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Demand for labor in agriculture

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DEMAND FOR LABOR IN AGRICULTURE

CAEA REPORT 13-T

DEPARTMENT OF ECONOMICS AND SOCIOLOGY
CENTER FOR AGRICULTURAL AND ECONOMIC ADJUSTMENT
Cooperating

IOWA STATE UNIVERSITY of Science and Technology

Ames, Iowa 1962
DEMAND FOR LABOR IN AGRICULTURE

by

Stanley S. Johnson

Earl O. Heady

Department of Economics and Sociology
Center for Agricultural and Economic Adjustment
Cooperating

Work of Center supported in part by a grant from the W.K. Kellogg Foundation

Iowa State University
of Science and Technology
Ames, Iowa
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SUMMARY

Problems of depressed prices and incomes in agriculture are directly the result of a large supply of farm products. But a large supply of farm products is a function of the quantity of resources used in agriculture. Hence, knowledge of demand for and supply of resources is essential for policy and education directed toward solution of price and income problems of agriculture. The major objective of this study is to estimate demand and supply functions for one resource: labor. Demand and supply functions are estimated for hired labor, family labor and the total farm work force. Regression equations also are estimated for different time periods and for geographic regions of the United States. Projections of future man-hour requirements also are made. Objectives of the study also include the estimation and comparison of demand and supply functions by various regression models and techniques. Estimates are made with general least-squares methods, small systems of equations, distributed lag models, autoregressive schemes, and the Theil-Basmann approach.

Among the several series of estimates of the farm labor force, the series of the U.S. Department of Agriculture was utilized in the regression analysis of this study. Hence, all estimates are based on time series data. Other farm employment series were limited either in the coverage of both hired and family labor or in the time interval encompassed.

Demand functions were derived for hired labor for an over-all period, 1910-57, and for the intervening periods, 1920-39, 1929-57 and 1940-57. The results provided support for the major hypotheses tested: The demand for hired labor appears to be responsive to changes in both the price of labor (the farm wage-rate) 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 especially is related to the period of the business cycle and the existence of non-farm employment opportunities.

The demand function 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, 31 of table 6, indicated that the short-run price elasticity of demand was -.256. 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 response in demand quantity to changes in prices received was also significant. A decrease in prices received of 10
percent was accompanied by a decline in the demand for hired workers of from 3 to 6 percent over the 1910-57 time span, 17 percent from 1920-39, and from 8 to 20 percent over the periods 1929-57 and 1940-57. There was little indication of any change in levels of response over time, as reflected in the regression coefficients, or the cross elasticities of "prices received" as derived from the equations.

Although 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 1910-57, 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 1910-57 period are biased. The adjustment coefficients in the intervening periods appeared to be consistent with theory and "common knowledge." These coefficients indicated that the rate of adjustment of farm-labor demand to a sustained price or other variable change has increased over time. This increase appears to stem from a growing mobility of the agricultural labor force.

Regionally, the hired-labor demand functions followed a pattern similar to those for the United States economy. The elasticity of the price of farm labor for functions with significant regression coefficients ranged from -.15 to -.51 over the regions. In four of the nine regions -- New England, South Atlantic, Mountain and Pacific -- the regression coefficients of the farm wage-rate are not significant at the 10-percent level. The special farm-labor problems which exist in these regions and are explained in the test perhaps account for these results. However, the sign of the regression coefficient for the farm wage-rate variable was negative in all regions, indicating a decline in demand for hired labor as its price increases.

The coefficients for the parity ratio, a measure of farming profitability, lagged 1 year, were significant at a 5-percent probability level in only four of the nine regions. The Midwestern and South Central areas are indicated to be responsive to changes in both the price of hired labor and the profitability of farming.

Empirical demand functions were also derived for family labor, both for the United States and by geographic region. The specification of the models was the same as that 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. The derived short-run elasticities of the farm wage rate ranged from -.14 to -.32 for the various equations.

For the over-all period 1910-57 for the United States, the coefficient of the "prices-received variable" for family-labor demand
was nonsignificant. However, the corresponding coefficients for the inter­
tervening periods, 1920-39 and 1940-57, were significant. This apparent
consistency for 1910-57 results because the sign of the 1920-39 coeffi­
cient was negative, while that for 1940-57 was positive. Due to the
depression and a resulting lack of off-farm employment opportunities
the negative sign for 1920-39 was realistic with "real-world" condi­
tions. Likewise, in a period of relative prosperity and ample off-farm
employment opportunities, as in the period 1940-57, positive coefficients
are consistent both with theory and expected effects of the specified
variable.

Supply functions for both hired and family labor were estimated
over the period 1929-57. Both supply functions were derived 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 nonfarm wage-rate adjusted for changes in the rate
of unemployment. The signs of the regression coefficients were con­
sistent for the hired-labor supply function. While the regression
coefficients for the farm wage-rate were nonsignificant, the regression
coefficient for the nonfarm wage-rate was larger than its standard error.

In the supply function for family labor, the farm wage-rate and
the nonfarm wage-rate regression coefficients were not statistically
significant at a level of 10 percent. Further, difficulties were
encountered in estimating the autoregressive least-squares equation,
evidently due to multicollinearity in the time and lagged dependent
variables.

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 substitutability;
empirically, the factors appear as complements. However, given the
form in which the index of machinery prices is presented, important
marginal changes are difficult to establish. Because of the nature
of the aggregate national data, it is impossible to isolate the
substitution process as it is affected by relative prices and actually
takes place between specific categories of machinery and labor.

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 depending on the estimating equations.
used. To predict the size of farm man-hour requirements for 1975, a
"naive" growth model was presented. Comparisons were made with other
methods of long-run estimation. For 1975, man-hour requirements for
United States agriculture were estimated at 40 percent of the 1947-58
average.
DEMAND FOR LABOR IN AGRICULTURE

by

Stanley S. Johnson and Earl O. Heady

INTRODUCTION

Agricultural income problems stem 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 a similar increase in income to the agricultural sector. The per capita demand for agricultural products decreases relative to other goods and services. Products of industries which have high income elasticities bid up prices of factors used in agriculture. Hence, the farmers' 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 farm factors of production. Evidently, the low short-run elasticity of factor supply, along with technical change and imperfection in the factor markets, has 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 risen accordingly.

One of the principal means often suggested for solving the farm income problem is in adjustments in the size of the farm labor force. Hence, greater knowledge of the factors which affect the demand and supply of farm labor is important in analysis of factors related to the supply of farm products and income of the industry. The demand for and supply of this particular resource, farm labor, is analyzed in this study. Labor, of course, is not an inanimate resource that can be shunted abruptly out of agriculture in immediate response to relative price changes. Rather, labor represents a human resource with a consuming unit attached to it. It has many sociological attributes which relate to its mobility. This study, however, emphasizes the economic aspects of labor as a resource and examines responses by it in respect to farm income, wage-rates, and other relevant variables.

While a study of the total labor force in agriculture would be preferred, emphasis in this study is primarily on the demand for hired labor. The primary reasons for studying hired labor separately (and, to some extent, family workers) are: (1) The farm operator's decision on marginal changes in human resources is concerned with hired and

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1/ Project 1406 of the Iowa Agricultural and Home Economics Experiment Station, Center for Agricultural and Economic Adjustment cooperating.
family labor. (2) Hired labor is a more mobile resource and may provide an indication of adjustment to price and other changes at the margin. (3) The "price" of hired labor is the farm wage-rate while the "price" of family workers and operators is not readily available. The demand for farm labor (or of hired farm labor) is much less independent of the supply of labor. While most of the demand functions in this study are estimated singly, some demand and supply functions are, however, estimated simultaneously.

OBJECTIVES

While information concerning the demand for and supply of farm labor is extremely important in output and price of farm products, relatively little quantitative research effort has been directed toward basic relationships surrounding the resource. Improved knowledge of quantitative demand and supply functions for farm labor is of importance to economists and national farm program administrators. The objective of this study is to predict these relations for different strata of farm labor, for different periods, and under different estimational models. It is expected that these predictions will lead to useful knowledge for such questions as: (1) How much time must elapse, for specified differentials between farm and nonfarm incomes, before a specified amount of labor leaves agriculture? (2) What is the effect of varying rates of unemployment in the national economy on the rate of migration from agriculture? (3) What is the elasticity of supply response for farm labor in respect to farm and nonfarm wage-rates? (4) What are the lagged relationships of farm labor in respect to price stimuli? (5) What are the important variables which affect the demand for farm labor and the amount of labor held on farms in the various geographic regions of the United States? (6) Is the supply of farm labor highly responsive to changes in the farm wage? The results of this study provide some initial answers to questions such as these, and to questions which are related in judging adjustment rates and potentials in agriculture.

While the general objective of this study is to investigate the demand for and supply of farm labor, the emphasis is principally on demand, supply functions for farm labor being specified in a two-equation simultaneous system to identify the farm-labor demand function more adequately.

The more specific objectives of the study 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 United States; (3) to summarize and appraise the quantitative estimates of the farm labor force; and (4) to offer some predictions on the size of the farm labor force for 1965 and 1975.
TRENDS IN FARM LABOR AND RELATED INPUTS

The farm labor market has undergone considerable change in recent decades, the general trend in agricultural employment since 1910 being downward. The total number of farm workers declined 45 percent between 1910 and 1959. (See fig. 1.) Estimated requirements for man-hours in agriculture declined 50 percent during the same period (fig. 2). However, the rate of decrease was far from constant over the 50-year period. Farm employment dropped by only 8 percent from 1910 to 1930. Due to depression and lack of off-farm opportunities, farm employment increased 2 percent between 1930 and 1935. After 1935, however, the rate of net migration from farms increased. Farm employment declined by 19 percent between 1935 and 1946, and by 26 percent between 1946 and 1957.

Of the 7.6 million farm workers in 1957, roughly one-fourth were hired workers. The hired labor force has constituted about 25 percent of the national farm labor force since 1910. Hence, changes in the numbers of hired and family workers over time have been similar to changes in 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 (fig. 3) are presented in table 1. Two general conclusions can be drawn from these data: (1) The percentage changes in total farm labor from 1910 to 1957 and from 1929 to 1957 are similar for nearly all regions. Farm employment decreased slowly from 1910 to 1929, but decreased rapidly from 1929 to 1957 in all but one region, the Pacific region. (2) Differential changes in employment of hired and family labor were greater for specific regions than for the United States. No consistent pattern of relative change in hired and family workers existed among all regions.

The seasonal pattern of farm employment also has changed somewhat, but more for family than for hired labor. As fig. 4 indicates, the absolute amplitude of employment fluctuations has diminished greatly for family labor, but only slightly for hired labor. The seasonal pattern of hired labor for four regions is compared between the years 1931 and 1957 in fig. 5. Total demand for seasonal hired labor increased in the Pacific region, but declined in the other three. Changes in mechanization and the cropping patterns brought a quite different peak in hired-labor requirements in the South Atlantic region, however. Of a total of 3.6 million farm workers who did any farm work for wages during 1956, 1.5 million or 40 percent of the total worked 25 days or less (fig. 6). Only 750,000 farm workers reported working 150 days or over.2/

Table 1. Size of the farm labor force, by regions, for 1957, and the percentage change in the labor force, by regions, 1910-57 and 1929-57, as a percentage of 1910.\(^a\)

<table>
<thead>
<tr>
<th>Region</th>
<th>Size of farm labor force, 1957 (Thousands)</th>
<th>Percentage change, 1910-57 (Percent)</th>
<th>Total farm employment (Percent)</th>
<th>Percentage change, 1929-57 (Percent)</th>
<th>Hired workers (Percent)</th>
<th>Family workers (Percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>New England</td>
<td>172</td>
<td>-53</td>
<td>-36</td>
<td>-33</td>
<td>-38</td>
<td></td>
</tr>
<tr>
<td>Mid. Atlantic</td>
<td>444</td>
<td>-53</td>
<td>-36</td>
<td>-47</td>
<td>-30</td>
<td></td>
</tr>
<tr>
<td>East North Central</td>
<td>1,307</td>
<td>-36</td>
<td>-22</td>
<td>-54</td>
<td>-12</td>
<td></td>
</tr>
<tr>
<td>West North Central</td>
<td>1,398</td>
<td>-36</td>
<td>-35</td>
<td>-65</td>
<td>-24</td>
<td></td>
</tr>
<tr>
<td>South Atlantic</td>
<td>1,345</td>
<td>-49</td>
<td>-42</td>
<td>-36</td>
<td>-44</td>
<td></td>
</tr>
<tr>
<td>East South Central</td>
<td>969</td>
<td>-58</td>
<td>-56</td>
<td>-47</td>
<td>-58</td>
<td></td>
</tr>
<tr>
<td>West South Central</td>
<td>1,000</td>
<td>-54</td>
<td>-57</td>
<td>-46</td>
<td>-61</td>
<td></td>
</tr>
<tr>
<td>Mountain</td>
<td>354</td>
<td>-18</td>
<td>-35</td>
<td>-46</td>
<td>-27</td>
<td></td>
</tr>
<tr>
<td>Pacific</td>
<td>588</td>
<td>+14</td>
<td>+1</td>
<td>+2</td>
<td>+1</td>
<td></td>
</tr>
<tr>
<td>United States</td>
<td>7,577</td>
<td>-44</td>
<td>-40</td>
<td>-44</td>
<td>-39</td>
<td></td>
</tr>
</tbody>
</table>

The demand for farm labor is affected by resources which serve as substitutes for labor. Relative prices of these several resources and the technology used determine the rate at which labor is replaced from farms. Inputs other than farm labor have changed greatly over time. Farmers have made large adjustments in the resource mix, shifting from resources which were more expensive to those which were less expensive. Relative changes in prices and use of major factors between 1940 and 1957 are shown in table 2. These data indicate that as the price of a factor rose relative to product prices, and relative to the price of other factors, use of the specific factor decreased. For example, the price of farm labor increased relative to prices of farm products and other resources, and the number of man-hours worked decreased by 34 percent over the period 1940-57.

