of $X$ on $Y$ using Equation (2.7) requires a large number of lagged variables; however, with the use of the lag operator, the infinite series can be expressed in closed form which allows the effect of $X$ on $Y$ to be estimated with only one lagged variable. To illustrate, the closed form of the infinite series in $L$ is expressed by Equation (2.8),

\begin{equation}
(2.8) \quad P(L) = \frac{U(L)}{V(L)} = \frac{\lambda}{1 - (1-\lambda) L}
\end{equation}

for the declining geometric distribution. When applied to Equation (2.7), the estimating equation becomes:

\begin{equation}
(2.9) \quad Y_t = (1-\lambda) Y_{t-1} + \beta \lambda X_t.
\end{equation}

A monotonically declining function throughout may not be the most desirable functional form for all situations; hence, by utilizing Jorgenson's class of rational distributed lag functions, the so-called best function can be estimated. This class is sufficiently general to include not only the geometric distribution but others more complicated as well.

II. WEIGHTS OF THE LAG DISTRIBUTION

Once the parameters of $U(L)$ and $V(L)$ have been estimated from the data, the division implied by $P(L) = U(L)/V(L)$ enables the desired weights ($P_0, P_1, P_2, \ldots, P_j \ldots$) of the distributed lag function
to be obtained (2, p. 38). If \( i \) is equal to \( j \) in Equation (2.5), this division will produce the following polynomial: \(^6\)

\[
A(L) = A_0 + A_1 L + A_2 L^2 + A_3 L^3 + \ldots + A_j L^j + \ldots
\]

where:

\[
A_0 = 1
\]

\[
A_1 = U_1 + V_1
\]

\[
A_2 = (U_2 + V_2) + V_1 A_1
\]

\[
A_3 = (U_3 + V_3) + V_2 A_1 + V_1 A_2
\]

\[
A_4 = (U_4 + V_4) + V_3 A_1 + V_2 A_2 + V_1 A_3
\]

\[
A_5 = (U_5 + V_5) + V_4 A_1 + V_3 A_2 + V_2 A_3 + V_1 A_4
\]

\[\vdots\]

\[
A_j = (U_j + V_j) + V_{j-1} A_1 + V_{j-2} A_2 + \ldots + V_2 A_{j-2} + V_1 A_{j-1}
\]

\[
A_{j+1} = V_j A_1 + V_{j-1} A_2 + V_{j-2} A_3 + \ldots + V_2 A_{j-2} + V_1 A_{j-1}
\]

\[
A_{j+2} = V_j A_2 + V_{j-1} A_3 + V_{j-2} A_4 + \ldots + V_2 A_{j-2} + V_1 A_{j-1} + V_1 A_j
\]

\[
A_{j+3} = V_j A_3 + V_{j-1} A_4 + V_{j-2} A_5 + \ldots + V_2 A_{j-1} + V_1 A_{j+1}
\]

\[\vdots\]

\[
A_t = V_j A_{t-j} + V_{j-1} A_{t-j+1} + \ldots + V_1 A_{t-1}
\]

\(^6\)Where the polynomial \( A(L) \) is an intermediate step in the derivation of the desired polynomial \( P(L) \). See Bauer (2, p. 29).
Since the desired weights \((P_0, P_1, \ldots, P_t)\) must sum to one, each of the terms in \(A(L)\) must be divided by \(\sum_{t=0}^{\infty} A_t\). The desired polynomial \(P(L)\) becomes:

\[
P(L) = \frac{A(L)}{\Sigma A_t} = \frac{A_0}{\Sigma A_t} + \frac{A_1}{\Sigma A_t} L + \frac{A_2}{\Sigma A_t} L^2 + \ldots + \frac{A_j}{\Sigma A_t} L^j + \frac{A_{j+1}}{\Sigma A_t} L^{j+1} + \ldots
\]

\[
P(L) = P_0 + P_1 + P_2 + \ldots + P_j + \ldots
\]

The sum of the series \(A(L)\) is:

\[
A_0 = 1
\]

\[
A_1 = U_1 + V_1
\]

\[
A_2 = (U_2 + V_2) + V_1 A_1
\]

\[
A_3 = (U_3 + V_3) + V_2 A_1 + V_1 A_2
\]

\[
\vdots
\]

\[
A_j = (U_j + V_j) + V_{j-1} A_1 + V_{j-2} A_2 + \ldots + V_2 A_{j-2} + V_1 A_{j-1}
\]

\[
A_{j+1} = V_j A_1 + V_{j-1} A_2 + V_{j-2} A_3 + \ldots + V_2 A_{j-1} + V_1 A_j
\]

\[
A_{j+2} = V_j A_2 + V_{j-1} A_3 + V_{j-2} A_4 + \ldots + V_2 A_j + V_1 A_{j+1}
\]

\[
\vdots
\]

\[
A_t = V_j A_{t-j} + V_{j-1} A_{t-j+1} + V_{j-2} A_{t-j+2} + \ldots + V_1 A_{t-1}
\]
\[
\sum_{t=0}^{\infty} A_t = 1 + (U_1 + V_1) + (U_2 + V_2) + \ldots + (U_j + V_j) + \\
A_1(V_1 + V_2 + \ldots + V_j) + A_2(V_1 + V_2 + \ldots + V_j) + \ldots + \\
A_j(V_1 + V_2 + \ldots + V_j) + \ldots
\]

\[
\sum_{t=0}^{\infty} A_t = 1 + (U_1 + U_2 + \ldots + U_j) + (V_1 + V_2 + \ldots + V_j) + \\
\sum_{t=1}^{\infty} A_t (V_1 + V_2 + \ldots + V_j)
\]

\[
\sum_{t=0}^{\infty} A_t = 1 + U_1 + U_2 + \ldots + U_j + \sum_{t=0}^{\infty} A_t (V_1 + V_2 + \ldots + V_j)
\]

\[
\sum_{t=0}^{\infty} A_t = \frac{1 + U_1 + U_2 + \ldots + U_j}{1 - V_1 - V_2 - \ldots - V_j}
\]

The desired weights are:

\[
P_0 = \frac{A_0}{\Sigma A_t} = \frac{1}{\Sigma A_t} = \frac{1 - V_1 - V_2 - \ldots - V_j}{1 + U_1 + U_2 + \ldots + U_j}
\]

\[
P_1 = \frac{A_1}{\Sigma A_t} = U_1 + V_1/\Sigma P_t = \frac{U_1 (1 - V_1 - V_2 - \ldots - V_j)}{1 + U_1 + U_2 + \ldots + U_j} + \\
\frac{V_1 (1 - V_1 - V_2 - \ldots - V_j)}{1 + U_1 + U_2 + \ldots + U_j} = U_1 P_0 + V_1 P_0 = (U_1 + V_1) P_0
\]

