JOHNSON, Stanley Spann, 1926–
A QUANTITATIVE ANALYSIS OF THE DEMAND FOR AND SUPPLY OF FARM LABOR.

Iowa State University of Science and Technology
Ph.D., 1961
Economics, agricultural

University Microfilms, Inc., Ann Arbor, Michigan

A QUANTITATIVE ANALYSIS OF THE DEMAND FOR AND SUPPLY OF FARM LABOR

by

Stanley Spann Johnson

A Dissertation Submitted to the
Graduate Faculty in Partial Fulfillment of
The Requirements for the Degree of
DOCTOR OF PHILOSOPHY

Major Subject: Agricultural Economics

Approved:

Signature was redacted for privacy.

In Charge of Major Work

Signature was redacted for privacy.

Head of Major Department

Signature was redacted for privacy.

Dean of Graduate College

Iowa State University
Of Science and Technology
Ames, Iowa

1961

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INTRODUCTION

Continual change and adjustment characterize the environment in which today's farmer must operate. Even though adjustments of important magnitude have taken place, a farm problem persists: farm resource earnings remain low relative to earnings in other segments of the economy. Hence, further change and adjustment will continue to be a dominant feature of agriculture.

The agricultural income problem stems from forces operating in the national economy which affect both the supply of and demand for agricultural products. Since consumer demand for farm products is characterized by low income elasticities, a rise in national and per capita income does not result in an increase in total income to the agricultural producer. The per capita demand for agricultural products decreases relative to other goods and services, and industries with products with high income elasticities bid up prices of factors used in agriculture. Hence, the farmer's costs rise relative to product prices, creating a "cost-price" squeeze. On the supply side, technological advancement causes changes in the marginal productivities and marginal rates of substitution of factors of production. Evidently, the low short-run elasticity of factor supply, along with technical change and imperfection in the factor markets have caused food output to increase more rapidly than can be absorbed by population growth and a rising national income. Substantial surpluses of agricultural products have arisen accordingly.

One of the principal means of solving the farm income problem is thought to be through adjustments in the size of the farm labor force. Hence, a knowledge of the factors which affect the demand for and supply of farm labor as well as the extent to which these factors influence farm labor is important. The demand and supply for this particular resource, farm labor, is analyzed in this thesis. Labor, of course, is not an inanimate resource that can be abruptly shunted out of agriculture in response to relative price changes. Rather, labor represents a human resource with a consuming unit embodied in it.

Despite the importance of information concerning the demand for and supply of farm labor, relatively little quantitative research effort has been directed toward verification of hypotheses in this area. However, the low-income problem in agriculture and developments in quantitative procedures have led to a resurgence of interest in farm labor demand and supply relationships.

Improved knowledge of quantitative demand and supply functions for farm labor is of importance to economists and national farm program administrators. Questions have arisen as to the demand and supply responses of farm labor to changes in important determining variables. For instance, of what effect on the demand for farm labor is an upward change in prices received? Is the supply of farm labor highly responsive to changes in the farm wage? This paper does not pretend to have final answers on these and other questions of farm labor elasticities of response. However, an investigation of some of these problems has been conducted and tentative solutions are presented.

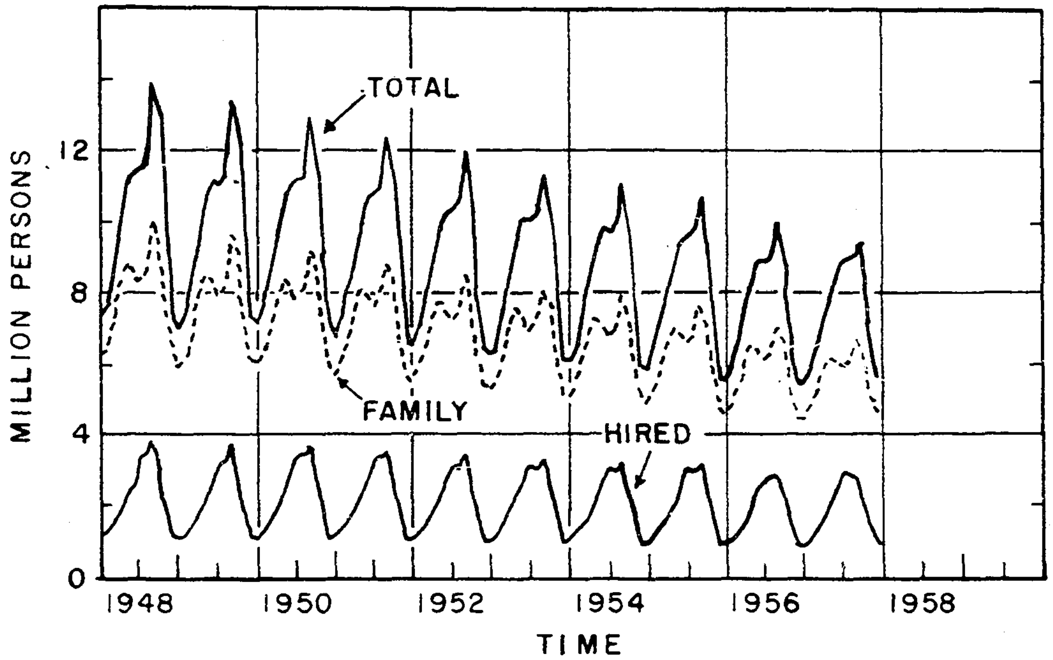
Trends in Farm Labor and Related Inputs

The farm labor market has undergone considerable change. The general trend in agricultural employment since 1910 has been in one direction - downward. By 1957, the total number of farm workers had declined 45 per cent from the 1910 total. (See Figure 2.) During the same period, estimated requirements for man-hours in agriculture declined 50 per cent (Figure 3). The annual rate of decrease has been far from constant, though, over the last 50 years. Total farm employment dropped only 8 per cent from 1910 to 1930. In 1935, due to the depression and a lack of off-farm opportunities, farm employment had increased 2 per cent over the 1930 total. Since 1935, however, the rate of net migration from the farm has been steadily increasing as farm employment by 1946 had declined 19 per cent from the 1935 level, and 26 per cent by 1957 from the 1946 level.

Included in total farm employment are several different groups of farm workers (52), of which the common distinction

Figure 1. Seasonal farm employment for the U.S., 1948 to 1958, with comparisons for seasonal family and hired employment.

Figure 2. Total farm employment, 1910 to 1957, with comparisons for hired and family labor (in millions of persons).


TOTAL
FAMILY
HIRED
MILLION PERSONS
0
4
8
12
1948
1950
1952
1954
1956
1958
TIME

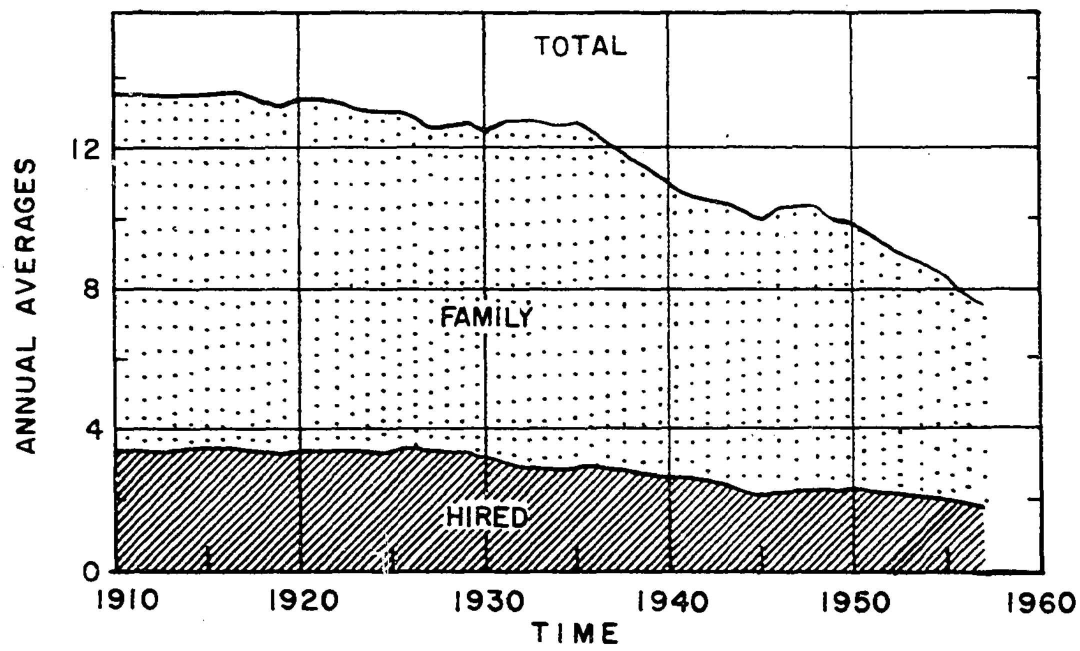
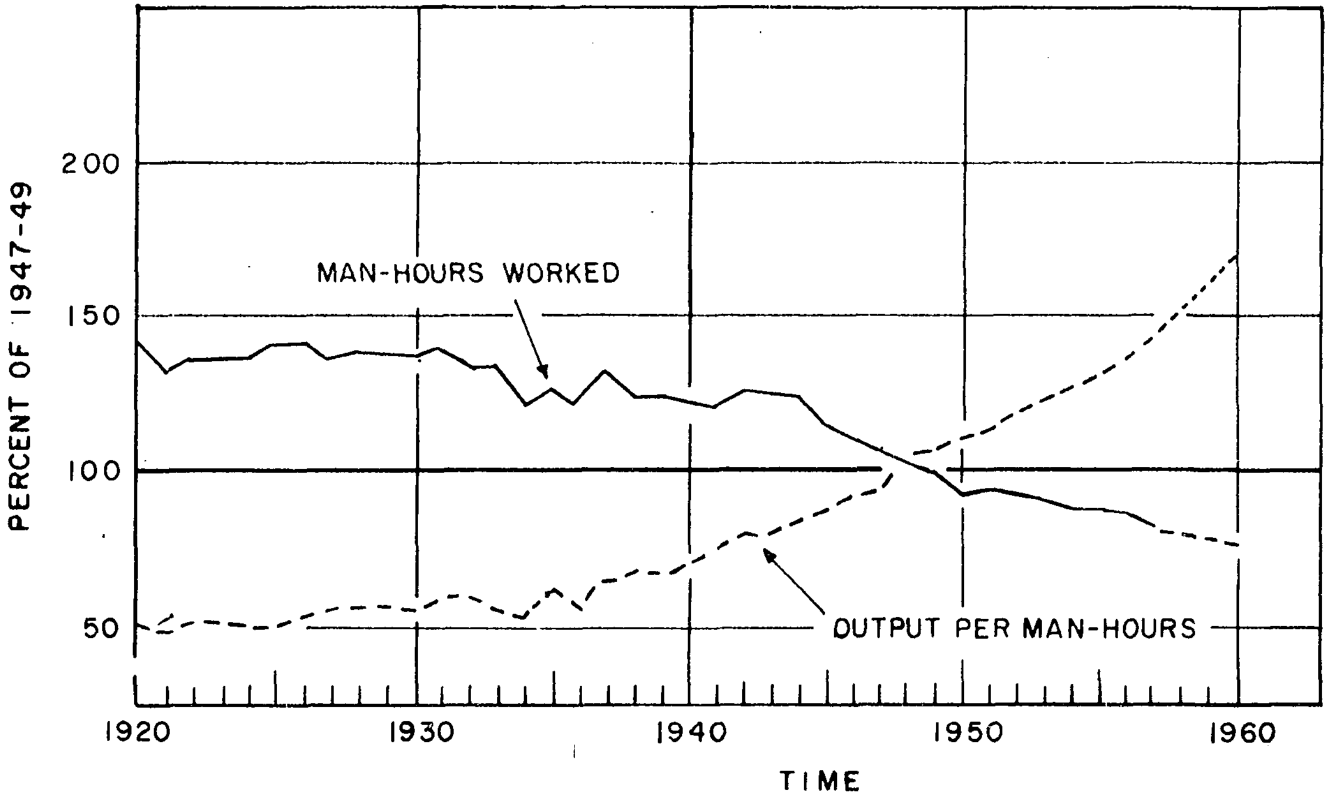

TOTAL
FAMILY
HIRED
ANNUAL AVERAGES
0
4
8
12
1910
1920
1930
1940
1950
1960
TIME

Figure 3. Man-hour requirements in agriculture and agricultural output per man-hour, 1920 to 1957.


MAN-HOURS WORKED
OUTPUT PER MAN-HOURS
PERCENT OF 1947-49
200
150
100
50
1920
1930
1940
1950
1960
TIME

is between hired and family workers. Roughly one-fourth of the 7.6 million farm workers in 1956 were hired laborers. Other than for minor changes, the hired labor force has constituted 25 per cent of the national farm labor force since 1910. Hence, the changes in the numbers of hired and family workers over time have been similar to those of the total farm labor force. However, this relative stability of the ratio of hired to total farm employment does not hold true on a regional basis.

Changes in farm labor over time for nine geographic regions (Figure 4) are presented in Table 1. Two general conclusions were drawn from the data in Table 1: (1) The percentage changes from 1910-1957 and 1929-1957 were similar. This similarity indicated that farm employment in all but one region decreased slowly from 1910-1929, but decreased rapidly from 1929-1957. In the Pacific region, farm labor increased in size from 1910-1957. (2) Changes in farm employment between regions fluctuated more widely than for the U.S. as a whole. No clear-cut pattern of relative change between hired and family workers was apparent among the regions. Hence, the consistency of the relative size of the national hired labor force was not corroborated on a regional level.

The seasonal pattern of farm employment has also changed. In Figure 1 the amplitude of employment fluctuations appeared to diminish over time for family labor, but not for hired labor. In Figure 5 the seasonal pattern of hired labor for

Figure 4. Map of regions used for analysis.

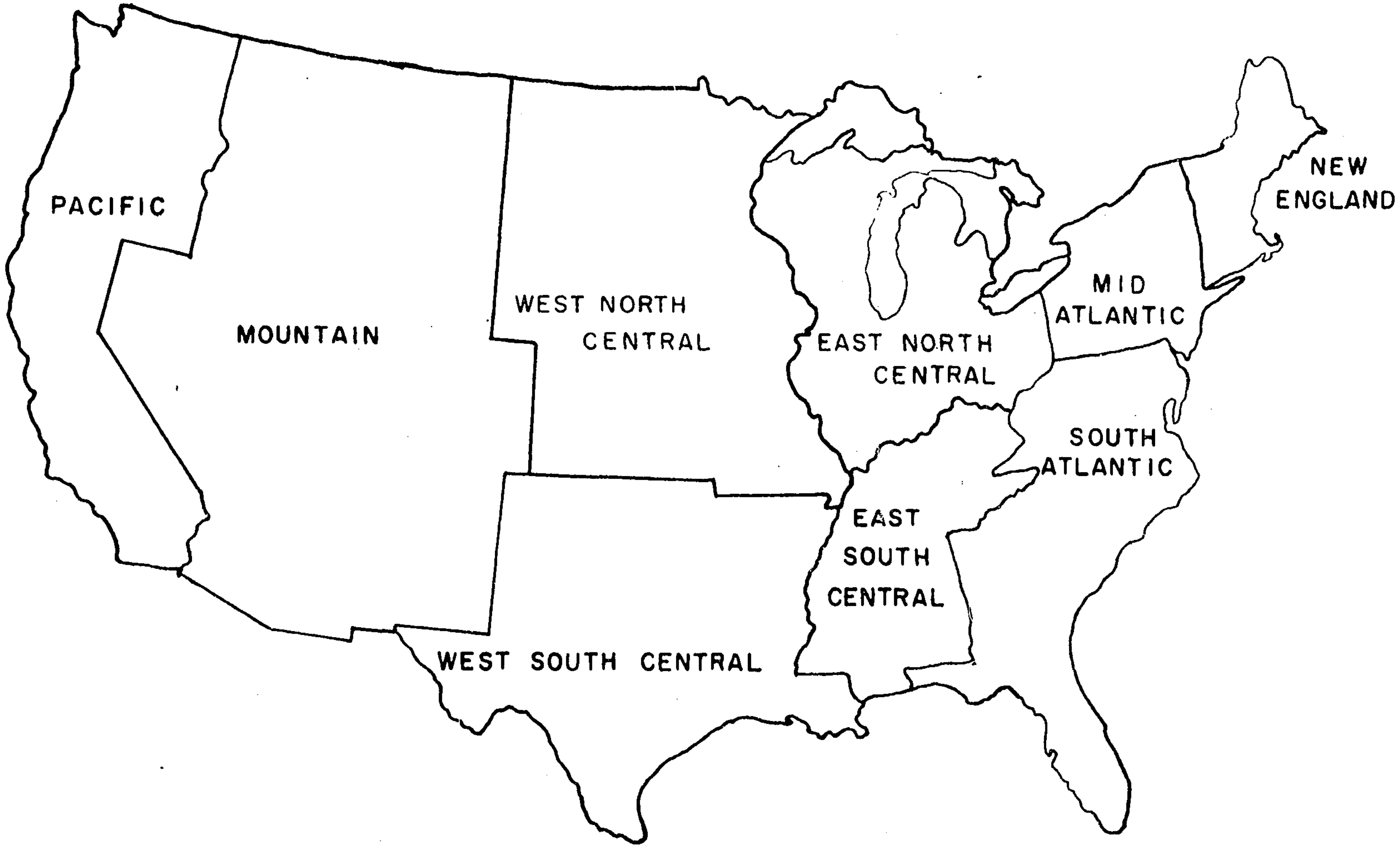

PACIFIC
MOUNTAIN
WEST NORTH CENTRAL
WEST SOUTH CENTRAL
EAST NORTH CENTRAL
EAST SOUTH CENTRAL
NEW ENGLAND
MID ATLANTIC
SOUTH ATLANTIC

Table 1. Size of the farm labor force, by regions, for 1957, and the percentage change in the labor force, by regions 1910 to 1957 and 1929 to 1957, as a percentage of 1910[a]

	Size of farm labor force 1957	Percentage change 1910-1957	Percentage change, 1929-1957		
		Total farm employment	Total farm employment	Hired workers	Family workers
	(thousands)	(per cent)	(per cent	(per cent)	(per cent)
New England	172	-53	-36	-33	-38
Mid. Atlantic	444	-53	-36	-47	-30
E.N. Central	1307	-36	-22	-54	-12
W.N. Central	1398	-36	-35	-65	-24
South Atlantic	1345	-49	-42	-36	-44
E.S. Central	969	-58	-56	-47	-58
W.S. Central	1000	-54	-57	-46	-61
Mountain	354	-18	-35	-46	-27
Pacific	588	+14	+ 1	+ 2	+ 1
United States	7577	-44	-40	-44	-39

[a]Source: (128); (130: Oct. 1953).

four regions is presented comparing the years 1931 and 1957. More workers were employed in 1931 than in 1957 for most of the months of the year. For the summer months, however, the number of workers employed was similar for the two periods. This seasonal pattern is brought out in Figure 6. For instance, of a total of 3.6 million farm workers who did any farm work

Figure 5. Seasonal hired farm employment for four regions, 1931 as compared to 1957.

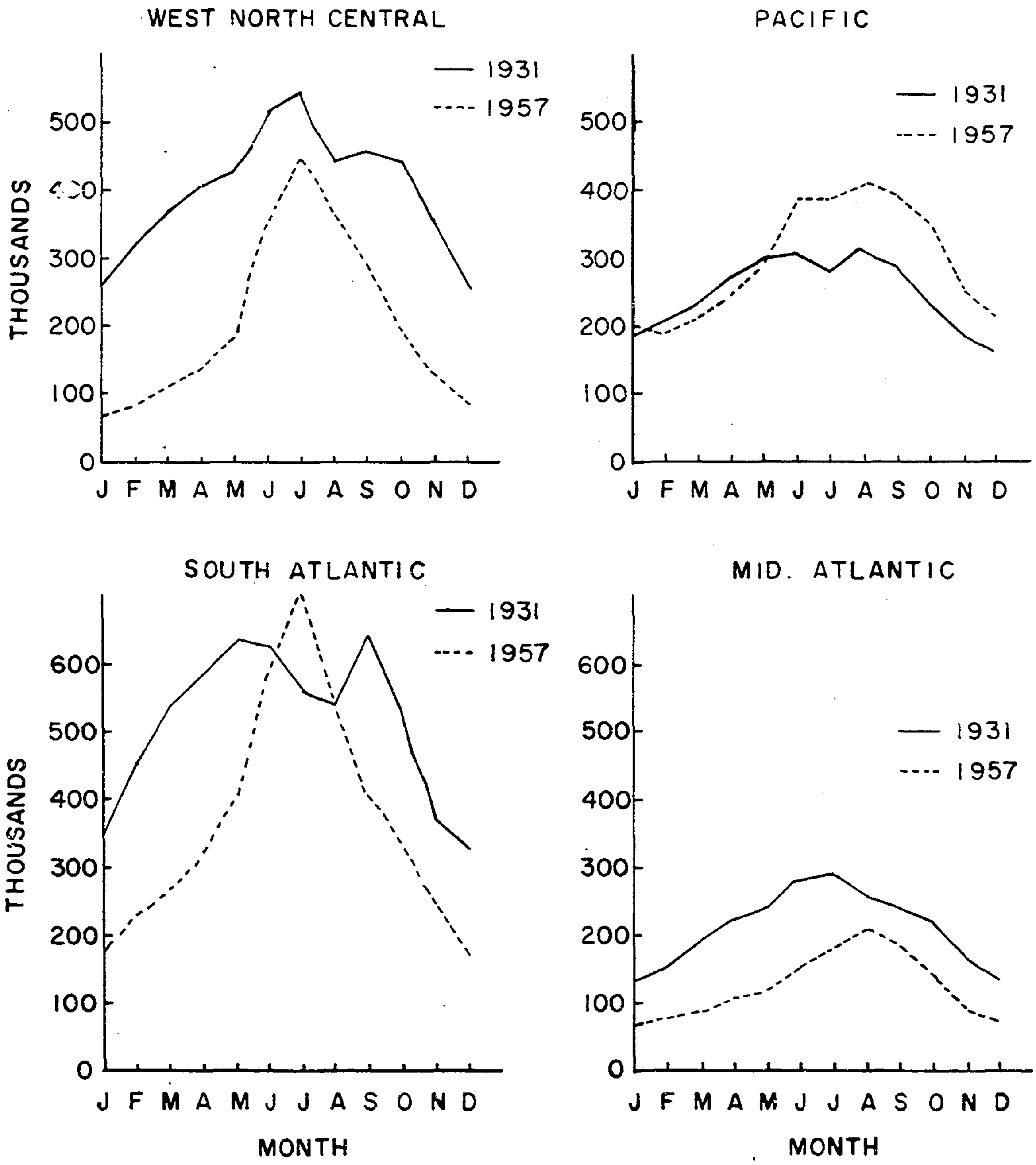
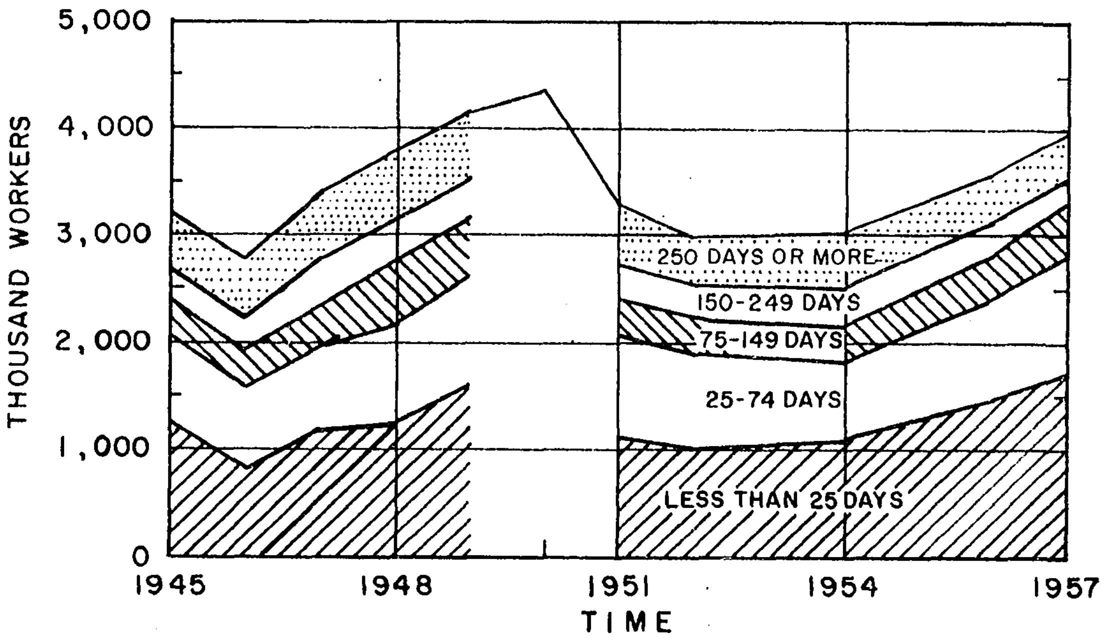

WEST NORTH CENTRAL
PACIFIC
SOUTH ATLANTIC
MID. ATLANTIC
1931
1957
THOUSANDS
MONTH
J F M A M J J A S O N D
0
100
200
300
400
500
600

Figure 6. Estimates of the hired farm working force (HFWF): the number of different persons by days worked in agriculture, 1945 to 1957.


5,000
4,000
3,000
2,000
1,000
0
THOUSAND WORKERS
250 DAYS OR MORE
150-249 DAYS
75-149 DAYS
25-74 DAYS
LESS THAN 25 DAYS
1945
1948
1951
1954
1957
TIME

for wages during 1956, 1.5 million or 40 per cent of the total worked 25 days or less. Only 750 thousand farm workers reported working 150 days or over (83, pp. 34-35). Hence, while decreasing the average need for farm workers, factors such as mechanization and the adoption of improved cropping practices have not reduced the seasonality of farm work, especially for hired labor.