SOURCES AND NATURE OF DATA

The data used in this study are time series observations of employment, prices and other relevant variables. The data are taken from USDA sources for the nation, except as otherwise indicated on a regional basis. Several sources of farm employment data exist, and each has somewhat different implications for empirical analysis. Accordingly, these several sources are discussed as a basis for indicating limitations in the data and to explain the logic in selecting particular measurements and variables.

Major Sources of Employment Data

The major sources of data on farm employment are: (1) employment estimates of the Agricultural Marketing Service of the U. S. Department of Agriculture (hereafter indicated as the AMS series); (2) estimates published by the Bureau of the Census, the Current Population Survey (hereafter indicated as CPS); (3) man-hour requirements estimated by the Agricultural Research Service of the U. S. Department of Agriculture (hereafter indicated as FERD); and (4) estimates of the hired farm

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

<table>
<thead>
<tr>
<th>Resource category and percentage change in price, 1940-57, as a percentage of 1940</th>
<th>Resource category and percentage change in use, 1940-57, as a percentage of 1940</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wage rates(^a/) 427</td>
<td>Man-hours(^b/) -34</td>
</tr>
<tr>
<td>Real estate(^c/) 302</td>
<td>Cropland(^d/) -2</td>
</tr>
<tr>
<td>Farm machinery(^e/) 228</td>
<td>Tractors(^f/) +203</td>
</tr>
<tr>
<td>Fertilizer(^g/) 154</td>
<td>Fertilizer(^h/) +258</td>
</tr>
<tr>
<td>Farm products(^b/) 235</td>
<td>Farm output(^i/) +41</td>
</tr>
</tbody>
</table>

\(^g/\) Ibid., p. 16.
working force of the Agricultural Marketing Service of the U. S. Department of Agriculture, and based on a survey of the Bureau of the Census (hereafter indicated as HFWF). Though the source is not described here, a rough estimate of the number of available farm workers also may be derived from farm population estimates.

Comparison of the major employment series

The most important sets of farm employment estimates are the AMS and the CPS series. These two series are emphasized in the discussion below. The remaining series are accorded separate analysis later.

The CPS and AMS total farm employment series on an annual basis are presented in table 3. The AMS series of average annual employment is higher than the CPS series in every year. The difference between the two series gradually widened from 1940 to 1950, but narrowed from 1951 to 1957. The difference between the two series may have decreased after 1951 as the Bureau of the Census enlarged its samples in 1954 and in 1956.

Table 4 contains hired seasonal employment for the AMS, CPS and HFWF series for 1957. During this year, the AMS estimates were higher than the CPS series for the summer months, but were lower during the winter months. The HFWF data 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 later in this section.

While the three hired employment series in table 4 agree on the months of minimum employment (December, January and February), they differ on periods of peak employment. The AMS series indicates July, August and September to be 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.1

Discrepancies between the CPS and AMS series exist because of differences in concept and method of enumeration. The AMS series essentially estimates the number of farm jobs, while the CPS series estimates the number of farm workers. Both series have relative advantages and

---

Table 3. Annual average of farm employment from CPS and AMS series and differences, 1940-57, family and hired workers.

<table>
<thead>
<tr>
<th>Year</th>
<th>CPSa/</th>
<th>AMSb/</th>
<th>Excess of AMS over CPS series</th>
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</thead>
<tbody>
<tr>
<td>1940</td>
<td>9,540</td>
<td>10,979</td>
<td>1,439</td>
</tr>
<tr>
<td>1941</td>
<td>9,100</td>
<td>10,669</td>
<td>1,569</td>
</tr>
<tr>
<td>1942</td>
<td>9,250</td>
<td>12,504</td>
<td>1,254</td>
</tr>
<tr>
<td>1943</td>
<td>9,080</td>
<td>10,446</td>
<td>1,366</td>
</tr>
<tr>
<td>1944</td>
<td>8,950</td>
<td>10,219</td>
<td>1,269</td>
</tr>
<tr>
<td>1945</td>
<td>8,580</td>
<td>10,000</td>
<td>1,420</td>
</tr>
<tr>
<td>1946</td>
<td>8,320</td>
<td>10,295</td>
<td>1,975</td>
</tr>
<tr>
<td>1947</td>
<td>8,266</td>
<td>10,382</td>
<td>2,116</td>
</tr>
<tr>
<td>1948</td>
<td>7,973</td>
<td>10,363</td>
<td>2,390</td>
</tr>
<tr>
<td>1949</td>
<td>8,026</td>
<td>9,964</td>
<td>1,938</td>
</tr>
<tr>
<td>1950</td>
<td>7,507</td>
<td>9,926</td>
<td>2,419</td>
</tr>
<tr>
<td>1951</td>
<td>7,054</td>
<td>9,546</td>
<td>2,492</td>
</tr>
<tr>
<td>1952</td>
<td>6,805</td>
<td>9,149</td>
<td>2,344</td>
</tr>
<tr>
<td>1953</td>
<td>6,562</td>
<td>8,864</td>
<td>2,302</td>
</tr>
<tr>
<td>1954</td>
<td>6,504</td>
<td>8,639</td>
<td>2,135</td>
</tr>
<tr>
<td>1955</td>
<td>6,730</td>
<td>8,364</td>
<td>1,634</td>
</tr>
<tr>
<td>1956</td>
<td>6,585</td>
<td>7,820</td>
<td>1,235</td>
</tr>
<tr>
<td>1957</td>
<td>6,222</td>
<td>7,577</td>
<td>1,355</td>
</tr>
</tbody>
</table>


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

<table>
<thead>
<tr>
<th>Month</th>
<th>AMS(^a/)</th>
<th>CPS(^b/)</th>
<th>HFWF(^c/)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Original</td>
<td>Adjusted</td>
<td></td>
</tr>
<tr>
<td>(Thousands of persons)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>January</td>
<td>896</td>
<td>1,154</td>
<td>757</td>
</tr>
<tr>
<td>February</td>
<td>1,040</td>
<td>1,180</td>
<td>768</td>
</tr>
<tr>
<td>March</td>
<td>1,284</td>
<td>1,209</td>
<td>856</td>
</tr>
<tr>
<td>April</td>
<td>1,543</td>
<td>1,322</td>
<td>1,085</td>
</tr>
<tr>
<td>May</td>
<td>1,985</td>
<td>1,710</td>
<td>1,394</td>
</tr>
<tr>
<td>June</td>
<td>2,684</td>
<td>2,138</td>
<td>1,924</td>
</tr>
<tr>
<td>July</td>
<td>2,983</td>
<td>2,354</td>
<td>2,189</td>
</tr>
<tr>
<td>August</td>
<td>2,883</td>
<td>1,971</td>
<td>2,058</td>
</tr>
<tr>
<td>September</td>
<td>2,805</td>
<td>1,911</td>
<td>1,872</td>
</tr>
<tr>
<td>October</td>
<td>2,237</td>
<td>2,112</td>
<td>1,706</td>
</tr>
<tr>
<td>November</td>
<td>1,450</td>
<td>1,654</td>
<td>1,405</td>
</tr>
<tr>
<td>December</td>
<td>951</td>
<td>1,533</td>
<td>1,073</td>
</tr>
<tr>
<td>Average</td>
<td>1,895</td>
<td>1,687</td>
<td>1,424</td>
</tr>
</tbody>
</table>


\(^c/\) Adjusted to include foreign workers.

disadvantages. There are five main differences between the AMS and CPS employment estimates. First, the data are compiled in the two series by means of different enumerative techniques. The AMS 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 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 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.§/

A second source of difference between the two series is in the counting method in relation to age limits. The AMS series sets no age limit while the CPS enumeration includes only persons 14 years of age and 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 USDA to be as high as a million.2/ A private estimate by Johnson placed the maximum at 2 million during peak periods.10/

A third difference arises over multiple job holding. The requirements for a worker to be included in the AMS enumeration are minimal for the survey week: 1 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 not only must be 14 years of age or over, but also must have earned a major share of his income in agriculture. Persons with multiple jobs who actually do some farm work, but who are not included in the CPS enumeration number from one-half to 1 million seasonally.11/

A further difference between the two series may arise because the CPS includes categories of workers on farms who engage in nonfarm occupations such as bookkeepers, typists and persons engaged in some

---

9/ Ibid.
processing activities.\textsuperscript{12} It also includes some unemployed farm operators. 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.

\textbf{The hired farm work force (HFWF)}

The HFWF series is relatively new, being started in 1945 for the purpose of providing more detailed information on work done by hired workers. It was 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 HFWF estimates are subject to memory bias, and provide a relatively low estimate of employment 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 employment estimates are expected to be larger than the monthly CPS estimates. The HFWF series is not available by regions.

\textbf{The series of man-hour requirements (FERD)}

Another farm employment estimate not directly comparable to the three previously discussed sets of estimates, is the FERD series of man-hour requirements. The purpose of the series is to estimate the number

\textsuperscript{12} An estimate of the number of nonfarm 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 198,000 persons were estimated to be engaged in these nonfarm activities. (See: Maitland and Fisher, op. cit.)
of man-hours required for annual farm output, rather than man-hours actually expended. Compiled by the Agricultural Research Service of the USDA, these estimates are "built up" by multiplying estimated average man-hours per acre of crops and per head or unit of livestock production by the official estimates of total acres and number of livestock reported by the Crop Reporting Board of the USDA.\(^\text{13}\) 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 requirements are multiplied by the total number of acres and animals. Too, a test of statistical reliability cannot be applied to them. The series includes both national and regional estimates, and covers the period 1910 to the present.

Data on Employment and Other Variables Used

Each of the employment series has been derived for a particular purpose. Each 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 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 series currently is a better measure of marginal changes in the farm labor force than is the CPS series.\(^\text{14}\). The FERD series is used for one set of long-run predictions since it best reflects changes in labor productivity.\(^\text{15}\)


\(^{15}\) The effectiveness of the AMS series would be greatly enhanced through measures of job duration. 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 work quantity done, the CFS series may be more reliable. The reliability of this series has increased since 1956 when the size of the sample was greatly enlarged. Too, measures of multiple job holdings have been developed. For future labor research, the CPS will be the more reliable series as the time period covered increases. The HFWF series is useful for comparisons of time worked by hired laborers. The value of the series will grow as the time period covered increases, especially if a reliable method is developed to compensate for memory bias. The FERD series is admirable in purpose: to measure the basic demand for labor (continued)
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. The sources of these data are contained in the appendix.