\[
P_2 = \frac{A_2}{\Sigma A_t} = [(U_2 + V_2) + V_1 A_1]/\Sigma P_t = (U_2 + V_2) P_0 + V_1 P_1
\]
The foregoing discussion is useful for the development of the general theory of the class of distributed lag functions as discussed by Jorgenson, but the use of large polynomials for \( U(L) \) and \( V(L) \) is of little practical value because data usually does not permit the estimation of coefficients of polynomials with several lagged values of the variables under consideration. There will probably be little interest in polynomials of orders higher than two or three. The eight functional forms listed in Table I will, therefore, be sufficient for most situations. The eight functions, \( A(L) = \frac{U(L)}{V(L)} \), are listed by number. Function 1 is the most general case. By allowing the parameters \( U_1, U_2, V_1, \) and \( V_2 \) of the most general case to assume zero values, the other seven functions can be estimated.
<table>
<thead>
<tr>
<th>Function Number</th>
<th>$U(L)$</th>
<th>$V(L)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$1 + U_1L + U_2L^2$</td>
<td>$1 - V_1L - V_2L^2$</td>
</tr>
<tr>
<td>2</td>
<td>$1 + U_1L$</td>
<td>$1 - V_1L - V_2L^2$</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>$1 - V_1L - V_2L^2$</td>
</tr>
<tr>
<td>4</td>
<td>$1 + U_1L + U_2L^2$</td>
<td>$1 - V_1L$</td>
</tr>
<tr>
<td>5</td>
<td>$1 + U_1L$</td>
<td>$1 - V_1L$</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>$1 - V_1L$</td>
</tr>
<tr>
<td>7</td>
<td>$1 + U_1L + U_2L^2$</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>$1 + U_1L$</td>
<td>1</td>
</tr>
</tbody>
</table>
III. CONSTRAINTS ON THE PARAMETERS OF THE LAG FUNCTIONS

As pointed out by Jorgenson, the roots of the auxiliary difference equation defined by \( V(L) \) in Equation (2.5) do not have to be equal, but they do have to be positive and less than one for a stable lag distribution. This places rather strict constraints on the admissible range of values for the parameters of the lag distribution to be estimated.

To aid the discussion, consider the rather simple rational function defined by Equation (2.10)

\[
U(L) = \frac{1}{1 - V_1 L - V_2 L^2}
\]

where \( U(L) \) is of zero order and \( V(L) \) is a second ordered polynomial in the lag operator.\(^7\) The rationale of the restrictions can be seen by considering the second ordered polynomial (2.11):

\[
V(L) = (1 - \lambda_1 L)(1 - \lambda_2 L) = 1 - \lambda_1 L - \lambda_2 L^2.
\]

Using the quadratic formula, it can be shown that \( V_1 \) equals \( \lambda_1 + \lambda_2 \) and \( V_2 \) equals \( -\lambda_1 \lambda_2 \).

\[
\lambda_1 = \frac{1}{2} (-V_1) + \frac{1}{2} \sqrt{(-V_1)^2 - 4V_2} = \frac{1}{2} (V_1 + \sqrt{V_1^2 + 4V_2})
\]

\(^7\)This discussion draws heavily on the work of Bauer (2) and Griliches (8).
\[
\lambda_2 = \frac{1}{2} - (-v_1) - \sqrt{(-v_1)^2 - 4 (-v_2)}
\]

\[
= \frac{1}{2} (v_1 - \sqrt{v_1^2 + 4v_2})
\]

\[
\lambda_1 + \lambda_2 = \frac{1}{2} (v_1 + \sqrt{v_1^2 + 4v_2}) + \frac{1}{2} (v_1 - \sqrt{v_1^2 + 4v_2})
\]

\[
= \frac{1}{2} v_1 + \frac{1}{2} v_1
\]

\[
= v_1
\]

\[
- \lambda_1 \lambda_2 = - \frac{1}{2} (v_1 + \sqrt{v_1^2 + 4v_2}) \cdot \frac{1}{2} (v_1 - \sqrt{v_1^2 + 4v_2})
\]

\[
= - \frac{1}{4} (v_1^2 - v_1^2 - 4v_2)
\]

\[
= v_2.
\]

Because \(0 < \lambda_1 < 1\) and \(0 < \lambda_2 < 1\), it follows that \(0 < v_1 < 2\), since \(v_1 = \lambda_1 + \lambda_2\). Also, the condition \(v_1^2 > 4v_2\) must be satisfied in order to have real numbers where the estimate of \(v_2\) is negative.

The weights for this distribution are:

\[
P_0 = (1 - v_1 - v_2)
\]

---

The general solution of the auxiliary difference equation defined by \(V(L) = (1 - \lambda_1 L) (1 - \lambda_2 L)\) is:

\[
A_1 \lambda_1^t + A_2 \lambda_2^t
\]

where \(\lambda_1\) and \(\lambda_2\) are unequal roots and the values of \(A_1\) and \(A_2\) are defined by the initial conditions.
\[ P_1 = (1 - V_1 - V_2) + V_1 P_0 \]
\[ P_2 = V_2 P_0 + V_1 P_1 \]
\[ P_3 = V_2 P_1 + V_1 P_2 \]
\[ \vdots \]
\[ P_t = V_2 P_{t-2} + V_1 P_{t-1} \]  

In order to have positive weights in all periods, the relationship \((1 - V_1 - V_2) > 0\) must be satisfied.

Four conditions can now be defined that must be satisfied by the estimates of \(V_1\) and \(V_2\) in order that the weights of the lag distribution be acceptable. These conditions are:

1. \(0 < V_1 < 2\)
2. \((1 - V_1 - V_2) > 0\)
3. \(-1 < V_2 < 1\)
4. \(V_1^2 \geq -4V_2\).

To fully comprehend how stringent these constraints are on the admissible range of values for the estimated parameters of the lag distribution, consider Figure 1. If all these conditions are satisfied but the estimated values of \(V_1\) and \(V_2\) satisfy the conditions \(0 < V_1 < 1\) and \(0 < V_2 < 1\), one root of the auxiliary difference equation will be positive and one will be negative. For large absolute values of the
Two equal positive roots: \( V_1^2 = -4V_2 \)

Two positive roots

Complex roots

Unstable: roots > 1.0

One positive, one negative root

Figure 1. Constraints on the admissible range of parameter estimates of the log distribution. (These constraints apply to the following log function: \( P(L) = \frac{1}{1-V_1} \frac{1}{L-V_2} L \),)

negative root, the estimated lag distribution becomes quite wiggly and unsatisfactory. The small area bounded by $V_1 < 1$, $V_2 < 0$, and $V_1^2 = -4V_2$ gives rise to lag distributions similar to the Koyck distributions but converging to zero somewhat faster. The thin pie-shaped area bounded by $1 < V_1 < 2$, $V_1 + V_2 = 1$, and $V_1^2 = -4V_2$ gives rise to lag distributions with the maximum relative effect of a change in X on Y after a passage of time rather than in the initial time period as with the Koyck distribution.

When the most general lag function used in this study was considered, additional constraints had to be satisfied to obtain an acceptable set of weights for the estimated lag distribution. The weights for a second ordered polynomial in L for both the numerator, $U(L)$, and denominator $V(L)$ are:

$$P_0 = \frac{1 - V_1 - V_2}{1 + U_1 + U_2}$$

$$P_1 = (U_1 + V_1) P_0$$

$$P_2 = (U_2 + V_2) P_0 + V_1 P_1$$

$$P_3 = V_2 P_1 + V_1 P_2$$

$$\vdots$$

$$P_t = V_2^t P_{t-2} + V_1^t P_{t-1}$$

The values of the parameters of $U(L)$ influence the weights of the estimated lag distribution only in the initial, first lagged and
second lagged periods; hence, in order for $P_0$, $P_1$ and $P_2$ to have positive weights, three additional constraints can be delineated. They are:

1. $(1 + U_1 + U_2) > 0$
2. $-U_1 < V_1$
3. $-U_2 < V_2 + V_1(U_1 + V_1)$.