Inputs other than farm labor, too, have demonstrated considerable change over time. A number of changes in resource use and structure of agriculture have resulted from changes in technology and prices of factors and products. Farmers have made large adjustments in the mix of resources used, shifting from resources which are more expensive relative to those which are less expensive at the margin. The relative changes in prices and inputs of major factors between 1940 and 1957 are shown in Table 2. In essence, these changes indicated that as the price of a factor rose relative to product prices, the use of the factor decreased. For example, the price of farm labor increased relative to product prices, and the number of man-hours worked decreased 34 per cent. The price of land was also relatively high, and the amount of cropland used decreased or remained constant. The non-farm inputs--tractors and fertilizer--decreased in price relative to prices received while the quantity used of these inputs increased.

Table 2. Relative change in prices and use of major resource categories, U.S., 1957 as compared with 1940

Resource category and percentage change in price, 1940 to 1957, as a per cent of 1940		Resource category and percentage change in use, 1940 to 1957, as a per cent of 1940	
Wage rates[a]	427	Man-hours[b]	-34
Real estate[c]	302	Cropland[d]	- 2
Farm machinery[e]	228	Tractors[f]	+203
Fertilizer[e]	154	Fertilizer[g]	+258
Farm products[h]	235	Farm output[i]	+ 41

[a]Source: (130: Jan. 9, 1959)

[b]Source: (133, p. 20)

[c]Source: (123: 1957, p. 526; 1958, p. 467)

[d]Source: (133, p. 10)

[e]Source: (123: 1957, p. 572; 1958, p. 467)

[f]Source: (133, p. 29)

[g]Source: (133, p. 16)

[h]Source: (124: p. 63); (127: Oct. 15, 1959, p. 56)

[i]Source: (133, p. 6)

Objectives

The problem of low relative income to farmers amid substantial surpluses of farm products has created interest in obtaining more knowledge of the structure of agriculture. The general objective of this thesis is to investigate the demand

and supply for farm labor. The emphasis is principally on demand; supply functions for farm labor were specified in a two-equation simultaneous system to identify the farm labor demand function more adequately. Too, this study offers an opportunity to present a methodological procedure which overcomes some of the disadvantages associated with the use of autocorrelated economic time series.

The specific objectives are: (1) to estimate and analyze empirical demand functions for both hired and family labor on a national and regional basis; (2) to estimate and analyze supply functions for hired and family labor for the U.S.; (3) to summarize and appraise the quantitative estimates of the farm labor force; and (4) to offer predictions on the size of the farm labor force in 1965 and 1975.

REVIEW OF LITERATURE

Little empirical work has been done in estimating quantitative agricultural resource demand and supply functions. The paucity of empirical knowledge of the factor markets, and of farm labor in particular, spurred research in the area during World War II. Early farm labor research of Schultz (107), Ducoff (19) and Ahearn (1) was directed at descriptive analyses of factors affecting farm employment of the farm wage rate.

Black (7) indicated that there are regular and progressive geographic gradations in farm wage rates in the U.S. that have persisted over time. Starting from a low in the southeastern states, successively higher wage belts follow in a northwesterly course across the U.S. This geography of farm wage rates was investigated by Weatherford (136), Maitland and Fisher (84), and Wolfson (139). Two of the studies concluded that farm wage payments tended to equal the marginal value of labor for the periods and areas studied (136, p. 82, 139, p. 256). These writers further hypothesized that the "demand for farm labor is not independent of the supply" (136, p. 83), and they noted "the complexity of factors that influence wage rate differentials" (84, p. 38).

T.W. Schultz was one of the first to note the particular problems of agricultural factor markets and their relations with industry (108).

Studies of a more empirical nature were published on the demand for fertilizer by Heady and Yeh (142) and Griliches (35; 37). They observed the effect of technical change on the utilization of this resource, and postulated that the rapid rise in fertilizer use was occasioned by the fall in the price of fertilizer relative to output and other input prices.

In a study of farm machinery, Cromarty (15) held that his results did not indicate that machinery is directly substituted for labor as farm wage rates rise. He inferred that the influence of new developments in farm machinery, which could not be adequately quantified, was of more importance than substitution between labor and existing machinery.

Empirical studies of the demand for hired farm labor have been presented by Griliches (36) and Schuh (105). Griliches utilized a distributed lag equation containing one explanatory variable, the farm wage rate. Schuh used a system of simultaneous distributed lag equations to study the supply of hired labor. To identify the supply function, he utilized a demand function similar to the Theil-Basmann equation presented in this study. A comparison of the results of Schuh's paper will be presented later in this study.

THEORY OF FACTOR DEMAND AND SUPPLY

Prior to the presentation of the models used to derive the demand and supply functions for farm labor, the underlying theory is presented. The models are sets of mathematical equations expressing economic theory. To determine proper form and specification in empirical model-building, the assumption is made that individuals and groups of individuals behave in some identifiable pattern which can be incorporated into the structure of the model. In this study, the representation of behavior patterns by economic models is derived essentially from the static and dynamic theory of demand. The purpose of this chapter is to outline briefly the theory from which the economic models are constructed, and to present hypotheses which are tested in this study.

Static Theory and Factor Demand and Supply

The marginal theory of the firm provides the analytical foundation for the empirical studies which follow. For the firm, the assumptions of this study are those of competition and profit maximization. A factor market is said to be perfect if: (1) the input is homogeneous and the buyers are uniform from the sellers point of view; (2) buyers and sellers are numerous; (3) both buyers and sellers are free to enter and leave the market.

A rational entrepreneur, with unlimited capital, optimizes his input combination by equating the price of each input with the value of the marginal product of the input:

(1) $p_x = vmp_x$,

where p_x is the price per unit of resource x, and vmp_x is the value of the marginal product of x. In this sense, labor should be used in quantity such that its marginal productivity is equal to the wage rate.

The demand function for a factor may be derived in the following manner. Assume that the i-th firm's production function is:

(2) $q = f(x_1, x_2)$,

where q is the output, and x_1 and x_2 are inputs. Profit, π , is equal to the output, q, multiplied by its price, less the amount of each factor, x_1 or x_2, multiplied by its price. This is:

(3) $\pi = p_q \cdot f(x_1, x_2) - p_{x_1} \cdot x_1 - p_{x_2} \cdot x_2$,

where p_q is the price per unit of output and p_{x_1} is the price per unit of the i-th input. To find the maximum profit position, the partial derivatives of π are taken with respect to the individual resources, and set to zero:

(4) $\dfrac{\partial \pi}{\partial x_1} = p_q \cdot f_1(x_1, x_2) - p_{x_1} = 0$, and

(5) $\dfrac{\partial \pi}{\partial x_2} = p_q \cdot f_2(x_1, x_2) - p_{x_2} = 0.$

From 4 and 5 solve for x_1, the quantity demanded of the first factor, and x_2, the quantity demanded of the second factor:

(6) $x_1 = f_1'(p_{x_1}, p_{x_2}, p_q)$, and

(7) $x_2 = f_2'(p_{x_1}, p_{x_2}, p_q)$.

The demand for labor is then a function of its own price, the prices of other factors and output price where the parameters depend on the production function. In the aggregate, the industry demand would be the summation of the individual demand functions (48, p. 107).

Factor supply

The static supply function for a primary input such as labor is based on the utility to an individual worker of leisure and work in terms of prospective income. Ostensibly, then, the labor supply function of the i-th individual is dependent on the wage rate. The aggregate supply function is obtained by a summation of individual supply functions.

Elasticities of demand and supply

The price elasticity of demand and supply is represented by:

(8) $$\epsilon = \frac{p}{q} \cdot \frac{\partial q}{\partial p} .$$

The price elasticity of demand, ϵ, is a functional relationship between the price, p, and the quantity, q, of the factor which will be demanded at each price. The price elasticity of supply is represented by the same equation (8), if q represents the quantity of labor offered at price p. Since the elasticity is independent of the units of measurement, it measures the responsiveness of the quantity demanded or supplied to changes in the price. Elasticities may be derived for other parameters, and represent the responsiveness of the quantity demanded or supplied to changes in the respective parameters.

Dynamic Theory and Factor Supply and Demand

The term dynamic is applied to the study of economic phenomena when the consideration of time is introduced. In dynamic systems values of the variables are partly or wholly determined by the past behavior of the system. The relation of statics and dynamics often is expressed in terms of the adjustment period of a variable relative to an equilibrium position. In the static case adjustment of the demand or supply quantities to a change in an explanatory variable is instantaneous. Adjustment in the dynamic case may lag over a period of time. It is commonly accepted in economic literature that the elasticity of a good will increase as the time period encompassed increases, i.e., as the time period passes from the short run to the long run. This concept implies then that past prices are important determinants of current demand.

The basic hypothesis of the models used in this study is that in response to a change in an explanatory variable there is a perceptible lag in the reaction of both producers in changing their demand for labor and of workers in changing their supply of labor. Considerable literature has been devoted to the analysis of the lag in consumer adjustments to a price or other explanatory variable change. Friedman (27), for instance, hypothesized that the consumers concept of a long-run normal income is important. Response by a consumer to a change in one of the explanatory variables would depend on past experience and expectations of the future.

What is true of a consumer is true, a fortiori, of a producer. Given a change in an independent variable that is expected to persist, the reaction of a producer to alter his demand for a factor or of a worker to alter the flow of his services will be cumulative. This lagged response of demand or supply of farm labor may result from a variety of reasons.

Factors that tend to lag the response of producers are: (1) the fixed period of production in agriculture deters changes in demand within the period; (2) contractual obligations with hired workers and obligations to family workers may limit changes in demand; (3) habit and uncertainty about the future may limit the extent of the changes in demand; (4) imperfect knowledge of changes in the determining variables; and (5) inability to immediately provide substitutes or complements for labor as changes in determining variables occur.

The response to price changes of farm workers in supplying their labor may lag over a period of time due to such factors as (1) uncertainty about the permanence of a price change; (2) lack of alternative employment opportunities or lack of information about them; (3) lack of either farm or non-farm skills; and (4) contractual obligations and fixed periods of production.

A lag arises, then, when a change in a determining variable produces its effect on supply or demand only after some lag in time. The effect of the change is not realized at once but is distributed over a period of time. Hence, the quantity of farm labor demanded as a function of the price of farm labor taken with a distributed lag means that the full effect of a change in the price of farm labor on the demand for farm labor is realized only after a period of time has elapsed.

Forms of distributed lags

Factor demand and supply equations taken with a distributed lag may differ considerably in form. In the static case, an equation such as the following is presented:

(9) $x = a + bp_1$

where x is the quantity demanded (or supplied) and p_1 is the price of x. If, in the non-static case, the variables are dated and x is assumed to depend on current and all past prices, equation 9 becomes:

(10) $x_t = a + b_o p_{1t} + b_1 p_{t-1} + b_2 p_{t-2} + \dots = a + \sum_{i=0}^{\infty} b_i p_{1t-i}$

Equation 10 states that x is determined by its price taken with a distributed lag.

The short-run elasticity of 10 is:

(11) $$\epsilon_{ar} = b_o \cdot \frac{\bar{p}}{\bar{x}} \quad ,$$

while the long-run elasticity of 10 is:

(12) $$\epsilon_{lr} = \left(\sum_{i=0}^{\infty} b_i\right) \cdot \frac{\bar{p}}{\bar{x}}$$

where $\bar{p}_1$ and $\bar{x}$ are values of p_1 and x at the mean or at specific points in time.

An effort was made by Alt (3) to estimate an equation such as equation 10. His procedure consisted of adding lagged prices until the signs of the coefficients became erratic. However, he was able to accept as consistent only from two to four of the independent variables. Three comments can be made about Alt's analysis: (1) when the intercorrelations among lagged variables are high, estimation of an equation similar to 10 is not very useful; (2) some *a priori* hypothesis concerning the distribution of the lags must be made so that consistent and inconsistent signs of the variables can be differentiated; and (3) as the number of variables and the lags are increased, the number of observations needed to perform the statistical analysis increase.

A specific form of the distribution of the lag may be assumed from which characteristics of the distribution may be estimated. Koyck (75) hypothesized that the hindrances causing the lags will be gradually overcome so that the effect of the price or other variable change will lessen over time. He assumed that after some period i = k the coefficients

b_i, i = o, 1, ..., could be approximated by a convergent geometric series:

(13) $b_{k+m} = \lambda b_{k+m-1}$

where $m \geq 0$ and $0 \leq \lambda \leq 1$. Hence, the coefficients are assumed to decrease by a consistent proportion over time.

Substituting 13 into 10 for the case where k = 0, the equation becomes:

(14) $x = a + b_o p_{1t} + b_o \lambda p_{1t-1} + b_o \lambda^2 p_{1t-2} + \cdots$.

If equation 14 is lagged by one year and both sides of the equation are multiplied by λ, the resulting equation is:

(15) $\lambda x_{t-1} = a\lambda + b_0 \lambda p_{1t-1} + b_0 \lambda^2 p_{1t-2} + \cdots$.

By subtracting 15 from 14, the following equation is derived:

(16) $x_t = a(1 - \lambda) + \lambda x_{t-1} + b_o p_{1t}$

such that the determination of x_t is dependent only on x_t lagged one year and the current value of p_{1t}. This method of reduction may be extended to include more than one explanatory variable under the assumption that the lags are the same for each variable. The distribution of the lags is given by λ and the short-run elasticity is the same as in 11. The cumulative effect of a maintained price change is:

(17) $b_0 \cdot \sum_{m=0}^{\infty} \lambda^m = \frac{b_o}{1-\lambda}$

and hence, the long-run elasticity is:

(18) $\epsilon_{1r} = \frac{b_o}{1-\lambda} \cdot \frac{\bar{p}_1}{\bar{x}}$.

Nerlove (94) arrives at results similar to Koyck by use of another set of assumptions concerning the cause of the lag in adjustment. He assumes both a long-run demand or supply equation and an adjustment equation. The long-run equation is of the form:

(19) $y_t^* = a_o + a_1x_{1t}$

where y_t^* is the long-run or equilibrium level of the quantity demanded or supplied, and x_1 is the price of y_t. Nerlove hypothesizes that the utilization of the current quantity demanded or supplied, y_t, "would change in proportion to the difference between the long-run equilibrium quantity and the current quantity" (93, p. 308). This adjustment in equation form is:

(20) $y_t - y_{t-1} = b(y_t^* - y_{t-1}),$ $\quad 0 \leq b < 1,$

where b, a constant of proportionality called the coefficient of adjustment, indicates the relative speed of adjustment.

Substituting 19 into 20, the resultant equation is:

(21) $y_t = ba_o + (1-b)y_{t-1} + ba_1x_t$

and is essentially the same as equation 16.

Hypotheses

In view of the purpose of the study and the aspects of economic theory presented, the following hypotheses are tested in this study. (1) The response of the demand or supply of farm labor to changes in explanatory variables may not be instantaneous within the initial time period, but may lag over several time periods. Consequently, the proper estimational form of the models used should be taken with a distributed lag. (2) The demand for farm labor is a function of its price-the farm wage rate, other input prices such as farm machinery prices, and the return on product sold relative to cost. (3) The supply of farm labor is dependent on the wage rate, both farm and non-farm.

THEORETICAL MODELS OF FARM LABOR DEMAND AND SUPPLY

Farm labor trends and relevant economic theories were presented in previous chapters. Particular models used in this study are specified in this chapter. Essentially, the model provides a well-defined statement of the economic hypotheses underlying the study and renders explicit the assumptions on the basis of which the investigation proceeds. In ideal form, a model should specify all of the relevant variables that influence the demand or supply of farm labor. In practice, however, some of the assumptions on which the analysis is based may be unrealistic resulting in specification errors. Examples of these assumptions are: (1) formulation of the models that over-simplify the dynamic phenomena whose generation is to be explained; and (2) the data contain errors of measurement or may otherwise imperfectly represent the variables as theoretically specified.

The Model for the Demand and Supply of Hired and Family Labor

The following demand and supply equations were employed:

(22) (D) $y_1 = a_{10} + a_{11} x_1 + a_{12} x_2 + a_{14} x_4 + a_{15} x_5$

(23) (S) $y_2 = a_{20} + a_{21} x_1 + \qquad + a_{25} x_5 + a_{26} x_6$

where the variables are:

y_1 is the quantity of farm labor demanded.

x_1 is the index of the aggregate average farm wage. The data were deflated by two principal deflators: (1) the index of prices paid by farmers in living expenses; and (2) the index of prices paid by farmers for production expenses, not including wages. The rationale for including the wage rate variable was that the farm wage rate is the price of hired labor and was assumed to be the "going" price of family labor.

x_2 is the index of prices received by farmers for all commodities. When deflated by the index of prices paid by farmers for production expenses, the series is a ratio of product price to cost.

x_3 is the aggregate index of farm machinery prices. Deflators of this series were the same as for x_1. The inclusion of this series should articulate substitutional relationships with farm labor. However, empirical demand functions including the price of farm machinery appeared to be inconsistent in sign and were non-significant. Equations containing the price of farm machinery as a variable are accorded a separate analysis later in the study.

x_4 is the index of the value of farm machinery. The series was compiled commencing with a deflated value of farm machinery on farms from the 1930 census. For succeeding years, the deflated additions to and depreciation of machinery and equipment were added (or subtracted) from the prior year's total. Inclusion of this variable should give an index of the change in the scale of farming.

x_5 is time as a variable. A linear trend variable was used to represent the technological changes that have occurred in farming, such as machinery innovation, improved seed, and new farming practices. The basic assumption was that these changes have occurred slowly over time so that they could be represented by a time trend.

y_2 is the quantity of farm labor supplied.

x_6 is a non-farm wage rate variable. This variable is a composite of an index of hourly factory wages with the percentage of unemployment as compared with the total work force. It was assumed that when the percentage unemployment of the total work force reached 20 per cent, no further off-farm opportunities exist. Consequently, at that level of unemployment or greater, changes in non-farm wage rates have a negligible effect in pulling labor from agriculture. Utilizing this assumption, the percentage unemployment was not allowed to rise over 20 per cent and was combined with the series of average hourly earning of factory workers in the following manner:

$$A\ (1 - 5U)$$

where A is the hourly earnings of factory workers and U is the percent of unemployment. When the unemployment rate reaches 20 per cent, this variable becomes zero; when the unemployment rate is zero, the variable reaches the total of the average earnings of factory workers.

EMPIRICAL PROCEDURES

The previous chapters have presented the study objectives, some prior quantitative work, farm labor trends and relevant economic theory of factor demand and supply. The actual estimation utilizes statistical methodology as well as economic concepts. This chapter presents the general statistical considerations on which the analysis of farm labor is based. These considerations include: (1) a presentation of the least squares method; (2) use of single and simultaneous equations; (3) an autoregressive least squares technique; and (4) a method of estimation of simultaneous systems containing autocorrelated errors.

The Least-Squares Method

The demand and supply functions presented later in this study were estimated by least squares methods. Wold states that "...no other estimate of the relation will give such small residual variance" (137, p. 43). In multiple regression, a general linear relationship of the form below is assumed where y denotes the variable to be explained, and x_1 to x_p, the explanatory variables:

(24) $y = b_1x_1 + \dots + b_px_p + e$,

where $x_i = X - \bar{X}$ are the deviations from the mean, the b_i are the regression coefficients, and e is a random disturbance. The assumptions are that the errors, e_i, are independently distributed with expected value zero and a constant variance over time (120, p. 27).

In the method of classical least squares, the sum of squares of the deviations is minimized. The sum of squares to be minimized is:

$$(25)\quad \sum_{i=1}^{n} (y - b_1x_1 - \dots - b_px_p)^2 = \sum_{i=1}^{n} e_i^2.$$

If the left hand side of 25 is differentiated with respect to the b_i, a set of normal equations is obtained whose solutions are the regression coefficients.

Single and Simultaneous Equations

The least squares method has been used primarily to solve single equations. Recent work in the estimation of the parameters of economic relationships has stressed adapting statistical methods to the type of data and objectives of economic research. Recognition of the simultaneous nature of the generation of economic data has led to the development of techniques consistent with this interdependent characteristic of the economic system (120, 118, 5). The set of equations specified in the model used in this study may be solved singly or simultaneously. Solved singly, the least squares method applies; solved simultaneously other techniques are needed.

The general form of equations 22 and 23 would appear as the following to be solved simultaneously and taken with a distributed lag:

(26) (D) $b_{11} y_1 + b_{12} y_2 + c_{11} z_1 + c_{12} z_2 + c_{13} z_3 = e_1$

(27) (S) $b_{21} y_1 + b_{22} y_2 + c_{21} z_1 + c_{22} z_2 + c_{24} z_4 = e_2$

where y_1 is the quantity of farm labor, y_2 is the farm wage rate, z_1 is the quantity of farm labor lagged one year, z_2 is time as a variable, z_3 is the index of prices received, z_4 is the composite non-farm wage rate variable, and the e_i are the disturbances in the respective equations. The y_i are endogenous variables determined from outside the system. In the system of equations above, both equations are just-identified since the number of exogenous variables excluded from each is one less than the number of endogenous variables included in the equation. If the number of exogenous v ariables excluded from the equation in question is larger than one less than the number of endogenous variables in the equation, the system is said to be overidentified. The overidentified case is usual in simultaneous equation estimation.

To estimate the regression coefficients in a system of equations in the overidentified case, the method of limited information was developed. More recently, an alternative estimating procedure was presented by Theil (118) and Basmann (5). It provides ease of computation utilizing least squares methods and permits rapid estimation of the standard errors of the coefficients.

Autoregressive Least-Squares Techniques

Distributed lag equations such as 21 may be solved either singly or simultaneously. However, difficulties of estimation arise using either method. If an error term is added to 21 this simplified form becomes:

(28) $y_t = \alpha x_t + \lambda y_{t-1} + v_t - v_{t-1}$

where the error terms $v_t - v_{t-1}$ are treated as a composite disturbance. Koyck (75) suggested that the usual least squares analysis of 28 will lead to biased estimates of α and λ, the true parameters, unless there is no autocorrelation in the residuals. Further, Klein (72) stated that the composite error term has an automatic serial correlation even if the v_t are serially independent. The error term in period t is correlated with that of period t-1 because both error terms contain a mutual term, v_{t-1}, i.e., $(v_t - v_{t-1})$ and $(v_{t-1} - v_{t-2})$.

Nerlove and Addison state that estimation using distributed lag equations overcomes the residual autocorrelation problem. The Durbin-Watson test for residual correlation (22) indicates that there is no significant autocorrelation among the residuals. However, it is likely that the use of the lagged dependent variable will extract most of the autocorrelation from the residuals, and will result in biased coefficients if there is residual correlation.

Koyck proposes a technique to obtain consistent estimators which depend on the assumption that the error term, u_t, is generated by an autoregressive scheme,

(29) $u_t = \beta u_{t-1} + e_t$.

The assumptions are that u_t has a zero mean and a constant variance, e_t is not correlated with u_{t-1} and there is no autocorrelation among the e's (75, p. 34). Further, he assumes specific values of β. Estimation by this technique is referred to as autoregressive least squares.

In an equation such as in 30, assuming that a first-order autoregressive scheme applies, the cases in which a variable b' is a consistent estimator of the real b has been outlined by Fuller (31). He shows that given Koyck's basic equation:

(30) $y_t = ax_t + by_{t-1} + u_t$

combined with the autoregressive scheme of equation 29 leads to:

(31) $u_t = \beta(y_{t-1} - ax_{t-1} - by_{t-2}) + e_t$.

By substituting equation 31 into 30, he shows that the probability limit of b' is given by

$$(32)\ \text{plim } b' = b + \frac{\beta}{1 + \beta b} \left\{ \frac{(1 - r^2_{x_t y_t}) - b^2}{(1 - r^2_{x_t y_{t-1}})} \right\}.$$

Under these assumptions, b' is a consistent estimator of b only when $\beta = 0$. These results indicate that a more accurate estimate of b can be obtained if the value of β were known. Since there is usually autocorrelation among economic time series, it is likely that estimates of b have an upward bias, depending on the value of β.

Methods for estimating β have been presented by Klein (72) and Orcutt and Cochrane (13). A simplified method for estimating β by an iterative process has been developed by W. Fuller, and will be published in a forthcoming paper (30). Basically, the method is as follows:

(33) $y_t = ax_t + (b + \beta)\, y_{t-1} - a\beta\, x_{t-1} - b\beta\, y_{t-2} + e_t$.

A regression on these variables provides initial values of estimates of a, b, and β. By a method of non-linear regression (79), a function containing the estimates of the coefficients is expanded in a first-order Taylor expansion about the point defined by the initial values above. The sums of squares and cross products for the Taylor expansion become linear combinations of those in 33. The results of the Taylor expansion yield:

(34) $y_t = y_0 + z_1\Delta\hat{a} + z_2\Delta\hat{b} + z_3\Delta\hat{\beta}$, where

$y_0 = y_t - \hat{y}_t$, the residuals in 33,

$z_1 = x_t - \hat{\beta}x_{t-1}$,

$z_2 = y_{t-1} - \hat{\beta}y_{t-2}$,

$z_3 = y_{t-1} - \hat{a}x_{t-1} - \hat{b}y_{t-2}$,

where $\hat{a}$, $\hat{b}$, and $\hat{\beta}$ are the initial estimates of the coefficients, and the Δa, Δb, and $\Delta\beta$ represent changes in the estimates for each iteration. The least squares method applied to 34 produces further changes in the estimates, and the iterative procedure continues until the change becomes sufficiently small. The final values are consistent estimates of the coefficients (30).

Since the models derived in this study are all "shock" models, the data are presumed to be measured without error. The results may be invalidated to some extent, since errors of observation in economic time series are usually present. A method of dealing with this problem is presented by Tintner (120), and an example involving labor has been analyzed by Mosbaek (90).