The Models of Farm Labor Demand and Supply

Particular models used as a basis for estimation are specified in this section. The models provide a statement of the economic hypotheses underlying the predictions and make explicit the assumptions behind the investigation and its empirical approach. The model for demand and supply of hired and family labor has the following general form:

\[
Y_1 = a_{10} + a_{11}X_1 + a_{12}X_2 + a_{13}X_3 + a_{14}X_4 + a_{15}X_5 + a_{16}X_6
\]

\[
Y_2 = a_{21}X_1 + a_{22}X_2 + a_{23}X_3 + a_{24}X_4 + a_{25}X_5 + a_{26}X_6
\]

where the variables are:

- \(Y_1\) = the annual quantity of labor employed on farms, with \(\bar{Y}_1\) designating the quantity of hired labor, and \(\hat{Y}_1\) the quantity of family labor.

- \(Y_2\) = the annual quantity of labor supplied by households, with \(\bar{Y}_2\) designating the quantity of hired labor, and \(\hat{Y}_2\) the quantity of family labor.

- \(X_1\) = the index of the annual farm wage-rate as an aggregate for the United States. The data were deflated principally by the index of prices paid by farmers for living expenses, not including wages, and the index of prices paid by farmers for production expenses. The wage-rate was included because it is the price of hired labor and perhaps is the "going" price of family labor.

- \(X_2\) = the index of annual prices received by farmers for all commodities as an average for the United States, deflated by the index of prices paid by farmers for production expenses and inputs in agriculture. 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.

(footnote 15 continued)
the index of farm machinery prices. The series thus deflated is the ratio of product price to factor costs and is lagged by 1 year in all equations.

\[ X_3 = \text{the annual aggregate index of farm machinery prices for the United States, deflated as for } X_1. \]  
This variable is included to allow expression of the substitution relationships of farm machinery for farm labor. (Empirical labor demand functions which included the price of farm machinery had regression coefficients which were inconsistent in sign and nonsignificant. Hence, equations for labor demand containing the price of farm machinery as a variable are accorded a separate analysis later in the study.)

\[ X_4 = \text{the index of the value of farm machinery on hand Jan. 1 for the United States, deflated by prices paid by farmers, to indicate the stock of resources which substitute for labor. The series was compiled commencing with a deflated value of farm machinery on farms from the 1930 census. For succeeding years, the deflated increments to (or depreciation of) the nation's stock of machinery and equipment were added (or subtracted) from the prior year's total.} \]

\[ X_5 = \text{time as a variable. Time in linear form is used to represent technological and other changes which have occurred, but are not readily quantified as separate and explicit variables.} \]

\[ X_6 = \text{a nonfarm wage-rate variable. This variable is a "composite" of the annual index of hourly factory wages altered to reflect the percentage of unemployment in the total work force. It was assumed arbitrarily that when unemployment of the total work force reached 20 percent, no further off-farm opportunities would exist. Consequently, with unemployment equal to or greater than this level, changes in nonfarm wage-rates are expected to have no effect in causing net migration from agriculture. To reflect conditions where nonfarm wage-rates would not cause migration when unemployment is 20 percent or greater, this variable was constructed:} \]

\[ A(1 - 5U) \]

where \( A \) is the hourly earnings of factory workers and \( U \) is the percent of unemployment. When the unemployment rate reaches 20 percent or more, this variable becomes zero; when the unemployment rate is zero, the variable reaches the average level of earnings by factory workers.
Variations of the general model were made for these purposes: (1) to examine the effect of the inclusion or noninclusion of variables assumed to have a pronounced effect on the use of farm labor; (2) to compare variables deflated by different deflators; (3) to use different time periods (1910-57, 1920-39, 1929-57, 1940-57) for estimation; (4) to compare equations containing observations entered in linear and in logarithmic form; (5) to compare estimation techniques such as single equations (some taken with a distributed lag), simultaneous-equation estimation by the reduced-form and the Theil-Basmann methods, and autoregressive least-squares methods; and (6) to include the quantity of farm labor, lagged one period \(Y_{it-1}\), as an additional independent variable (i.e., as a predictor of \(Y_i\)). The results of the empirical analysis are presented in a later section.

Further variations in notation from that listed under equations 1 and 2 will be defined in the appropriate section. Use is made of an additional variable designation, \(X_7, X_8, \ldots, X_4\), to indicate that the variable differs from those defined under equations 1 and 2. To indicate variables representing regional data, an asterisk is added to the variable notation, along with individual regional identification.

**EMPIRICAL PROCEDURES**

This section 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) a discussion of single and simultaneous equations; (3) an autoregressive least-squares technique; and (4) a note on a method of estimation of simultaneous systems containing autocorrelated errors.

**Single- and Simultaneous-Equation Estimates**

The empirical demand and supply functions presented later in this study were estimated by least-squares methods. 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.\(^{16}\) The set of equations specified in the general model used

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in this study may be solved singly or simultaneously. Several variations
of the least-squares method have been used in this study. However, solved
singly, the least squares method applies; solved simultaneously, other
techniques are needed.

Equations 1 and 2 may be solved singly. Solved simultaneously and
taken with a distributed lag, these equations in theoretical form would
appear as the following:

\[
\begin{align*}
(3) & \quad \delta_{11} w_1 + \delta_{12} w_2 + z_{11} z_1 + z_{12} z_2 + z_{13} z_3 + z_{14} z_4 = \epsilon_1 \\
(4) & \quad \delta_{21} w_1 + \delta_{22} w_2 + z_{21} z_1 + z_{22} z_2 + z_{23} z_3 + z_{24} z_4 = \epsilon_2
\end{align*}
\]

where \( w_1 \) is the quantity of farm labor, \( w_2 \) is the average farm wage-rate,
\( z_1 \) is the quantity of farm labor lagged 1 year, \( z_2 \) is time as a linear
variable, \( z_3 \) is the index of prices received, \( z_4 \) is the composite non-
farm wage-rate variable, and the \( \epsilon_i \) are the disturbances in the re-
spective equations. The \( w_i \) and \( z_i \) correspond to the \( X_i \) and \( Y_i \) of
equations 1 and 2. The \( w_i \) are determined within the systems of equations
and are called endogenous variables. The \( z_i \) are exogenous variables
which are either determined from outside the system or are endogenous
variables lagged one or more periods. In the system of equations above,
both equations would be "just identified" if the number of exogenous
variables excluded from each were one less than the number of endogenous
variables included in the equation. If the number of exogenous variables
excluded from the equation in question were larger than one less than
the number of endogenous variables in the equation, the system
would, in conventional terminology, be overidentified. The over-
identified 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\(^{17/}\) and Basmann.\(^{18/}\) It provides ease of computation,

\(^{17/}\) Theil, Henri. Estimation and simultaneous correlation in complete
Mimeo. report. June 23, 1953. (Original not available for examination;
cited in Wallace, T. D. and Judge, G. G. Discussion of the
Theil-Basmann method for estimating equations in a simultaneous
system. Oklahoma State University. Processed series P-301. Aug.
1958.)

\(^{18/}\) Basmann, R. L. A generalized classical method of linear estimation
1957.
utilizes least-squares methods, and permits rapid estimation of the standard errors of the coefficients.

Forms of Distributed Lag Models

Numerous distributed lag models are utilized in the empirical analysis which follows. Hence, the foundation of this approach is examined in this section. 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.

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:

\begin{equation}
\hat{w} = \hat{\alpha} + \hat{\beta}p
\end{equation}

where \( \hat{w} \) is the quantity of labor demanded (or supplied) and \( \hat{p} \) is the price of \( w \). If, in the nonstatic case, the variables are dated and \( \hat{w} \) (now indicated as \( w_t \)) is assumed to depend on current and all past prices, equation 5 becomes

\begin{equation}
w_t = a + \beta_0 p_{1t} + \beta_1 p_{t-1} + \beta_2 p_{t-2} + \ldots = a + \sum_{i=0}^{\infty} \beta_i p_{t-i}.
\end{equation}

Equation 6 states that \( w_t \) is determined by its price taken with a distributed lag.

A specific form of the distribution of the lag may be assumed, allowing estimation of the characteristics of the distribution. Koyck\(^{19}\) assumed that hindrances causing lags will be overcome gradually so that changes resulting from price or other variable will decline with time. After some period \( t=k \), the coefficients \( \beta_i \) (\( i = 0, 1, \ldots \)) can be approximated by a convergent geometric series:

\begin{equation}
\beta_k = \lambda \beta_{k+m-1}
\end{equation}

where \( m > 0 \) and \( 0 < \lambda < 1 \). Hence, the coefficients are assumed to decrease by a consistent proportion over time.

Substituting equation 7 into equation 6 for the case where $k = 0$, the equation becomes:

$$ w_t = a + b_0 p_{1t} + b_0^2 p_{1t-1} + b_0^2 p_{1t-2} + \ldots $$

If equation 8 is lagged by 1 year and both sides of the equation are multiplied by $\lambda$, the resulting equation is

$$ \lambda w_{t-1} = a\lambda + b_0^2 p_{1t-1} + b_0^2 p_{1t-2} + \ldots $$

By subtracting equation 9 from equation 8, the following equation is derived:

$$ w_t = a(1 - \lambda) + \lambda w_{t-1} + b_0 p_{1t} $$

such that the determination of $w_t$ is dependent only on $w_t$ lagged 1 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 $\lambda$ and the short-run elasticity is:

$$ E_{sr} = \frac{b_0}{1 - \lambda} \cdot \frac{\lambda}{w} $$

The cumulative effect of a maintained price change is:

$$ b_0 \cdot \sum_{m=0}^{\infty} \lambda^m = \frac{b_0}{1 - \lambda} \cdot \frac{\lambda}{w} $$

Hence, the long-run elasticity is

$$ E_{lr} = \frac{b_0}{1 - \lambda} \cdot \frac{F}{w} $$

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

$$ w^* = a_0 + a_1 z_{1t} $$

where $w_t^*$ is the long-run or equilibrium level of the quantity demanded.

---

or supplied and \( z_1 \) is the price of \( \bar{w}_t \). Nerlove proposes the utilization of the current quantity demanded or supplied, \( \bar{w}_t \), "to change in proportion to the difference between the long-run equilibrium quantity and the current quantity."\(^{21}\) This adjustment in equation form is:

\[
\bar{w}_t - \bar{w}_{t-1} = \gamma(\bar{w}_t - \bar{w}_{t-1}), \quad 0 \leq \gamma < 1,
\]

where \( \gamma \), a constant of proportionality called the coefficient of adjustment, indicates the relative speed of adjustment. Substituting equation 13 into equation 14, the resultant equation is:

\[
\bar{w}_t = \gamma a_0 + (1 - \gamma) \bar{w}_{t-1} + \gamma a_1 z_{1t}
\]

which is inessentially the same form as equation 10.

**Autoregressive Least-Squares Techniques**

Distributed lag equations may be solved either singly or simultaneously. However, difficulties of estimation arise using either method. If error terms \( (v_t) \) are added to equations 8 and 9, the difference formed between the two equations becomes:

\[
v_t = a(1 - \gamma) + \gamma \bar{w}_{t-1} + b p_t + v_t - v_{t-1}
\]

where the error terms \( v_t - v_{t-1} \) are treated as a composite disturbance. Koyck\(^{22}\) suggested that the usual least-squares analysis of equation 16 will lead to biased estimates of \( a \) and \( \gamma \), the true parameters, since \( v_{t-1} \), part of the composite disturbance, is not independent of \( w_{t-1} \). The composite error term has an automatic serial correlation even if the \( v_t \) are serially independent.\(^{23}\) The error term in period \( t \) is


\(^{22}\) Koyck, op. cit.

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 \((v_{t-1} - v_{t-2})\).

Tests for residual correlation of distributed lag equations have frequently been made using the Durbin-Watson test.\(^{24}\) However, Fuller and Martin\(^{25}\) demonstrated that the Durbin-Watson statistic computed from the residuals of such equations is of very "low power." It is likely that the lagged dependent variable extracts some of the autocorrelation from the residuals, which may bias the coefficients and nullify the use of the Durbin-Watson statistic.

Koyck\(^{26}\) proposed the model in equation 17 to obtain consistent estimators in distributed lag equations, wherein the error term, \( u_t \), is assumed to generate from an autoregressive scheme.

\[
(17) \quad u_t = \beta u_{t-1} + e_t.
\]

The assumptions are that \( e_t \) 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. Further, he assumes specific values of \( \beta \). Estimation by this technique is referred to in this study as autoregressive least-squares or ALS.