If $U(L)$ is a first ordered polynomial in $L$, the values of the parameters of $U(L)$ influence only the weights in the initial and first lagged periods; hence, constraint 3 can be ignored and constraint 1 must be modified.

An acceptable estimated lag distribution was evaluated in terms of these constraints for each of the eight functions in Table I, page 17, and for the accelerator and expected profits theories of investment, respectively.
CHAPTER III
THE STRUCTURAL MODEL AND ESTIMATION PROCEDURE

In this study desired capital as defined by the accelerator theory and the expected profits theory was used in the fundamental flexible accelerator model to estimate a representative individual farm firm investment behavior function. The flexible accelerator model used assumed that actual capital is a lagged function of all levels of desired capital. The adjustment model, Equation (3.1), assumed net investment, $I_t$, is a lagged function of all changes in desired capital. Because of the importance of the proper specification of the lag distribution in determining the time structure of the investment process, Equation (3.1) was generalized to include the class of rational distributed lag functions as described by Jorgenson (12). When the polynomial $P(L)$ was used to represent this general class of lag functions, the adjustment model became Equation (3.2),

$$I_t = \sum_{j=0}^{\infty} \beta_j (K^*_t - K^*_{t-j-1})$$

The polynomial $P(L)$ can be written as a polynomial in the rational form $U(L)/V(L)$. For estimating purposes, the second order was the highest ordered polynomials of $U(L)$ and $V(L)$ used in this study.
I. SOURCE OF DATA USED

This study utilized observations on 180 Tennessee test demonstration farms for the four-year period, 1965 through 1968. The Tennessee test demonstration program was originated in the mid-1930's to demonstrate the effectiveness of fertilizer use and erosion control practices on achieving agricultural progress in the Tennessee Valley. The emphasis has shifted in recent years to demonstrate the effectiveness of resource use adjustment in achieving agricultural progress in the Tennessee Valley. The program requires farmers with the assistance of special extension agents working in this program to keep accurate records on the farm business. Records are consistent for all farms, checked for accuracy by competent personnel, and systematically analyzed at the end of each calendar year. Because of the procedures used in record keeping, collection, and summarization of this data, it can be considered highly reliable.

Four classifications of farms were included in the study. Farmers were classified on the basis of income source. If 50 percent or more of gross farm income was derived from Grade A dairy, manufacturing milk, swine or beef, the farm was classified into one of these four groups.

The sample included 63 Grade A dairy farms, 22 farms producing manufacturing milk, 35 swine farms, and 60 beef farms. The average change in net investment for the period to be explained, 1967 to 1968, was $851.27 for all farms. The average farm size measured in total
dollar value of all inventories including land, buildings, equipment, livestock, feeds, and supplies was $57,792.02. Each farmer had an average equity of $46,810.86 in the farm business. The average age and number of dependents of each farmer included in the sample was 46.6 years and 1.75 dependents, respectively.

II. THE STRUCTURAL MODEL

The structural model used in this study utilized the generalized flexible accelerator model of Equation (3.2) as the basic model for adjusting actual capital to changes in desired capital. But, in addition, several variables were believed to have a significant effect on the farmers' attempts to convert changes in desired capital into changes in actual capital. These were nonfarm income, size of the farm firm, age of the farmer, number of dependents of the farmer, and equity of the farmer in the farm business. These variables were not considered to have an effect on the farmers' level of desired capital, but they were viewed as having an effect on his willingness to convert changes in desired capital into changes in actual capital.

The nonfarm income variable, $\bar{Y}_{it}$, was included in the structural model because it allows funds that might otherwise be used for support of the farm family to be used for investment expenditures.

The size of the farm business, $S_{it}$, measured in total dollar value of all inventories including land, buildings, equipment, livestock, feeds, and supplies was thought to be an important variable in the investment behavior function because operators of large farms were
thought to behave differently than operators of small farms. Also, the base size of the farm was thought to be quite important in determining growth.

The age variable, $A_{it}$, was considered to be an important variable affecting the investment expenditures of farmers because of the nature of most farm businesses. In contrast to the industrial corporation, most farms are discontinued as a business entity once the farmer retires. That is to say, in most cases, the farmer is forced to dispose of his fixed assets once he relinquishes the management responsibilities of the farm business. Hence, the nearer he is to retirement age, the greater the constraint age will place on his attempts to convert changes in desired capital into changes in actual capital.

The number of dependents of the farmer, $D_{it}$, determines the amount of internal funds of the farm firm that must be siphoned off for support of the farm family. The fewer dependents, the more internal funds available for investment expenditures, and vice versa. Consequently, when viewed in this context, the number of dependents can be considered a constraint on converting changes in desired capital into changes in actual capital.

Because the equity position of the farmer, $E_{it}$, places a constraint on the amount of external funds a farmer can obtain for investment purposes, this variable was included in the structural model.

A dummy variable was added to the estimating equation for each of the four classifications of farms included in the study to account
for the effect of farm classifications on the investment expenditures of the cross section of farms.

The structural model is given by Equation (3.3),

\[ I_{it} = P(L) \beta_0(K^*_{it} - K^*_{it-1}) + \beta_1 Y_{it} + \beta_2 S_{it} + \beta_3 A_{it} + \beta_4 D_{it} \]  

\[ + \beta_5 E_{it} + \beta_6 M_{it} + \beta_7 C_{it} + \beta_8 H_{it} + \beta_9 B_{it} \]

where:

\[ I_{it} = K_{it} - K_{it-1} \]

\( K_{it} \) = actual capital

\( K^*_{it} \) = desired capital defined as:

\( K^*_{it} = a I^*_{G_{it}} \) for accelerator model

\( K^*_{it} = a I^*_{N_{it}} \) for expected profits model

\( I^*_{G_{it}} \) = gross farm income

\( I^*_{N_{it}} \) = net farm income

\( Y_{it} \) = nonfarm income of the farm family

\( S_{it} \) = size of the farm business measured in total dollar value of all inventories including land, buildings, equipment, livestock, feeds, and supplies

\( A_{it} \) = age of the farmer

\( D_{it} \) = number of dependents
\[ F_{it} = \text{equity of the farmer in the farm business measured in dollars} \]
\[ M_{it} = 1 \text{ if Grade A dairy farm; 0 otherwise} \]
\[ C_{it} = 1 \text{ if dairy farm producing manufacturing milk; 0 otherwise} \]
\[ H_{it} = 1 \text{ if hog farm; 0 otherwise} \]
\[ B_{it} = 1 \text{ if beef farm; 0 otherwise} \]
\[ i = 1 \ldots 180 \text{ for 180 Tennessee test demonstration farms} \]
\[ t = \text{time, for the years 1965 through 1968} \]
\[ P(L) = \text{a polynomial in the rational form } U(L)/V(L). \]

III. DISTRIBUTED LAG FUNCTIONS

To estimate the investment behavior function for a representative farm firm, it was necessary to estimate the parameters of the distributed lag function which in some sense best describes the data used in the estimating procedure. This will allow inferences to be made about the time structure of the investment process. Bauer has suggested three criteria for use in selecting the best lag distribution (2, p. 28). They are: (1) The coefficient of determination or \( R^2 \) because we are obviously interested in explaining as much of the variance in the data as possible, (2) The reasonableness of the estimated lag distributions. We are only interested in positive weights that have a finite sum. (3) "The sign and magnitude of the structural parameters" (2, p. 28). Economic theory and \textit{a priori} knowledge should be useful in making these judgment decisions.
A class of rational distributed lag functions as proposed by Jorgenson was imposed on the data to estimate the so-called best lag distribution. A class of eight functions, \( A(L) = \frac{U(L)}{V(L)} \) were estimated for both the expected profits theory and the accelerator theory of investment. These are listed by number in Table I, page 17. The lag distribution parameters \( U_1, U_2, V_1, \) and \( V_2 \) were estimated along with the structural parameters of the investment behavior model.