Estimation of Simultaneous Systems Containing Autocorrelated Errors

A distributed lag equation may be solved simultaneously by the same techniques as a general least squares equation not containing a lag. A single equation of a system of equations may be written as:

$$(35)\quad y_{1t} = \sum_{i=2}^{g} \beta_i y_{it} + \sum_{i=1}^{h} \alpha_i z_{it} + u_{it},$$

where y and z are as defined under equations 26 and 27 and α and β are the parameters to be estimated. Theil and Basmann (5, 118) have shown that consistent estimates are obtainable for α and β when the y_{it} are replaced by $\hat{y}_{it}$, obtained by regressing each y_{it} on all of the exogenous variables. Equation 35 may be rewritten as:

$$(36)\quad y_{1t} = \sum_{i=2}^{g} \beta_i \hat{y}_{it} + \sum_{i=1}^{h} \alpha_i z_{it} + e_t,$$

where e represents a new error term. The regression coefficients are estimated by classical least squares applied to the transformed equation. Since the Theil-Basmann solution uses information contained in all the exogenous variables in the complete system, it approaches the efficiency of the method of limited information (70, p. 13).

Fuller (30) shows that autoregressive least squares equations may also be estimated simultaneously. His procedure is outlined in Appendix D.

SOURCES AND NATURE OF DATA

Several sources of farm employment data exist. To indicate the basis of choice, all of the major farm employment series are presented and analyzed critically in this chapter. Sources of data other than those for farm employment which are necessary in the following labor analysis are also explained.

Major Sources of Employment Data

The major sources of farm employment data are: (1) employment estimates of the Agricultural Marketing Service of the U.S.D.A. herein referred to as the AMS series (128); (2) estimates published by the Bureau of the Census, the Current Population Survey, herein referred to as CPS (121); (3) man-hour requirements estimated by the Agricultural Research Service of the U.S.D.A. herein referred to as FERD (133); and (4) estimates of the hired farm working force of the Agricultural Marketing Service of the U.S.D.A., and based on a survey by the Bureau of the Census, herein referred to as HFWF (85). Though not described here, a rough estimate of the number of available farm workers may be derived from farm population estimates.

Comparison of the major employment series

The most important of the sets of farm employment estimates are the AMS and the CPS series. A discussion of these sets of data are presented immediately below, while the remaining sets of employment data are accorded separate analysis later.

The CPS and AMS farm employment series on an annual and seasonal basis are presented in Tables 3 and 4. The AMS series of average annual employment in Table 3 is higher than the CPS series in every period. The difference between the two series gradually widened from 1940 to 1950, but narrowed again from 1951 to 1957. A factor in the decrease in the difference between the two series may lie in the fact that the Bureau of the Census enlarged its sample in 1954 and again in 1956. However, though the differences became less pronounced during this period, no causal relation has been established.

Table 4 contains series of hired seasonal employment of the AMS, CPS, and HFWF for 1957. During this year, the AMS estimates were higher than those of the CPS for the summer months, but were lower during the winter months. The HFWF estimates are similar to the CPS estimates since both sets of data are collected by the Census Bureau. However, the employment estimates for the HFWF are much below the CPS estimates for the earlier months of the year, but similar over the latter months. This bias in the HFWF series will be discussed further in this study.

While each of the hired farm employment series in Table 4 agree on the months of minimum employment, December, January, and February, they differ on periods of peak employment. The

Table 3. Total farm employment by annual averages: CPS with AMS series, 1940 to 1957, and differences

Year	CPS[a]	AMS[b]	Difference
	(Thousands of persons)		
1940	9540	10979	1439
1941	9100	10669	1569
1942	9250	12504	1254
1943	9080	10446	1366
1944	8950	10219	1269
1945	8580	10000	1420
1946	8320	10295	1975
1947	8266	10382	2116
1948	7973	10363	2390
1949	8026	9964	1938
1950	7507	9926	2419
1951	7054	9546	2492
1952	6805	9149	2344
1953	6562	8864	2302
1954	6504	8639	2135
1955	6730	8364	1634
1956	6585	7820	1235
1957	6222	7577	1355

[a]Source: (121).

[b]Source: (128).

Table 4. Average employment of hired farm workers by months, U.S., AMS, CPS, and HFWF series, 1957

Month	AMS[a]	CPS[b]	HFWF[c]	
			Original	Adjusted[c]
		(Thousands of persons)		
January	896	1154	757	827
February	1040	1180	768	839

[a]Source: (128).

[b]Source: (121).

[c]Adjusted to include foreign workers; source: (85).

Table 4 (Continued).

Month	AMS[a]	CPS[b]	HFWF[c]	
			Original	Adjusted[c]
	(Thousands of persons)			
March	1284	1209	856	935
April	1543	1322	1085	1177
May	1985	1710	1394	1538
June	2684	2138	1924	2058
July	2983	2354	2189	2364
August	2883	1971	2058	2219
September	2805	1911	1872	2121
October	2237	2112	1706	1944
November	1450	1654	1405	1568
December	951	1533	1073	1174
Average	1895	1687	1424	1564

AMS series indicates that July, August, and September were very similar in the number employed, while the CPS series is bimodal. In previous years, the AMS series also has been bimodal, with September being the month of greatest employment (128).

The discrepancies between these two series, CPS and AMS, exist because of differences in concept and method of enumeration. The AMS series essentially estimates the number of farm jobs, while the CPS estimates the number of farm workers. Both series have relative advantages and disadvantages. The basic differences between the series are explained below.

There are five main differences between the AMS and CPS sets of employment estimates. First, the data are compiled in the two series by means of two different enumerative techniques. The U.S.D.A. derives farm employment estimates from selected representative farmers who report on their own particular farm. This method of data collection is referred to as the "establishment" method, since the information is obtained about all of the workers on the establishment. On the other hand, the CPS series is derived from Bureau of Census data which are collected from households. The household method obtains information only on actual members of the household. Consequently, a worker who is employed on more than one farm during the survey period may be counted more than once under the establishment method, but only once under the household method. Double counting under the establishment method has been estimated to be at a minimum of a quarter of a million persons, and may be considerably larger seasonally (126, p. 12).

A second source of difference between the AMS and CPS series lies in the method of counting workers based on specified age limits. While the AMS sets no age limit in their enumeration, the CPS enumeration includes only persons 14 years of age or over. When unpaid members of the family who work 15 hours or more a week are included, the number of children under 14 years of age is estimated by the U.S.D.A. to be as high as a million (126, p. 12). A private estimate by D.G. Johnson of the number of children employed during the peak period placed the maximum at two million (66).

A third difference between the two sets of employment estimates arises over the issue of multiple job holding.

The requirements for a farm worker to be included in the enumeration of the AMS are minimal but must occur during the survey week: one or more hours of farm work for a hired worker, any work at all for an operator, and 15 or more hours for unpaid family workers. However, to be included in the CPS enumeration, the worker must not only be 14 years of age or over, but must have earned a major share of his income in agriculture. Persons with multiple jobs who are not counted by the CPS enumeration but who actually do some farm work are estimated to number one-half to one million seasonally (126, p. 12).

A further difference between the two series may arise because the CPS includes categories of workers on farms who engage in certain non-farm occupations - such as bookkeepers and typists, workers engaged in some processing activities, and unemployed farm operators. An estimate of the number of non-farm workers included in the CPS series may be obtained by subtracting the number of persons employed in agricultural occupations (farm operators and farm laborers) from the total number of persons employed in agriculture. For 1957, an annual average of 198 thousand persons were estimated to be engaged in these non-farm activities (85).

A difference between the two series also may occur because of different dates of the surveys. While the dates of the surveys of the CPS relate to the week ending nearest the 15th of the month, AMS estimates relate to the last full calendar week of the month.

Besides these five differences between the two major series, other factors are important in the selection of a series to use in the analysis. The estimates of the CPS series are derived from a statistically selected sample, so that standard errors of the estimates can be computed. Standard errors of the estimates are not obtainable from the AMS series. A further and important consideration is the length of time covered by the two series. The AMS estimates cover the period 1910 to the present, include separate series for hired and family labor, and include regional as well as national estimates. The CPS series, inaugurated in 1940, presents estimates of hired and family labor on a national basis only.

Two other sets of farm employment estimates, the HFWF and the FERD series, will be discussed.

<u>The hired farm work force (HFWF)</u>

The HFWF is a relatively new series started in 1945 for the purpose of providing more detailed information on work done by hired workers. The HFWF is derived from information obtained by the Agricultural Marketing Service from the Bureau of the Census through supplementary questions included in one of the regular Current Population Surveys. Employment data for the year are collected at the beginning of the following year, and questions are asked about any farm work done over the past year. Consequently, the data are subject to errors in the memory of those who report. This memory bias partially explains why the estimates of the HFWF are relatively low in the earlier months of the year. Since the enumeration covers work for the whole month rather than for a survey week and is derived from the same sample as the CPS, the HFWF series monthly estimates should be larger than the monthly CPS estimates. Were the CPS adjusted downward for the number of non-farm workers included in the series, the hired farm work force, augmented by the number of foreign workers, should be the higher of the two series. The HFWF is not available by regions.

The series of man-hour requirements (FERD)

Another farm employment estimate not directly comparable to the three previously discussed sets of farm employment estimates is the FERD series of man-hour requirements. The purpose of the series is to estimate the number of man-hours required for annual farm output, rather than man hours actually expended. Compiled by the Agricultural Research Service of the U.S.D.A. these estimates are "built up" by multiplying estimated average man-hours per acre of crops and per head or unit of production of livestock by the official estimates of total acres and numbers of livestock reported by the Crop Reporting Board of the U.S.D.A. For a detailed account of the estimating procedure see source (125). A limitation of this series is that errors in the magnitude of the estimates of man-hours per acre or per head of livestock are greatly enlarged when these initial estimates of man-hour requirements are multiplied by the total number of acres and animals. Too, a test of statistical reliability cannot be applied. The series includes both national and regional estimates, and covers the period 1910 to the present.

Usefulness of the Sets of Employment Estimates

Each of the above four sets of employment estimates has been derived for a particular purpose. Each employment estimate, because of its particular advantages and disadvantages is unique and suitable only for specific analyses. The AMS series has been utilized more than the other series for labor analyses. It also is used in this study for the following reasons: (1) the AMS series covers a relatively long period, from 1910 to the present; (2) the series encompasses both the hired and family components of farm labor; (3) since no age limits are imposed in the enumeration and all farm work is included, the AMS series at the present time is probably a better measure of marginal changes in the farm labor force than is the CPS series (2, p. 496).[1]

[1]However, the effectiveness of the AMS series would be greatly enhanced through measures of job duration (1, p. 205). Since the AMS estimates are basically estimates of the number of jobs, detail on job duration would lead to a more reliable estimation of work actually done.

As an indicator of the quantity of work done, the CPS series of farm employment estimates may be more reliable. The reliability of the series has increased since 1956 when the size of the sample was greatly enlarged. Too, analyses of multiple job holdings have been developed. For future labor research use, as the time period covered by the CPS increases, the CPS will be the more reliable series, unless the AMS series is improved.

The HFWF series is useful for comparisons of time worked by hired laborers. The value of the series will be enhanced as the time period covered increases in length, especially if a reliable method is developed to compensate for the bias in memory recall.

The FERD series is admirable in purpose, to measure the basic demand for labor inputs in agriculture, but the reliability of the series cannot be statistically estimated. However, the long-run trend of man-hour requirements follows the trends in the AMS and CPS series. Use is made of the FERD series in long-run prediction in this study because year-to-year changes in man-hour requirements of labor should indicate changes in farm labor productivity.

A synopsis of the comparisons of the different employment series is presented in Appendix A.

Sources of Other Data

Labor estimates provide only part of the data needed for predicting labor demand. Other sets of data used are the price of farm labor, the prices of other inputs such as farm machinery, the price of products produced by farm labor, and the value of farm machinery. These data with appropriate sources are contained in Appendix B.

EMPIRICAL ESTIMATES OF THE NATIONAL DEMAND FUNCTIONS FOR HIRED LABOR

The previous chapters have presented farm labor trends, discussed types of employment estimates, cited economic theory and statistical methodology, and introduced the models to be estimated. The results of the estimation of the empirical demand and supply functions for farm labor are presented in the remaining chapters. The objective of this thesis was to investigate the farm labor market. The focus of this study, though, has been primarily on demand, and among the demand functions for farm labor the best results have come from the estimation of the demand for hired labor. These results are not unexpected inasmuch as hired farm labor in contrast to family labor has an overt wage or price which is reported nationally and regionally.

Furthermore, this chapter has the task of testing the hypothesis, as presented in the introduction, that the demand for hired labor is a function of its price, the farm wage rate, other inputs such as the price of farm machinery, the scale of farming as exemplified by the value of farm machinery, and the return on product sold. The price of inputs, such as the series of aggregate farm machinery prices, were originally included in the model. However, the inclusion of the farm machinery price variable resulted in inconsistent results when combined with the other explanatory variables. Because of the importance of this variable to the determination of the demand for hired labor, it is accorded a separate analysis later in this thesis. The results of the inclusion of the remaining variables will be individually analyzed in this chapter.

Initially an analysis of the results of different techniques employed in the estimation of the demand functions for hired labor will be presented. The analysis of the regression coefficients and elasticities of the demand for hired labor will follow. The estimated demand functions for hired labor are presented in Tables 5 and 6. Two demand functions, 3 and 12 of Table 5, are plotted against the actual data in Figures 7 and 8.

An Analysis of the Results of Different Techniques Used to Estimate the Demand Functions for Hired Labor in the U.S.

In estimating the demand functions for hired labor for the U.S. several techniques were employed over the different time periods. So that attention can be focused on the characteristics of the important variables, the effects of these different techniques will be analyzed. The demand functions as shown in Tables 5 and 6 are differentiated by: (1) the form of the equations; (2) the inclusion or lack of inclusion of time as a variable; (3) the inclusion of different independent variables; (4) the use of different deflators; (5) equations using variables in linear or logarithmic form; (6) the use of

Table 5. Regression coefficients and standard errors for the demand functions for hired labor for the U.S.[a,b]

Equation number	Time period	Constant	X_1	X_2	X_3	X_4	Y_{t-1}	R^2
		Regression coefficients						
1	1910-1957	40.74	-.077*	-	-.297	-	.777	.983
			(.045)		(.141)		(.082)	
2	1910-1957	15.23	-.091	-	-	-	.931	.981
			(.044)				(.047)	
3	1910-1957	27.89	-.098*	-.054*	-.179**	-	.826	.983
			(.055)	(.033)	(.119)		(.073)	
4	1910-1957	12.86	-.122	.079	-	-	.907	.982
			(.053)	(.029)			(.054)	
5[c]	1910-1957	.3521	-.095	.057	-.021***	-	.871	.984
			(.034)	(.022)	(.017)		(.054)	
6	1910-1957	23.86	-.046***	.048***	-.240	-	.841	.982
			(.058)	(.064)	(.114)		(.073)	
7	1920-1939	68.40	-.054***	.248	-.686	-	.478*	.935
			(.187)	(.111)	(.262)		(.271)	
8[d]	1929-1957	52.47	-.168**	.099**	-.335	-	.658	.970
			(.108)	(.069)	(.119)		(.041)	

[a]The regression coefficients are deflated by the variables listed in Table 6. The variables are:

X_1: the hired farm wage rate
X_2: the index of prices received by farmers for all commodities
X_3: time as a variable
X_4: the value of farm machinery and equipment
Y_{t-1}: the number of hired workers lagged one year

[b]The significance levels of the regression coefficients are at the 5-per cent level or better unless accompanied by the following notation:

*Significant at the 10-per cent level
**Significant at the 20-40-per cent level
***Significant at the 40-per cent level

[c]Equation 5 is in logarithms

[d]Equation 8 is estimated by reduced forms

Table 5 (Continued).

Equation number	Time period	Regression coefficients: Constant	X_1	X_2	X_3	X_4	Y_{t-1}	R^2
9[e]	1929-1957	116.32	-.341	.243	-.687***	-	.206***	.977
			(.122)	(.112)	(.523)		(.195)	
10[e]	1929-1957	94.49	-.287	.245	-1.64	.00207	.237***	.980
			(.091)	(.081)	(.674)	(.00085)	(.265)	
11	1940-1957	122.03	-.458	.119	-.311**	-	.236**	.980
			(.091)	(.040)	(.244)		(.159)	
12	1940-1957	98.22	-.232	-	-.120***	-	.530**	.936
			(.081)		(.325)		(.491)	
13	1940-1957	153.23	-.475	.127	-.492***	-	-	.979
			(.178)	(.031)	(.504)			

both single and simultaneous equations; and (7) the use of an autoregressive scheme. The differences of the equations are analyzed below in this order. The analysis of the regressions as a whole will be presented in the following section.

<u>The form of the hired labor demand equations</u>

The demand equations were initially estimated by general least-squares methods, such as were used to estimate 13 of Table 5. However, distributed lag equations were more efficient in terms of information obtained from the limited number of explanatory variables available. Hence, all of the equations in Table 5 other than 13 are distributed lag equations.

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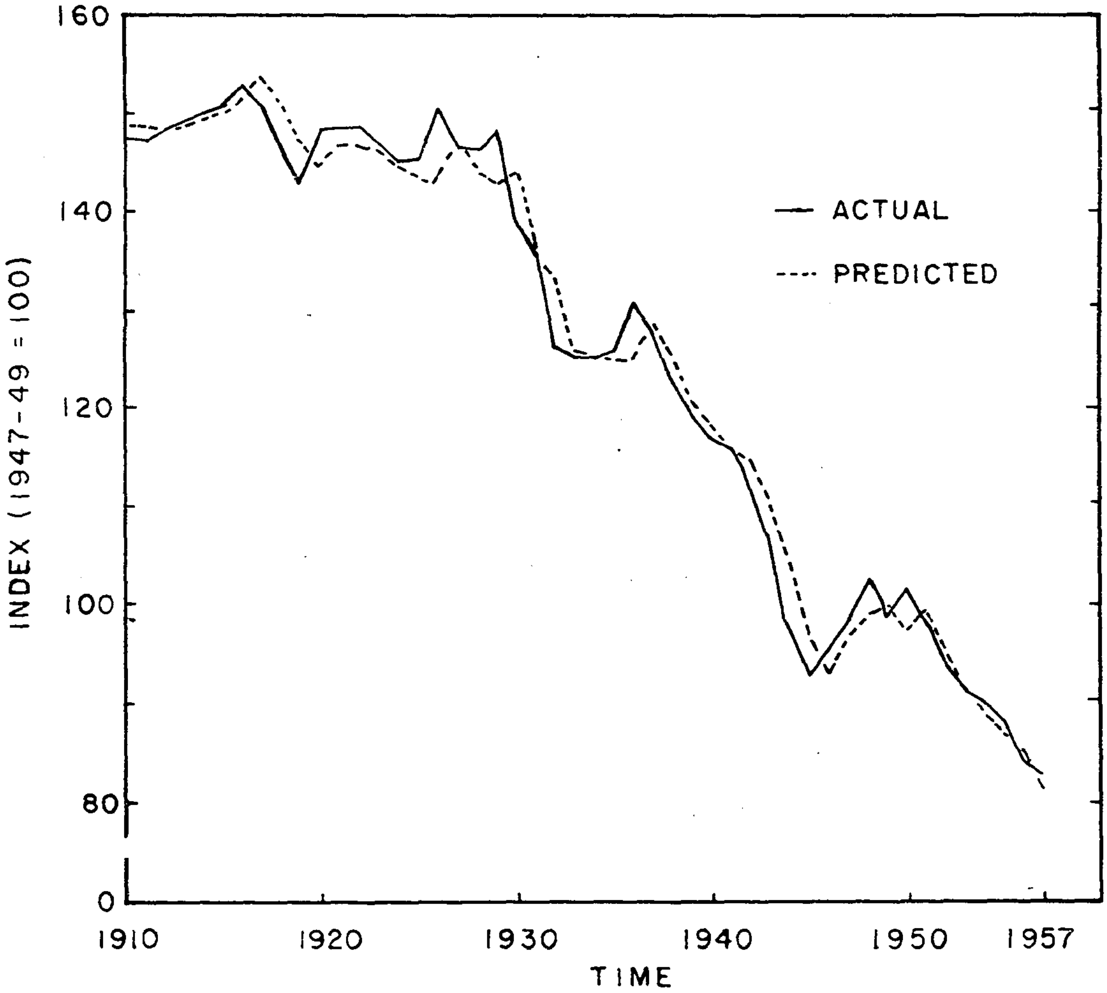
[e]Equations 9 and 10 are autoregressive least-squares equations estimated by the Theil-Basmann technique.

[f]Equation 13 is not taken with a distributed lag.

Figure 7. Actual and predicted number of hired farm workers in the U.S., 1910-1957 (by demand function 3 of Table 5).

Figure 8. Actual and predicted number of hired farm workers in the U.S., 1940-1957 (by demand function 12 of Table 5).


160
140
120
100
80
0
INDEX (1947-49 = 100)
ACTUAL
PREDICTED
1910
1920
1930
1940
1950
1957
TIME

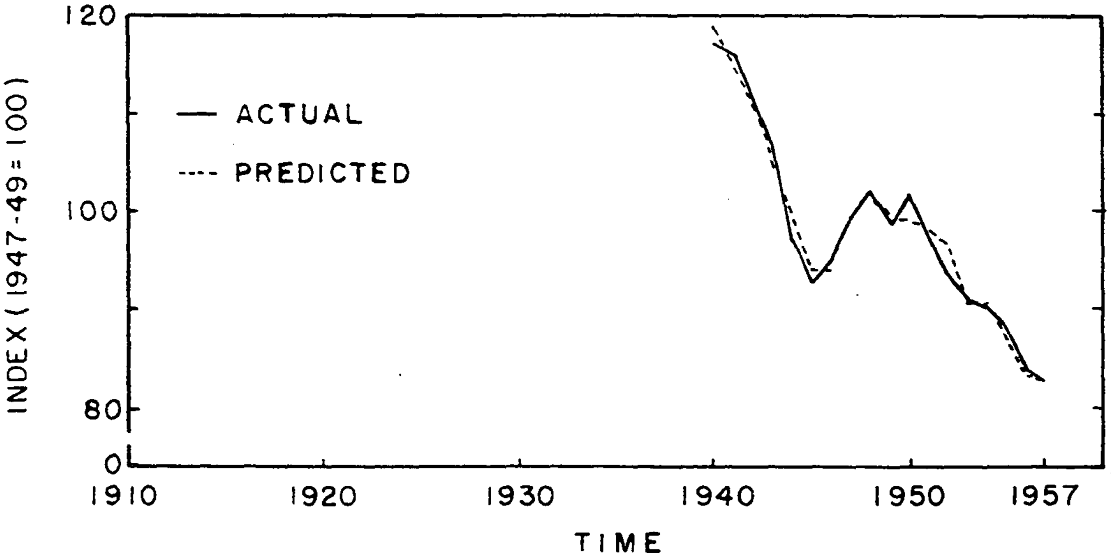

120
100
80
0
INDEX (1947-49= 100)
ACTUAL
PREDICTED
1910
1920
1930
1940
1950
1957
TIME

Table 6. Elasticities of demand for the demand functions for hired labor, U.S.

Equation number	Time period	Deflator of the farm wage rate	Elasticity of the farm wage rate: Short-run (Mean)	Short-run (1957)	Long-run (Mean)	Long-run (1957)	Form of prices receiv
1	1910-1957	--[a]	-.0529	-.1374	-.2376	-.6173	-
2	1910-1957	--[a]	-.0627	-.1646	-.9092	-.2.387	-
3	1910-1957	--[b]	-.0576	-.1301	-.331	-.7747	--[c]
4	1910-1957	--[b]	-.0718	-.1621	-.7754	-1.751	--[c]
5[e]	1910-1957	--[b]	-.0953	-.0953	-.7365	-.7365	--[c]
6	1910-1957	--[f]	-.0276	-.0663	-.1737	-.4173	--[f]
7	1920-1939	--[e]	-.0245	-	-.0469	-	--[f]
8[g]	1929-1957	--[b]	-.1261	-.2229	-.3683	-.6510	--[f]
9[h]	1929-1957	--[b]	-.256	-.452	-.32	-.57	--[f]
10[h]	1929-1957	--[b]	-.215	-	-.28	-	--[f]
11	1940-1957	--[b]	-.4595	-.608	-.6010	-.795	--[c]
12	1940-1957	--[a]	-.2517	-.4142	-.5351	-.8805	-
13[i]	1940-1957	--[f]	-.4803	-.6813	-	-	--[f]

[a]Index of prices received by farmers in year t

[b]Index of prices paid by farmers for living expenses in year t

[c]Index of farm machinery prices in year t, except for equation 11 where it is year t

[d]A non-significant regression coefficient

[e]The data were in logarithms

[f]Index of prices paid by farmers for production expenses in year t-1 except as a def

[g]Estimated by reduced-forms

[h]Estimated by the Theil-Basmann method

[i]Not a distributed lag equation

Form of prices received	Elasticity of the prices received				Adjustment coefficient	Time variable included
	Short-run		Long-run			
	(Mean)	(1957)	(Mean)	(1957)		
-	-	-	-	-	.223	Yes
-	-	-	-	-	.052	No
--[c]	.0347	.0394	.1995	.2265	.174	Yes[d]
--[c]	.0519	.0584	.5603	.6302	.093	No
--[c]	.0574	.0574	.4434	.4434	.129	Yes[d]
--[f]	.0338[d]	.0474[d]	.2128[d]	.2984[d]	.159	Yes
--[f]	.1715	-	.3283	-	.523	Yes
--[f]	.0826[d]	.0982[d]	.2412[d]	.2868[d]	.342	Yes
--[f]	.20	.241	.255	.303	.794	Yes
--[f]	.203	-	.266	-	.7635	Yes
--[c]	.1016	.0887	.1329	.1160	.7645	Yes[d]
-	-	-	-	-	.4704[d]	Yes[d]
--[f]	.1238	-	-	-	-	Yes[d]

t is year t-1

pt as a deflator of the farm wage rate in equations 6 and 13 where it is year t

As a comparison, some of the results of the general least squares equations are included in Appendix C.