In an equation such as in 18 below, 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.\(^{27}\) He shows that, given Koyck's basic equation

\[
(18) \quad w_t = a p_t + b w_{t-1} + u_t
\]

combined with the autoregressive scheme of equation 17 leads to

\[
(19) \quad u_t = \beta (w_{t-1} - a p_{t-1} - b w_{t-2}) + e_t.
\]


\(^{26}\) Koyck, op. cit., p. 34.

By substituting equation 19 into equation 18, he shows that the probability limit of \( b' \) is given by

\[
\text{plim } b' = b + \frac{\beta}{1 + \beta b} \left( \frac{1 - r^2}{1 - r^2} \right)^2 - b^2
\]

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 \( \beta \) 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 \( \beta \).) Methods for estimating \( \beta \) have been presented by Klein and Orcutt and Cochrane.\(^{28}\)

A simplified method for estimating \( \beta \) by an iterative process has been developed by Fuller.\(^{29}\) Basically, the method is as follows, using the notation of equations 18 and 19. By substituting 19 into 18, the following equation is formed:

\[
w_t = a p_t + (b + \beta) w_{t-1} - a \beta p_{t-1} - b \beta w_{t-2} + e_t
\]

A regression on these variables provides initial values for estimates of \( a, b, \) and \( \beta \). By a method of nonlinear regression,\(^{30}\) 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 from the Taylor expansion become linear combinations of those in equation 21. Retaining only the first-order terms, the results of the Taylor expansion yield:

\[
w_t = w^0 + m_1 \Delta \hat{a} + m_2 \Delta \hat{b} + m_3 \Delta \hat{\beta}
\]

where \( w^0 = w_t - \hat{w}_t \), the residuals in equation 21,


where $a$, $b$, and $\theta$ are the initial estimates of the coefficients, and $\Delta a$, $\Delta b$, and $\Delta \theta$ represent changes in the estimates for each iteration. The least-squares method applied to equation 22 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.\(^{31}\)

While the data in this study are presumed to be measured without error, the results may be invalidated to some extent since errors of observation usually are present in time series data. A method of dealing with this problem is presented by Tintner,\(^{32}\) and an example involving labor has been analyzed by Mosback.\(^{33}\)

Equations taken with a distributed lag, as well as the more common form of equations, have been used in this study. For the national demand and supply functions for hired labor, distributed lag equations were used. Both conventional and autoregressive least-squares equations were estimated for national data. Since the regional data were less reliable, only conventional least-squares methods were employed for them.

EMPIRICAL ESTIMATES OF THE NATIONAL DEMAND FUNCTIONS FOR HIRED LABOR

The results of the estimation of the empirical demand and supply functions for farm labor are presented in the following sections. Among the labor demand functions estimated, results are better for hired labor than for family labor.\(^{34}\) In contrast to family labor, hired labor has

\(^{31}\) Fuller, Wayne. Autocorrelated errors and the estimation of distributed lag models, *op. cit.*

\(^{32}\) Tintner, *op. cit.*


\(^{34}\) For other empirical studies of the demand for hired farm labor, see: Griliches, Zvi. The demand for inputs in agriculture and a derived (continued)
an explicit wage or price which is reported nationally and regionally. This section presents the empirical results testing the hypothesis that the demand for hired labor is a function of its own price (the farm wage-rate); the prices of other inputs such as farm machinery, the scale of farming as exemplified by the value of farm machinery, and the return on or price of products sold. The price of inputs such as the series of aggregate farm machinery prices, was originally included in the model as illustrated in equations 1 and 2. However, farm machinery price resulted in inconsistent results when this variable was included with other explanatory variables. Because of the importance of this variable to the demand for hired labor, it is accorded a separate analysis later in the study. The results for the remaining individual variables are presented in this section.

Initially, an analysis of the results from the different techniques employed to estimate labor demand functions will be presented. Analysis of the regression coefficients and elasticities of the demand for hired labor follows. The estimated demand functions for hired labor are presented in tables 5 and 6. Two of these demand functions, 25 and 34 of table 5, are plotted against the actual data in figs. 7 and 8.

Results of Different Techniques to Estimate the Demand Functions for Hired Labor in the United States

In estimating the demand functions for hired labor for the United States, variations of the basic model of equations 1 and 2 and different techniques were employed. So that attention can be focused on the characteristics of the important variables, the different results under these several techniques or variations will be analyzed. The demand functions in tables 5 and 6 have been estimated using a variety of algebraic forms and estimating methods. The statistics in table 5 are

(footnote 34 continued) supply elasticity. Jour. Farm Econ. 41:309-322. 1959; and Schuh, George E. The demand and supply relations for hired labor in agriculture. Paper presented at the Joint Meetings of the Econometric Society and the American Farm Economic Association, Washington, D. C., December 28-30, 1959. (Mimeo.) Department of Agricultural Economics, Purdue University, Lafayette, Indiana. 1959. Griliches specified a distributed lag model representing the demand for hired labor for the period 1912-56, containing one independent variable, the farm wage-rate. Schuh estimated demand functions for hired labor over the period 1929-57 simultaneously with hired-labor supply functions. Schuh's time period and model specification are similar to equation 30 of table 5 (to be presented further in this study). The demand functions in this study, other than the ALS equations, were estimated simultaneously with Schuh's work and without knowledge of it.
Fig. 7. Actual and predicted number of hired farm workers in the United States, 1910-57 (demand function 25 of table 5).
Fig. 8. Actual and predicted number of hired farm workers in the United States, 1940-57 (demand function 34 of table 5).
Table 5. Regression coefficients and standard errors for United States hired-labor demand functions.

<table>
<thead>
<tr>
<th>Equation number</th>
<th>Form and method</th>
<th>Regression coefficients$^a/$</th>
<th>$x^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Constant</td>
<td>$x_{1t}$</td>
<td>$x_{2t}$</td>
</tr>
<tr>
<td>23.</td>
<td>Linear, b/ least squares</td>
<td>40.74</td>
<td>-.077$^c/$</td>
</tr>
<tr>
<td></td>
<td>1910-57 period</td>
<td>(.045)</td>
<td></td>
</tr>
<tr>
<td>24.</td>
<td>Linear, b/ least squares</td>
<td>15.23</td>
<td>-.091</td>
</tr>
<tr>
<td></td>
<td>(.044)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25.</td>
<td>Linear, b/ least squares</td>
<td>27.89</td>
<td>-.098$^c/$</td>
</tr>
<tr>
<td></td>
<td>(.055)</td>
<td>(.033)</td>
<td></td>
</tr>
<tr>
<td>26.</td>
<td>Linear, b/ least squares</td>
<td>12.86</td>
<td>-.122</td>
</tr>
<tr>
<td></td>
<td>(.053)</td>
<td>(.029)</td>
<td></td>
</tr>
<tr>
<td>27.</td>
<td>Log, b/ least squares</td>
<td>.35</td>
<td>-.095</td>
</tr>
<tr>
<td></td>
<td>(.034)</td>
<td>(.022)</td>
<td></td>
</tr>
<tr>
<td>28.</td>
<td>Linear, b/ least squares</td>
<td>23.86</td>
<td>-.046$^e/$</td>
</tr>
<tr>
<td></td>
<td>(.058)</td>
<td>(.064)</td>
<td></td>
</tr>
<tr>
<td>29.</td>
<td>Linear, b/ least squares</td>
<td>68.40</td>
<td>-.054$^e/$</td>
</tr>
<tr>
<td></td>
<td>(.187)</td>
<td>(.111)</td>
<td></td>
</tr>
<tr>
<td>30.</td>
<td>Linear, b/ reduced form</td>
<td>52.47</td>
<td>-.168$^d/$</td>
</tr>
<tr>
<td></td>
<td>(.108)</td>
<td>(.069)</td>
<td></td>
</tr>
<tr>
<td>31.</td>
<td>Linear, b/ Theil-Basmann</td>
<td>116.32</td>
<td>-.341</td>
</tr>
<tr>
<td></td>
<td>(.122)</td>
<td>(.112)</td>
<td></td>
</tr>
<tr>
<td>32.</td>
<td>Linear, b/ Theil-Basmann</td>
<td>94.49</td>
<td>-.287</td>
</tr>
<tr>
<td></td>
<td>(.091)</td>
<td>(.081)</td>
<td></td>
</tr>
</tbody>
</table>
The regression coefficients are deflated by the variables listed in table 6. The variables, in index form, corresponding to the general model of equation 1 are:

- $X_{1t}$: the average hired farm wage-rate for the United States.
- $X_{2t}$: the index of average prices received by farmers for all commodities for the United States.
- $X_{4t}$: the average value of farm machinery and equipment for the United States.
- $X_{5t}$: time as a linear variable.
- $Y_{1t-1}$: the number of hired workers lagged 1 year for the United States.

Linear refers to original observations introduced in models in linear form; log refers to observation in logarithmic form; reduced form and Theil-Basmann method refers to the techniques used to solve simultaneous equations. Equations 23, 24, 31 and 32 were estimated using autoregressive least-squares methods.

The number in parentheses is the standard error of the regression coefficient above it. No superscript of the regression coefficient indicates significance at the 5-percent level. The superscript c denotes that the regression coefficient is statistically significant at the 10-percent level. The regression coefficient is significant at the 20- to 40-percent level. The regression coefficient is significant only beyond the 40-percent level.

<table>
<thead>
<tr>
<th>Equation</th>
<th>Form</th>
<th>$X_{1t}$</th>
<th>$X_{2t}$</th>
<th>$X_{4t}$</th>
<th>$X_{5t}$</th>
<th>$Y_{1t-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>33</td>
<td>Linear, least squares</td>
<td>122.03</td>
<td>-0.458</td>
<td>0.119</td>
<td>-0.311</td>
<td>0.236</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.091)</td>
<td>(0.040)</td>
<td></td>
<td>(0.244)</td>
</tr>
<tr>
<td>34</td>
<td>Linear, least squares</td>
<td>98.22</td>
<td>-0.232</td>
<td></td>
<td>-0.120</td>
<td>0.530</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.081)</td>
<td></td>
<td>(0.325)</td>
<td>(0.491)</td>
</tr>
<tr>
<td>35</td>
<td>Linear, least squares, not distributed lag</td>
<td>153.23</td>
<td>-0.475</td>
<td>0.127</td>
<td>-0.492</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.178)</td>
<td>(0.031)</td>
<td></td>
<td>(0.504)</td>
</tr>
</tbody>
</table>
Table 6. Elasticities of demand for the demand functions for hired labor, United States.