Function 1 is the most general case and will be used to develop a general mathematical statement of the estimating model. By allowing \( U_1, U_2, V_1, \) and \( V_2 \) to take on values of zero, the other seven equations were estimated.

Taking the most general case, function 1, and imposing it on the adjustment mechanism for converting changes in desired capital into changes in actual capital in the structural model, Equation (3.3), the mathematical results are Equation (3.4) for the accelerator theory of investment,

\[
I_{it} = \beta_0 \left( \frac{1 + U_1 L + U_2 L^2}{1 - V_1 L - V_2 L^2} \right) (K_{it} - K_{it-1}) + \beta_1 Y_{it} + \beta_2 S_{it} + \beta_3 A_{it} + \beta_4 D_{it} + \beta_5 E_{it} + \beta_6 M_{it} + \beta_7 C_{it} + \beta_8 H_{it} + \beta_9 B_{it}
\]

where:

\[
I_{it} = (K_{it} - K_{it-1})
\]

\[
K_{it}^* = \alpha I_{G_{it}}
\]
The estimating equation becomes:

\[ (3.5) \quad I_{it} = V_1 (K_{it-1} - K_{it-2}) + V_2 (K_{it-2} - K_{it-3}) + \]
\[ + \beta_0 \alpha \left[ (I_{G_{it-1} - I_{G_{it-2}}}) + U_1 (I_{G_{it-1} - I_{G_{it-2}}}) + U_2 (I_{G_{it-2} - I_{G_{it-3}}}) \right] \]
\[ + \beta_1 (Y_{it} - V_1 Y_{it-1} - V_2 Y_{it-2}) + \beta_2 (S_{it} - V_1 S_{it-1} - V_2 S_{it-2}) \]
\[ + \beta_3 (A_{it} - V_1 A_{it-1} - V_2 A_{it-2}) + \beta_4 (D_{it} - V_1 D_{it-1} - V_2 D_{it-2}) \]
\[ + \beta_5 (E_{it} - V_1 E_{it-1} - V_2 E_{it-2}) + \beta_6 (M_{it} - V_1 M_{it-1} - V_2 M_{it-2}) \]
\[ + \beta_7 (C_{it} - V_1 C_{it-1} - V_2 C_{it-2}) + \beta_8 (H_{it} - V_1 H_{it-1} - V_2 H_{it-2}) \]
\[ + \beta_9 (B_{it} - V_1 B_{it-1} - V_2 B_{it-2}) \].

There are 32 independent variables in this regression model, and 180 observations on these variables will be used to estimate the 15 parameters of the model.

IV. ESTIMATING PROCEDURE

The estimating equation, Equation (3.5), is nonlinear in the parameters, and ordinary least squares regression is not applicable; hence, some nonlinear estimating technique must be used to estimate the individual parameters. A procedure discussed by Clark Edwards (3) uses ordinary linear analysis to estimate the parameters through an iterative series of approximations. This procedure can be used to estimate the
parameters of any differentiable function. To illustrate, let $\gamma$ represent the vector of "true" parameters in Equation (3.5), $\hat{\gamma}$ represent the vector of estimated values of the true parameters, and $\Delta$ represent the vector of differences between $\gamma$ and $\hat{\gamma}$, then:

$$\gamma = \hat{\gamma} + \Delta$$

where:

$$\gamma = \begin{pmatrix} \gamma_1 \\ \gamma_2 \\ \gamma_3 \\ \gamma_4 \\ \gamma_5 \\ \gamma_6 \\ \gamma_7 \\ \gamma_8 \\ \gamma_9 \end{pmatrix}$$

and

$$\hat{\gamma} = \begin{pmatrix} \hat{\gamma}_1 \\ \hat{\gamma}_2 \\ \hat{\gamma}_3 \\ \hat{\gamma}_4 \\ \hat{\gamma}_5 \\ \hat{\gamma}_6 \\ \hat{\gamma}_7 \\ \hat{\gamma}_8 \\ \hat{\gamma}_9 \end{pmatrix}$$

Equation (3.5) can be approximated to any degree of accuracy by the expansion of Taylor's series evaluated for the parameter estimates $\hat{\gamma}$. That is:

9 True value in this sense represents the value of the unknown parameters which minimize the sum of the squares of the residuals. See Clark Edwards (4, p. 102).  

10 See Koores (18, p. 191) for a complete description of Taylor's series.
(3.6) \[ I_{it} = f(X, \hat{\gamma}) + \frac{3[f(X, \hat{\gamma})]}{3\hat{\gamma}} (\gamma - \hat{\gamma}) + \frac{3[f'(X, \hat{\gamma})]}{3\hat{\gamma}} (\gamma - \hat{\gamma})^2/2! + \ldots \]

where \( X \) is the vector of observed independent variables for the \( i \)th set of observations.

Rewriting Equation (3.6) and ignoring derivatives of orders higher than one, Equation (3.7) is obtained,\(^{11}\)

\[(3.7) \quad I_{it} - f(X, \hat{\gamma}) = \frac{3[f(X, \hat{\gamma})]}{3\hat{\gamma}} \Delta . \]

The left-hand side of Equation (3.6) represents the difference between the observed and the estimated value of \( I_{it} \) using \( \hat{\gamma} \) as the parameters of the estimated equation. By regressing these residuals on the linear combination of known constants obtained by evaluating the first partial derivatives of \( I \) with respect to each parameter for each observed value of the explanatory variables, it is possible to obtain ordinary least squares estimates of the unknown correction factors \( \Delta \).

These estimates, denoted \( \hat{\Delta} \), will be the ones which best explain the variation in the unexplained residuals \( (I_{it} - \hat{I}_{it}) \). If \( \hat{\gamma} \) is an approximation to \( \gamma \), then \( (\hat{\gamma} + \hat{\Delta}) \) will be a better approximation. By iterating this procedure, it is possible to make \( \hat{\gamma} \) approach \( \gamma \) as close as one desires. To summarize the steps:

\(^{11}\)For sufficiently close approximations of \( \hat{\gamma} \) to \( \gamma \), second and higher ordered derivatives can be ignored (4, p. 102).
(1) Select initial values, \( \hat{y}^o \), for the parameters to be estimated.

(2) Evaluate the first partial derivative of the dependent variable with respect to each parameter, and calculate \( \hat{f}_{it} \) for all observations on the explanatory variables.  