The inclusion of time as a variable

The rationale for the inclusion of time as a variable was given in a previous chapter. Essentially, time was included in the demand function because of the absence of an index of aggregate changes in technology in agriculture, and to act as a "catch-all" of other long-run changes in agriculture. It was deemed likely that the inclusion of time as a variable removed some of the trend from the lagged endogenous variable as well as from the independent variables, permitting less biased estimates of the regression coefficients, and hence, the elasticities. Equations 1 through 4 were designed so that comparisons of equations containing and not containing time as a variable could be made. Equations 1 and 3 contain time while 2 and 4 do not. The major difference between the two sets of equations is in the size of the lagged dependent variable. The coefficients of the dependent lagged variable in 2 and 4 are relatively high. Since these coefficients estimate the long-run adjustment period, the estimated long-run elasticities in Table 6 are high, being -2.39 and -1.75 for 2 and 4 respectively. With the time variable included, the coefficients of the lagged dependent variable in 1 and 3 were lower, with consequent long-run elasticities considerably less than one.

Equation 7 of Tables 5 and 6 is similar to a demand equation estimated by Schuh (105). The time period is the same and both equations were estimated simultaneously with a labor supply equation. Schuh, however, used an index of technology as a variable while time as a variable was used in 7. Further, 7 was estimated by reduced forms while Schuh employed the Theil-Basmann method of simultaneous estimation. Neither of the two equations utilized an autoregressive assumption. The equations in Tables 5 and 6 other than the autoregressive least-squares equations were estimated before knowledge of Schuh's work was received. The short-run elasticity of the agricultural wage in Schuh's equation was -.14 and the long-run elasticity was -.43. His short-run "real" price of farm products was .17 and his long-run elasticity was .53. The index of farm technology was non-significant and his estimate of the lagged endogenous regression coefficient was .68. The short-run price elasticity of demand estimated by Griliches (36) using the single-equation method for the period 1912-1956 was -.11. His long-run price elasticity was -.62. These elasticity estimates are similar to those of 7 in Tables 5 and 6. The primary difference lies in the use of time as a variable in 7 which reduced the statistical significance of the farm wage rate and prices received variables.

The effect of the inclusion of an additional independent variable

The price of hired labor, the farm wage rate, was the principal explanatory variable used in each equation. By the inclusion of other variables in the specification of the model, the values of the coefficients of the originally-included variables may be altered substantially. The effect of the addition of time as a variable was demonstrated above. Other variables included in the specification of the model were the index of prices received by farmers and the value of farm machinery and equipment. The effect of the addition of the index of the value of farm machinery and equipment can be demonstrated by an analysis of equations 9 and 10. The specification of both equations is identical except for the farm machinery variable. The most evident change in 10 from 9 is in the value of the regression coefficient of the time variable which changed from -.687 to -1.635. The two equations were modified by the assumption of an autoregressive scheme, and the value of the autoregressive coefficient dropped from .75 in 9 to .34 in 10. Evidently the better specification of the model afforded by the addition of the value of farm machinery and equipment variable caused the decrease in the value of β , the autoregressive coefficient. Basically, then, the effect of the addition of another variable was accommodated through changes in the trend variable and the autoregression coefficient. The values of other regression coefficients were not substantially changed.

The use of different deflators

Comparisons of the demand functions using different deflators can be made principally from the first six equations which covered the period 1910-1957. Equations 1 and 2 were estimated using the index of prices received as the deflator of the farm wage rate. The index of prices paid for farm living expenses was used to deflate the variables in 3, 4, and 5, while the variables in 6 were deflated by the index of prices paid in production. The results of the six equations do not indicate that the elasticities of the demand functions for hired labor were effectively changed by the use of different deflators. However, the regression coefficient for the farm wage rate in 6 was not statistically significant. Deflators used in the remaining equations are cited in Tables 5 and 6.

Equations with variables in linear or logarithmic form

Some equations were estimated in logarithmic form such as equation 5 of Tables 6 and 7. The time variable was converted also to logs starting with the value 1. Hence, it is a power function. Since the time variable is non-significant in 5 but significant for the linear equations, it may be that time entered in some other form could have been significant. The significance level of the other regression coefficients was higher. Otherwise, there was little difference between

Table 7. Regression coefficients, standard errors, and elasticities for the demand

Time period	Region	Regression coefficients[a] Y_{t-1}	X_1	X_2	R^2	Adjustment coefficient	Farm wage Short-run
1929-1957	NE	.721 (.126)	-.031[b] (.056)	-	.945	.28	-.05
1929-1957	MA	.750 (.122)	-.343 (.122)	32.2 (9.98)	.967	.25	-.19
1929-1957	ENC	.830 (.107)	-.440 (.200)	.101 (.148)	.980	.17	-.15
1940-1957	WNC	.278 (.110)	-1.06 (.167)	101 (16.8)	.986	.72	-.51
1929-1957	SA	.615 (.172)	-.862[d] (.608)	-2.25[b] (34.8)	.933	.39	-.12
1929-1957	ESC	.573 (.110)	-1.71 (.413)	83.7 (19.9)	.955	.43	-.35
1929-1957	WC	.612 (.123)	-1.59 (.477)	94.0 (34.9)	.930	.39	-.26
1940-1957	MTN	.351[d] (.273)	-.133[d] (.132)	2.34[b] (13.2)	.906	.65	-.11
1947-1957	PAC	.299 (.053)	-.356[d] (.395)	-	.839	.70	-.19
1929-1957[e]	US	.206[b] (.195)	-.341 (.122)	.243[f] (.112)	.977	.79	-.26

[a]The regression coefficients are:
Y_{t-1} = hired labor, lagged one year
X_1 = regional farm wage rate
X_2 = regional parity ratio

[b]Beyond the 30-per cent level of significance

[c]Significant at the 10-per cent level

[d]Significant at the 20-30-per cent level

[e]Estimated by reduced-forms

[f]$\frac{\text{Prices received}}{\text{Prices paid in production}_{t-1}}$

for the demand functions for hired labor for the nine geographic regions

Elasticities				
Farm wage rate		Parity ratio		
Short-run	Long-run	Short-run	Long-run	Time
-.05	-.17	-	-	-.457[c] (.241)
-.19	-.75	.16	.64	-.201[b] (.467)
-.15	-.90	-	-	.162[b] (.939)
-.51	-.71	.36	.50	-.659[b] (.731)
-.12	-.32	-	-	-.921[b] (1.21)
-.35	-.82	.29	.68	-.251[b] (.656)
-.26	-.67	.19	.50	-.127[b] (1.46)
-.11	-.18	-	-	-2.12[c] (1.17)
-.19	-.27	-	-	-2.16 (.802)
-.26	-.32	.20	.26	-.687[d] (.523)

the results of the equations using variables in logarithms or in linear form. Consequently, because of the computational time involved, variables in linear form were subsequently used.

The use of single and simultaneous equation estimation

Single equation estimation was used to compare the demand equations over the different time periods. However, since it was necessary to estimate a supply function for hired labor so that the demand function for hired labor could be identified in a system of equations, and since there was a lack of data prior to 1929 for one of the supply variables, unemployment, the time period for the systems of equations was limited to 1929-1957. The hired farm labor demand functions estimated from a system of equations are 8, 9, and 10 of Table 6. Equation 8 differs from 9 and 10, for 8 was estimated by the method of reduced forms, while 9 and 10 were autoregressive equations estimated by the Theil-Basmann technique.

The effect of the assumption of an autoregressive scheme

As mentioned previously, several equations were modified by the assumption that the error term of the distributed lag equation followed a first-order autoregressive scheme. Because of the time and expense involved in performing the necessary iterations, not all of the equations could be estimated in this manner. Two hired labor demand functions taken with a distributed lag were estimated initially using autoregressive least squares (A.L.S.). The results of the A.L.S. equations are presented in Table 6 as equations 1 and 2. Both equations cover the period 1910-1957, and include the variables hired labor lagged one year, and the farm wage rate. In addition, equation 1 contains time as a trend variable.

Equation 2, the (A.L.S.) equation which does not include time as a variable, may be compared with the following original equation:

$$(37) \quad Y_t = 11.97 + \underset{(.039)}{.9480}\, Y_{t-1} - \underset{(.037)}{.0783}\, X_{1t}$$

where Y_t = the hired labor force,

X_{1t} = the farm wage rate deflated by the index of prices received. The standard errors of the regression coefficients are contained in parentheses below the regression coefficients. The notation of levels of statistical significance is the same as in Table 6: no mark indicates significance at the 5 per cent level or better; "a" indicates significance at the 10 per cent level.

The original equation corresponding to equation 1 in Table 6 which included time as a variable was estimated as:

$$(38) \quad Y_t = 29.02 + \underset{(.0643)}{.8397}\, Y_{t-1} - \underset{(.0383)}{.0530}\, X_{1t}{}^{b} - \underset{(.1080)}{.2252}\, X_{2t}$$

where X_{2t} = time as a variable, "b" indicates that the regression coefficient for the farm wage rate was significant at the 20-40 per cent level of significance, and the other variables and indicators of levels of significance are the same as described for 37.

A comparison of the different equations can be made through recourse to Tables 6 and 7 and equations 37 and 38. The coefficients of the lagged dependent variables were all highly significant. For the coefficients of the lagged variable in equations not including time as a variable, 37 has a coefficient of .948, while the corresponding A.L.S. equation 2 in Table 6 had a value of .931. For the equations including time, the coefficients of the lagged endogenous variable were .8397 and .777 for the original and A.L.S. equations, respectively. In both instances, the value of the lagged endogenous variable in the A.L.S. equation was less than in the ordinary least squares equations. Concurrently, in the A.L.S. equations the coefficients of the farm wage rate and time increased. The residual sums of squares in the A.L.S. equations were reduced in both cases, from 461.4 to 441.9 for the equations containing time, and from 507.0 to 490.0 for the other two equations.

Essentially, the differences of the original and A.L.S. equations were: (1) the A.L.S. equations reduced the residual sum of squares; (2) the regression coefficients of the lagged variables in the A.L.S. equations were lower; and (3) in the A.L.S. equations the regression coefficients of the other independent variables increased and became more significant. The long-run elasticities were less, then, with the A.L.S. variables because of the decrease in the value of the lagged coefficients.

The estimate of β, the autoregression coefficient, might be expected to decrease when a trend variable is included in the equation. However, in the case of equations 1 and 2 of Table 6, the results were indeterminate. The estimated values of β were:

$$(39) \quad u_t = .1385\, u_{t-1}{}^{a}$$

for equation 1, and:

$$(40) \quad u_t = \underset{(.1338)}{.1710}\, u_{t-1}{}^{ns}$$

for equation 2. Neither of the estimates of β were highly significant, although the estimate of 39 was significant at the 10 per cent level. Since the initial value of the coefficient of the lagged dependent variable in equation 40 approached one, it is possible that the autoregressive structure of the equation could not be adequately ascertained. The results indicated that the β's were small, and that the original equations estimated for 1910-1957 likely could be accepted per se.

A further comparison of the effect of the autoregressive assumption can be made between demand functions for hired labor for the period 1929-1957 which were estimated from a system of equations. Equation 8 of Tables 6 and 7 was estimated by reduced forms with no autoregressive assumptions. Equations 9 and 10 were estimated by the Theil-Basmann technique under the assumption of an autoregressive scheme.

In equation 8, the farm wage rate and prices received regression coefficients were non-significant. Both regression coefficients were significant in equations 9 and 10. The use of A.L.S. equations increased the significance of these regression coefficients. Further, the coefficient of determination in 8 is .97, but .977 and .98 in 9 and 10. Although a change of .01 is small, the increase represents one-third of the error term. Thus, the introduction of the autoregressive assumption provided a better fit. The time period of adjustment is represented by the adjustment coefficient. The adjustment coefficient in 8 is .34, but .79 and .76 respectively for 9 and 10. Since the lagged endogenous coefficient picks up part of the residual term, the autoregressive assumption provides a better estimate of the adjustment coefficient. Hence, it is likely that equations 9 and 10 more accurately reflect the demand for hired labor.

The estimated autoregressive structure of equations 9 and 10, respectively, were:

(41) $$u_t = \underset{(.120)}{.753}\, u_{t-1}$$

(42) $$u_t = \underset{(.326)}{.339}\, u_{t-1}^{ns}$$

In contrast to the estimated autoregressive coefficients for equations estimated for the 1910-1957 period, the estimate of β in equation 9 of Table 6 was large and significant. However, the additional specification of equation 10 of Table 6 reduced the estimated β in value and in significance.

One may conclude there is no hard and fast rule concerning the application of autoregressive schemes. In general, it would be desirable that the autoregressive structure of each equation be known, but the costs of doing so may outweigh the benefits when many equations are to be estimated.

Analysis of the National Demand Functions for Hired Labor

Having appraised the effects of different techniques employed in the estimation of the demand functions for hired labor in the preceding section, this section will analyze the hired labor demand functions by major variable. The equations estimated cover an over-all period, 1910-1957, and intervening periods of 1920-1939, 1929-1957, and 1940-1957.

Since all of the equations other than 13 are estimated taken with a distributed lag, the coefficient of determination is high for each demand function. The values of the coefficients of determination ranged from .935 to .984.

The elasticities of demand are presented in Table 7. These elasticities have been derived both at the mean and for 1957 for the short- and long-run periods. Table 7 also contains the adjustment coefficients, information on the deflators of the principal independent variables and the type of equation, and an indication that the time variable has or has not been included in the equation.

The farm wage rate as an indicator of the price of hired labor

One of the basic objectives of this study was to ascertain the responsiveness of the demand for hired labor to the farm wage rate. To reach this objective, demand functions for hired labor were estimated in various forms and for different time periods. Apparently conflicting results were obtained from a comparison of the results of the demand functions estimated over the whole period, 1910-1957, and the intervening periods, 1920-1939 and 1940-1957. The values of the regression coefficients of the farm wage rate variable for the equations estimated over the entire period, 1910-1957, were low; the estimates in the six equations ranged in value from -.046 to -.122. For the linear equations, 1, 3, and 6, which included time as a variable, the regression coefficients of the farm wage rate were significant only at the 10-per cent level in two and non-significant in the third. Hence, the results indicate that the hired labor force for the 48-year span was not highly responsive to the farm wage rate.

Demand functions were derived for the intervening periods to check possible structural changes over time. For the period 1920-1939, the value of the wage rate regression coefficient was -.054 and was not significantly different from zero. This lack of significance need not be inconsistent, for the period covered was one of agricultural recession. In a depression period a change in the farm wage rate may not reflect any substantial change in the demand for hired workers. In the 1940-1957 period, a time of relative prosperity in agriculture, the demand for hired labor should theoretically have been more responsive to changes in the farm wage rate.

The regression coefficients of the price of farm labor in equations 11, 12, and 13 ranged from -.232 to -.475 and were significant at the 5-per cent level or better. Hence, there was a significant demand response to price changes during this period. Lack of significance of the wage rate for the over-all period, 1910-1957, was apparently due to the combination of a depression period, in which the wage rate coefficient was non-significant, with a period of full employment when the wage rate variable was highly significant.

A comparison of the demand functions for hired labor analyzed above with demand functions estimated for the period 1929-1957 support this conclusion. This time period encompassed a depression period as well as one of full employment. The estimated demand functions for hired labor are equations 8, 9, and 10. These functions differ from those discussed above, for they are estimated from a system of equations. The regression coefficient of the farm wage rate for 8 was -.168, but non-significant. The corresponding regression coefficients for the demand functions 9 and 10, which were estimated under the assumption of autocorrelated errors, were -.341 and -.287, respectively. These coefficients were significant at the 1-per cent level. Evidently the use of A.L.S. equations resulted in a rise in the coefficients to significance. These results then corroborate the findings of the demand functions for the period 1940-1957, that the demand for hired labor has been responsive to changes in the farm wage rate.

The price elasticity of demand denotes in standardized terms the responsiveness of the demand for hired farm labor to a change in the farm wage rate. The short-run elasticities taken at the mean and for 1957 are presented in Table 7.

For equations 1 through 6, which were estimated over the period 1910-1957, the short-run price elasticities at the mean ranged from -.03 to -.09. For these equations, the short-run price elasticities derived for the year 1957 ranged from -.07 to -.16. In the short run, then, for the over-all period, given a 10 per cent increase in the farm wage rate, there has been an accompanying decrease in the demand for hired labor of less than 1 per cent when the elasticities were estimated at the mean, and from .7 to 1.6 per cent when estimated for 1957. Basically, the price elasticities for the over-all period were low but increasing over time.

The short-run price elasticities taken at the mean for the 1929-1957 period ranged from -.13 to -.26. For the 1940-1957 period, the short-run elasticities at the mean varied from -.25 to -.48. Hence, for the more recent time periods the responsiveness of the demand for hired labor to wage rate changes, while statistically significant, has still been inelastic.

The short-run elasticities estimated for 1957 over the 1929-1957 and 1940-1957 periods ranged from -.22 to -.68. These results suggest different levels of responsiveness over time of the demand for hired labor to farm wage rate changes for the depression and prosperity periods.

Price elasticities of demand were derived also for the long-run period and are included in Table 7. In distributed lag equations, the long-run elasticities depend on the size of the adjustment coefficients. This coefficient estimates the period of time needed for the dependent variable to adjust to a sustained change in the independent variable. The value of the adjustment coefficients for the six demand functions covering the 1910-1957 period ranged from .05 to .22. As these values are low, the estimated time of adjustment is long. For these six equations, the long-run price elasticities at the mean ranged from -.17 to -.90. The short-run elasticities for the same period ranged from -.03 to -.09. Under the assumption that the errors in the equations followed an autoregressive scheme, the long-run demand elasticities of equations 1 and 3 were -.24 and -.33, respectively. The long-run price elasticities at the mean for the 1929-1957 period are of similar size, from -.28 to -.36. However, the range of elasticities was higher for the 1940-1957 period, varying from -.53 to -.60. These results demonstrate again the inelasticity of the demand, though the response of the demand for hired labor to a farm wage rate change was high for the more recent period.

The long-run elasticities estimated for the year 1957 varied considerably. Disregarding the demand functions not including time as a variable, the long-run elasticities ranged from -.41 to -.88 for all of the periods. The similarity of these long-run elasticities for 1957 was likely a result of the rise in the values of the adjustment coefficients over time while there was a concurrent rise in short-run elasticities. The two occurrences have offset each other.

To briefly summarize the results of an analysis of the role of the farm wage rate in the demand for hired farm labor for the U.S. as a whole, (1) the farm wage rate variable was found to be statistically significant for the more recent periods of time, which denoted the responsiveness of the demand for hired labor to changes in the farm wage rate; (2) the lack of significance of the farm wage rate variable over the whole period, and especially for the 1920-1939 period, was attributed to the depression occurring during that period; (3) the regression coefficients and price elasticities of demand increased for the more recent period which meant that the demand for hired labor had been more responsive to price changes in a period of relative prosperity; (4) the rise over time of the adjustment coefficients indicated that the time period of adjustment in agriculture to a price change had become shorter; and (5) in spite of recent rises in demand elasticities, the elasticities remained inelastic.

<u>The prices received variable as an indicator of the relative profitability of farming</u>

Another variable which has been included in the estimation of most of the hired labor demand functions is the index of prices received by farmers. The cross-elasticity of demand of the index of prices received with respect to the size of the hired labor force indicates the responsiveness of the demand for hired labor to changes in agricultural prices. Essentially, in parity ratio form, the prices received variable could be at best an indicator of the relative profitability of farming. The series does relate product prices to cost. The deflator of the index of prices received for each equation is listed in Table 7. The index of prices received has been lagged one year in all of the hired labor demand functions other than those for the period 1910-1957. The assumption behind this lag was that farmers react to product price changes in the previous year since the present year's price is known relatively late in the year.

As in the previous section, the initial task is to ascertain the significance of the prices received variable. Secondly, trends in the regression coefficients and elasticities can be examined.

In the demand functions estimated over the period 1910-1957, the value of the regression coefficients of the prices received variable ranged from .048 to .079. However, discounting equations not including time as a variable and equations in logs, the regression coefficients were not highly significant. The non-significance of the variables indicates a lack of responsiveness of the demand for hired labor to product price changes for the over-all period, 1910-1957.

The demand functions estimated over the intervening periods do not explain the lack of significance of the prices received variable over the whole period. For the period 1920-1939 the regression coefficient of the prices received variable in the short-run at the mean was .248 and statistically significant. Over the period 1929-1957, though the justidentified demand function, 8, has a non-significant prices received variable, the functions estimated by A.L.S. equations, 9 and 10, contained significant product price coefficients. Essentially, though the prices received regression coefficients were non-significant for the whole period, the coefficients were significant in the intervening periods.

From the demand function for 1920-1939 the inference is made that the demand for hired labor varied directly with a change in prices received. This result appears logical on the grounds that while family labor may not be fired, hired labor can be released or not hired when agricultural prices drop. The demand for hired labor was equally responsive to changes in farm product prices for the periods 1929-1957 and 1940-1957. In spite of the adverse findings for the whole period studied, an analysis of the intervening periods indicates that the demand for hired labor is significantly responsive to changes in the index of prices received by farmers.

For the entire period, 1910-1957, the short-run cross-elasticities taken at the mean ranged from .03 to .06. The corresponding elasticities for the intervening periods were:

1920-1939, .17; 1929-1957, .08 to .20; and 1940-1957, .10 to .12. Basically, the cross-elasticities were found to be quite inelastic. Furthermore, discounting the low elasticities for 1910-1957, there apparently is no trend upward or downward in the cross-elasticities over time. Possibly the inclusion of the 1910-1919 period may have had an effect on the low elasticities for the over-all period.

In the long-run, there is a like absence of an over-all trend. The adjustment coefficients, as mentioned earlier, did rise over time. However, the long-run elasticities computed from these adjustment coefficients varied. The cross-elasticities in the long-run ranged from .13 for the period 1940-1957 to .56 for the period 1910-1957. The only conclusion reached was that even in the long-run the elasticities were quite inelastic.

In summary, the conclusions reached from the analysis of the prices received variable were: (1) the prices received variable as an indicator of the profitability of farming was significant for the intervening periods 1920-1939, 1929-1957, and 1940-1957; these results indicated that the demand for hired labor for the U.S. has been responsive to changes in the index of prices received by farmers; (2) there was apparently little change in response to product price changes in the depression and the war-postwar periods; and (3) the cross-elasticities, even in the long-run, were quite inelastic.

The value of farm machinery and equipment variable

As described in the chapter on specification of the model, a value of farm machinery and equipment variable was constructed and added to equation 10 in Table 6 for the period 1929-1957. The purpose of including this variable was to aid in the identification of a supply function for hired labor in a system of equations. The demand function for hired labor which included this variable was estimated utilizing the Theil-Basmann technique of solving a system of equations. A.L.S. equations were estimated so that except for the addition of the value of farm machinery variable the demand function, 10, was specified the same as 9. Theoretically, the variable should indicate the response of the demand for hired labor to changes in the scale of farming as exemplified by the value of the stock of farm machinery and equipment. The resultant coefficient of the farm machinery variable is significant at the 5-per cent level, and has a short-run elasticity taken at the mean of .13. Hence, the estimated response of the demand for hired labor to changes in the stock of machinery is significant and positive. In the past, then, an increase of 10 per cent in the value of farm machinery and equipment has been accompanied by an increase in the number of hired workers of 1.3 per cent. Hence, as the scale of farming has increased, the number of hired workers has increased. This result could bear closer examination on a less aggregated level.

Summary of the results of the estimation of the demand functions for hired labor in the U.S.

In summary, the original hypothesis that the demand for hired labor was responsive to the farm wage rate, prices received, and the value of farm machinery has not been disproved. In general, the results corroborate the hypothesis. The demand for hired labor was found to be generally responsive to changes in the farm wage rate, especially in the more recent periods. Apparently there was considerable difference in response to a wage rate change in the depression and war-postwar periods. The results indicated that during the depression period, 1920-1939, changes in the farm wage rate had little apparent effect on the demand for hired labor. Subsequent to this period, however, the demand for hired labor has demonstrated a significant response to price changes.

The response of the demand for hired labor to agricultural product prices, though not highly significant for the entire period, 1910-1957, was significantly responsive in the intervening periods, 1920-1939, 1929-1957, and 1940-1957.

A demand function was presented that included the value of farm machinery and equipment as a variable. The results indicated a significant response of the demand for hired labor to the value of farm machinery and equipment, but the interpretation of the results is difficult to make. Further investigation of the role of this variable was suggested.

The number of demand functions provided a basis of comparison of the ordinary distributed lag estimation with that of estimation utilizing an autoregressive transformation. Those demand functions modified by the autoregressive assumption were superior to the original form of the demand functions.

In the long-run, the rate of adjustment in the demand for hired workers in response to sustained changes in the farm wage rate and prices received was estimated to be low for the over-all period, 1910-1957. This result appeared to be inconsistent with the results of the intervening periods. Changes in structure may have occurred to such an extent that the long-run estimates for the 1910-1957 period are biased. The adjustment coefficients in the intervening periods appeared to be consistent. These coefficients indicated that the rate of adjustment of producers to a sustained price or other variable change has increased over time. An increase in the mobility of farm resources could be a factor in lessening the lagged response.

What then are the effects of either a natural or induced change in the farm wage rate or prices received on the demand for hired labor? The price and cross-elasticities are both low. The short-run response would be especially small because of the inelastic demand. The timing of the change of the explanatory variable could be important. The response of the demand for hired labor apparently is affected by the business cycle, for the response is larger during the war-postwar period than during the depression. However, the results indicate that during either period of the business cycle the response of the demand for hired labor to a change in an explanatory variable would be inelastic.

EMPIRICAL ESTIMATES OF THE REGIONAL DEMAND FOR HIRED LABOR

In addition to the demand functions for hired labor that were derived for the U.S. as a whole, demand functions for hired labor were estimated for each of nine geographic regions. Although the regional data on hired labor is highly aggregated, the regional analysis does present the response to the important variables on a less aggregated scale than that presented nationally. Too, it is important to know how the independent variables differ among regions, and between these regions and the U.S. as a whole.

A discussion of the method used to estimate the regional demand functions for hired labor will be presented initially. The analysis of the demand functions will follow.

Methodology Used for the Regional Analysis

Demand functions were derived for hired labor for each of nine geographic regions and are presented in Table 7. The different regions are presented in map form in Figure 5. Given the hypothesis that the variables that affect the regional demand for hired labor are the same as those that affect the demand for hired labor nationally, the specification of the equations is essentially the same regionally as nationally. The principal independent variables are the farm wage rate, the parity ratio, time as a trend variable, and the hired labor force lagged one year.