<table>
<thead>
<tr>
<th>Equation number</th>
<th>Form and method</th>
<th>Deflator of the farm wage-rate variable</th>
<th>Elasticity of the farm wage-rate variable</th>
<th>Deflator of prices received variable</th>
<th>Elasticity of the prices received variable</th>
<th>Adjustment coefficient</th>
<th>Time variable included</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Short-run</td>
<td>Long-run</td>
<td>Short-run</td>
<td>Long-run</td>
<td></td>
<td></td>
</tr>
<tr>
<td>23....</td>
<td>Linear, least squares</td>
<td>-- a/</td>
<td>-.0529</td>
<td>-.1374</td>
<td>-.2376</td>
<td>-.6173</td>
<td>--</td>
</tr>
<tr>
<td>24....</td>
<td>Linear, least squares</td>
<td>-- a/</td>
<td>-.0627</td>
<td>-.1646</td>
<td>-.9092</td>
<td>-.2387</td>
<td>--</td>
</tr>
<tr>
<td>25....</td>
<td>Linear, least squares</td>
<td>-- b/</td>
<td>-.0576</td>
<td>-.1301</td>
<td>-.331</td>
<td>-.7747</td>
<td>-- c/</td>
</tr>
<tr>
<td>26....</td>
<td>Linear, least squares</td>
<td>-- b/</td>
<td>-.0718</td>
<td>-.1621</td>
<td>-.7574</td>
<td>-.1751</td>
<td>-- c/</td>
</tr>
<tr>
<td>27....</td>
<td>Log, least squares</td>
<td>-- b/</td>
<td>-.0953</td>
<td>-.0953</td>
<td>-.7365</td>
<td>-.7365</td>
<td>-- c/</td>
</tr>
<tr>
<td>28....</td>
<td>Linear, least squares</td>
<td>-- d/</td>
<td>-.0276</td>
<td>-.0663</td>
<td>-.1737</td>
<td>-.4173</td>
<td>-- e/</td>
</tr>
<tr>
<td>29....</td>
<td>Linear, least squares</td>
<td>-- e/</td>
<td>-.0245</td>
<td>-.0469</td>
<td>--</td>
<td>--</td>
<td>-- e/</td>
</tr>
<tr>
<td>30....</td>
<td>Linear, reduced form</td>
<td>-- b/</td>
<td>-.1261</td>
<td>-.2229</td>
<td>-.3683</td>
<td>-.6510</td>
<td>-- e/</td>
</tr>
<tr>
<td>31....</td>
<td>Linear, Theil-Basmann</td>
<td>-- b/</td>
<td>-.256</td>
<td>-.552</td>
<td>-.32</td>
<td>-.57</td>
<td>-- e/</td>
</tr>
<tr>
<td>32....</td>
<td>Linear, Theil-Basmann</td>
<td>-- b/</td>
<td>-.215</td>
<td>-.28</td>
<td>--</td>
<td>--</td>
<td>-- f/</td>
</tr>
<tr>
<td>33....</td>
<td>Linear, least squares</td>
<td>-- b/</td>
<td>-.4595</td>
<td>-.608</td>
<td>-.6010</td>
<td>-.795</td>
<td>-- f/</td>
</tr>
<tr>
<td>34....</td>
<td>Linear, least squares</td>
<td>-- a/</td>
<td>-.2517</td>
<td>-.4142</td>
<td>-.5351</td>
<td>-.8805</td>
<td>--</td>
</tr>
</tbody>
</table>
35.... Linear, least squares, not distributed lag  

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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<th>Yes</th>
</tr>
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<td></td>
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<td></td>
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<td></td>
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<td></td>
</tr>
</tbody>
</table>

- **a/** Index of average prices received by farmers, United States.
- **b/** Index of prices paid by farmers for living expenses, United States.
- **c/** Index of average farm machinery prices for the United States.
- **d/** Index of prices paid by farmers for production expenses, United States.
- **e/** Index of average farm machinery for the United States, lagged 1 year.
- **f/** Index of prices paid by farmers for production expenses, United States, lagged 1 year.
the results of the estimated equations while table 6 presents the elasticities of hired labor with respect to the variables indicated. The deflators of the farm wage-rate and prices received variables are listed in table 6. Wherever a space is blank, the corresponding variable was omitted from the model. These demand functions also refer to different time periods as shown. The forms and estimating methods include: (1) linear observations in all equations other than for equations 5, which is in logarithms; (2) least-squares method for equations 23 to 29 and 33 to 35, inclusive, and simultaneous-equation estimation by reduced forms for equation 30 and by the Theil-Basmann technique in equations 31 and 32; (3) autoregressive least-squares were employed for equations 23, 24, 31 and 32; (4) the variables of equations 25 and 28 were deflated by different deflators. All equations in table 5, other than 35, include a distributed lag.

Inclusion of additional independent variables

The price of hired labor, the farm wage-rate, was the principal explanatory variable in each equation. Inclusion of other variables in the specification of the model caused the values of the coefficients of the original variables to be altered substantially. The inclusion of time as a variable in the specification of the model caused the largest change in the value of the other coefficients. Equations 23 through 26 were estimated to allow comparisons with or without time and with or without prices received. The more apparent result of the inclusion of time as a variable is the effect on the size of the lagged dependent variable. The coefficients of the dependent variable lagged 1 year in equation 24 and 26, not containing time, are relatively high as compared to equations 23 and 25. The coefficients allow estimates of the adjustment coefficient and long-run elasticities of demand for hired labor. The estimated long-run elasticities of labor quantity in respect to farm wage-rate are high for equations 24 and 26 respectively, being -2.39 and -1.75 for 1957 in table 6. The long-run elasticities of equations 23 and 25 were considerably less than one. Hence, the time variable materially reduces the estimate of the long-run elasticity of demand quantity in respect to the price of hired labor.

The effect of adding the index of the value of farm machinery and equipment is demonstrated by equations 31 and 32 both estimated by ALS. The specification of both equations is identical except for the farm machinery variable in equation 32. The value of the regression coefficient for the time variable changed from -.687 to a significant -1.635 between equations 31 and 32 respectively. The value of the farm machinery variable, X4, is also significant at the 10-percent level of probability. Otherwise, the values of other regression coefficients were not substantially changed.
The effect of different deflators and form of equation

The effect of different deflators upon demand estimates is illustrated in the first six equations covering the period 1910-57. Only the long-run elasticities of hired-labor demand were substantially changed by the use of different deflators. However, the regression coefficient for the farm wage-rate was not statistically significant in equation 28 where the deflator was the index of prices paid for all production items.

Observations for the time variable were converted to logarithmic values, along with other variables, in equation 27. Since the time variable is significant in equation 27 at an extremely low level as compared to the other equations, we suppose the power function to be less appropriate than equations linear in form of observations. Aside from the time variable, there was little difference between coefficients of comparable equations using variables in logarithms or in linear form.

The effect of the assumption of an autoregressive scheme

Four hired-labor demand functions taken with a distributed lag were estimated initially using autoregressive least-squares (ALS). Because of the time and expense involved in performing the necessary iterations, not all of the equations could be estimated in this manner. The results of the ALS equations are presented in tables 5 and 6 as equations 23, 24, 31 and 32. Equations 23 and 24 are analyzed first. They cover the period 1910-57, and include the variables hired labor lagged 1 year and the farm wage-rate. In addition, equation 23 contains time as a trend variable.

Equation 24, the ALS equation which does not include time as a variable, may be compared with the ordinary least-squares equation using the same variables.35/

\[
\bar{Y}_{1t} = 11.97 + .9480\bar{Y}_{t-1} - .0783X_t \\
(.039) \quad (.037)
\]

35/ The regression coefficients are as defined under equations 1 and 2. The variable \(X_{1t}\) was deflated by the index of prices received by farmers for all commodities, United States. The notation of the significance levels of the regression coefficients are as defined under table 5.
The original equation (not ALS) corresponding to equation 23 in table 6 which included time as a variable was estimated as:

\[
\bar{Y}_{1t} = 29.02 - 0.8397\bar{Y}_{t-1} - 0.0530X_{t-1} + 0.2252X_{t-2}.
\]

The coefficients of the lagged dependent variables were highly significant in equations 36 and 37 as well as in equations 23 and 24. For the coefficients of the lagged variable in equations not including time as a variable, equation 36 has a coefficient of .948, while the corresponding ALS equation 24 in table 5 has a coefficient of .931. For the equations including time, 37 and 23, the coefficients of the lagged endogenous variable were .840 and .777, respectively. In both comparisons, the value of the lagged endogenous variable in the ALS equation was slightly less than in the ordinary least-squares equations. Concurrently, in the ALS equations, the coefficients of the farm wage-rate and time increased relative to their respective original non-ALS equations. The residual sums of squares in the ALS equations were reduced in both cases, from 461.4 to 441.9 for the equations containing time, and from 507 to 490 for the other two equations.

In summary, the slight differences between the ALS equations and the ordinary least-squares equations were: (1) the ALS equations reduced the residual sum of squares, implying a better "fit"; (2) the regression coefficients of the lagged endogenous variables in the ALS equations were lower with an accompanying shorter time period of adjustment; and (3) in the ALS equations, the regression coefficients of the other independent variables increased and became significant at lower probability levels. The long-run elasticities were less in the ALS equations because of the decrease in the value of the lagged coefficients.

The estimate of $\beta$, the autoregression coefficient, would be expected to decrease when a trend variable is included in the equation. However, in the case of equations 23 and 24 of table 5, the results were indeterminate. The estimated values of $\beta$ are the numerical coefficients in these two estimated equations.

---

36/ The regression coefficients are as defined under equations 1 and 2, with the notation of the significance levels as defined under table 5. The deflator of $X_{1t}$ is the index of prices received by farmers for all commodities, and $X_{2t}$ is deflated by the index of prices paid by farmers for living expenses, United States.

37/ See equation 17. The level of significance notation is as defined under table 5.
for equation 23, and:

\[(39) \quad u_t = 0.1710u_{t-1}^{e} (0.1328)\]

for equation 24. Neither of the estimates of \(\beta\) were significant at low probability levels, although the estimate of \(\beta\) in equation 38 was significant at the 10-percent level. Since the initial value of the coefficient of the lagged dependent variable in equation 24 approached one, it is possible that the autoregressive structure of the equation could not be adequately ascertained. Though the results indicated that the \(\beta\)'s are small, their statistical significance was such (along with the differences of the ALS equations as described above) that the ALS equations estimated for 1910-57 were preferred over the non-ALS equations.

Further comparison of the autoregressive assumption is made for hired-labor demand functions over the period 1929-57. Equation 30 of tables 5 and 6 was estimated by reduced form with no autoregressive assumptions. Equations 31 and 32 were estimated by the Theil-Basmann technique under the assumption of an autoregressive scheme. In equation 30, the regression coefficients for the farm wage-rate and prices received variables were nonsignificant. Both regression coefficients were significant in ALS equations 31 and 32. The adjustment coefficient in equation 30 is .34 but .79 and .76 respectively for ALS equations 31 and 32. Since the lagged endogenous coefficient "picks up" part of the residual term, the autoregressive assumption perhaps provides a better estimate of the adjustment coefficient. In this sense, equations 31 and 32 may serve most effectively in the analysis of demand for hired labor.

The estimated autoregressive coefficient, \(\beta\), of equations 31 and 32, respectively, is the numerical quantity in these two equations:

\[(40) \quad u_t = 0.753u_{t-1} (0.120)\]

\[(41) \quad u_t = 0.339u_{t-1}^{e} (0.326)\]

\[38/\] See footnote 37.
The estimate of $\beta$ for equation 31 was large and significant, while the value of $\beta$ for equation 32 was small though larger than its standard error. Evidently, the inclusion of the additional variable in equation 32 aided in the specification of the model, and reduced the value of $\beta$. We again conclude that the ALS equations are preferable to non-ALS equations when distributed lags are used. However, because of the time and costs involved in the ALS estimates, the autoregressive scheme was not assumed for other equations.

Analysis of the National Demand Functions for Hired Labor

Having appraised different techniques for estimation of hired labor demand functions in the preceding paragraphs, we now turn to an analysis of demand quantity and response relative to major variables.

Demand relative to farm wage-rate

The values of the single equation regression coefficient for the farm wage-rate estimated over the entire period, 1910-57, were low relative to their standard errors: the estimate in the six equations ranging in value from -.046 to -.122. For the linear equations 23, 25 and 28, including time as a variable, the regression coefficients of the farm wage-rate were significant at the 10-percent level in the first two and nonsignificant in the third. The 48-year period, however, stretches over a span of time when the structure of agriculture and labor demand changed greatly. For this reason, equations have been estimated for subperiods of this span. For the period 1920-39, the value of the wage-rate regression coefficient was -.054 and was not significantly different from zero (equation 29 in table 5). This lack of significance may not have great importance, however, since the period included was one of agricultural recession. In the 1940-57 period, a period of relative prosperity in agriculture, single-equation regression coefficients for the price of farm labor in equations 33, 34 and 35 (table 5) ranged from -.232 to -.475 and were significant at a probability level of 5 percent or lower. Significant response of demand for labor in respect to the price is indicated in this period. Lack of significance of the wage-rate regression coefficient for the over-all period, 1910-57, then, does not accurately reflect the response of labor demand for intervening periods. The 1910-57 period combines periods both of great depression and great prosperity, as well as periods varying greatly in the structure of technology.

This conclusion also tends to be substantiated for estimates over a shorter period by means of simultaneous-equation methods for the period 1929-57. The "system of equations" demand function for hired labor are equations 30, 31 and 32 in table 5. The regression coefficient
of the farm wage-rate for equation 30 was -.168, but nonsignificant. The corresponding regression coefficients for the demand functions 31 and 32, estimated under the assumption of autocorrelated errors, were -.341 and -.287, respectively. The coefficients were significant at the 1-percent level. These results correspond with the findings of the demand functions for the shorter period 1940-57; demand for hired labor is indicated as responsive to 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 of the observations and for 1957 are presented in table 6.