These first partial derivatives are:

\[
\frac{\partial I_{it}}{\partial V_1} = (K_{it-1} - K_{it-2}) - \hat{\beta}_1^S Y_{it-1} - \hat{\beta}_2^S Y_{it-1} - \hat{\beta}_3^A Y_{it-1} - \hat{\beta}_4^D Y_{it-1} - \hat{\beta}_5^E Y_{it-1} \\
- \hat{\beta}_6^M Y_{it-1} - \hat{\beta}_7^C Y_{it-1} - \hat{\beta}_8^H Y_{it-1} - \hat{\beta}_9^B Y_{it-1}
\]

\[
\frac{\partial I_{it}}{\partial V_2} = (K_{it-2} - K_{it-3}) - \hat{\beta}_1^S Y_{it-2} - \hat{\beta}_2^S Y_{it-2} - \hat{\beta}_3^A Y_{it-2} - \hat{\beta}_4^D Y_{it-2} - \hat{\beta}_5^E Y_{it-2} \\
- \hat{\beta}_6^M Y_{it-2} - \hat{\beta}_7^C Y_{it-2} - \hat{\beta}_8^H Y_{it-2} - \hat{\beta}_9^B Y_{it-2}
\]

\[
\frac{\partial I_{it}}{\partial U_1} = \hat{\beta}_0^u (I_{G_{it-1}} - I_{G_{it-2}})
\]

\[
\frac{I_{it}}{U_2} = \hat{\beta}_0^u (I_{G_{it-2}} - I_{G_{it-3}})
\]

\[
\frac{\partial I_{it}}{\partial \alpha} = \hat{\alpha}_0 \left[ (I_{G_{it}} - I_{G_{it-1}}) + \hat{U}_1 (I_{G_{it-1}} - I_{G_{it-2}}) + \hat{U}_2 (I_{G_{it-2}} - I_{G_{it-3}}) \right]
\]

\[
\frac{\partial I_{it}}{\partial \beta_0} = \hat{\alpha}_0 \left[ (I_{G_{it}} - I_{G_{it-1}}) + \hat{U}_1 (I_{G_{it-1}} - I_{G_{it-2}}) + \hat{U}_2 (I_{G_{it-2}} - I_{G_{it-3}}) \right]
\]
\[
\frac{\partial \hat{I}_{it}}{\partial \beta_1} = Y_{it} - \hat{V}^{o}_{1it-1} - \hat{V}^{o}_{2it-2}
\]
\[
\frac{\partial \hat{I}_{it}}{\partial \beta_2} = S_{it} - \hat{V}^{o}_{1it-1} - \hat{V}^{o}_{2it-2}
\]
\[
\frac{\partial \hat{I}_{it}}{\partial \beta_3} = A_{it} - \hat{V}^{o}_{1it-1} - \hat{V}^{o}_{2it-2}
\]
\[
\frac{\partial \hat{I}_{it}}{\partial \beta_4} = D_{it} - \hat{V}^{o}_{1it-1} - \hat{V}^{o}_{2it-2}
\]
\[
\frac{\partial \hat{I}_{it}}{\partial \beta_5} = E_{it} - \hat{V}^{o}_{1it-1} - \hat{V}^{o}_{2it-2}
\]
\[
\frac{\partial \hat{I}_{it}}{\partial \beta_6} = M_{it} - \hat{V}^{o}_{1it-1} - \hat{V}^{o}_{2it-2}
\]
\[
\frac{\partial \hat{I}_{it}}{\partial \beta_7} = C_{it} - \hat{V}^{o}_{1it-1} - \hat{V}^{o}_{2it-2}
\]
\[
\frac{\partial \hat{I}_{it}}{\partial \beta_8} = H_{it} - \hat{V}^{o}_{1it-1} - \hat{V}^{o}_{2it-2}
\]
\[
\frac{\partial \hat{I}_{it}}{\partial \beta_9} = B_{it} - \hat{V}^{o}_{1it-1} - \hat{V}^{o}_{2it-2}
\]

The ° refers to the initial estimates of the parameters.

(3) Calculate the residuals \((I_{it} - \hat{I}_{it})\), and regress these residuals on the first partial derivatives using ordinary least squares to estimate the adjustment factors that
will improve the initial estimates of \( y \), denoted \( \hat{A} \). The linear regression equation becomes:

\[
(I - \hat{I}) = \frac{\partial I}{\partial y} \Delta + \varepsilon.
\]

(4) Calculate the improved estimates by adding these estimated adjustment factors, \( \hat{A} \), to the initial estimates:

\[\hat{y}^1 = \hat{y}^0 + \hat{A}.\]

(5) This new set of parameters are now used to calculate a new set of residuals, and the process is repeated until \( \hat{A} \) approaches zero. Edwards suggests that in most cases four to six iterations will be sufficient (4, p. 103). The final estimates will be the least squares solution.
CHAPTER IV

RESULTS OF THE STUDY

I. MODIFICATION OF THE ESTIMATING EQUATION

This study assumed desired capital to be proportional to gross farm income or net farm income for the accelerator or expected profits models, respectively. However, in the estimation procedure the problem of linear dependency in the independent variables forced a modification of the estimating equation. In Equation (3.5), \( \beta_0 \) represents the coefficient of total net investment expenditures for the current period associated with all past changes in desired capital stock, and \( \alpha \) represents the coefficient of proportionality between desired capital and gross farm income or net farm income for the two models, respectively. Using this estimating equation, the vectors obtained by the evaluation of the first partial derivatives with respect to \( \beta_0 \) and \( \alpha \) for all 12 observations, Equation (4.1) and Equation (4.2) are linearly dependent.  

\[
(4.1) \quad \frac{\partial I_{it}}{\partial \alpha} = \beta_0 \left[ (I_{G_{it}} - I_{G_{it-1}}) + U_1 (I_{G_{it-1}} - I_{G_{it-2}}) + U_2 (I_{G_{it-2}} - I_{G_{it-3}}) \right]
\]

\[\text{The sum of } \beta_0 \text{ times Equation (4.2) plus } -\alpha \text{ times Equation (4.1) is zero.}\]
Consequently, when these vectors are used as independent variables in
the estimation of the adjustment factors to be added to the initial
estimates of the parameters, the ordinary least squares procedure breaks
down. For this reason, \( a \) was dropped from the estimating equation. It
is apparent, however, that the results of the study were not altered.
The equation relating all past changes in gross farm income to invest-
ment expenditures as formulated in Chapter III is presented in
Equation (4.3),

\[
(4.3) \quad I_{it} = \beta_0 \alpha P(L) \left[ (I_G)_{it} - (I_G)_{it-1} \right].
\]

Total net investment expenditures for the current period associated with
all past changes in gross farm income is indicated by the value of \( \beta_0 \alpha \).
When \( a \) is dropped from the estimating equation, \( \beta_0 \) becomes the coeffi-
cient of net investment expenditures for the current period associated
with all past changes in gross farm income. The only unknown coefficient
is the proportionality coefficient relating gross farm income to desired
capital. Since the objective of the study was simply to estimate a
stable investment behavior function for individual farm firms, the
elimination of this information did not place a constraint on reaching
this objective.
II. THE ESTIMATED DISTRIBUTED LAG FUNCTIONS