All of the regional demand functions for hired labor are estimated by single equation least squares methods. The time period covered is 1929-1957, except for three of the regions. The Mountain, Pacific, and West North Central regions were estimated over more recent time periods which are listed in Table 7. For these regions, the regression coefficients were either inconsistent in sign or non-significant for the whole period.

The analysis of the regional demand functions for hired labor can proceed by region or by variable. In this chapter the analysis is by principal variable because the pattern of regional response is of greater importance.

All of the relevant regional data discussed in this chapter are contained in Table 7. The information included consists of the time period covered, the region, the regression coefficient of the lagged variable, the farm wage rate and parity ratio variables, the coefficient of determination, the adjustment coefficient, the elasticities of the farm wage rate and parity ratio variables for both short- and long-run periods, and the estimate of the time variable.

The coefficient of determination, the R^2, is high for each region. The values of R^2 range from .839 for the Pacific region to .986 for the West North Central region. Tests for serial correlation in the residuals were not derived.

Analysis of the Results of the Regional Demand Functions for Hired Labor

The order of presentation of the results of the regional demand functions for hired labor will be first to analyze the regional significance of the farm wage rate by region, and then to compare short and long-run elasticities. Secondly, a similar analysis will be presented for the regional parity ratio variable. Third, the time trend will be evaluated.

The farm wage rate

As in the demand functions derived for the U.S. as a whole, the principal independent variable is the farm wage rate. The price elasticity of demand with respect to the regional number of hired workers indicates the responsiveness of the demand for hired labor to changes in the price of labor. The results of the national demand functions for hired labor indicate that the farm wage rate variable is highly significant. A national demand function for hired labor, equation 9 of Table 5, was included in Table 7 for comparison. The farm wage rate variable in the regional estimates has been deflated by the prices paid by farmers for living expenses.

Direct comparison of regression coefficients was not possible on the regional level, for the data were in actual numbers rather than in indices as in the demand for hired labor for the U.S. However, the regression coefficients of the farm wage rate were significant at the 5 per cent level or better in five of the nine regions. Furthermore, all of the regression coefficients of the farm wage rate variable had a consistent negative sign. A better means of comparison of the price coefficients is through the analysis of the short-run price elasticities. The range of short-run elasticities of the price variable was from -.05 in New England to -.51 in the West North Central. Discounting the elasticities derived from non-significant regression coefficients, the range is from -.15 to -.51. In other words, as the farm wage rate has increased in the past by 10 per cent, *ceteris paribus*, there has been a concurrent decrease in the regional demand for hired labor of from less than one to 5 per cent.

The regions in which non-significant regression coefficients of the price variable were computed were New England, South Atlantic, Mountain, and Pacific. However, in the South Atlantic and Pacific regions, there are a large number of seasonal hired workers. These workers commonly are paid by piece rates, a type of wage that is not included in the reported farm wage rate. Thus, it is possible that the reported regional wage rates were not as typical in these two regions as they might be for some of the other regions.

These results of the analysis of the price variable indicate that while some of the regions have significant wage rate coefficients, others do not. However, the Pacific and South Atlantic regions present atypical situations with regard to hired labor analysis because of the numbers of seasonal farm workers who are commonly paid a piece rate. The Mountain region may also fit into this category. The data which exists on migratory and other seasonal farm workers as compiled in source 83 are not presented on a regional basis. Hence, a separate analysis cannot be conducted on regional migratory farm workers.

For those regions in the central and southern U.S., including the Middle Atlantic region, the farm wage rate variable was significant. The demand for hired labor in these regions is apparently responsive to changes in the farm wage rate. These regional findings corroborate the national findings.

Elasticities of the price variable were estimated also for the long-run period. Discounting those estimates for the non-significant regression coefficients, the long-run price elasticities of demand of the regions ranged from -.67 to -.90. As in the analysis of the long-run price elasticities for the national demand functions for hired labor, the long-run price elasticities were inelastic.

In summary, significant regression coefficients of the price of hired labor were derived regionally for five of the nine regions. The non-significance of the coefficients for these regions may be partially due to the unique hired labor problems in those regions. The hypothesis that the same variables that affect the demand for hired labor nationally affect the demand for hired labor regionally seems to be corroborated to some extent. The long-run price elasticities that were derived for each region were inelastic.

The parity ratio variable

The parity ratio is not computed by federal sources on a regional basis. As a consequence, the index of the parity ratio for each region was of necessity computed for a typical state in the region. These states with the appropriate data are presented in Appendix B. The ratio could not be computed for New England or for the Pacific region because data were not available for the desired years.

As stated in the previous chapter, the cross-elasticity of demand of the parity ratio with respect to the regional number of hired workers indicates the responsiveness of the demand for hired labor to changes in the parity ratio.

Direct comparison of the regression coefficients of the parity ratio are impossible because the data were in original form rather than in indices. However, the regression coefficients of the parity ratio variable were significant in four of the regions, non-significant in three, while the data were not available in two regions. The non-significant regions were East North Central, South Atlantic, and Mountain. For the significant regression coefficients, the short-run elasticities estimated at the mean ranged from .16 to .36. These results indicate that as the regional parity ratio has increased 10 per cent in the past in the four regions which had significant regression coefficients, ceteris paribus, there has been an accompanying 1.6 to 3.6 per cent increase in the demand for hired labor. Hence, the demand for hired labor on a regional basis appeared to be responsive to changes in the parity ratio in only four of the seven regions which included the parity ratio as a variable.

The long-run cross-elasticities of demand for these four regions ranged in value from .50 to .68. Hence, even in the long-run, the cross-elasticities of the parity ratio variable were inelastic.

The trend variable as an indicator of technology changes

Time as a variable was included in each of the regional demand functions for hired labor as a technology variable and to complete the specification. In only one region was the time variable significant, the Pacific region. Consequently, the time variable was not likely to have been a reasonable indicator of changes in technology by region.

The time path of adjustment

The adjustment coefficients, which indicate the relative speed of adjustment of a sustained change in an independent variable, ranged in value from .17 in the East North Central to .72 in the West North Central. The higher the value of the adjustment coefficient, the steeper the slope of the time path of adjustment. The results indicated that the New England, Middle Atlantic and East North Central regions have been slow to adjust to a sustained price change. In the southern regions there has been a moderate rate of adjustment, while the West North Central, Mountain and Pacific regions have been adjusting at a more rapid rate.

Summary

In summary the results of the regional demand functions for hired labor do not negate the hypothesis that the regional demand for hired labor is affected by the same factors as for the national demand functions. For those regions that contain significant price and parity ratio regression coefficients, the results are similar to those derived nationally. However, certain of the regions do not respond to the same variables. A tentative argument was presented that the hired labor force in these regions may be atypical of the rest of the country. Hence, a separate study of these regions on a less aggregated basis would be desirable.

EMPIRICAL ESTIMATES OF DEMAND FUNCTIONS FOR FAMILY LABOR

Demand functions for hired labor have been analyzed in the preceding chapters. However, for an understanding of the total farm labor market the analysis of hired labor is not sufficient. An understanding of the farm labor force can come only through an analysis of both hired and family labor. Therefore, this chapter presents a quantitative analysis of the demand for family labor, both nationally and regionally.

The underlying hypothesis, to be consistent with the previously estimated demand functions for hired labor was that the demand for family labor is responsive to the farm wage rate as an indicator of the price of family labor, and to the parity ratio which is an indicator of the relative profitability of farming. To complete the specification and as an indicator of farm technology, time has been included as a variable. Hence, the estimation of the demand function for family labor should have significant regression coefficients for the farm wage rate and parity ratio variables if indeed these factors are determinants of farm labor demand.

In the specification of the model the problem arose as to the type of data that could adequately represent the "price" of family labor. The net return to a farm operator and his family for their labor alone is difficult to ascertain (77). Some economists have argued that the hired farm wage rate is the indication of the wage accruing to family labor (32; 18).

For lack of a better indication of the remuneration of family labor, and to preserve comparability between hired and family labor studies, the hired farm wage rate was utilized as the "price" of family labor.

The parity ratio should serve as an approximate indicator of the profitability of farming. However, since it is the ratio of product price to product cost, the parity ratio does not directly measure profits.

As a means of comparison of the family labor demand functions with a demand function for total farm labor, a demand function for total farm labor was specified and estimated. The model for total farm employment contained the following variables: the ratio of the farm wage rate to the index of prices received, time as a variable, an index of farm machinery deflated by the index of prices paid for living expenses by farmers, and a ratio of the farm wage rate to farm machinery prices. The results of this estimation will be presented at the end of this chapter and will be compared to results obtained from the estimation of a similar family labor demand function.

The empirical estimation of the demand for family labor is tentative because of the diverse factors, not necessarily economic, which may affect the number of farm operators and unpaid family workers.

Demand functions were derived for the periods 1910-1957, 1920-1939, and 1940-1957 for the U.S., and from 1929-1957 for the nine geographic regions. The form of the regressions for the national and several of the regional equations is that of single-equation general least-squares. Distributed lag equations were utilized, however, for five of the nine regions. The demand functions for the U.S. and the nine regions are presented in Table 8. The order of presentation will be initially to present and analyze the national demand functions for family labor. Following this analysis, the regional demand functions for family labor will be presented. Lastly, a demand function for total farm employment will be presented and compared with the results of the family labor demand functions.

The National Demand Functions for Family Labor

The results of the estimation of the family labor demand functions for the U.S. are presented in this section and are included in Table 8 as equations 1 through 4. The residuals of two of the demand functions for family labor are graphically plotted against the actual numbers of family workers in Figures 9 and 10. These figures show that the functions estimated over the more recent period, 1940-1957, fit the data better than the over-all period, 1910-1957.

The regressions are single-equation general least-squares equations and are similar in specification for the different time periods. The sole difference between the equations is that the farm wage rate is lagged one year in equations 1 through 3. Since the number of family workers changes slowly

Table 8. Regression coefficients and elasticities for the demand functions for family labor, U.S. and nine geographic regions

Equation number	Time period	Region	Regression coefficients[a] Y_{t-1}	X_1	X_2[c]	X_3	X_4	Elasticities[b] X_1	X_4	R^2	d'
1	1910-1957	U.S.	-	-.300 (.06)	-.629 (.10)	-	.040[d] (.04)	-.20	.03	.91	sc[e]
2	1920-1939	U.S.	-	-.932 (.12)	-.315 (.07)	-	-.168 (.06)	-.16	-.11	.81	i
3	1940-1957	U.S.	-	-.139[f] (.11)	-1.22 (.33)	-	.313 (.11)	-.14	.30	.89	sc
4	1940-1957	U.S.	-	-.878 (.20)	-.302 (.07)	-	.409 (.07)	-.32	.39	.95	i
5	1940-1957	NE[g]	.971 (.12)	-.167[f] (.142)	-	-	-	-	-	.87	-
6	1929-1957	MA	.908 (.12)	-.303[f] (.246)	-.413[f] (.38)	-	.318[f] (.23)	-.07	.07	.98	-
7	1929-1957	ENC	.263 (.16)	-2.71 (.71)	4.08 (1.9)	-	1.93 (.38)	-.21	.02	.87	-
8	1929-1957	WNC	-	-.155 (.51)	-	-12.2 (2.0)	-	-	-	.75	-
9	1929-1957	SA	.859 (.13)	.605[d] (1.5)	-8.08 (3.41)	-	.426[d] (.962)	-	-	.98	-
10	1929-1957	ESC	-	-1.32[d] (2.3)	-39.1 (4.4)	-	-	-	-	.94	-
11	1929-1957	WSC	-	-1.51[d] (1.85)	-35.7 (5.43)	-	-	-	-	.92	-
12	1929-1957	MTN	.974 (.08)	-.096[f] (.065)	-	-	-	-	-	.96	-
13	1947-1957	PAC	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

				(.51)		(2.0)					
9	1929-1957	SA	.859 (.13)	.605[d] (1.5)	-8.08 (3.41)	-	.426[d] (.962)	-	-	.98	-
10	1929-1957	ESC	-	-1.32[d] (2.3)	-39.1 (4.4)	-	-	-	-	.94	-
11	1929-1957	WSC	-	-1.51[d] (1.85)	-35.7 (5.43)	-	-	-	-	.92	-
12	1929-1957	MTN	.974 (.08)	-.096[f] (.065)	-	-	-	-	-	.96	-
13	1947-1957	PAC	.110[d] (.28)	-.085[d] (.26)	-5.94 (1.52)	-	-	-	-	.98	-

[a]The regression coefficients are:
Y_{t-1}: the family labor force, lagged one year
X_1: the farm wage rate
X_2: time as a variable
X_3: the value of farm machinery and equipment
X_4: for the U.S., the index of prices received by farmers relative to the index of prices paid by farmers for production expenses, for the regions, the parity ratio, lagged one year
The significance level of each regression coefficient is at the 5-per cent level unless otherwise designated.

[b]In the short-run

[c]The farm wage rate is deflated by the index of prices paid in production in the four national equations, and by the index of prices paid in living expenses for the regional equations.

[d]Significant at the 30-per cent level or below

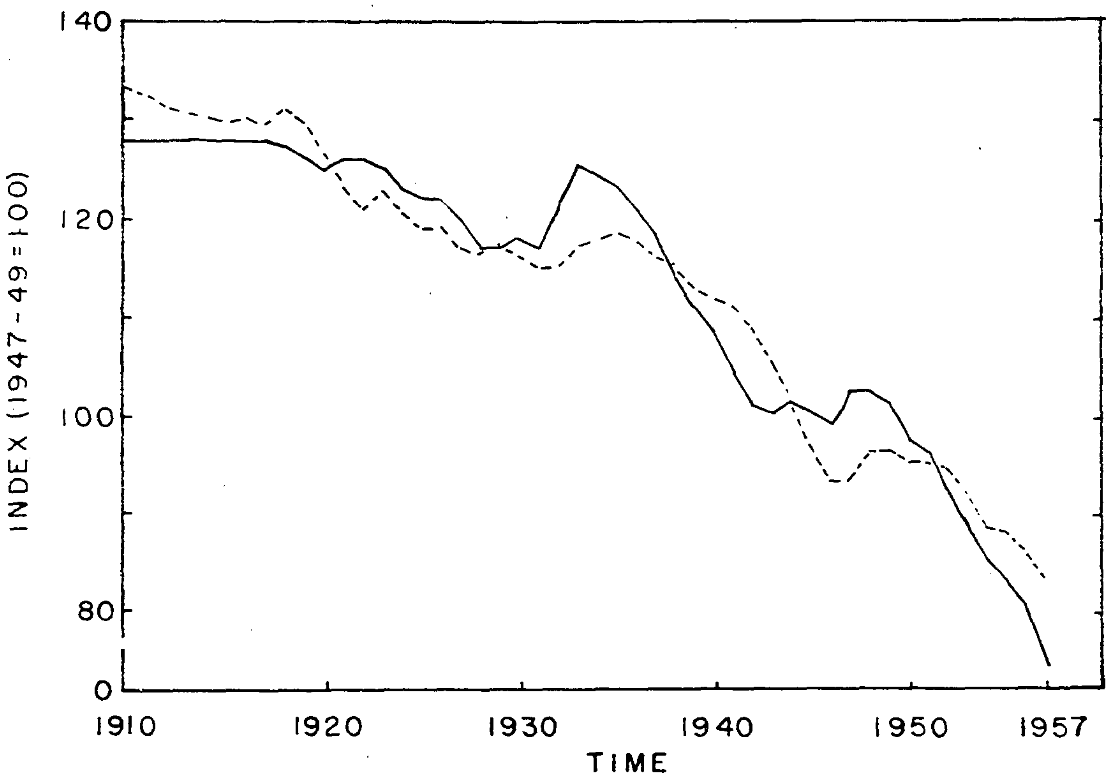
[e]Serial correlation among the residuals is indicated by sc, and indeterminate results by i.

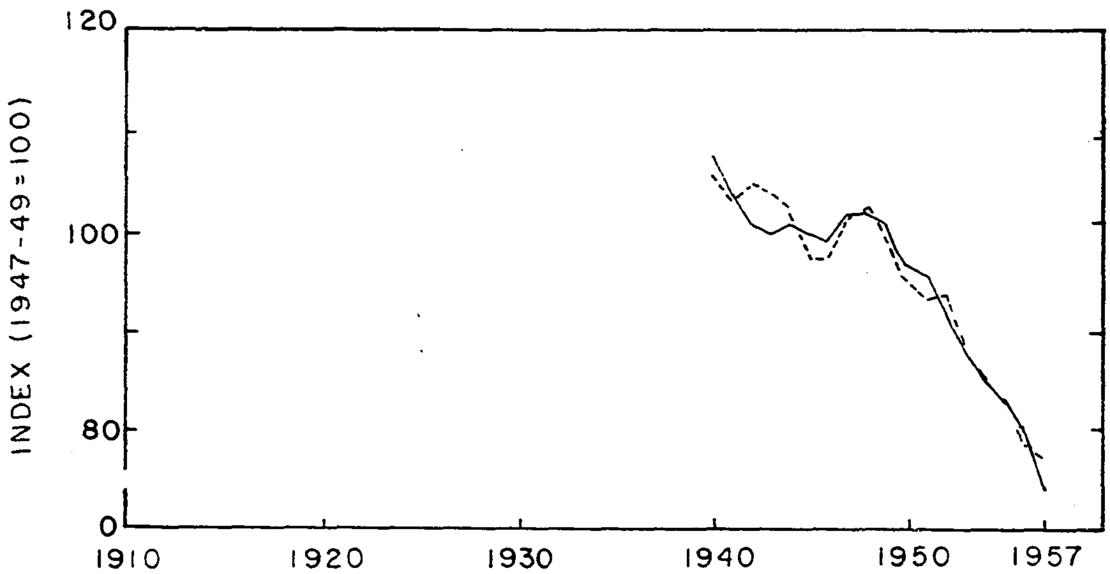
[f]Significant at the 10-30 per cent level

[g]The regions are as indicated in Figure 4.

Figure 9. Actual and predicted number of family farm workers in the U.S., 1910-1957 (by demand function 1 of Table 8). Actual numbers: the solid line.

Figure 10. Actual and predicted number of family farm workers in the U.S., 1940-1957 (by demand function 4 of Table 8). Actual numbers: the solid line.


140
120
100
80
0
INDEX (1947-49=100)
1910
1920
1930
1940
1950
1957
TIME


120
100
80
0
INDEX (1947-49=100)
1910
1920
1930
1940
1950
1957

over the years, and because of estimation problems, correlation of the residuals becomes a serious statistical problem. As an indication of correlation, the d' statistic of the Durbin-Watson test (22) was computed for each of the four equations. Two of the equations showed positive serial correlation, while the other two were indeterminate, even though time was included as a trend variable and was significant in all of the equations. Ordinarily, such significant residual correlation would call for some type of transformation, such as for the use of first differences or for an autoregressive scheme. In this case, the use of highly refined techniques was held to be undesirable in view of the tentative structure of the model and the relatively poor data available.

The farm wage rate as the price of family labor

Data for the series on family labor are in index form for the U.S., thus permitting a comparison of regression coefficients, as well as elasticities. Three of the four coefficients of the farm wage rate were significant. The coefficients ranged in value from -.14 to -.93. There is some theoretical basis for lagging the wage rate when using general least squares equations, but this contention was not corroborated by the regressions for the period 1940-1957. Over this period, equation 3 contained the wage rate lagged one year, while 4 was not lagged. However, the regression coefficient in 4 was more significant than the coefficient in 3. The results indicated that the demand for family labor has been responsive to changes in the farm wage rate.

The price elasticities of the first three farm wage rate variables were similar in value while that for 4 was somewhat larger, though all were inelastic. For the over-all period, 1910-1957, given a 10-per cent increase in the farm wage rate, ceteris paribus, there has been an accompanying decrease in the demand for family labor of 1.4 to 4.1 per cent. The regression coefficients and elasticities over time appear to have remained relatively unchanged. However, if one assumes that the more valid form of the equation is as included in 1, 2, and 4, i.e., no lag in the wage rate for 4, then there is some basis for the contention that the elasticities were higher for the recent period.

From the analysis of the farm wage rate variable, several results have been noted. First, the demand for family labor apparently has been responsive to changes in the farm wage rate. This result would support the hypothesis that the farm wage rate is an indicator of the wage accruing to family workers. Second, there is some basis for the contention that the price elasticity has increased for the more recent periods. A consequent implication is that the demand for farm labor has shifted from a lower level of response to farm wage rate changes prior to World War II to a higher level of response in the subsequent period.

The prices received variable

The regression coefficients and elasticities of the prices received variable over time differed considerably. For the period, 1910-1957, the regression coefficient and cross-elasticity of demand approached zero, and was non-significant. For the two intervening periods, however, the signs of the regression coefficients were different. During the years 1920-1939, the regression coefficient for the prices received variable was negative; during the 1940-1957 period, the corresponding sign of the regression coefficient was positive. Further, both coefficients were statistically significant. A comparison of cross-elasticities in which those of 1940-1957 were averaged, is as follows. For the period 1920-1929, in equation 2, given a 10-per cent increase in the index of prices received for all commodities, other things being equal, there was an accompanying decrease of 1.6 per cent in the number of family workers. To phrase it differently, since there was little decrease and even some increase in the number of family workers during the period, along with a 10-per cent decrease in the index of prices received, there was a corresponding increase of 1.6 per cent in the demand for family workers. The depression, with a consequent lack of non-farm opportunities, could have given rise to such a situation. For the more recent period, 1940-1957, as the index of prices received rose 10 per cent, other things being equal, the demand for family workers decreased 3.5

per cent. Since this period was one in which considerable off-farm work could be secured, this sign of the elasticity was also consistent.

In brief, the regression coefficient of the prices received variable was non-significant for the period 1910-1957. As estimated over the intervening periods, the regression coefficient of the prices received variable for the 1920-1939 period was negative in sign and significant; for the 1940-1957 period, the sign of the prices received regression coefficient was positive and significant. There is considerable basis, then, to contend that to ascertain the effect of the prices received variable on the demand for family labor, the analysis should proceed by separate time periods. In the depression period, 1920-1939, as the profitability of farming decreased, there was an accompanying increase in the family labor force. With few off-farm employment opportunities during the depression, this result appears to be consistent. During the war-postwar period, 1940-1957, as the profitability of farming decreased, the number of family workers decreased. With ample off-farm job opportunities, this result also appears consistent.

Comparison of the demand for total farm labor with the demand for family labor

A demand function for total farm employment was specified and estimated for the over-all period, 1910-1957, as a means of comparison with the demand functions for family labor. As noted in the introduction of this chapter, the demand for total farm labor was assumed to be a function of the farm wage rate relative to farm product prices in the previous year, the farm wage rate relative to farm machinery prices in the previous year, expenditures on farm machinery in the previous year, and time as a variable.

The estimated demand function for total farm employment was:

$$(43) \quad Y = 156.14 - \underset{(.053)}{.2054}X_1 - \underset{(.103)}{.7003}X_2 - \underset{(.039)}{.1423}X_3 - \underset{(.041)}{.0131}X_4$$

where: Y = total farm employment,

X_1 = the farm wage rate relative to the index of prices received, t-1, fwr/ipr,

X_2 = farm machinery expenditures, t-1,

X_3 = time as a variable, and

X_4 = the farm wage rate relative to the index of farm machinery prices, t-1.

The coefficient of determination was .95. In order to compare the results of the demand for total farm employment with a demand function for family labor, a demand function for family labor was similarly specified as 43 and derived for the 1910-1957 period. The resulting equation was:

$$(44) \quad Y = 153.89 - \underset{(.084)}{.1974}X_1 - \underset{(.162)}{.4338}X_2 - \underset{(.062)}{.1716}X_3 - \underset{(.065)}{.0821}X_4$$

where Y = the number of family workers, and the other variables in 44 are the same as those explained in 43. The coefficient of determination was .86 for equation 44.

The similarity of the two demand functions, 43 and 44, suggests that demand functions derived for family labor may be interpreted to apply to all farm labor. However, differences do exist between the two equations. The ratio of farm wage rates to the index of prices received indicates the response of the demand for family or total employment to a rise in the farm wage rate relative to farm product prices. As the farm wage rate rose relative to prices received by 10 per cent, ceteris paribus, there were corresponding decreases in the total farm working force of 1.6 per cent and in the family labor force of 1.5 per cent. Both of the corresponding regression coefficients are significant at the 5-per cent level. Hence, the response of the demand for total and family labor to changes in the farm wage rate was similar for the two demand functions.

The effect on family or total labor demand of the series on investment in farm machinery in the previous year as deflated by the index of prices paid in farm living, would indicate the response of farm labor to additions in farm machinery in the previous year. As the investment in farm machinery has risen by 10 per cent in the past, there has been a concurrent decrease of 3.1 per cent in the total farm labor force, and 1.9 per cent decrease in the family labor force. Both of the corresponding regression coefficients were significant at the 5-per cent level or better. The total demand for farm labor appeared to be the more responsive to changes in investment in farm machinery in the previous year.

The demand for total and family labor responded somewhat differently to changes in the ratio of farm wage rates to farm machinery prices. However, the regression coefficients in both equations were non-significant.

Both of the regression coefficients for the time variable were significant and similar in size. Evidently, factors that could be explained by a linear trend were of similar importance to the two dependent variables.

In summary, demand functions containing identical independent variables were estimated for total and family farm employment for the period, 1910-1957. The major similarities of the two demand functions were in the regression coefficients and elasticities of the farm wage rate-prices received ratio and the time variables. These coefficients were close in value and statistically significant. These results indicated that the response of the demand for total and family farm labor to changes in these variables was significant, though inelastic. The major difference between the two demand functions was in the value of the regression coefficients for expenditures on farm machinery. The relatively high significant value of this regression coefficient for total farm employment signified that expenditures on farm machinery in the previous year were more important to the demand for total farm labor than to the demand for family labor. The time variable for the family labor demand function was also significant, indicating incomplete specification. The size of the coefficient of determination for 44 was relatively less than for 43.