**Price elasticities of demand**

For equations 23 through 28, estimated over the period 1910-57, the short-run price elasticities (labor demand with respect to farm wage-rate) at the mean of the observations ranged from -.03 to -.09. Basically, the price elasticities for the over-all period were low.

The short-run price elasticities taken at the mean observation for the 1929-57 period ranged from -.13 to -.26. For the 1940-57 period, the short-run elasticities at the mean ranged from -.25 to -.48. These statistics suggest that the short-run elasticity of labor demand with respect to farm wage-rate has been increasing, although it has remained considerably smaller than unity.

Long-run price elasticities of demand also were derived and are included in table 6. In a distributed lag equation, the long-run elasticity depends on the size of the adjustment coefficient. The adjustment coefficients for the six demand functions covering the 1910-57 period ranged from .05 to .22. Correspondingly, the long-run price elasticities (demand quantity relative to wage-rate) at the mean ranged from -.17 to -.90 for the six equations. (In comparison, the short-run elasticities for the same period ranged from -.03 to -.09.) With the assumption that the errors in the equations followed an autoregressive scheme, the long-run demand elasticities for equations 23 and 25 were -.24 and -.33, respectively. The long-run price elasticities at the mean observation for the 1929-57 period ranged from -.28 to -.36. For the 1940-57 period, they ranged from -.53 to -.60. These results again suggest a higher level of response of labor demand relative to the farm wage-rates with time.

**Demand relative to farm product prices**

The cross-elasticity of demand of the size of the hired labor force with respect to the index of prices received indicates the responsiveness
of the demand for hired labor to changes in agricultural product prices. The series, deflated by an index of prices paid for production expenses, relates product prices to factor costs and serves as an indicator of the relative profitability of farming. The deflator of the index of prices received for each equation is listed in table 6. The index of prices received has been lagged 1 year in all of the hired-labor demand functions other than those for the period 1910-57. Farmers react to product price changes in the previous year, since the present year's price is known relatively late in the year.

In general, the regression coefficients relating hired-labor demand to prices received were significant at acceptable levels of probability for the several time periods analyzed. Similarly, the signs of the regression coefficients were positive for all equations and all time periods. We conclude that the demand for hired farm labor has been responsive to farm product prices and the profitability of farming in all of the time periods analyzed.

The cross elasticities of labor demand with respect to farm product prices again were considerably higher for the long-run as compared to the short-run. This difference is, of course, consistent with the original hypothesis that time is required before farmers can change the organization of their farms and increase resource inputs in response to more favorable product prices. The long-run elasticity is much less than unity, however, for all time periods and equations or estimating techniques. Elasticities of less than unity for labor or resource demand are expected when the production function elasticity is less than 1.0. Periods of increasing product prices also have been those of increasing wage-rates; the effect of the former on labor demand being somewhat offset by the latter. Neither the short-run or long-run cross elasticities show an upward trend with time period (as in the case of elasticities with respect to farm wage-rate).

Demand in relation to farm machinery inventory

As explained under model specification, the value of farm machinery and equipment in January, was constructed and added to equation 32 of table 5 for the period 1929-57. The equation was estimated using the ALS method so that, except for the farm machinery variable, equation 32 was specified the same as equation 31. 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 positive and significant at the 5-percent level, and has a short-run elasticity at mean observation of .13. As the scale of farming (size of farms) has increased, the number of hired workers has increased. This result could bear closer examination on a less aggregated level.
EMPIRICAL ESTIMATES OF THE REGIONAL DEMAND FOR HIRED LABOR

In addition to the demand functions for hired labor derived for the United States, 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 the national analysis. We wish to examine differential response in labor demand among regions. 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 derived for hired labor in each of nine geographic regions are presented in table 7. (The regions are presented in map form in fig. 5.) Given the hypothesis that the variables affecting the regional demand for hired labor are the same as those affecting national demand, the specification of the regional equations is essentially the same as the national equations. 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 were estimated by single-equation least-squares methods. The time period covered was 1929-57, except for three of the regions. Estimates for the Mountain, Pacific and West North Central regions were made for the more recent time periods listed in table 7. For these regions, the regression coefficients for the whole period were either inconsistent in sign or nonsignificant.

All relevant regional data are included in table 7. The coefficient of determination, R^2, is high for each region. It ranges from .839 in the Pacific region to .986 in the West North Central region. Tests for serial correlation in the residuals were not made.

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

The order of presentation for the regional demand functions for hired labor is: First, the significance of the farm wage regression coefficients will be analyzed. Second, the short- and long-run elasticities will be compared. Third, the parity ratio will be examined as it relates to the demand for hired labor. Finally, the time trend will be evaluated.
Table 7. Regression coefficients, standard errors, and elasticities of the demand functions for hired labor for the nine geographic regions.

<table>
<thead>
<tr>
<th>Equation number</th>
<th>Time period</th>
<th>Region</th>
<th>$\bar{Y}_{1t-1}$</th>
<th>$X_{1t}$</th>
<th>$X_{2t}$</th>
<th>$X_{3t}$</th>
<th>$X_{4t}$</th>
<th>$R^2$</th>
<th>Adjustment coefficient</th>
<th>Elasticities (mean)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Farm wage-rate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Short-run</td>
<td>Long-run</td>
</tr>
<tr>
<td>42....</td>
<td>1929-57</td>
<td>NE</td>
<td>.721*</td>
<td>-.031%</td>
<td>--</td>
<td>-.457</td>
<td>.945</td>
<td>.28</td>
<td>-.05</td>
<td>-.17</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MA</td>
<td>.750</td>
<td>-.343</td>
<td>32.2</td>
<td>-.201%</td>
<td>.967</td>
<td>.25</td>
<td>-.19</td>
<td>-.75</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ENC</td>
<td>.830</td>
<td>-.440</td>
<td>.101</td>
<td>.132%</td>
<td>.980</td>
<td>.17</td>
<td>-.15</td>
<td>-.90</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WNC</td>
<td>.278</td>
<td>-1.06</td>
<td>.101</td>
<td>-.659%</td>
<td>.986</td>
<td>.72</td>
<td>-.51</td>
<td>-.71</td>
</tr>
<tr>
<td>47....</td>
<td>1929-57</td>
<td>SA</td>
<td>.615</td>
<td>-.862%</td>
<td>-2.25%</td>
<td>-.921%</td>
<td>.933</td>
<td>.39</td>
<td>-.12</td>
<td>-.32</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ESC</td>
<td>.573</td>
<td>-1.71</td>
<td>83.7</td>
<td>-.251%</td>
<td>.955</td>
<td>.43</td>
<td>-.35</td>
<td>-.82</td>
</tr>
<tr>
<td></td>
<td></td>
<td>WSC</td>
<td>.612</td>
<td>-1.59</td>
<td>94.0</td>
<td>-.127%</td>
<td>.930</td>
<td>.39</td>
<td>-.26</td>
<td>-.67</td>
</tr>
<tr>
<td>49....</td>
<td>1940-57</td>
<td>MTN</td>
<td>.351%</td>
<td>-1.137%</td>
<td>2.34%</td>
<td>-2.12%</td>
<td>.906</td>
<td>.65</td>
<td>-.11</td>
<td>-.18</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PAC</td>
<td>.299</td>
<td>-.356%</td>
<td>--</td>
<td>-.216</td>
<td>.839</td>
<td>.70</td>
<td>-.19</td>
<td>-.27</td>
</tr>
</tbody>
</table>

a/ The regression coefficients are:

$\bar{Y}_{1t-1}$: the number of hired workers for each region, lagged 1 year.

$X_{1t}$: the average hired farm wage-rate for each region, deflated by the index of prices paid by farmers for living expenses, United States.

$X_{2t}$: the regional parity index, which is the ratio of the index of prices received by farmers for all commodities for each region to the index of prices paid by farmers for production expenses, interest, taxes and wages, United States, (as computed for a "typical" state within each region).

$X_{5t}$: time (linear).
The identifying letters under the "Region" heading stand for the nine regions depicted in fig. 3 as follows: NE, New England; MA, Middle Atlantic; ENC, East North Central; WNC, West North Central; SA, South Atlantic; ESC, East South Central; WSC, West South Central; MTN, Mountain; PAC, Pacific.

The significance levels of the regression coefficients are as indicated in table 5; no superscript on the coefficients indicates significance at the 5-percent level. The superscript c indicates significance at the 10-percent level.

Indicates significance at the 20- to 40-percent level.

Indicates significance only beyond the 40-percent level.
The farm wage-rate

Paralleling the demand functions for the United States, the important independent variable in the regional functions is the farm wage-rate. The regression coefficients for the farm wage-rate were significant at the 5-percent level or better in five of the nine regions. Regression coefficients for the farm wage-rate were consistently negative in sign. The short-run elasticities of labor quantity in respect to wage-rate varied from -.05 in New England to -.51 in the West North Central region. Disregarding the elasticities derived from regression coefficients at low significance levels, the range was from -.15 to -.51.

The regions in which regression coefficients of the wage-rate variable were significant at low levels included New England, South Atlantic, Mountain and Pacific. The South Atlantic and Pacific regions use a large number of seasonal hired workers. These workers commonly are paid by piece rates, a type of wage not included in the reported farm wage-rate. Hence, the reported regional wage-rates may not have been as appropriate in these two regions, as for other regions.

Long-run elasticities of the price variable also were estimated for each region. Excluding estimates for regression coefficients at low levels of significance, the long-run elasticities of demand in respect to wage ranged from -.67 to -.90. Similar to the long-run price elasticities for the national demand functions, the long-run price elasticities were less than unity but much larger than the short-run elasticities.

The parity ratio variable

The ratio of the index of prices received by farmers for all commodities to the index of prices paid by farmers for production expenses, interest, taxes and wages, called the parity ratio, was used as the indicator of farming profitability for the regions. 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 computed for a typical state in each region. The ratio could not be computed for a state of the New England or Pacific regions because data were not available for the desired years.

The regression coefficients for the parity ratio variable were significant at the 5-percent level of probability in four of the regions, only beyond the 40-percent level in three, while the data were not available in two regions. The regions with regression coefficients significant at low probability levels were East North Central, South Atlantic and Mountain. For regions with regression coefficients significant at the 5-percent level of probability, the short-run cross elasticities estimated at the mean observation ranged
from .16 to .36. The long-run cross elasticities for these four regions ranged in value from .50 to .68. While the cross elasticities for the parity ratio variable were less than 1.0 in the long-run, they again were much larger than the short-run elasticities.

The trend variable as an indicator of technological change

Time as a variable was included in each of the regional hired labor demand functions as a technology variable and to complete the specification. This variable was significant at the probability level of 5-percent in only one region, the Pacific region. Consequently, the time variable is not considered to be a reasonable indicator of changes in technology by region.

Family workers do not comprise a homogeneous group; to qualify as a family worker they must: (1) be a member of the operator's family; and (2) have done 15 or more hours of farm work during the survey week. This group of men, women and children may respond diversely to economic stimuli. In this section we are testing this response with a simple hypothesis.

The adjustment coefficients, which differentiate the magnitude of short-run and long-run elasticities, 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 is the slope of the time path of adjustment. The results suggest that the New England, Middle Atlantic and East North Central regions have been slower than other regions in adjusting to sustained price changes.

EMPIRICAL ESTIMATES OF DEMAND FUNCTIONS FOR FAMILY LABOR

An analysis of hired labor is not sufficient for a complete understanding of the total farm labor market. Hence, this section presents the quantitative analysis of the demand for family labor, both nationally and regionally.

The underlying hypothesis, consistent with the demand functions previously estimated for hired labor, is: the demand for family labor is responsive to (a) the hired farm wage-rate as an indicator of the price of family labor, and (b) to the index of prices received by farmers for all commodities as 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, along with the two price variables. In the model specification, the question arose as to the type of data that could adequately represent the "price" of family
The net return to the labor of a farm operator and his family is difficult to ascertain. Some economists argue that the hired farm wage-rate is the indication of the wage accruing to family labor. For lack of a better indication of the return to family labor and to preserve comparability between hired and family labor estimates, the hired farm wage-rate is used as the "price" of family labor.

A demand function for total farm labor also was specified and estimated, as a means for comparison with the family labor demand functions. The model for total farm employment differed slightly from the general model in equations 1 and 2. It contained the following variables: the ratio of the farm wage-rate to the index of prices received, time, the index of the value of farm machinery deflated by the index of prices paid for living expenses by farmers, and the ratio of the farm wage-rate to farm machinery prices. The results of this equation are presented at the end of this section and will be compared to results obtained from a similar family labor demand function.