The estimations were completed as described in the preceding chapter for each of the eight lag functions (Table I, page 17) using the accelerator and expected profits theories of investment, respectively. The results of these estimations are presented in Table II. When evaluated in terms of the constraints on the admissible range of values for the parameters of the lag distribution as previously described, only function 8 for the accelerator model was acceptable. The $R^2$ for function 8 was .86. The seven remaining functions for the accelerator model and all eight functions for the expected profits model yielded parameter estimates outside the acceptable range; thus, producing lag distributions with negative weights for some periods. Although these distributions were unacceptable, some appeared to be more reasonable than others. All estimated lag distributions for the expected profits model were highly unreasonable, while function 2 and function 5 of the accelerator model seemed more reasonable because the first two changes in gross sales accounted for approximately 100 percent of the effect of all changes in gross sales on net investment. But beyond the first two periods, lag weights alternate in sign and had very small absolute values. Almon (1) points out that frequently when a "longer-than-optimal" distribution is estimated, the weights in the latter periods may go negative at small absolute values.\(^{13}\) When this

\(^{13}\)Almon points out that mathematically it is very difficult to find a distributed lag function with weights that approach zero asymptotically as the number of lagged periods increase beyond the optimum.
### TABLE II

**ESTIMATED LAG FUNCTIONS FOR THE ACCELERATOR AND EXPECTED PROFITS THEORIES OF INVESTMENT**

<table>
<thead>
<tr>
<th>Function Number</th>
<th>Accelerator Model</th>
<th>Expected Profits Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$1 - 0.6662L - 1.1570L^2$</td>
<td>$1 - 3.6241L - 2.3682L^2$</td>
</tr>
<tr>
<td></td>
<td>$1 - 0.1754L - 0.1212L^2$</td>
<td>$1 + 0.2770L + 0.4882L^2$</td>
</tr>
<tr>
<td>2</td>
<td>$1 + 0.1929L$</td>
<td>$1 - 1.1793L$</td>
</tr>
<tr>
<td></td>
<td>$1 + 0.1184L - 0.0019L^2$</td>
<td>$1 + 0.1763L + 0.1869L^2$</td>
</tr>
<tr>
<td>3</td>
<td>$1 + 0.0015L - 0.9858L^2$</td>
<td>$1 + 0.0293L + 0.0078L^2$</td>
</tr>
<tr>
<td>4</td>
<td>$1 - 0.2189L - 0.6847L^2$</td>
<td>$1 + 0.9935L + 0.9580L^2$</td>
</tr>
<tr>
<td></td>
<td>$1 + 0.0745L$</td>
<td>$1 - 0.0094L$</td>
</tr>
<tr>
<td>5</td>
<td>$1 + 0.1949L$</td>
<td>$1 + 1.5788L$</td>
</tr>
<tr>
<td></td>
<td>$1 + 0.1209L$</td>
<td>$1 - 1.2122L$</td>
</tr>
<tr>
<td>6</td>
<td>$1 + 0.1094L$</td>
<td>$1 + 0.0213L$</td>
</tr>
<tr>
<td>7</td>
<td>$1 - 0.3848L - 0.9352L^2$</td>
<td>$1 - 0.9754L - 0.9425L^2$</td>
</tr>
<tr>
<td>8</td>
<td>$1 + 0.2052L$</td>
<td>$1 - 0.4153L$</td>
</tr>
</tbody>
</table>
occurs, she suggests using only the number of periods that yield positive weights to re-estimate the equation. In effect, this was what was done when function 8 was estimated. However, function 2 and function 5 for the accelerator model are worthy of consideration. The $R^2$ associated with function 2 and function 5 was .91 for each function.

The weights generated by function 2, function 5, and function 8 for the accelerator model are presented in Table III. Function 8 produced a lag distribution with only two weights. Changes in gross sales between the current and preceding period accounted for approximately 83 percent of the total effect of all changes in gross sales on net investment, while changes in gross sales lagged one period accounted for the remaining 17 percent. This lag distribution seems somewhat naive, but the less constrained models (model 2 and model 5) tend to substantiate a two period lag distribution.

Function 2 and function 5 yielded similar distributions. In both cases, change in gross sales between the current and previous period accounted for approximately 93 percent of the total effect of all changes in gross sales on net investment, while change in gross sales lagged one period accounted for the remaining 7 percent. Using Almon's criterion, the remaining weights are beyond the optimum number of lags for the data.

III. ESTIMATES OF THE STRUCTURAL PARAMETERS

The estimates of the structural parameters were obtained simultaneously with the lag distribution parameters as described in
TABLE III

THE NUMERICAL WEIGHTS, $p_t$, OF THE ESTIMATED LAG DISTRIBUTION FOR FUNCTIONS 2, 5, AND 8 OF THE ACCELERATOR THEORY OF INVESTMENT

<table>
<thead>
<tr>
<th>Time Period $t$</th>
<th>Function 2</th>
<th>Function 5</th>
<th>Function 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.9359</td>
<td>0.9380</td>
<td>0.8297</td>
</tr>
<tr>
<td>1</td>
<td>0.0696</td>
<td>0.0694</td>
<td>0.1703</td>
</tr>
<tr>
<td>2</td>
<td>-0.0064</td>
<td>-0.0439</td>
<td>--</td>
</tr>
<tr>
<td>3</td>
<td>0.0009</td>
<td>0.0053</td>
<td>--</td>
</tr>
<tr>
<td>4</td>
<td>-0.0001</td>
<td>-0.0006</td>
<td>--</td>
</tr>
<tr>
<td>5</td>
<td>0.0000</td>
<td>0.0000</td>
<td>--</td>
</tr>
</tbody>
</table>
the previous chapter. The estimates of the structural parameters varied with the model and lag function being estimated because of the influence of the lag function on the estimating equation and estimating procedure.

**Accelerator Model**

The estimates of the structural parameters for each of the eight lag functions using the accelerator theory of investment are presented in Table IV. Since only function 8 of the accelerator model yielded a truly acceptable lag distribution and function 2 and function 5 yielded fairly reasonable distributions based on the Almon criterion, the structural parameter estimates associated with the remaining lag functions are of no real value except to help substantiate weak conclusions concerning parameter estimates of functions 2, 5, and 8. But any conclusions concerning the structural parameters of the accelerator model must be made on very weak relationships because of weak grounds for acceptance of the lag distribution and instability in structural parameter estimates between lag functional forms.

The coefficient relating changes in gross sales to net investment was positive and varied in magnitude from 1.31 to 1.72 for all lag functional forms. Function 8, which had an $R^2$ of .86, yielded a coefficient of 1.53 for changes in gross sales. Function 2 and function 5, both having an $R^2$ of .91, yielded an equal coefficient of 1.69 for this variable. These results can be interpreted to mean as changes in gross sales increase by $1.00$, net investment increases by $1.53$ and $1.69$ for function 8 and functions 2 and 5, respectively, given time for this adjustment to occur.
### TABLE IV