On the basis of similarity of demand response, there may be a tendency to consider a demand function for family labor as typical of a demand function for total farm labor. However, the dissimilarity of machinery expenditure coefficients could indicate substantial differences between the two equations.

Summary of the demand functions for family labor

Four demand functions for family labor were presented. These demand functions when tested for serial correlation in the residuals gave evidence of some positive serial correlation. Consequently, in interpreting these equations, this factor should be considered. Essentially, the demand functions for family labor proved to be responsive to the farm wage rate. The prices received variable, too, was significant, though the analysis of the equations had to be made separately for the periods 1920-1939 and 1940-1957. Basically, then, the hypothesis that the demand for family labor was responsive to the farm wage rate and prices received was supported by this analysis.

A comparison of demand functions for family and total farm employment demonstrated a similarity of response between the demand functions. However, the effect of expenditures for farm machinery on labor demand differed sufficiently so that it is not necessarily true that a demand function for family labor is typical of the demand function for total farm labor.

The Regional Demand Functions for Family Labor

Following the estimation of national demand functions for family labor, the results of the national regression coefficients and elasticities can be compared with those obtained on a regional basis. Consequently, demand functions for family labor by regions were estimated and are presented in Table 8 as equations 5 through 13. In this section, the order of presentation will be: (1) to make general comments concerning the regional labor demand functions, and (2) to analyze the coefficients and elasticities of these functions.

General comments on the regional demand functions for family labor

The hypothesis again is that the regional demand functions for family labor, as estimated in this study, are similar to those demand functions for family labor derived for the total U.S. Family labor is held to be a function of the farm wage rate and the parity ratio. The basic explanatory variable is the hired farm wage rate. The reasons for the adoption of this variable were explained in the previous chapter on model specification. Essentially, the farm wage rate was construed to be the price of family labor in the absence of a better indicator of family labor remuneration.

Another explanatory variable included in the analysis was the parity ratio computed on a regional basis. Lagged one year, this ratio served as an indicator of the relative change in the profitability of farming in the previous year. Since these data were lacking on a regional basis, the series had to be constructed on a "typical" state basis. The parity ratio consists of the ratio of the index of prices received by farmers for all commodities and livestock to the index of prices paid for production, living interest, taxes, and wage rates. As there was relatively little change regionally in the prices paid, data for the U.S. were used. However, since prices received vary regionally according to the product mix, regional estimates are requisite. These estimates are not published regionally or for all states. As a result, data on prices received from states typical of the region were utilized.

Other variables used in the demand function for family labor were a linear time trend and a regional approximation of the total value of farm machinery.

Both linear general least-squares and distributed lag equations were estimated. The demand functions for family labor for the regions were initially estimated by general least-squares methods. Because of inconclusive results, some equations were estimated by distributed lags. Since the distributed lag equations failed to improve the significance of the independent variables, it was not deemed worth while to estimate functions for all of the regions by this method.

A test of residual correlation was not performed for the regional equations for the results of the regional demand functions did not warrant further refinements. The tests for the national demand functions for family labor have demonstrated that serial correlation does exist. Too, the distributed lag equations, as noted previously, usually will not show residual correlation.

The series of the total numbers of family workers used is again that series estimated by the AMS, but is in actual numbers rather than in index form. Hence, a direct comparison of the regression coefficients is not possible.

Analysis of the regional demand functions for family labor

The regression coefficients in the regional demand equations may vary according to the period covered, the size of the labor force, and the influence of the variable. Briefly, the regression coefficients for the farm wage rate, the price variable, ranged from -2.71 to .605. Only one of the regression coefficients was significant at the 5-per cent level, however, and only in the distributed lag equations are the coefficients significant even at the 30-per cent level. Basically, the demand functions indicate that the family labor force by region has not been particularly responsive to changes in the hired farm wage rate. Only in the East North Central region was the family labor force significantly responsive to the farm wage rate, with a price elasticity of -.207. Three other regions had regression coefficients larger than the standard errors. Since the other regression coefficients were not statistically significant, price elasticities were not derived.

The parity ratio was included as a variable in three of the regional demand functions. Of the three regions, the regression coefficient was significant at the 5-per cent level in the Middle Atlantic, and non-significant in the South Atlantic region. Because the parity ratio was included in only three of the nine regional demand functions for family labor, no definite conclusion as to the importance of this variable can be drawn. However, the parity ratio does seem to have been important in the northeastern region of the U.S.

The third variable included in the regional demand functions for family labor was a time variable entered in linear form. The time variable was significant at the 5-per cent level in five of the six regional demand functions in which it was included. Of the regional demand functions in which time as a variable was either not included or non-significant, three of the demand functions were estimated by distributed lags and contained a significant lagged dependent variable. These results indicate that variables representing specific influences on the regional demand for family labor other than the farm wage rate and the parity ratio were not included in the equations.

Two general conclusions can be made from an analysis of the results of the regional demand functions. First, the demand functions for family labor for the individual regions did not indicate that the hired farm wage rate was significantly important in determining the demand for family labor. Second, the significance of the trend variable in the regional demand functions for family labor indicates an incomplete specification of the model.

Why are the coefficients for the U.S. demand functions for family labor significant while the corresponding regional coefficients are non-significant? A possible answer may lie in the significance of the trend in these regional demand functions. If the data collected for each region does not reflect year-to-year marginal changes in the family labor force, then a trend variable would explain the smooth variations quite well. When the data are aggregated on a national scale, the accumulation of data may bring the year-to-year changes into more prominence.

Another factor in the non-significance of the farm wage rate variable is that the time period covered by the demand functions regionally and nationally is different.

In brief, the regional demand functions for family labor for the 1929-1957 period were not significantly responsive to changes in the farm wage rate. Most of the change in the regional family labor force can be accounted for by a linear trend variable or by the dependent variable lagged one year. The reason for the non-significance of the farm wage rate variable may be that the data as reported for each separate region do not reflect enough year-to-year change.

EMPIRICAL ESTIMATES OF THE NATIONAL SUPPLY FUNCTIONS FOR FARM LABOR

References were made in the previous chapters to the supply function for farm labor. Briefly, the main points presented were: (1) the supply function for hired labor was specified in order that a demand function for hired labor could be identified from a system of equations; (2) the theory of labor supply utilizes assumptions concerning the utility of work and leisure with income as a frame of reference; and (3) the supply function for either hired or family labor was specified in terms of the farm wage rate, a composite non-farm wage rate adjusted by the percentage of unemployment, time as a variable, and the lagged endogenous variable.

A current hypothesis relative to the supply of farm labor was tested in this chapter. Essentially, the hypothesis was that the supply of farm labor is less responsive to changes in the farm wage rate than to changes in non-farm wage rates, subject only to the availability of non-farm employment opportunities. This hypothesis leads to the quantification of the "push-pull" migration theory under the assumption that the rate of off-farm migration, which directly affects the supply of farm labor, is subject more to the "pull" of non-farm wage rates and employment opportunities than to the "push" of the introduction of labor-saving machinery and techniques (28, 40, 78, 82, 115).

Supply functions were derived individually for hired and family labor. The presentation and analysis of the supply functions for hired labor will precede the analysis of the supply functions for family labor. Following this analysis, a function predicting net off-farm migration will be presented.

The Estimation of a Supply Function for Hired Labor for the U.S.

To accompany the demand functions for hired labor, supply functions for hired labor have been derived. As mentioned earlier, the hypothesis tested was that the supply of hired labor is not responsive to the farm wage rate, but is responsive to off-farm opportunities for employment. For the purposes of this thesis, the hired and family categories of farm employment are hypothesized as responding to the same variables but differing in degree of response. Actually, the factors determining the supply of these different types of workers may be entirely separate. However, little is known in a quantitative sense of the factors affecting farm labor. Consequently, the study will proceed under the assumption that the variables affecting each category of worker are the same, thus providing a mutual starting point for future aggregative supply studies.

The supply functions for hired labor were estimated from a system of equations, one estimated by reduced-forms, and the other estimated by the Theil-Basmann technique. In addition, the Theil-Basmann supply function was estimated using auto-regressive least-squares equations.

The method of presentation differs from that used in the preceding chapters; the analysis will proceed by type of equations, rather than by variable. A comparison of regression coefficients and elasticities of these and other studies will conclude the section.

<u>A just-identified (reduced-form) supply function for hired labor</u>

A two-equation just-identified system of equations was utilized initially to estimate a supply function for hired labor. The just-identified demand function for hired labor is presented as equation 8 of Table 5. The consequent supply function for the period 1929-1957 was:

(45) $Y = 22.869 + .8145\ Y_{t-1} + .1757\ X_1 - .3654\ X_2 - .1036\ X_3$

where Y = the supply of hired labor

X_1 = the composite farm wage rate deflated by the index of prices paid for living expenses

X_2 = time as a variable

X_3 = a composite non-farm wage variable, $A(1-5U)$.

The non-farm wage variable has been described in the chapter on model specification. A is the average hourly earnings of factory workers, and U is the percentage total unemployment which is not allowed to rise above 20 per cent. The standard errors of the regression coefficients were not estimated because of time limitations and because the Theil-Basmann estimates contain standard errors.

The signs of the regression coefficients appeared to be consistent. The elasticity of supply of the farm wage rate in the short-run was .13 and .71 in the long-run. In the past, then, as the farm wage rate has increased by 10 per cent, *ceteris paribus*, there has been a concurrent rise in the supply of hired labor of 1.3 per cent in the short-run, and 7.1 per cent in the long-run period. Both short-run and long-run price elasticities of supply were inelastic.

The cross-elasticity of the non-farm wage rate variable was .057 in the short-run and -.31 in the long-run. With an increase of 10 per cent in the non-farm wage rate variable in the past, there has been an accompanying decrease in the supply of hired labor of .6 per cent in the short-run and 3.1 per cent in the long run. The cross-elasticities appeared to be quite inelastic.

The coefficient of adjustment, .1855, indicated a relatively long time period of adjustment to a sustained price change.

A supply function for hired labor estimated by autoregressive least squares from a system of equations

The procedure involved in performing an autoregressive modification has been discussed in a previous chapter of this study. To estimate an autoregressive least-squares equation containing several variables, a program has been developed by the Iowa State University Statistical Laboratory for the IBM-650.

The variables included in the system of equations are the same as those in the just-identified system, except for an additional non-farm variable lagged one year. The corresponding demand function is presented in Table 5 as equation 9.

When the estimation of the supply function for hired labor was initially attempted, difficulty was encountered in the iteration procedure. All of the coefficients of the supply function increased in absolute value rather than following a converging sequence. A likely source of the trouble was the failure of the demand shifter, the parity index, to sufficiently identify the supply function. To derive a satisfactory supply function for hired labor the inclusion of another demand shifter was deemed necessary. Consequently, the existing supply function, 45, was held to be insufficiently identified to provide adequate estimates of long-run elasticities.

The system of equations was enlarged by the addition of another demand shifter, the value of farm machinery and equipment, lagged one year. With the inclusion of this variable in the system, a supply function for hired labor for the 1929-1957 period was:

$$(46)\quad Y = 140.95 + \underset{(.357)}{.4862}\, Y_{t-1} + \underset{(.237)}{.1667}\, X_1 - \underset{(.574)}{.8548}\, X_2 - \underset{(.095)}{.1411}\, X_3$$

where the variables are the same as those explained under 30. The signs of the regression coefficients appeared to be consistent, and the values of the coefficients of the wage rate, X_1, and the composite non-farm wage rate variable, X_3, were much the same as in 45. However, in terms of statistical significance, the coefficient of the farm wage rate variable is less than the corresponding standard error. The remaining coefficients were significant at only the 20-per cent level. Since autoregressive least-squares equations were used, the estimate of β was:

$$(47)\quad u_t = \underset{(.3305)}{.5155}\, u_{t-1}$$

and was significant at the 20-per cent level.

The elasticity of supply for the farm wage rate was .125 in the short-run and .24 in the long-run. In the past, then, an increase of 10 per cent in the farm wage rate has been accompanied by an increase in the supply of hired labor of 1 per cent in the short-run and 2.4 per cent in the long-run. However, the regression coefficient was non-significant.

The supply elasticity of the composite non-farm wage rate variable was -.078 and -.15 in the short- and long-run periods, respectively. An increase of 10 per cent in the non-farm wage rate variable has been accompanied in the past by a decrease in the supply of hired labor of .78 per cent in the short-run and 1.5 per cent in the long-run. However, the regression coefficient of this variable was also non-significant.

The coefficient of determination was .974. The adjustment coefficient was .51, which indicated a rather short adjustment time period.

<u>A comparison of regression coefficients for the supply of hired labor</u>

The results of the supply functions for hired labor may be compared with the results of Schuh (105). The work done by Schuh was not known until after a majority of these equations were estimated. He was primarily interested in supply estimation and derived his supply functions by the Theil-Basmann method. The variables used in his supply functions were the farm wage rate, non-farm earnings, unemployment, and the civilian labor force. The time period was the same, 1929-1957. Schuh, of course, did not utilize autoregressive least-squares equations in his supply functions.

The short-run elasticities of the farm wage rate were similar between the two studies. Schuh's estimates ranged from .07 to .20, while for equation 46 the estimate was .125. The large differences arose in the long-run estimates. The long-run price elasticity of supply was .24 for equation 46, while .71 for equation 45, and from .32 to 2.03 in Schuh's equations. With the equation modified by the autoregressive scheme, the long-run elasticity was estimated to be much lower than that derived by ordinary estimational techniques. The essential difference, of course, is that the modified form of equation 46 permits a lower estimation of the coefficient of the lagged endogenous variable, which in turn, results in a higher adjustment coefficient.

The non-farm wage rate variable was not directly comparable with the estimate of Schuh. He presented non-farm earnings and unemployment separately. However, they may be compared indirectly. The estimates of the regression coefficients of 45 and 46 are similar; in the short-run the elasticity of the non-farm wage rate variable was -.057 for 45 and -.078 for 46. The corresponding short-run elasticity for Schuh's estimates were higher, averaging -.46. In the long-run, since Schuh's estimated adjustment coefficients were very low, the elasticities of his non-farm earnings variable ranged from -2.14 to -4.67. The corresponding elasticities in the long-run for 45 and 46 were -.31 and -.15. Though the variables are not directly comparable, one comment can be made. The estimational technique used by Schuh permits a very wide range of long-run estimates of elasticities. Had Schuh used an autoregressive transformation and possibly included time as a trend variable, his estimates would likely have been similar to those found in this study. This is not to say, of course, that his work is not excellent otherwise.

In summary, a supply function for hired labor was estimated using autoregressive least squares. The results of this estimation, equation 46, tend to confirm the initial part of the hypothesis that the supply of hired labor was relatively unresponsive to changes in the farm wage rate. The computed coefficients of the farm wage rate variable were consistent in sign and indicated that the long-run elasticity was quite inelastic. Any interpretation of the size of the elasticities must be qualified by the non-significance of the regression coefficient.

The results of the estimation of the non-farm wage rate variable did not affirm the remaining part of the hypothesis that the non-farm wage rate is a dominant force in determining the size of the hired farm labor force. The regression coefficient was significant at only the 20-per cent level. The cross-elasticity in both the short- and long-run were of consistent sign but quite inelastic.

The adjustment coefficient was computed to be .51. The time period of adjustment in the long-run was fairly short. A comparison with a supply function for hired labor by Schuh indicated that Schuh's estimates of the adjustment coefficient were very low, and hence, his long-run time period of adjustment was long.

In general, the estimation of the supply function for hired labor appeared to be consistent: variables which were assumed to affect the supply of farm labor were included in the specification; the effect of the farm wage rate and a composite non-farm wage rate variable were tested; and the function was modified by an autoregressive scheme. However, the analysis was of a tentative nature, for the focus of this thesis was on labor demand.

The Estimation of a Supply Function for Family Labor for the U.S.

The analysis of the supply functions for hired labor does not necessarily reflect the relationship of the variables tested to the supply for all farm labor. Hence, a tentative analysis of the supply function of family labor for the U.S. was conducted. With no quantitative analysis done in this field, the hypothesis was adopted that the same variables that affect the supply of hired labor should affect the supply of family labor. Thus, the supply function for family labor was specified with the same variables as used for the hired labor analysis. The estimating technique was again that of the Theil-Basmann technique using autoregressive least-squares equations. To assist further in the determination of the dominant factors affecting the supply of family labor, an analysis was made of the variables affecting the net migration from farms.

The results of the supply function for farm labor will be presented initially, followed by the analysis of net farm migration.

The supply function for family labor in the U.S.

As described in a previous chapter, the supply of farm labor was estimated as a function of the farm wage rate, a non-farm wage rate variable, time as a trend or technology variable, and the family labor force lagged one year.

In the estimation of autoregressive least-squares equations, several iterations are "run" until negligible changes occur among the estimated coefficients. The results of the second iteration estimating the supply function for family labor indicated large and inconsistent changes from the previous iteration among the lagged variable, time, and the estimate of β. However, the regression coefficients of the farm wage rate and non-farm wage rate had little change. Evidently, without highly significant independent variables other than time and the lagged dependent variable, problems of multicollinearity arose. On the initial iteration, however, as the iteration was beginning to "settle down," the estimated family labor supply function, taken as deviations from the mean, was:

$$(48) \quad y_t = \underset{(.21)}{.17}\, x_1 - \underset{(.053)}{.013}\, x_2 - \underset{(.072)}{.079}\, x_3 - \underset{(.743)}{1.08}\, x_4 + \underset{(.36)}{.52}\, y_{t-1}$$

where: y_t = the family labor force

x_1 = the farm wage rate deflated by the index of prices paid for living expenses by farmers

x_2 = the composite non-farm wage rate

$x_3 = x_2$, lagged one year

x_4 = time as a variable

$x_5 = y_{t-1}$.

The regression coefficients of 48 were consistent in sign, but were all non-significant. The estimate of the autoregression coefficient, β, was .65 and non-significant. Upon the completion of the next iteration, the coefficients of x_1, x_2, and x_3 were relatively unchanged, but the coefficients of the remaining variables changed erratically. Consequently, because of the unfinished estimation of the supply function for family labor, elasticities were not derived. However, the size and significance of the primary explanatory variables are of interest. Non-significant results were obtained both for the farm wage rate and for the non-farm wage rate variables. These results are similar to those obtained in the estimate of the supply function for hired labor.

The supply of family labor was also estimated for the same period, 1929-1957, by ordinary least-squares methods. In these equations, the non-farm wage rate and the percentage of unemployment were fitted separately. The supply functions are presented below, with the data taken as functions from the mean:

$$(49) \quad y_t = \underset{(.101)}{.136}\,x_1 - \underset{(.096)}{.152}\,x_2 + \underset{(.137)}{.139}\,x_3 - \underset{(.176)}{.408}\,x_4 + \underset{(.145)}{.773}\,y_{t-1}$$

$$(50) \quad y_t = \underset{(.059)}{.132}\,x_1 - \underset{(.078)}{.149}\,x_2 + \underset{(.103)}{.135}\,x_3 - \underset{(.153)}{.405}\,x_4 + \underset{(.136)}{.774}\,y_{t-1}$$

where 49 was estimated from a system of equations and 50 was estimated singly, and:

y_t = the family labor force

x_1 = the farm wage rate deflated by the index of prices paid for living expenses

x_2 = the non-farm wage, deflated by the same deflator as x_1

x_3 = percentage unemployment of the total work force

x_4 = time as a variable

y_{t-1} = y_t lagged one year.

The farm wage rate coefficients of 49 and 50 were similar to 48. The significance levels were higher, however, in 49 and 50, reaching the 5-per cent level in 50.

The non-farm wage rate coefficients were also more significant, though not directly comparable. If the iterative procedure had "settled down," it is likely that the coefficients of 48 would have been significant at or better than the 20-per cent level.

However, based on the results of 48, the supply of family labor apparently is neither highly responsive to the farm wage rate nor to the non-farm wage rate. This conclusion is tentative and is correct only to the extent that the data and specification of the model were correct for the particular time period, 1929-1957.

Analysis of net farm migration

As discussed at the start of this chapter, a current hypothesis exists that the migration from farms is more in response to off-farm employment opportunities than to the "push" of new farm technology which would obviate the need for much of the farm labor. The estimated supply functions tested this hypothesis to some extent, and the results indicated a relative lack of response of the supply of farm labor to both of the variables. To approach the problem from the aspect of net changes in the farm population, in essence, is to analyze the net changes in the supply of labor. The determinants of the net farm migration series were held to be the farm wage rate, the parity ratio lagged one year, the composite non-farm wage rate lagged one year, time as a variable, and the net farm migration lagged one year. No autoregressive transformation was performed, and the time period covered was again 1929-1957. The resultant equation with the data taken as deviations from the mean was:

$$(51) \quad y_t = \underset{(.184)}{.255}\, x_1 - \underset{(.053)}{.099}\, x_2 - \underset{(.071)}{.069}\, x_3 - \underset{(.210)}{.492}\, x_4 - \underset{(.022)}{.023}\, y_{t-1}$$

where: y_t = the net migration from farms

x_1 = the farm wage rate

x_2 = the parity ratio, lagged one year

x_3 = the composite non-farm wage rate, lagged one year

x_4 = time as a variable

$y_{t-1} = y_t$, lagged one year.

The net migration series is presented in terms of "+" which signifies a net return to the farm, and "-" which signifies a net departure from the farm. Hence, the sign of the farm wage rate indicates that as the farm wage rate has risen, there has been an accompanying net return to the farm. Similarly, as the composite non-farm wage rate in the previous year has risen, there has been an accompanying net departure from the farm. For this equation, the coefficient of determination, or R^2, was .36. Only 36 per cent of the change in the net migration from the farm was explained by this equation. However, the signs of the regression coefficients appear consistent for all but one of the variables. The regression coefficients with the consistent signs indicate: (1) as the farm wage rate rose, there was an accompanying net return to the farm; (2) as the non-farm wage rate rose in the previous year, there was a concurrent net departure from the farm; and (3) over time there was a net departure from the farm. However, the sign of the parity ratio is negative, and indicates that as the parity ratio has increased in the previous year, there has been an accompanying net departure from the farm. Evidently, the time periods when the parity ratio has increased have been periods of relative abundance of non-farm employment opportunities.

The non-significance of the farm wage rate and non-farm wage rate variables indicated that though the signs of the regression coefficients were consistent, the response to changes in these parameters was not significant in terms of farm migration.

However, the farm migration series consists of farm people moving to the farm as well as people moving from the farm. An analysis of the movement of farm people away from the farm might give different results.

Summary of the results of the estimation of supply functions for family labor

A tentative analysis of the supply of family labor and of net farm migration has been presented. In general, the supply of family labor did not appear to be responsive to changes in farm wages, and similarly, rather unresponsive to changes in the composite non-farm wage rate. These results corroborate the original hypothesis only to the extent that the supply of family labor was unresponsive to farm wage rate changes. Although the unresponsiveness of the supply of family labor to changes in non-farm wages did not negate the hypothesis that the supply of family labor is responsive to off-farm employment opportunities, the results did not corroborate the hypothesis.

An analysis of this type is only as good as the data available and the estimation techniques used. Improvement of the data, especially for family labor, could bring significantly better results.

The results of the analysis of net migration were of interest but did not change the results obtained from the analysis of the supply functions for family labor. Both the farm wage rate and the non-farm wage rate had consistent signs of the regression coefficients though they were not statistically significant. These results again indicate that the supply of farm labor is not significantly responsive to changes in the farm wage rate or to changes in the non-farm wage rate.

THE SUBSTITUTION OF FARM LABOR AND MACHINERY

Equations which contain the price of farm machinery have not been included in the foregoing analysis of labor demand because of inconsistent empirical results. Since the substitution between these two classes of inputs has been difficult to estimate quantitatively, the discussion of this relationship was accorded a separate chapter. In this section, the objective is to examine the factors affecting farm labor and farm machinery so that the reason inconsistent results were obtained may be better understood. Equations are presented which include as independent variables both the farm wage rate and machinery prices either as single variables or as ratios.

Relationship of the Farm Labor and Farm Machinery Markets

Essentially, the substitution of labor and machinery is affected by four factors: the price and availability of labor and the price and availability of machinery (15). The relationship of these variables to the demand for labor has not been clearly empirically established. However, it may be contended that the so-called "push-pull" migration hypothesis holds (28, 40, 78, 82), but that the main impulse of off-farm migration is generated by farm-non-farm relative wages subject to off-farm employment opportunities. Mechanization would increase as the number of workers declined. A simultaneous determination of labor supply and demand with the value of farm machinery may be needed.

Several of the important determining variables of farm labor (Table 2) have changed simultaneously. As farm wage rates have risen, and farm machinery expenditures have increased, farm machinery prices have increased and the farm population has decreased. These changes have been coincident, but, as shown in Table 2, have occurred at different relative rates. Contributing factors to the concurrent change in these variables are: (1) machinery innovations have increased the value of machinery relative to machinery prices; (2) farm wage rates may follow industrial wage rates; and (3) farm machinery prices have followed steel and industrial product prices.

Cromarty hypothesizes that a farm machine's earning power is dependent not only on price, but also on the changes in technology in farm machinery and farm production methods (15). The structural relationship of farm labor and farm machinery apparently is constantly changing.

Two other factors are important in analyzing the machinery-labor situation. Farm labor and machinery on a firm level are in one sense complementary. If a new tractor were added, an additional man must be hired to operate the machine. This situation could more aptly apply to areas already well-mechanized. The other factor is that substitution of labor and machinery may be a one-way relationship. As labor leaves the farms, machinery is introduced. To reverse this process, and accommodate labor returning to the farm, machinery must be sold or left idle. According to the Johnson "fixed-asset theorem" (67) machinery will be sold only under the unlikely circumstances that its marginal value product is less than its salvage value.

These features of the farm labor-machinery relationship indicate that price comparisons alone may not lead to a complete understanding of the relationships involved. However, due to lack of better data the relationship of machinery and labor was analyzed using only relative price considerations.

Empirical Demand Functions Containing a Machinery Price Variable

Four equations are presented which are based on the specification of two different models. One model was specified to predict the demand for hired labor, and the other to predict farm capital expenditures on farm machinery and equipment. All equations were taken with a distributed lag, both in linear form and in logs.