National Family Labor Demand Functions

The family labor demand functions for the United States are included in table 8 as equations 51 through 54. The predicted quantities for two of the family labor demand functions are plotted against the actual numbers of family workers in figs. 9 and 10. As indicated by these figures, the functions for the more recent period, 1940-57, fit the data better than those for the over-all period, 1910-57.

All regression equations presented are general single-equation least-squares estimates and are similar in specification for the different time periods. The sole difference between the equation is: the farm wage-rate is lagged one year in equations 51 through 53. Since the number of family workers changes slowly over time, and because of estimation problems, the possibility of correlation in the residuals is an important question for family labor. As an indication of correlation in the residuals, the d statistic for the Durbin-Watson test was computed for each of the four equations. Two of the equations showed positive serial correlation, while the other two were indeterminate.

41/ Durbin, op. cit.
Table 8. Regression coefficients and elasticities for the demand functions for family labor, United States and nine geographic regions.

<table>
<thead>
<tr>
<th>Equation number</th>
<th>Time period</th>
<th>Region</th>
<th>Regression coefficients</th>
<th>Elasticities</th>
<th>$R^2$</th>
<th>$d'$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>$\hat{Y}_{t-1}$</td>
<td>$X_{1t}$</td>
<td>$X_{2t}$</td>
<td>$X_{4t}$</td>
</tr>
<tr>
<td>51.</td>
<td>1910-57</td>
<td>U.S.</td>
<td>--</td>
<td>-.300</td>
<td>.040 $e$/</td>
<td>--</td>
</tr>
<tr>
<td>52.</td>
<td>1920-39</td>
<td>U.S.</td>
<td>--</td>
<td>-.932</td>
<td>-.168</td>
<td>--</td>
</tr>
<tr>
<td>53.</td>
<td>1940-57</td>
<td>U.S.</td>
<td>--</td>
<td>-.139 $d$/</td>
<td>.313</td>
<td>--</td>
</tr>
<tr>
<td>54.</td>
<td>1940-57</td>
<td>U.S.</td>
<td>--</td>
<td>-.787</td>
<td>.409</td>
<td>--</td>
</tr>
<tr>
<td>55.</td>
<td>1940-57</td>
<td>NE</td>
<td>.971</td>
<td>-.167 $d$/</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>56.</td>
<td>1929-57</td>
<td>MA</td>
<td>.908</td>
<td>-.303 $d$/</td>
<td>.318 $d$/</td>
<td>--</td>
</tr>
<tr>
<td>57.</td>
<td>1929-57</td>
<td>ENC</td>
<td>.263 $d$/</td>
<td>-2.71</td>
<td>1.93</td>
<td>--</td>
</tr>
<tr>
<td>58.</td>
<td>1929-57</td>
<td>WNC</td>
<td>--</td>
<td>-.155 $e$/</td>
<td>--</td>
<td>-12.2</td>
</tr>
<tr>
<td>59.</td>
<td>1929-57</td>
<td>SA</td>
<td>.859</td>
<td>.605 $e$/</td>
<td>.426 $e$/</td>
<td>--</td>
</tr>
<tr>
<td>60.</td>
<td>1929-57</td>
<td>ESC</td>
<td>--</td>
<td>-1.32 $e$/</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>61.</td>
<td>1929-57</td>
<td>WSC</td>
<td>--</td>
<td>-1.52 $e$/</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>62.</td>
<td>1929-57</td>
<td>MTN</td>
<td>.974</td>
<td>-.096 $d$/</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>63.</td>
<td>1947-57</td>
<td>PAC</td>
<td>.110 $e$/</td>
<td>-.085 $e$/</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

---

1/ The regression coefficients are:

- $\hat{Y}_{t-1}$: the number of family farm workers for the United States or by region as indicated, lagged 1 year.
- $X_{1t}$: the average hired farm wage-rate for the United States or by region indicated, (lagged 1 year in equations 51 to 53).
- $X_{2t}$: the index of prices received by farmers for all commodities, United States for the national estimates, and the parity ratio for each region as explained under table 7, lagged 1 year.
- $X_{4t}$: The value of the stock of farm machinery and equipment, United States and regionally, as indicated.
- $X_{5t}$: time entered in linear form.

For the national estimates, $X_{1t}$, $X_{2t}$ and $X_{4t}$ were deflated by the index of prices paid by farmers for production expenses, United States; for the regional estimates $X_{1t}^*$ and $X_{4t}^*$ were deflated by the regional index of prices paid by farmers for living expenses.
b/ The identifying letters under the "Region" heading stand for the nine regions depicted in fig. 3 and explained under table 7.
c/ The significance levels of the regression coefficients are as indicated in table 5; no superscript on the coefficients indicates significance at the 5-percent level; the superscript c indicates significance at the 10-percent level.
d/ Significance at the 20- to 40-percent level.
e/ Significance only beyond the 40-percent level.
f/ The results of the Durbin-Watson test for serial correlation for the four conventional least-squares equations are indicated by either sc (serial correlation likely) or i (indeterminate).
Fig. 9. Actual and predicted number of family farm workers in the United States, 1910-57 (by demand function 51 of table 8). Actual numbers: the solid line.
Fig. 10. Actual and predicted number of family farm workers in the United States, 1940-57 (by demand function 54 of table 8). Actual numbers: the solid line.
even though time was included as a trend variable and was significant in all of the equations. Other techniques to eliminate serial correlation were not performed because of lack of time and finances.

Family labor demand in relation to the wage-rate

Three of the four coefficients relating family labor employment to the farm wage-rate were significant at a probability level of 5 percent with coefficients ranging in value from -.30 to -.93. There is some theoretical basis for lagging the wage-rate in general least-squares equations. However, no advantage is indicated for regression equations over the period 1940-57. For this period, equation 53 contained the wage-rate lagged 1 year, while it was not lagged in equation 54. The regression coefficient in equation 54 was larger relative to its standard error than that of equation 53.

The demand for family labor is indicated to be responsive to changes in the farm wage-rate. While all were inelastic, the price elasticities for the first three farm wage-rate variables were similar of magnitude. The elasticity for 54 was somewhat larger. For the overall period, 1910-57, given a 10-percent increase in the farm wage-rate, *ceteris paribus*, the equations indicate an accompanying decrease in the demand for family labor ranging from 1.4 to 4.1 percent. The regression coefficients and elasticities over time appear to have increased some with time.

Family labor demand in relation to farm product prices

The response of family labor demand to prices received differed considerably for the time periods analyzed. For the period, 1910-57, the regression coefficient and cross elasticity of demand approached zero. The regression was not significant at an acceptable probability level. For two intervening periods, the signs of the regression coefficients were different. The regression coefficient for the prices received variable was negative for the 1920-39 period and positive for the 1940-57 period. Further, both coefficients were statistically significant. For the 1920-39 period, equation 52, a 10-percent increase in the index of prices received for all commodities, other things being equal, was associated with a decrease of 1.6 percent in the number of family workers. There was some increase in the number of family workers over the entire period, along with a 10-percent decrease in the index of prices received. The depression, with a consequent lack of nonfarm opportunities, led to this situation during the 1930's. For the more recent period, 1940-57, as the index of prices received rose 10 percent, other things being equal, the demand for family workers decreased 3.5 percent. Since this period was one in which considerable off-farm work could be secured, the sign of the elasticity was also 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, 1910-57, for comparison with the demand functions for family labor alone. The demand for total farm labor is formulated to be a function of the index of the farm wage-rate deflated by the index of farm machinery prices and lagged one year ($X_{8t-1}$), the value of the stock of farm machinery deflated by prices paid by farmers lagged one year ($X_{4t-1}$), time ($X_5$) and the farm wage-rate deflated by the index of prices received by farmers for all commodities ($X_{7t-1}$). The estimated total farm employment demand function is:

\[
Y_{lt} = 156.14 - 0.205X_{7t-1} - 0.700X_{4t-1} + 0.142X_5
\]

The coefficient of determination for this equation is .95. In order to compare the results of the demand for total farm employment with a demand function for family labor, a demand equation for family labor was similarly estimated for the 1910-57 period. The resulting equation is:

\[
Y_{2t} = 153.89 - 0.0821X_{d} - 0.4338X_{4t-1} + 0.1716X_5
\]

The regression coefficients are as defined under equations 1 and 2, with the notation of the significance levels as defined under table 5. The variables $X_{lt}$, $X_{4t}$ and $X_{7t}$ are lagged one year. The variable, $X_{7t}$, is the average hired farm wage-rate relative to the index of prices received by farmers for all commodities, United States, and the deflators of $X_{lt}$ and $X_{4t}$ are the indices of farm machinery prices, United States, and prices paid by farmers for production expenses, United States, respectively.

The regression coefficients and notation of significance levels are the same as those defined in footnote 42.
The coefficient of determination is .86 for equation 65.

An apparent similarity of the two demand functions, equations 64 and 65, suggests that demand functions derived for family labor may be interpreted to apply to all farm labor. While differences do exist between the two equations, the coefficients lead to similar elasticity estimates. As the variable of "farm wage-rate relative to prices received" rose by 10 percent, there were corresponding decreases in the total farm working force of 1.6 percent and in the family labor force of 1.5 percent. (Both of the corresponding regression coefficients were significant at the 5-percent level.) Hence, response in demand for total and family labor to changes in the price of farm labor relative to farm output price was similar for the two functions.

The farm machinery variable, \( X_4 \), indicates the response of farm labor to additions in farm machinery in the previous year. As the investment in farm machinery rose by 10 percent in the past, there was a concurrent decrease of 3.1 percent in the total farm labor force, and 1.9 percent decrease in the family labor force. (Both of the corresponding regression coefficients were significant at the probability level of 5 percent or smaller.)

The demand for total and family labor responded somewhat differently to changes in the variable, \( X_1 \), relating farm wage-rates to farm machinery prices. However, the regression coefficients in both equations were nonsignificant at the 20-percent probability level. 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 labor groups.

On the basis of similarity of the demand functions in equations 31 and 32, the equation for family labor dominates the equation for total farm labor. Dissimilarity is suggested only for the variable representing machinery expenditure.

The Regional Demand Functions for Family Labor

Regional demand functions for family labor are presented in table 8 as equations 55 through 63. The demand functions for family labor for the regions first were initially estimated by general least-squares methods. Because of inconclusive results in these first equations, distributed lag models were then applied for some regions. Since the distributed lag equations generally failed to improve the level of significance of the regression coefficients, demand equations using this model were not estimated for the remaining regions.
Analysis of the regional demand functions for family labor

The regression coefficients for the farm wage-rate variables ranged from -2.71 to .605 among regions. Only one of the regression coefficients was significant at the 5-percent level, however, and only in the distributed lag equations were the coefficients significant even at the 30-percent level. (Three regions had regression coefficients larger than their standard errors.) The regional demand functions would indicate that the family labor force by regions 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; the price elasticity being -.207. Since the other regression coefficients were not statistically significant, price elasticities were not derived for them.

The parity ratio was included as a variable in three of the regional demand functions. Of the three regions, its regression coefficient was significant at the 5-percent level in the East North Central, 20- to 40-percent probability level in the Middle Atlantic, and significant only beyond the 40-percent level in the South Atlantic region. Because the parity ratio was included in only three of the nine regional demand functions for family labor, particular analysis is not made for this variable in the Northeastern region.

The third variable included in the regional demand functions for family labor was time in linear form. The time variable was significant at the 5-percent 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 was nonsignificant, three of the equations were estimated by a distributed lag model; the lagged variable being significant at the 5-percent level of probability. These results suggest that, aside from the farm wage-rate and the parity ratio, relevant variables with influences on the regional demand for family labor were not included in the equations. The significance of the trend variable in the regional demand functions for family labor also suggest an incomplete specification of the model.