**STRUCTURAL PARAMETER ESTIMATES FOR THE ACCELERATOR THEORY OF INVESTMENT**

<table>
<thead>
<tr>
<th>Function Number</th>
<th>Change in Gross Sales</th>
<th>Nonfarm Income</th>
<th>Size of Farm</th>
<th>Age</th>
<th>Number of Dependents</th>
<th>Grade A Dairy</th>
<th>Grade C Dairy</th>
<th>Beef Farm</th>
<th>Hog Farm</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.3537</td>
<td>-39.2724</td>
<td>0.4661</td>
<td>343.7887</td>
<td>83.5354</td>
<td>-41,116</td>
<td>-23,492</td>
<td>-29,937</td>
<td>-26,695</td>
<td>.97</td>
</tr>
<tr>
<td>2</td>
<td>1.6900</td>
<td>-11.5933</td>
<td>0.1165</td>
<td>-33.8400</td>
<td>250.1040</td>
<td>-9,412</td>
<td>-3,273</td>
<td>45</td>
<td>-4,107</td>
<td>.91</td>
</tr>
<tr>
<td>3</td>
<td>1.3835</td>
<td>-15.2128</td>
<td>0.0574</td>
<td>-29.6138</td>
<td>113.2472</td>
<td>-10,017</td>
<td>-4,079</td>
<td>2,251</td>
<td>-4,791</td>
<td>.91</td>
</tr>
<tr>
<td>4</td>
<td>1.7279</td>
<td>-25.8612</td>
<td>0.3616</td>
<td>203.1423</td>
<td>318.7747</td>
<td>-26,967</td>
<td>-16,382</td>
<td>-17,640</td>
<td>-20,360</td>
<td>.94</td>
</tr>
<tr>
<td>5</td>
<td>1.6930</td>
<td>-11.4895</td>
<td>0.1172</td>
<td>-33.8515</td>
<td>250.7969</td>
<td>-9,391</td>
<td>-3,265</td>
<td>21</td>
<td>-4,104</td>
<td>.91</td>
</tr>
<tr>
<td>6</td>
<td>1.3066</td>
<td>-9.0833</td>
<td>0.0907</td>
<td>-26.6238</td>
<td>28.6049</td>
<td>-8,176</td>
<td>-3,926</td>
<td>1,819</td>
<td>-5,125</td>
<td>.90</td>
</tr>
<tr>
<td>7</td>
<td>1.6533</td>
<td>-30.8690</td>
<td>0.4565</td>
<td>248.8372</td>
<td>-172.4843</td>
<td>-30,282</td>
<td>-17,839</td>
<td>-17,471</td>
<td>-22,963</td>
<td>.93</td>
</tr>
<tr>
<td>8</td>
<td>1.5310</td>
<td>-13.0910</td>
<td>0.1151</td>
<td>-111.6304</td>
<td>796.0404</td>
<td>-2,974</td>
<td>2,963</td>
<td>13,913</td>
<td>2,394</td>
<td>.86</td>
</tr>
</tbody>
</table>
The coefficient relating nonfarm income to net investment was negative for all lag functions. This might be due to the competitive nature of farm versus nonfarm work for the commercial farmers. Time devoted to nonfarm endeavors tended to make farmers with off-farm jobs less growth oriented. Each dollar of nonfarm income decreased net investment by $13 and $11, respectively, for function 8 and functions 2 and 5. It should be noted, however, that about half of the farmers in this study had no nonfarm income; hence, this coefficient may be invalid because the variable was entered as a continuous variable.

The coefficient relating size of the farm to net investment was positive for all lag functions indicating larger farmers tend to be more growth oriented. The size coefficient was just under 0.12 for functions 2, 5, and 8.

A general conclusion about the effect of age on net investment cannot be drawn from this study. The sign was not consistent for all functions; however, for functions 2, 5 and 8 the sign was negative. Better results might be expected with a nonlinear relationship between age and net investment.

The effect of the number of dependents on net investment is inconclusive because of positive and negative signs on the coefficient for different lag functions. Functions 2 and 5 indicate net investment increases by $250 for each increase in number of dependents, while function 8 indicates a decrease of $796.
Equity in the farm firm showed a positive relationship to net investment in all cases except one. Functions 2 and 5 had a coefficient of 0.12, and function 8 had a coefficient of 0.08.

The coefficients on the four dummy variables varied considerably for the various lag functions. But in general, a weak relationship could be interpreted. That is, Grade A dairy farmers were the least likely to invest all other variables held constant followed by swine farmers, dairy farmers producing manufacturing milk, and beef farmers in order of unwillingness to invest.

Expected Profits Model

Since an acceptable lag distribution was not obtained for the expected profits model, the structural parameter estimates are questionable. The structural parameter estimates for the expected profits theory model are presented in Table V.

For all lag functions, the coefficient relating changes in net income to net investment was negative ranging from -3.44 to -0.84. The sign on the coefficients relating nonfarm income, age of the farmer, number of dependents and equity to net investment was unstable for different lag functions. Size of the farm firm showed a positive effect on net investment for all lag functions ranging from 0.02 to 5.62. The coefficients on the four dummy variables dividing farms into type classifications failed to reveal a general pattern of investment behavior by the farmers included in this study.
<table>
<thead>
<tr>
<th>Function Number</th>
<th>Changes in Net Income $\beta_0$</th>
<th>Size of Nonfarm Income $\beta_1$</th>
<th>Size of Farm Income $\beta_2$</th>
<th>Age $\beta_3$</th>
<th>Number of Dependents $\beta_4$</th>
<th>Equity $\beta_5$</th>
<th>Grade A Dairy $\beta_6$</th>
<th>Grade C Dairy $\beta_7$</th>
<th>Beef Farm $\beta_8$</th>
<th>Hog Farm $\beta_9$</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-0.8440</td>
<td>15.5274</td>
<td>0.0252</td>
<td>50.1959</td>
<td>-987.5537</td>
<td>-0.3008</td>
<td>-2,411</td>
<td>-3,471</td>
<td>817</td>
<td>4,660</td>
<td>.83</td>
</tr>
<tr>
<td>2</td>
<td>-0.8832</td>
<td>5.0414</td>
<td>0.1730</td>
<td>38.6663</td>
<td>-957.3938</td>
<td>-0.1534</td>
<td>-5,483</td>
<td>-3,523</td>
<td>3,902</td>
<td>-2,075</td>
<td>.80</td>
</tr>
<tr>
<td>3</td>
<td>-1.8570</td>
<td>1.0409</td>
<td>0.1392</td>
<td>318.4557</td>
<td>-1,295.5682</td>
<td>-0.1522</td>
<td>-18,680</td>
<td>-20,549</td>
<td>-7,714</td>
<td>-18,452</td>
<td>.79</td>
</tr>
<tr>
<td>4</td>
<td>-1.9736</td>
<td>5.4635</td>
<td>0.2959</td>
<td>366.8460</td>
<td>-2,071.0187</td>
<td>-0.4673</td>
<td>-14,823</td>
<td>-21,437</td>
<td>-1,773</td>
<td>-13,179</td>
<td>.82</td>
</tr>
<tr>
<td>5</td>
<td>-3.4454</td>
<td>-2.1509</td>
<td>3.4996</td>
<td>-1,352.0744</td>
<td>27,013.7176</td>
<td>0.5734</td>
<td>-126,113</td>
<td>-49,987</td>
<td>-140,489</td>
<td>-105,080</td>
<td>.63</td>
</tr>
<tr>
<td>6</td>
<td>-1.8706</td>
<td>0.6624</td>
<td>0.1397</td>
<td>326.4398</td>
<td>-1,321.3852</td>
<td>-0.1546</td>
<td>-19,089</td>
<td>-21,009</td>
<td>-7,956</td>
<td>-18,828</td>
<td>.79</td>
</tr>
<tr>
<td>7</td>
<td>-1.9354</td>
<td>5.6291</td>
<td>0.2814</td>
<td>356.5086</td>
<td>-1,957.3629</td>
<td>-0.4431</td>
<td>-14,769</td>
<td>-21,004</td>
<td>-2,181</td>
<td>-13,100</td>
<td>.82</td>
</tr>
<tr>
<td>8</td>
<td>-1.7502</td>
<td>-2.9535</td>
<td>0.2073</td>
<td>268.3048</td>
<td>-1,496.1926</td>
<td>-0.2219</td>
<td>-15,834</td>
<td>-17,039</td>
<td>-4,852</td>
<td>-13,522</td>
<td>.81</td>
</tr>
</tbody>
</table>
The $R^2$ coefficient was lower for each lag function using the expected profits theory of investment than for the accelerator theory of investment.