The time series on hired labor is the same as that presented in the chapters on the demand for hired labor, while the series of farm capital and expenditures is composed of farmer expenditures on tractors, trucks, automobiles for farm business use, and other machinery and equipment as contained in reference (129:July 1959, p. 51). The explanatory variables which contain the price of farm machinery and the farm wage rate are presented in one of two ways: either separately or as a ratio.

Two equations predicting the demand for hired labor for the period 1910 to 1957 are presented first. A linear equation utilizing the farm wage rate and the price of farm machinery as a ratio was estimated as follows:

$$(52)\quad Y = 25.66 - \underset{(.0401)}{.0588}\,X_1 - \underset{(.1115)}{.2054}\,X_2 + \underset{(.0727)}{.8570}\,X_3 + \underset{(.0320)}{.0169}\,X_4$$

where: X_1 = the farm wage rate deflated by the index of prices received,

X_2 = a linear time variable

X_3 = the hired labor force lagged one year

X_4 = the farm wage rate deflated by an index of farm machinery prices.

The coefficient of determination was .982. Though the sign of X_4 on intuitive grounds should be positive, the sign of the coefficient, though insignificant, is negative. The results of equation 52 are corroborated by a similar equation in logs in which the machinery price and wage rate are entered singly:

$$(53)\quad Y = .7923 + \underset{(.053)}{.8470}\,X_1 - \underset{(.016)}{.0094}\,X_2 - \underset{(.039)}{.1375}\,X_3$$

$$- \underset{(.031)}{.0994} X_4$$

where: X_1 = the hired labor force lagged one year

X_2 = an exponential trend

X_3 = the index of farm machinery prices deflated by the index of prices paid in living expenses

X_4 = the farm wage rate deflated by the index of prices paid in living expenses.

The coefficient of determination was .985. In this equation the regression coefficient for the index of machinery prices is significant and has a negative elasticity of -.1375. Were the time variable, X_2, entered in the equation so as to be more statistically significant, the X_3 coefficient may not have been significant.

The predictions of farm capital expenditures for farm machinery are presented in equation 54 in logs, and in 55 in linear form. The equations are:

$$(54) \quad Y = 1.2353 + \underset{(.1113)}{.6764} X_1 \div \underset{(.1568)}{.2132} X_2 - \underset{(.2876)}{.5213} X_3$$

$$(55) \quad Y = -3.83 + \underset{(.092)}{.753} X_1 + \underset{(.092)}{.134} X_2 + \underset{(.057)}{.315} X_4$$

where: Y = farm capital expenditures on farm machinery and equipment

X_1 = Y lagged one year

X_2 = the ratio of the farm wage rate to the index of farm machinery prices

X_3 = the hired labor force in the year t, and

X_4 = a linear time trend.

In neither of the equations is the ratio of wages to machinery prices significant at the 5 per cent level, although the values are at least greater than their standard errors.

What implications do these equations have on the analysis of the substitution of machinery and labor? First, the results may indicate that in equations 52 and 53 the data have not been entered in such form as to demonstrate the substitution between farm wages and farm machinery prices as it actually occurs on a firm level. Cromarty, too, found that in predicting the quantity of machinery purchased by farmers "the negative sign on farm wage rates does not support the hypothesis that machinery is substituted for labor as farm wages rise" (15, p. 40). However, as pointed out earlier in this section, and according to Table 3, wage rates, machinery prices, and machinery purchases have all increased together while the labor force has decreased. The data is not contradictory for it has explained in an aggregative sense what has happened in the past. Similarly, equations 54 and 55 appear to be quantitatively consistent for the same reasons.

Second, to perceive the substitutibility of labor and machinery, consideration must be given to changes in quality of farm machinery, changes in crop production methods, and technological changes that affect the substitution of labor and machinery.

In conclusion, the four estimated equations are of interest because they explain the dependent variables in terms of what has transpired in the past in accordance with the aggregative data used. To more adequately specify the substitution of labor and machinery, two requirements should be met: (1) the inclusion in or along with the price of machinery of quality changes in the machinery, and (2) to subdivide the scope of the analysis into smaller areas and/or crops, so that specific instances of machinery replacing labor can be observed.

PREDICTIONS ON THE SIZE OF THE FARM LABOR FORCE

In the preceding chapters, empirical demand and supply functions for farm labor were presented and analyzed to gain information on the structure of the farm labor market as it has existed in the past. The test of a demand function lies in its predictive accuracy. In this chapter actual predictions of the size of the farm labor force for 1965 and 1975 are presented. Short-run predictions based on a few of the previously discussed demand functions are presented first. Secondly, methods of current predictions of long-run estimates of the farm labor force are discussed, and a naive long-run predictive model based on man-hour requirements is presented.

Short-Run Predictions of Farm Labor Size

In this section, probable future trends in the demand for farm labor are presented, given that past and present tendencies will continue. Several demand functions for labor were utilized, including separately the demand for hired, family, and total farm employment. The basic assumption underlying these predictions was that reasonable demand functions have been derived which provide reliable estimates of the future.

The term "short-run" is used to indicate a time period short enough that a firm is unable to vary the quantity of some resources used. For the purposes of this paper using time series data, the time periods are definitionally determined as consisting of yearly periods varying in span from one to five years, or up to 1965.

Forecasting procedure

Good forecasting procedure should incorporate the following characteristics: (1) it should be quantitative analysis; (2) the procedure should be flexible enough to permit judgment and imagination to temper the results; (3) it should draw on all available sources although accepting only those that fit into the changing economic situation; and (4) Judgment should be utilized, but without facts and a means of analysis, no dependable judgment is possible.

To present forecasts for 1965, projections of the independent variables were constructed. Basically, they are simple extensions of trend, for price analysis is not the purpose of this study. Data were available for 1958 and 1959 so that comparisons of predictions with actual data was possible.

Predictions for 1958, 1959, and 1965

The equations used as the basis of the predictions are: (1) hired labor, equation 9 of Table 5; (2) family labor, equation 4 of Table 8; and (3) total farm employment, equation 43. Predictions for these equations are illustrated in Table 9. The term y in Table 10 refers to actual numbers of workers while $\hat{y}$ refers to the predicted number of workers.

Table 9. Predicted farm employment for 1958, 1959, and 1965

Year	Total farm employment		Family workers		Hired workers	
	Y	$\hat{Y}$	Y	$\hat{Y}$	Y	$\hat{Y}$
	(In thousands of workers)					
1958	7,525	8,100	5,570	6,000	1,955	1,900
1959	7,384	7,800	5,459	5,900	1,925	1,800
1965	--	6,750	--	4,800	--	1,600

As expected, the computed trend in the demand for farm labor is downward over time. The demand function for total farm employment covered the period 1910 to 1957, and was not as sensitive to changes in 1958 and 1959 as were the demand functions for family and hired workers. The demand function for family labor was estimated over a much shorter period, 1940 to 1957, but even then was only slightly closer to the actual data. The best fit was accomplished using the demand function for hired labor over the period 1929 to 1957 in which autoregressive least-squares equations were employed.

For 1965 a total farm employment of from 6.4 to 6.75 million workers is anticipated. Separated into component sectors, there is a predicted demand for 4.8 million family workers and 1.6 million hired workers. The total of 4.8 and 1.6 million workers derived by independent means came very close to the estimated total of 6.75 million workers. This total of 6.75 million workers in 1975 would be a decline of

33 per cent from the 1947-1949 average of the total number of farm workers.

For a comparison with estimates for 1975, longer-run models are used in the following section.

The Long-Run Demand for Farm Labor

In the inquiry into future requirements and supplies of agricultural products, predictions of the demand for farm labor were necessary. Several exhaustive studies have been compiled in the last few years which estimated the future course of agriculture and presented estimates of the long-run demand for farm labor. Among these were publications by Daly and Barton (16), Bonnen and Black (9), The President's Materials Policy Commission (135), Koffsky (74), Cochrane and Lampe (14), Ruttan (103), and Clark (12).

A common method of this type of prediction was to assess consumer needs and projected supplies of agricultural products as a basis for employment predictions. Basically, long-run predictions of the labor force are assessments of the most probable needs for labor under a rigid set of conditions. For instance, Bonnen and Black stated the following assumptions (9): (1) a continued high level of employment; (2) no all-out war; (3) no basic change in the tax structure; (4) "average" weather; (5) an assumption on future population size. Given these restrictions, the factors affecting the rate of food consumption have been listed as: (1) population growth; (2) per capita consumer income; (3) price and income elasticities; and (4) changes in world supply and demand affecting exports. Perhaps the most important single determinant is the growth in population since the demand for agricultural products is relatively inelastic in price and income, and the status of foreign trade is difficult to determine.

Population predictions used by these researchers for the U.S. for 1975 have varied according to the year that the report was written, because estimates of the fertility rate have changed practically from year to year. For instance, some of the estimates are, in millions of persons, Colin Clark (12), 234; Nathan Koffsky (74), 210; Paley Commission (135), 193.6; Rex Daly (16), 215.8 to 243.9. Given a population prediction, and accounting for income and price elasticities and foreign trade, estimates of the needs of consumers of agricultural products were assessed.

Estimates of future production are then computed. It was assumed that farmland will remain constant and that employment will decrease while output per man-hour will increase. Factors tending to increase output per man-hour are: (1) larger farms which promote economy of use of existing equipment; (2) increases in yields of crops and livestock; (3) increases in technological development; and (4) further specialization of production.

The estimates of the size of the farm labor force, such as for 1975, were then calculated so as to furnish the manpower needed either to fulfill the production estimates, or to produce the amount necessary for consumers' needs. Among the predictive methods were educated guesses, as in Black (9), and extensions of linear trends as utilized by Clark (12).

A comparison of some predictions of labor force size for 1975 are: Daly (16), 5.5 million workers; Black (9), a decrease of 10 per cent in the labor force from 1950, or about 8.4 million workers; Clark, 2 million workers, calculated from the Bureau of Census CPS estimates of farm employment, or approximately 3 to 3.5 million workers on a comparable scale with the U.S.D.A.'s AMS series.

In summary, long-run estimates of the farm labor force have been derived for 1975 in conjunction with inquiries into the probable future demand and supply for food.

A Long-Run Predictive Model for Farm Labor

As discussed above, estimates of the future size of the farm labor force are extensions of trends, or fairly complex computations as to the future size of the labor force. The obvious difficulty of extending trends is that they soon approach zero and become negative. Complex computational methods also may be far removed from reality, and speculation on what "ought" to be should be supported by analytical tools. What is needed is a simple model that can be applied using available data, which will take into account changes in output per man-hour and population changes. One such model is a logistic one, but it is difficult to estimate.

The model used for long-run prediction in this paper was a growth model similar to that used by Hicks (49, p. 87). Hick's model was:

(56) $E_n = E_o (1 + g)^n$

where g = the growth rate, E_o = equilibrium output in period o, and n = the n-th period. This model was one in which the rate of growth is constant, and the function increases at an increasing rate. To predict farm labor force size, the equation was altered so that the function decreases at a decreasing rate, as follows:

(57) $M_n = M_o (1 - p)^n$

where M_n = man-hour requirements of agricultural labor in the year n, M_o = man-hour requirements in the base year, and p = the rate of change of agricultural output per man-hour. Since output will change according to consumer needs, change in population was added to the model:

(58) $M_n = M_o (1 - p)^n (1 + g)^n$

where g = the yearly average change in population in the U.S., and the other parameters are the same as explained above.

The advantage of a model of this type is that: (1) it is a function of man-hours in the present or some base year;

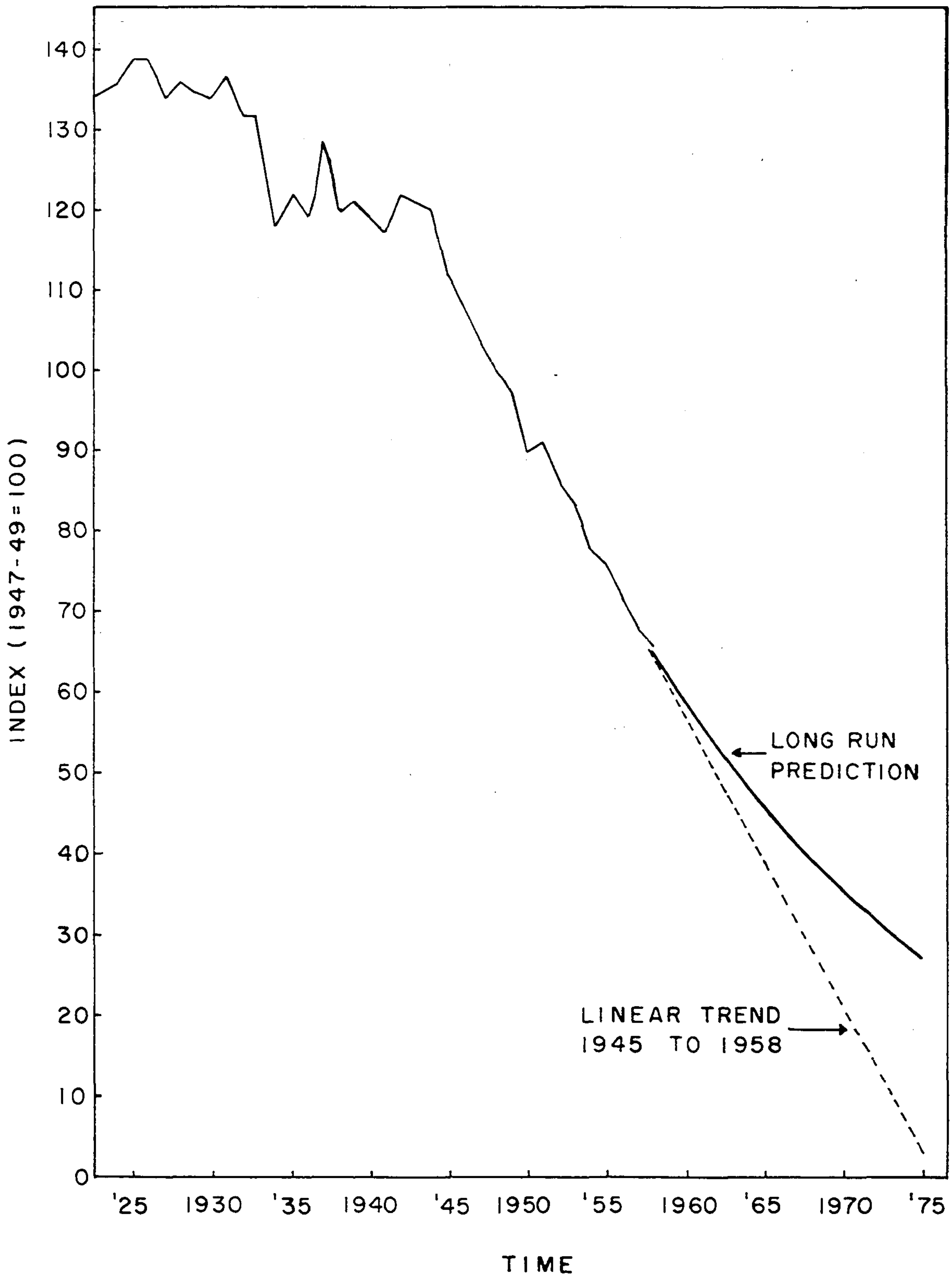
(2) it is modified with variations in man-hour productivity; and (3) it takes into consideration growth in the consumer sector. In addition, the properties of the model are that it converges slowly to some lower asymptote, zero, with the rate of convergence subject to productivity and population changes.

A convenient method of estimating p, the change in productivity, was to determine the average yearly rate of change in man-hour requirements for the last few years utilizing data from reference (133, p. 18). Let $M_o = 76$, the index of man-hour requirements for 1955, and substitute in various years from 1946 to the present to determine an average value for p. For instance, for 1956,

(59) $72 = 76\ (1 - p)^1(1 + g)^1$

where g was estimated to be .0172. Taking the logarithms of both sides and solving, p = .068. Similarly, the values of p for 1957 and 1958 were determined, and an average value for p was .067. To predict, then, this value of p was substituted into equations for 1965 and 1975, using 1958 as the base period. The resultant point estimates were in index form based on the 1947 to 1949 average of man-hour requirements. The man-hour needs in 1965 were estimated to be 45.7 per cent of the 1947 to 1949 average, while the estimated labor needs in 1975 were 27.1 per cent of the 1947 to 1949 average. These points were plotted graphically and presented with a linear trend in Figure 11. Roughly, these man-hour requirements correspond

Figure 11. A prediction of agricultural man-hour-requirements and an extension of linear trend. 1957-1975


140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
INDEX (1947-49=100)
'25
1930
'35
1940
'45
1950
'55
1960
'65
1970
'75
TIME
LONG RUN
PREDICTION
LINEAR TREND
1945 TO 1958

to estimates of 5 million and 3 million farm workers. The two series, AMS and FERD, however, are not directly comparable. Man-hour requirements may be considerably lower than the number of farm workers, for man-hour requirements tend to decrease more rapidly than the number of farm workers.

Since the productivity of labor is not constant over long periods of time, frequent testing of the yearly changes in man-hour requirements with a concomitant adjustment in the long-run estimates will be necessary.

Briefly, then, the model presented in this section is one which can be utilized for simple predictions of the labor requirements in future periods. For the two periods, 1965 and 1975, man-hour requirements were estimated to be 45.7 and 27.1 per cent, respectively, of the 1947-1949 average. For policy purposes, these estimates indicate that with the present rate of change in man-hours needed in agriculture projected into the future, agricultural labor requirements will decrease by 1965 to 70 per cent and by 1975 to 40 per cent of the 1957-1958 average requirements.

SUMMARY AND CONCLUSIONS

In view of the importance of inputs to the problems of imbalance and adjustment in agriculture, a reappraisal of the forces affecting factor markets is requisite. A particular factor, farm labor, was analyzed in this investigation by means of empirical demand and supply functions.

The hypotheses tested were: (1) the demand for hired and family labor is responsive to changes in the price of farm labor as represented by the farm wage rate, the prices of other agricultural inputs such as the price of farm machinery, and product price relative to cost as indicated by the ratio of the index of prices received by farmers to the index of prices paid in production expenses; (2) the supply of hired and family farm labor is responsive to the wage rate, both farm and non-farm; and (3) since the response of the demand or supply of farm labor may lag over several time periods, the estimated form of the models should be taken with a distributed lag.

The principal objectives of this study in line with the hypotheses to be tested were: (1) to derive and analyze empirical demand functions for both hired and family labor for the U.S. and nine geographic regions; (2) to derive and analyze a supply function for hired and family labor for the U.S.; (3) to summarize and appraise the quantitative estimates of the farm labor force; and (4) to offer predictions on the size of the farm labor force in 1965 and 1975.

Among the several series of estimates of the farm labor force, the series of the U.S.D.A. as contained in reference (128) was utilized in this research. Other farm employment series were limited either in the coverage of both hired and family labor or in the time interval encompassed.

To estimate the demand functions, two methods were used: (1) single equation least squares, and (2) Theil-Basmann simultaneous equations. A dynamic economic model taken with a distributed lag was employed to describe the relationship of the explanatory variables and the quantity of farm labor demanded or supplied. Distributed lag equations have the desirable property of presenting explanatory variables in terms of a weighted series of past prices. Since the coefficients in distributed lag equations may be biased, a modification was imposed on the model. A first-order autoregressive scheme was assumed for the error term so that the regression coefficients would be statistically consistent estimators.

Demand functions were derived for hired labor for the period 1910-1957, and for the intervening periods 1920-1939, 1929-1957, and 1940-1957. The results provided support for the hypotheses tested, for both the farm wage rate and prices received variables were significant. The demand for hired labor appeared to be responsive to changes in both the price of labor and agricultural product price. Furthermore, the level of response of demand to a sustained price change was higher in the war-postwar period than in the depression period.

These results indicate that hired farm labor demand response is related to the period of the business cycle.

The demand functions for hired labor judged to be the most efficient estimators were the simultaneously estimated autoregressive least-squares equations. The results of one of these equations, 9 of Table 6, indicated that the short-run price elasticity of demand was -.256 and inelastic. This inelasticity indicates that as the price of hired labor has risen 10 per cent, *ceteris paribus*, there has been an accompanying decrease in the number of hired workers of 2.56 per cent. The computed long-run elasticity was -.32. The similarity of the short- and long-run elasticities is indicative of the relatively short time period of adjustment of the demand for hired labor to a sustained price change.

The hired labor demand response to changes in prices received was also significant and inelastic. A decrease in prices received of 10 per cent has been accompanied by a decline in the demand for hired workers of from 3 to 6 per cent over the 1910-1957 time span, 3 per cent from 1920-1939, and from 8 to 20 per cent over the periods 1929-1957 and 1940-1957, *ceteris paribus*. There was little indication of any change in levels of response over time in the regression coefficients or cross-elasticities of the prices received variable.

A demand function for hired labor that included the value of farm machinery and equipment as a variable yielded a positive sign for this variable. The cross-elasticity was .133 in the short-run, indicating that as the scale of machinery inputs has increased there has been an accompanying increase in the number of hired workers. These results suggested a complementary relationship of the scale of operations in farming and the demand for hired workers. However, more research on the significance and sign of this variable is needed before definite conclusions can be reached.

The rate of adjustment in the demand for hired workers in response to sustained changes in the farm wage rate and prices received was estimated to be low for the over-all period, 1910-1957. This result appeared to be inconsistent with the results of the intervening periods. Changes in structure may have occurred to such an extent that the long-run estimates for the 1910-1957 period are biased. The adjustment coefficients in the intervening periods appeared to be consistent. These coefficients indicated that the rate of adjustment of producers to a sustained price or other variable change has increased over time. This adjustment may be due to an increase in the mobility of agricultural resources.

Regionally, the demand functions for hired labor followed a pattern similar to the hired labor demand functions for the total farm economy. The elasticity of the price of farm labor for the significant regression coefficients ranged from -.15 to -.51. In four of the nine regions, New England, South Atlantic, Mountain, and Pacific, the regression coefficients of the farm wage rate are not significant. The special farm labor problems which exist in these regions could account for the computed lack of demand response. However, all regional estimates of the farm wage rate coefficient contained a negative sign, which is consistent with economic theory.

The regional coefficients of the parity ratio, lagged one year, were significant in only four of the nine regions. Other than for the East North Central region, the non-significant regions were the same as those listed above as non-significant in the wage rate variable. The range of cross-elasticities of the significant regression coefficients of the parity ratio was from .16 to .36. In general, the midwestern and southcentral areas were responsive both to changes in the price of hired labor and the profitability of farming.

Empirical demand functions were also derived for family labor, both for the U.S. and by region. The specification of the models was the same as that used for hired labor, except that both conventional and distributed lag equations were used. These results, however, may be biased due to autocorrelation in the residuals.

Nationally, the results of the demand functions for family labor indicated a significant response to changes in the farm wage rate. As computed, the elasticities of the farm wage rate ranged from -.14 to -.31. The hypothesis that the farm wage rate was indicative of the price of family labor appeared to be justified from these results.

For the over-all period, 1910-1957, for the U.S., the coefficient of the prices received variable for family labor demand was non-significant. However, the corresponding coefficients for the intervening periods, 1920-1939 and 1940-1957, were both significant. This seeming inconsistency apparently results because the sign of the coefficient for 1920-1939 was negative while that for 1940-1957 was positive. Along with a 10 per cent decrease in the profitability of farming for 1920-1939, _ceteris paribus_, there was an accompanying 1.1 per cent increase in the family labor force, other things being equal. Due to the depression and a resulting lack of off-farm opportunities, these results appeared consistent. Likewise, for 1940-1957, given a 10 per cent increase in the index of prices received, _ceteris paribus_, there was an increase of 3 per cent in the demand for family workers. In a period of relative prosperity and ample off-farm opportunities, these results were also consistent. A better understanding of the effect of farm product prices can be obtained by analyzing these periods separately. Hence, the demand for family labor was responsive to both changes in the farm wage rate and prices received.

The estimation of regional demand functions for family labor indicated a lack of responsiveness to the farm wage rate. General least squares and distributed lag equations were equally unresponsive. The lack of significance of the farm wage rate indicated that the data for each region articulated only small changes in the family labor force over time. Consequently, a linear time trend could approximate the slow changes over time.

Supply functions for both hired and family labor were estimated for the period 1929-1957. Both supply functions were estimated by the Theil-Basmann technique of simultaneous solution, and modified by an autoregressive assumption. In form, both models contained the farm wage rate and the non-farm wage rate adjusted for changes in the rate of unemployment. The hypothesis was assumed that the farm wage rate was not as important a determinant of the supply of farm labor as were non-farm employment opportunities.

The signs of the regression coefficients were consistent for the supply function for hired labor. The farm wage rate regression coefficient was non-significant. The non-farm wage rate regression coefficient was greater in value than its standard error, but was significant only at the 20-per cent level. As the adjusted non-farm wage rate has increased by 10 per cent, the supply of hired labor apparently decreased by .8 per cent, ceteris paribus. Although the non-farm wage rate variable was more significant than the farm wage rate, the significance levels were such that no definite conclusions could be reached about the tested hypothesis.

In the supply function for family labor, neither the farm wage rate nor the non-farm wage rate coefficients were significant. Further, in estimating the autoregressive least-squares equation, the inverse matrix apparently deteriorated, probably due to the lack of significance of the explanatory variables and multicollinearity of the time and lagged dependent variable.

Demand functions for hired labor which included both the farm wage rate and farm machinery prices were estimated. Theoretically, the relationship of these prices should demonstrate substitutibility; empirically the factors appear as complements. However, given the form in which the index of machinery prices is presented, important marginal changes may be difficult to perceive. Aggregation of all types of machinery and trucks coupled with the lack of inclusion of adjustments for quality changes in machinery are deficiencies of the series.

Predictions of the demand for farm labor based on the empirically derived labor demand functions were presented for the years 1958, 1959, and 1965. The estimate of total farm employment for 1965 ranged from 6.4 to 6.75 million farm workers. To predict the size of the farm labor force for 1975, a naive growth model was presented. Comparisons were made with other methods of long-run estimation. For 1975 the man-hour requirements were estimated at 40 per cent of the 1957-1958 average.