Based on the criterion of an acceptable lag distribution, reasonableness of the structural parameter estimates, and the coefficient of determination, the expected profits model was rejected in this study as an explanation of investment behavior of this group of farmers.
CHAPTER V

SUMMARY AND CONCLUSIONS

To study farm firm growth, some notion concerning the investment behavior of the individual farm firm is needed. The purpose of this study was to estimate the investment behavior function of individual farm firms using the concept of rational distributed lag functions developed by Jorgenson to estimate the time structure of the investment process.

In this study the fundamental flexible accelerator model was used to estimate a representative individual farm firm investment behavior function. The model assumed net investment to be a lagged function of all changes in desired capital. The accelerator and expected profits theories of investment were used to define desired capital. In testing the accelerator theory, desired capital was assumed to be proportional to gross farm income measured as total cash receipts plus changes in inventory of feed, supplies, and nonbreeding livestock. The expected profits model assumed desired capital to be proportional to net farm income measured as gross farm income minus total cash expenses.

Because of the importance of the proper specification of the lag distribution in determining the time structure of the investment process, eight lag functions were imposed on the estimating equation for the accelerator and expected profits theory of investment. Three criteria
were established for selecting the best lag distribution. They were: (1) The coefficient of determination or $R^2$ since the objective was to explain as much of the variance in net investment as possible, (2) The sign and magnitude of the structural parameters, and (3) The reasonableness of the estimated lag distribution. Only lag distributions with positive weights that have a finite sum were considered acceptable. A set of constraints on the range of admissible values for the estimated lag function parameters that would yield acceptable lag distributions were derived. The estimated lag function parameters were evaluated in terms of these constraints.

In addition to the mechanism for converting changes in desired capital into changes in actual capital, nonfarm income, size of the farm firm, age of the farmer, number of dependents of the farmer, and equity of the farmer in the farm business were added to the estimating equation in a linear fashion to establish the effect of these variables on net investment.

Observations on 180 Tennessee test demonstration farms for the four-year period, 1965 through 1968, were used to estimate the parameters of the lag distribution and structural equation. The data included observations on Grade A dairy farms, farms producing manufacturing milk, swine farms, and beef farms. A dummy variable for each of these farm classifications was added to the estimating equation to account for the effect of farm classification on the investment expenditures of the cross section of farms.
Because the estimating equation was nonlinear in the parameters, an iterative procedure utilizing ordinary least squares was used to obtain the parameter estimates.

The expected profits theory of investment, which assumed desired capital to be proportional to net farm income, was rejected as an explanation of the investment behavior of this group of farmers.

The accelerator theory of investment, which assumed desired capital to be proportional to gross farm income, appeared to be a better explanation of investment behavior. The lag distribution relating changes in gross sales to net investment involved only two periods. One distribution accounted for 83 percent of the total effect in the first year while a second accounted for 93 percent in the first year.

The estimates of the structural parameters of the accelerator model varied considerably with the lag function being estimated; however, some weak relationships were revealed. It appeared that as changes in gross sales increased by $1.00 net investment increased by approximately $1.53 to $1.69 given time for the adjustment to occur. Each $1.00 increase in nonfarm income seemed to have a negative effect on net investment ranging from -$13.00 to -$11.00. It should be noted, however, that all farmers in this study did not have nonfarm income although it was included in the estimating equation as a continuous variable. Each $1.00 increase in the size of the farm business measured in total dollar value of all inventories, including land, buildings, equipment, livestock, feeds, and supplies, increased net investment by about $0.12. The effect of age and number of dependents
of the farmer on net investment could not be determined from this study because of variations in sign and magnitude of the parameter estimates with the lag function being estimated. A nonlinear relation between age of the farmer and net investment might yield better results for the age variable. A positive relationship was estimated between equity of the farmer in the farm business and net investment ranging from 0.08 to 0.12.

A weak relationship was interpreted regarding the effect of farm classification on net investment. In general, Grade A dairy farmers were the least likely to invest, all other variables held constant. They were followed in order of unwillingness to invest, all other variables held constant, by swine farmers, manufacturing milk dairy farmers, and beef farmers.

The distributed lag theory and estimating procedure used in this study are theoretically sound for studying investment behavior of farm firms, but the results of this study were not encouraging because of the instability of the structural parameter estimates between lag function specifications and the problem of obtaining an acceptable lag distribution. The problems encountered in this study could partly be due to the variation in the investment behavior of the cross section of farmers included in the study. Although this study accounted for farm classification, homogeneity was assumed between farms within classes. But the evidence suggests that factors other than those accounted for in the study play an important role in determining the investment
behavior of individual farm firms. These may be such things as the farmer's attitude toward debt, notions concerning the effect forced savings in paying off farm debts have on asset accumulation, anticipated effects of inflation on asset accumulation, etc. More research is needed to determine the effects of these factors on investment behavior of the farm firm.

One possible source of difficulty in this study was multicollinearity among the independent variables in the estimating equation which was increased due to the nature of the reduction technique used in estimating the distributed lag function. A second problem intensified by the reduction technique used in this study was that of serial correlation in the residual terms. The use of the Almon (1) method which uses varying numbers of periods for only the lagged variable in the estimating equation would help to alleviate the seriousness of these two problems induced by the rational distributed lag reduction technique. This study suggests a short lag in investment response to changes in desired capital which would permit the use of the Almon method with relatively few years data.

This study indicated that when the rational distributed lag method is used to investigate farm firm investment behavior, the restrictions outlined in Chapter III on the lag function parameters to be estimated may have to be built into the estimation procedure to obtain acceptable lag distributions. This involves utilizing quadratic programming in which the sum of squares would be minimized subject to a set of linear constraints (13, p. 14).
This study also indicates caution should be used when estimating the distributed lag function for farm investment by the rational distributed lag technique. Although this method allows the data to determine the form of the lag distribution, the researcher should not expect a clear-cut answer about its exact form. If the general shape of the lag distribution is known a priori to the study, better results than those obtained in this study might be obtained by imposing a particular lag distribution on the data.
BIBLIOGRAPHY
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VITA

The author was born September 3, 1941, in Sevier County, Tennessee, where he lived on a general farm. In 1951, he moved to a general farm in Todd County, Kentucky.

He attended Austin Peay State University for three academic years, 1959-1962. In the fall of 1962, he entered dairy farming for a three-year period, 1962-1965, in Todd County, Kentucky.

In 1966, the author received his Bachelor of Science Degree from Austin Peay State University with a major in Economics. He was recipient of a three-year NDEA Fellowship in the fall of 1966 to do graduate work at The University of Tennessee, Knoxville, Tennessee. Since August, 1969, the author has been an instructor in the Department of Agricultural Economics at The University of Tennessee, Knoxville, Tennessee.

The author was married to the former Betty Lou Coppage in 1962. They have two children, Billy and Lisa.