ACKNOWLEDGMENTS

The author wishes to express his sincere gratitude to Dr. Earl O. Heady for his guidance and criticism in the preparation of this thesis and for his direction throughout the period of graduate study.

Particular thanks are due Dr. Wayne Fuller whose influence is apparent throughout the text of the thesis.

My wife, Beth, has been patient and a source of encouragement throughout my graduate program.

The author is also indebted to Norman Landgren, Jay Anderson, and many other fellow graduate students.

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APPENDIX A

A Comparison of Sources of Farm Employment Estimates

AMS-U.S.D.A. Series	Census CPS Series	Hired Working Force
1. Relates to a particular week. (Last full calendar week of the month.)	1. Relates to a particular week. (Week ending nearest to the 15th of the month.	1. Relates to the whole month. (Subject to memory recall.)
2. Uses the establishment method. (Man may be counted more than once. This may amount to one-fourth of a million workers.)	2. Uses the household method. (Can skip migratory workers on the road, foreign workers, and inmates of institutions.)	2. Same as CPS. Number of foreign workers estimated separately for 1956 and 1957.
3. Includes persons of all ages.	3. Includes only persons over age 14. This may miss from one-half to one million workers seasonally.	3. Same as CPS.
4. Includes anyone who meets minimum work requirements, regardless of work done elsewhere.	4. In addition to minimum work requirements, a person must work on farm more than non-farm occupations. (May be a cause of a difference of one-half to one million persons seasonally.)	4. Includes any farm work.
5. Numerically the highest of the series.	5. This series should be numerically the lowest of the three series.	5. This series should be less than the AMS series, but greater than the CPS, for it relates to a full month rather than to a survey week. It

		may miss those who, during the year, entered institutions, died, or left the country.
6. The AMS revised the series in 1949 and 1950 back to 1931. Later they revised estimates from 1950 to 1957.	6. The Bureau of the Census enlarged its sampling base from a 68-area sample to a 230-area sample. Again in 1956 it was enlarged to a 330-area sample.	6. Same as CPS.
7. The series extends back to 1910.	7. The series extends back to 1940.	7. The series extends back to 1945.

APPENDIX B

Table 10. Actual values for the variables used in the statistical analysi

Year	y_1	y_2	y_3	x_1	x_2	x_3	x_4	x_5
1910	132.4	147.9	128	58	54	54		107
11	132.3	147.5	128	66	57	56		96
12	132.4	148.6	128	65	59	56		98
13	132.5	149.4	128	63	59	56		101
14	152.7	150.2	128	65	57	56		98
15	132.8	151.1	128	65	56	55		94
16	133.1	152.6	128	59	55	53		103
17	132.5	150.8	128	50	56	50		120
18	130.8	146.1	127	34	59	54		119
19	129.4	143.3	126	60	58	59		110
1920	131.2	148.4	125	72	60	68		99
21	130.9	148.6	126	78	53	67		80
22	130.3	148.8	126	75	57	61		87
23	128.6	147.2	125	79	64	71		89
24	127.3	145.5	123	79	66	71		89
25	127.4	145.3	122	72	64	69		95
26	126.8	151.0	122	80	66	73		91
27	123.5	147.2	120	83	68	73		88
28	124.0	146.6	117	78	67	69		91
29	124.7	148.9	117	78	68	69	113.6	92
1930	122.1	139.6	118	87	68	70	119.5	83
31	124.5	135.8	117	97	61	65	134.6	67
32	125.2	126.6	121	96	53	55	151.3	58
33	124.4	125.4	125	81	47	50	144.9	64
34	123.4	125.2	124	70	46	48	130.9	75
35	124.4	125.9	123	63	49	49	131.8	88
36	120.5	130.4	124	61	53	53	132.8	92
37	117.0	127.9	118	69	59	55	133.3	93
38	113.5	122.8	114	83	60	59	141.7	78
39	110.8	119.3	111	86	61	59	140.9	77
1940	107.3	117.2	108	81	60	58	138.0	81
41	104.2	116.0	104	80	69	67	129.8	93
42	102.6	111.8	101	81	79	77	117.5	105
43	102.0	106.6	100	89	93	91	105.4	113
44	99.8	97.6	101	104	126	104	100.4	108
45	97.7	92.7	100	111	112	114	96.9	109
46	100.6	95.8	99	106	111	114	93.0	113
47	101.4	99.2	102	96	101	103	92.4	115
48	101.2	102.3	102	97	100	98	98.5	110
49	97.3	98.5	101	108	99	99	108.9	110
1950	97.0	101.9	97	105	99	96	109.7	101
51	993.3	97.8	96	99	101	97	109.2	107
52	89.4	93.8	92	110	105	101	109.3	100
53	86.6	91.4	88	127	107	110	110.7	92
54	84.4	92.1	85	129	104	109	110.1	89
55	81.7	88.3	83	140	107	118	111.2	84
56	76.4	84.1	80	147	110	119	113.5	82
57	74.0	82.9	74	148	110	119	115.4	83

statistical analysis, 1910-1957

x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}	x_{12}
54		107	93	90	28.3				
56		96	85	83	29.3				
56		98	86	88	30.0				
56		101	88	90	29.3				
56		98	86	86	31.3				
55		94	84	86	34.7				
53		103	90	98	32.6				
50		120	100	127	31.0				
54		119	100	117	26.8				
59		110	98	119	29.3				
68		99	95	111	34.7				
67		80	85	69	18.9				
61		87	89	80	22.5				
71		89	90	84	29.5				
71		89	90	82	26.3				
69		95	95	89	31.3				
73		91	82	83	34.1				
73		88	88	60	32.4				
69		91	89	85	35.6		—		
69	113.6	92	89	86	40.7	63.5	3.2	74.7	5728
70	119.5	83	81	72	34.5	42.0	8.7	74.3	5793
65	134.6	67	67	51	23.8	15.0	15.9	77.4	5728
55	151.3	58	57	41	14.0	0.0	23.6	74.0	5280
50	144.9	64	62	45	12.2	0.0	24.9	71.3	5473
48	130.9	75	69	55	24.8	0.0	21.7	69.3	3999
49	131.8	88	78	65	34.4	0.0	20.1	74.7	3891
53	132.8	92	82	67	47.2	12.5	16.9	80.7	4015
55	133.3	93	80	70	52.8	24.7	14.3	86.5	4395
59	141.7	78	71	55	39.9	4.2	19.0	84.0	5793
59	140.9	77	69	54	44.5	12.8	17.2	91.5	4783
58	138.0	81	71	38	49.1	25.8	14.6	95.6	4895
67	129.8	93	84	71	67.9	52.9	9.9	104.7	5105
77	117.5	105	95	86	60.1	86.7	4.7	113.3	5767
91	105.4	113	103	100	36.9	108.1	1.9	119.5	5644
04	100.4	108	100	100	63.6	113.7	1.2	121.0	5130
14	96.9	109	103	103	60.5	101.4	1.9	112.0	5351
14	93.0	113	107	114	47.3	80.3	3.9	99.8	5754
03	92.4	115	107	119	77.3	79.6	3.5	96.9	6129
98	98.5	110	101	105	103.5	83.7	3.4	100.9	7128
99	108.9	110	92	81	118.5	75.3	5.5	103.9	8543
96	109.7	101	91	83	116.4	83.2	5.0	110.9	9880
97	109.2	107	97	90	111.2	94.4	3.0	111.0	10899
01	109.3	100	91	82	98.2	99.7	2.7	115.3	11649
10	110.7	92	87	72	104.5	106.8	2.5	122.1	11923
09	110.1	89	85	69	88.3	90.5	5.0	120.6	12297
18	111.2	84	81	66	90.1	103.1	4.0	128.9	12252
19	113.5	82	81	62	77.6	107.2	3.8	132.3	12212
19	115.4	83	81	61	82.2	103.9	4.3	132.4	11820

Supplement to Appendix B

y_1: Total farm employment; index: 1947-1949 = 100 (128).

y_2: Hired farm employment; index: 1947-1949 = 100 (128).

y_3: Family farm employment; index: 1947-1949 = 100 (128).

x_1: Deflated farm wage rate; index: 1947-1949 = 100.

$$x_1 = 1/2$$

1. Farm wage rate (130, January 9, 1959).
2. Index of prices received by farmers (129, July 1959).

x_2: Deflated farm wage rate; index: 1947-1949 = 100.

$$x_2 = 1/3$$

3. Index of prices paid by farmers for living expenses (124, p. 64; 127, October 15, 1959).

x_3: Deflated farm wage rate; index: 1947-1949 = 100.

$$x_3 = 1/4$$

4. Index of prices paid by farmers for production expenses (124, p. 64; 127, October 15, 1959).

x_4: Deflated index of farm machinery prices; index: 1947-1949 = 100.

$$x_4 = 5/3$$

5. Index of farm machinery prices (123, 1952, 1958).

x_5: The parity ratio.

$$x_5 = 2/6$$

6. Index of prices paid by farmers for production expenses, interest, taxes, and wages (124, p. 64; 127, October 15, 1959).

x_6: Deflated index of prices received by farmers

$$x_6 = 2/4$$

x_7: Deflated index of prices received by farmers

$$x_7 = 2/5$$

x_8: Deflated expenditures on farm machinery and equipment

$$x_8 = 7/3$$

7. Index of expenditures on farm machinery and equipment (123, 1952, 1958).

x_9: Adjusted non-farm wage rate

$$x_9 = 8/3$$

8. NFWR (1 - 5 Un), where NFWR is the index of average hourly earnings of factory workers (129, July 1959) and Un is unemployment as a percentage of the total work force (122).

x_{10}: Unemployment as a percentage of the total work force

$$x_{10} = 9$$

9. Unemployment as a percentage of the total work force (123, 1957).

x_{11}: Deflated non-farm wage rate

$$x_{11} = 10/3$$

10. Index of the average hourly earnings of factory workers (129, July 1959, p. 40).

x_{12}: Deflated value of farm machinery and equipment

$$x_{12} = 11/4$$

11. A computed value of farm machinery. A starting point was taken for 1930 and deflated. For succeeding years, net additions to farm equipment are deflated and added to the previous year's total (129, July 1959).

Table 11. Actual values for the number of hired workers variable used in the statistical analysis for the nine regions, 1929-1957[a]

Year	NE	MA	SA	ENC	ESC	WNC	WSC	MTN	PAC
1929	99	230	572	410	347	579	619	255	289
30	101	238	525	386	321	521	558	244	296
31	101	231	533	377	312	510	531	233	275
32	100	209	529	355	290	495	480	199	237
33	95	213	511	355	296	458	484	207	246
34	86	214	546	353	309	407	474	202	271
35	85	216	542	360	320	376	486	191	302
36	85	219	555	366	365	339	540	214	298
37	82	233	529	354	347	321	559	195	314
38	78	218	504	341	334	334	530	194	303
39	75	209	496	328	315	307	513	189	295
1940	75	207	488	319	297	315	504	183	291
41	72	199	452	300	294	321	510	197	307
42	68	197	438	278	277	310	489	190	308
43	68	188	424	261	270	290	443	187	305
44	67	175	378	228	242	264	394	172	311
45	65	174	358	214	216	241	375	164	312
46	63	185	373	222	227	265	379	159	316
47	63	183	400	220	230	290	391	166	324
48	61	181	425	229	250	296	409	165	321
49	60	181	401	231	247	274	371	172	315
1950	71	185	417	237	240	275	423	151	330
51	75	177	407	236	221	257	395	144	324
52	71	169	395	226	219	239	362	145	318
53	72	159	384	213	221	232	359	135	314
54	72	150	380	215	228	360	360	132	308
55	69	137	382	206	209	216	374	135	299
56	69	128	367	196	198	201	336	132	297
57	66	123	365	192	183	204	332	136	294

[a]The regions are depicted in Figure 4; source: (130, Oct. 9, 1953), (128)

Table 12. Actual values for the family labor force variable used in the statistical analysis for the nine regions, 1929-1957[a]

Year	NE	MA	SA	ENC	ESC	WNC	WSC	MTN	PAC
				(Thousands of persons)					
1929	171	459	1754	1264	1854	1566	1702	298	292
30	169	453	1786	1247	1817	1560	1678	304	293
31	175	461	1830	1288	1890	1582	1803	311	302
32	176	461	1914	1329	1964	1646	1801	313	318
33	172	471	1863	1363	1930	1642	1769	326	338
34	172	484	1817	1361	1897	1638	1717	332	347
35	169	492	1916	1390	1892	1667	1642	332	355
36	164	480	1831	1358	1742	1594	1510	323	398
37	164	474	1786	1341	1697	1538	1386	308	360
38	161	474	1250	1354	1623	1519	1273	307	354
39	162	476	1705	1321	1548	1515	1223	301	360
1940	160	472	1622	1285	1483	1489	1158	291	340
41	156	453	1544	1258	1388	1468	1119	293	338
42	164	454	1560	1260	1360	1455	1064	292	340
43	168	457	1557	1250	1375	1490	1063	293	349
44	162	455	1566	1257	1352	1502	1046	294	354
45	160	452	1522	1257	1329	1503	1022	282	354
46	156	455	1552	1295	1388	1565	1056	283	353
47	148	452	1560	1303	1369	1610	1031	284	358
48	140	446	1505	1300	1371	1617	1013	273	361
49	130	433	1441	1241	1345	1535	977	263	347
1950	148	431	1395	1331	1192	1504	984	267	395
51	141	418	1331	1306	1108	1448	962	256	340
52	136	405	1267	1295	1022	1407	894	251	328
53	135	390	1197	1274	965	1384	862	249	319
54	129	383	1156	1259	924	1350	828	242	317
55	118	365	1114	1218	882	1314	792	233	311
56	112	336	1012	1163	802	1231	708	231	304
57	106	321	980	1115	786	1194	668	218	294

[a]Source: (130, Oct. 9, 1953), (128)

Table 13. Actual values for the farm wage rate variable used in the statistical analysis for the nine regions, 1929-1957[a]

Year	NE	MA	SA	ENC	ESC	WNC	WSC	MTN	PAC
				(Dollars x 10^2)					
1929	106.0	91.8	51.4	79.1	45.9	75.9	55.4	85.4	109.2
30	108.3	93.1	49.1	75.3	44.8	75.3	53.3	84.6	113.4
31	108.1	88.4	45.2	67.8	39.3	65.8	46.2	76.6	104.1
32	98.9	79.3	39.1	57.5	33.3	56.3	41.4	62.8	92.0
33	84.7	65.5	36.1	49.7	32.7	47.4	39.5	60.9	81.3
34	80.8	62.9	36.9	48.9	32.9	45.9	39.9	62.9	82.8
35	81.5	63.9	38.3	55.0	34.4	54.0	42.2	68.8	88.4
36	86.4	69.7	39.3	62.9	36.3	59.9	45.2	74.7	96.3
37	91.4	78.1	42.9	72.4	39.0	65.7	48.6	80.0	108.6
38	94.8	80.8	43.9	73.9	39.9	68.9	48.9	82.8	109.8
39	99.6	81.3	45.7	75.2	40.7	70.1	48.8	84.3	109.8
1940	97.6	84.5	46.3	76.5	41.2	71.4	49.3	83.5	112.7
41	110.7	97.6	50.7	90.1	45.0	84.4	59.1	97.6	127.6
42	119.5	104.7	55.6	98.2	50.7	101.5	68.7	116.2	158.8
43	132.2	114.5	65.3	108.7	59.5	120.4	82.2	135.1	192.4
44	140.7	122.6	75.2	118.4	69.6	133.7	92.5	149.0	206.1
45	141.6	127.2	83.0	123.2	72.3	140.6	103.1	155.3	208.8
46	141.1	127.9	85.6	121.8	73.6	135.1	98.9	146.0	197.8
47	128.5	118.2	78.1	113.1	67.8	123.3	91.5	136.7	170.6
48	128.2	117.5	77.7	116.5	68.0	129.1	90.3	135.9	163.1
49	125.4	117.4	78.2	117.4	66.2	130.4	94.3	136.4	152.5
1950	121.9	116.0	78.3	116.9	66.4	127.8	92.2	135.8	155.6
51	126.4	119.1	80.9	121.8	69.1	120.0	94.5	132.3	155.5
52	132.1	124.9	83.6	127.6	71.0	136.6	98.8	144.7	162.6
53	137.6	129.4	86.9	132.1	71.5	140.3	98.6	145.7	166.5
54	136.9	128.8	85.6	130.6	69.4	137.8	97.3	141.4	164.9
55	142.6	130.9	86.6	133.6	71.3	139.0	100.2	147.1	162.9
56	150.4	136.1	90.7	137.0	74.7	138.8	102.3	147.7	172.6
57	150.4	137.4	90.8	143.6	73.5	140.9	102.9	148.7	171.1

[a]Source: (130, Dec. 10, 1950, Jan. 11, 1951, Jan. 10,1958)

Table 14. Actual values for the parity ratio variable used in the statistical analysis for the nine regions, 1929-1957[a]

Year	NE	MA	SA	ENC	ESC	WNC	WSC	MTN	PAC
				(Per cent)					
1929		99	89	91	99	92	99	94	
30		99	74	82	85	83	77	72	
31		81	57	65	65	67	58	62	
32		71	53	53	61	52	50	58	
33		75	65	56	69	53	62	73	
34		83	78	63	81	65	76	72	
35		82	81	87	91	95	84	85	
36		91	82	94	109	96	83	94	
37		88	81	99	87	102	81	98	
38		79	71	85	76	84	68	78	
39		82	70	80	75	78	72	92	
1940		90	73	78	80	79	77	91	
41		97	85	96	90	97	92	106	
42		103	101	108	103	110	103	109	
43		116	108	110	111	111	106	105	
44		119	105	102	106	101	101	101	
45		122	104	104	108	102	100	104	
46		125	113	111	114	112	111	107	
47		109	112	124	113	128	116	122	
48		112	105	117	109	123	113	122	
49		99	100	98	100	102	104	108	
1950		93	103	99	102	105	112	127	
51		97	105	106	109	113	122	134	
52		98	97	97	105	101	109	110	
53		87	95	95	98	98	94	87	
54		80	93	92	92	95	90	89	
55		80	90	78	89	81	88	83	
56		81	87	78	85	79	85	85	
1957		82	83	78	84	81	85	91	

[a]Source: MA (124), (57), SA (124), (41), (56), ENC (124), (23), (55), ESC (124), (58), WNC (124), (99), WSC (124), (59), MTN (124), (141)

Table 15. Actual numbers for the value of farm machinery and equipment used in the statistical analysis for the West North Central region, 1929-1957[a]

Year	WNC
	(Millions of dollars)
1929	1.63
30	1.85
31	2.05
32	2.18
33	1.79
34	1.40
35	1.40
36	1.45
37	1.52
38	1.79
39	1.87
1940	1.75
41	1.73
42	1.84
43	2.01
44	2.07
45	2.33
46	1.72
47	1.44
48	1.85
49	2.55
1950	3.02
51	3.17
52	3.65
53	3.77
54	3.88
55	3.89
56	3.97
57	3.98

[a]Source: (129, July 1959)

APPENDIX C

Demand and Supply Functions for the Period 1910-1957 Which Were Not Included in the Text of the Thesis

Demand functions[1]

(1)* $Y_{1t} = 2.7014 - \underset{(034)}{.0870} X_{7t} - \underset{(.058)}{.4657} X_{1t-1} + \underset{(.048)}{.1774} X_{10t-1}$

$R^2 = .89$

(2)* $Y_{1t} = .0466 + \underset{(.032)}{1.028} Y_{1t-1} - \underset{(.0093)}{.0102} X_{7t}{}^{c} - \underset{(.0086)}{.00038} X_{5t-1}{}^{c}$

$R^2 = .99$

(3) $Y_{4t} = 167.1 - \underset{(.071)}{.2903} X_{3t-1} - \underset{(.138)}{.4061} X_{6t-1} - \underset{(.052)}{.2907} X_{7}$

$+ \ .0275 X_{4t-1}{}^{c} \qquad R^2 = .98$

(4) $Y_{5t} = 143.1 - \underset{(.070)}{.4446} X_{3t} - \underset{(.113)}{.0232} X_{7t}{}^{c} - \underset{(.050)}{.005} X_{4t}{}^{c}$

$R^2 = .80$

(5)* $Y_{2t} = .2827 + \underset{(.051)}{.9246} X_{1t} - \underset{(.031)}{.0635} X_{2t} - \underset{(.018)}{.0175} X_{7t}{}^{c}$

$+ \ .0098 X_{4t}{}^{c} \qquad R^2 = .98$

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[1]The significance levels of the regression coefficients are significant at the 5 per cent level or better unless marked with a lower-case letter a, b or c which indicates:

[a]Significance at the 10 per cent level
[b]Significance at the 20 per cent level
[c]Significance beyond the 20 per cent level

*The equations marked with the asterisk indicate that the data is in logarithms

$$(6)^{*}\ Y_{2t} = 3.011 - \underset{(.032)}{.2060}\, X_{7t} - \underset{(.036)}{.0257}\, X_{6t}{}^{c} - \underset{(.073)}{.3108}\, X_{1t}$$

$$R^2 = .87$$

Supply functions

$$(7)\ Y_{1t} = 145.7 + \underset{(.028)}{.0697}\, X_{5t-1} - \underset{(.112)}{.1425}\, X_{7t}{}^{b} - \underset{(.048)}{.2206}\, X_{9t-1}$$

$$- \underset{(.003)}{.0192}\, X_{8t} \qquad R^2 = .986$$

$$(8)\ Y_{3t} = 154.7 + \underset{(.064)}{.1444}\, X_{5t-1} - \underset{(.253)}{.1355}\, X_{7t}{}^{c} - \underset{(.108)}{.476}\, X_{9t-1}$$

$$- \underset{(.006)}{.0120}\, X_{8t}{}^{b} \qquad R^2 = .88$$

$$(9)\ Y_{2t} = 26.5 + \underset{(.092)}{.8212}\, Y_{2t-1} + \underset{(.045)}{.0142}\, X_{2t}{}^{c} - \underset{(.212)}{.1541}\, X_{7t}{}^{c}$$

$$- \underset{(.004)}{.0034}\, X_{8}{}^{c} \qquad R^2 = .98$$

$$(10)^{*}\ Y_{2t} = .0842 - \underset{(.024)}{.0260}\, X_{7t}{}^{c} + \underset{(.032)}{.0079}\, X_{2t}{}^{c} + \underset{(.054)}{.9669}\, Y_{2t-1}$$

$$R^2 = .98$$

Y_1: total farm employment (128)

Y_2: hired farm employment (128)

Y_3: family farm employment (128)

Y_4: man-hour requirements in agriculture (133)

Y_5: the ratio of the farm wage bill to the farm wage rate (129, July 1959)

X_1: the composite farm wage rate deflated by the index of prices paid by farmers for living expenses (130, Jan. 9, 1959; 124; 127, Oct. 15, 1959)

X_2: the composite wage rate deflated by the index of non-farm wage rates (average hourly wages of factory workers) (130, Jan. 9, 1959; 129, July 1959)

X_3: the composite farm wage rate deflated by the index of prices received by farmers (130, Jan. 9, 1959; 129, July 1959)

X_4: the composite farm wage rate deflated by the index of farm machinery prices (130, Jan. 9, 1959; 123, 1952, 1958)

X_5: net farm income per farm deflated by the index of prices paid by farmers for living expenses (129, July 1959)

X_6: farm expenditures on farm machinery and equipment deflated by the index of prices paid by farmers for living expenses (123, 1952, 1958)

X_7: time as a linear trend in the linear equations; the log of time in the logarithmic equations

X_8: the square of time as a variable (in linear equations only)

X_9: non-farm net income, source: Graham, Robert E. and Schwartz, Charles F., Personal Income by States Since 1929, U.S. Government Printing Office, Washington, D.C., 1956

X_{10}: the ratio of the index of prices received by farmers to the index of farm machinery prices (129, July 1959; 123, 1952, 1958)

APPENDIX D

Estimation of Simultaneous Systems Containing Autocorrelated Errors*

Fuller (30) demonstrates that autoregressive least squares can be solved in a simultaneous system. Using matrix notation, he starts from an initial specification of a simultaneous system:

$$By_t = \Gamma z_t + u_t$$

$$u_t = \beta u_{t-1} + e_t$$

where: y_t is the column vector of m endogenous variables

B is an mxm matrix of coefficients

Γ is an mxk matrix of coefficients

z_t is a column vector of K exogenous variables

u_t is a column vector of disturbances

β is a diagonal $(\beta_1, \beta 2, \ldots, \beta m)$ of autocorrelation coefficients

e is a column vector of disturbances assumed to be distributed independently of time with zero means and variance covariance matrix constant.

He then gives the reduced form of the system as:

$$y_t = B^{-1}\Gamma z_t + B^{-1}u_t$$

*The content of this Appendix is taken almost literally from Fuller (30).

which may be written as:

$$y_t = Az_t + v_t.$$

Substituting for u_t from the initial equation above, he derives:

$$\begin{aligned} y_t &= B^{-1}\Gamma z_t + B^{-1}\{\beta u_{t-1} + e_t\} \\ &= B^{-1} \quad z_t + B^{-1}\{\beta(By_{t-1} - z_{t-1}) + e_t\} \\ &= B^{-1}\Gamma z_t + B^{-1}\beta By_{t-1} - B^{-1}\beta\Gamma z_{t-1} + B^{-1}e_t \end{aligned}$$

The reduced form may then be written as:

$$y_t = B^{-1}z_t + \beta_c \bar{I}\{y_{t-1} - B^{-1}z_{t-1}\} + B^{-1}e_t$$

under the assumption that the autocorrelation coefficient is identical and equal to β_c in all the equations, i.e., $\beta = \beta_c I$. Equation fourth from the top of this page is essentially:

$$y_t = Az_t + v_t$$

where:

$$v_t = \beta_c I v_{t-1} + \epsilon.$$

He concludes, then, that the errors in each of the reduced form equations follows the same autoregressive scheme as in the original system.