Why are the coefficients for the United States demand functions for family labor significant while the corresponding regional coefficients generally are not significant? A possible answer may lie in the dominance of the trend variable in the 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 yeat-to-year changes into greater prominence. (We should also note that the time periods covered by the regional and national demand functions are different.) Also, we believe that the dominant force explaining the magnitude of family labor employment is the availability of nonfarm
jobs. In general, rapid migration of family workers has taken place in periods of ample nonfarm employment opportunities, even though the return to labor in agriculture has been high, or has temporarily increased relative to nonfarm wage returns. In contrast, migration has been low during periods of national unemployment, even though returns in agriculture declined. Finally, technological change has been a rather continuous and "smooth" function of time, as has migration of family labor from farm, causing complexities in relating demand for family labor with the price magnitudes mentioned in the previous section. We analyze the effect of employment opportunity or magnitude of the farm labor force in a subsequent section.

EMPIRICAL ESTIMATES OF NATIONAL SUPPLY FUNCTIONS FOR FARM LABOR

This section includes empirical estimates of supply functions for hired and family labor in the United States. As given earlier in the study, the hypothesis tested was that the supply of farm labor is responsive to changes in the farm wage-rate and the nonfarm wage-rate. This hypothesis relates to quantification of the "push-pull" migration theory: the assumption that the rate of off-farm migration, which directly affects the supply of farm labor, is subject more to the "pull" of nonfarm wage-rates and employment opportunities than to the "push" of the introduction of labor-saving machinery and techniques.  

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 United States

The supply functions for hired labor were estimated from a system of equations, one estimated by reduced form method, and the other

estimated by the Theil-Basmann technique. In addition, the supply function derived by the Theil-Basmann method was estimated using auto-regressive least-squares equations.

The method of presentation of this section differs from that used in preceding sections: the analysis proceeds by type of equation, rather than by variable. A comparison of regression coefficients and elasticities estimated in this study and in other studies concludes the section.

A just-identified (reduced-form) supply function for hired labor

A two-equation just-identified system of equations was utilized initially to estimate a supply function for hired labor. The just-identified demand function of this system for hired labor was presented as equation 30 of table 5. The corresponding supply function of the system is estimated as equation 66 where the coefficient of adjustment is $\theta = 0.185$:

$$\bar{Y}_{2t} = 22.869 + 0.8145\bar{Y}_{2t-1} + 0.1757X_{1t} - 0.3654X_5 - 0.1036X_6t.$$  

The composite nonfarm wage variable was described in the chapter on model specification: $A$ is the average hourly earnings of the factory workers, and $U$ is the percentage total unemployment. The model supposes that when unemployment rises to 20 percent, the nonfarm wage-rate has zero effect in pulling labor from farms. The standard error of the regression coefficients were not estimated because the Theil-Basmann estimates presented elsewhere contain standard errors and because of the added cost of computing them.

The signs of the regression coefficients appeared are consistent with theory and the hypotheses underlying the estimates. The elasticity of supply quantity with respect to the farm wage-rate is estimated at $0.13$ in the short-run and $0.71$ in the long-run. In the past, as the farm wage-rate has increased by 10 percent, ceteris paribus, there has been a corresponding rise of 1.3 percent in the supply of hired labor in the short-run and 7.1 percent in the long-run period. In other words, the long-run elasticity is predicted to be more than five times the short-run elasticity.

The regression coefficients are as defined under equations 1 and 2. The variable, $X_{1t}$, is deflated by the index of prices paid by farmers for living expenses.
The cross elasticity of supply quantity with respect to the non-farm wage-rate variable is predicted as -0.06 in the short-run and -0.31 in the long-run. With an increase of 10 percent in the nonfarm wage-rate variable in the past, there has been an accompanying decrease in the supply of hired labor of 0.6 percent in the short-run and 3.1 percent in the long-run. Again, the long-run elasticity is predicted to be more than five times the short-run elasticity.

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

A two-equation system also was used in estimating a supply function for hired labor by autoregressive least-squares methods. The variables included in the system of equations are the same as those used in the just-identified system, except that the nonfarm variable was lagged one year for the former. The demand function estimated from this equation system was presented in table 5 as equation 31.

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 with successive iterations, rather than following a converging sequence. The source of the trouble evidently was the failure of the demand shifter, the prices received variable, to provide sufficient identification of the supply function. Hence, use of another demand shifter was deemed necessary to derive a satisfactory supply function for hired labor. 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 was identified and is presented as equation 67:

\[
(67) \quad \bar{X}_{2t} = 140.95 + 0.4862\bar{Y}^{d}_{2t-1} + 0.166X^{e}_{5t} - 0.8548X^{d}_{5t} - 1.1411X^{d}_{6t-1}
\]

\[
(0.357) \quad (0.237) \quad (0.574) \quad (0.095)
\]

46/ An equation specified like the supply function in equation 66 is insufficiently identified when the autoregressive assumption is applied.

47/ The regression coefficients and significance level notations are as defined for equation 66, except \(X_{6t}\) is lagged one year.
The value of \( R^2 \) for this equation is .974, while the adjustment coefficient is .51. The signs of the regression coefficients are consistent with theory and expected effect of the variables. The coefficients of the wage-rate, \( x_{1t} \), and the composite nonfarm wage-rate variable, \( x_{3t} \), are of magnitude similar to those in equation 66. The coefficient of the farm wage-rate variable is smaller than the corresponding standard error and the remaining coefficients are significant at the 20-percent level. Since autoregressive least-squares equations were used, the estimate of \( \beta \), the autoregressive coefficient, has the numerical value of .5155, and with its standard error, .3305, is significant at the 20-percent level.\(^{48/}\)

The corresponding elasticity of supply quantity with respect to the farm wage-rate is estimated at .13 in the short-run and .24 in the long-run. In the past, then, the supply response to an increase in the farm wage-rate has been twice as great in the long-run as in the short-run, other things being equal -- if we are willing to accept the regression coefficients which are small relative to their standard errors.

The supply elasticity of the composite nonfarm wage-rate variable \( A(1 - 5U) \) is estimated at -.078 in the short-run and -.15 in the long-run. Again, however, the regression coefficient of this variable is significant at only the 20-percent level.

A comparison of regression coefficients for the supply of hired labor

The results of the supply functions for hired labor may be compared with the results of Schuh.\(^{49/}\) At the time the estimates reported in this study were being made, a parallel set was being estimated by Schuh. The two sets of estimates were made independently with lack of knowledge of the simultaneous efforts. Schuh was primarily interested in supply estimation and derived his supply function by the Theil-Basmann method. The variables used in his supply functions were the farm wage-rate, nonfarm earnings, unemployment, and the civilian labor force. The time period was the same, 1929-57. Schuh did not utilize autoregressive least-squares equations in his supply functions.

The short-run elasticities of hired labor supply with respect to the farm wage-rate were similar between the two studies. Schuh's estimates ranged from .07 to .20, while for equation 67, the estimate was .125. The large differences arose in the long-run estimates. The estimated long-run price elasticity of supply was .24 for equation 67 using ALS, .71 for equation 66, and from .32 to 2.03 for Schuh's

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\(^{48/}\) See equation 17.
\(^{49/}\) Schuh, op. cit.
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 67 permits a lower estimation of the coefficient of the lagged endogenous variable, which in turn, results in a corresponding higher adjustment coefficient and lower long-run elasticity.

The nonfarm wage-rate variable was not directly comparable with the estimate of Schuh. He employed nonfarm earnings and unemployment as separate variables. However, the effects of these variables may be compared indirectly. The estimates of the regression coefficients of equations 66 and 67 were similar; in the short-run of elasticity of labor quantity relative to the nonfarm wage-rate variable was -.057 for equation 66 and -.078 for equation 67. The corresponding short-run elasticity of Schuh's estimates were higher, averaging -.46. In the long-run, since Schuh's estimated adjustment coefficients were very low, the elasticities of his nonfarm earnings variable ranged from -2.14 to -4.67. The corresponding elasticities in the long-run for equations 66 and 67 were -.31 and -.15. Though the variables are not directly comparable, the choice and form of variables used by Schuh and ourselves probably account for the wide range of long-run estimates of elasticities, from inelastic to highly elastic for his, and the smaller range for our estimates. 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.)

In general, the estimates of the supply function for hired labor are consistent with theory and expected "real world" effects of relevant variables: Variables which are assumed to affect the supply of farm labor were included in the specification; the effect of the farm wage-rate and a composite nonfarm wage-rate variable were tested; and the function was modified by an autoregressive scheme. While the focus of this study was on labor demand, the supply estimates, even though including coefficients with relatively large standard errors, provide information necessary in analysis of the quantity of labor employed in agriculture.

The Estimation of a Supply Function for Family Labor for the United States

The analysis of the supply functions for hired labor does not necessarily reflect the relationship of the variables specified to the supply quantity of all farm labor. Hence, a supply function for family labor for the United States also was estimated. With no previous quantitative analysis for family labor, the hypotheses adopted were the same as those for hired labor. Thus, the supply function for family labor was specified with the same variables as for hired labor, except
that the nonfarm wage-rate variable was included for the present year and lagged 1 year. The estimating technique again was 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 first, and will be followed by the analysis of net farm migration.

The supply function for family labor in the United States

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 $\beta$. However, the regression coefficients of the farm wage-rate and nonfarm 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:

$$\hat{y}_{2t} = 1.08x_{1t} - .079x_{6t-1} + .52y_{6t-1}$$

The regression coefficients of equation 68 were "consistent" in sign, and had significance levels as follows: The variables for the composite nonfarm wage-rate lagged one year, time and the family labor force lagged one year were significant at the 20- to 40-percent probability level, while the farm wage-rate and nonfarm wage-rate (for the present year) were significant only beyond the 40-percent level. The autoregression coefficient, $\beta = .65$, was not significant at the 20-percent level. Upon the completion of the next iteration, 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. Nonsignificant results (i.e., not significant at the 40-percent probability level) were obtained both for

50/ The regression coefficients are as defined under equations 1 and 2, with the notation of the significance levels as defined under table 5. The variable $X_{6t-1} = X_{6t}$ lagged one year.
the farm wage-rate and for the nonfarm wage-rate variables. The 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, 1929-57, by ordinary least-squares methods. In these equations, coefficients for the nonfarm wage-rate and the percentage of unemployment were estimated separately. The resulting supply functions are presented below, with the observations measured as deviations from the mean:

\[
\hat{y}_{2t} = 0.136x_{1t} - 0.408x_{5t} - 0.152x_{7t} + 0.139x_{8t} + 0.773\hat{y}_{2t-1}
\]

\[
\hat{y}_{2t} = 0.132x_{1t} - 0.405x_{5t} - 0.149x_{7t} + 0.135x_{8t} + 0.774\hat{y}_{2t-1}
\]

where equation 69 was estimated from a system of equations and equation 70 was estimated singly. The farm wage-rate coefficients of equations 69 and 70 are similar to 68. The significance levels were higher in equations 69 and 70, however; reaching the 5-percent level in equation 70. The nonfarm wage-rate coefficients were also significant at a lower probability level though not directly comparable. (Had the iterative procedure "settled down," it is likely that the coefficients of equation 68 all would have been significant at a level of 20 percent or smaller.)

Based on the tentative results of equation 68, the supply of family labor appears to respond only slightly to the farm wage-rate and the nonfarm wage-rate. Again, we believe the availability of nonfarm employment to have dominated the farm labor supply function over the last several years of rapid mechanization of agriculture.

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51/ The regression coefficients are as defined under equation 1 and 2, with the notation of the significance levels as defined under table 5. The x's and y's are in lower case to denote that the observations are taken as deviations from the mean. The variable, \(x_{7t}\), is the nonfarm wage-rate deflated by the index of prices paid by farmers for living expenses, \(x_{8t}\) is the percentage unemployment of the total work force, and \(x_{1t}\) is deflated like \(x_{7t}\).
Analysis of net farm migration

Our hypothesis is that the migration from farms is mainly and directly in response to off-farm employment opportunities. The estimated supply functions presented above provide one test of this hypothesis; the results indicating a relative lack of response of the farm labor supply to both wage-rate variables. Hence, we now analyze farm labor from the standpoint of net changes in the farm population. An autoregressive transformation was not used in these estimates. The time period covered again was 1929-57. The resultant equation with the observations measured as deviations from the mean was:

\[ \hat{y}_{2t} = 0.255x_{1t} + 0.095x_{2t} + 0.492x_{5t} + 0.069x_{6t-1} - 0.023x_{7t-1} \]

\( (1.84) \quad (0.53) \quad (2.10) \quad (0.71) \quad (0.22) \)

The value of \( R^2 \) for equation 71 is .36. The sign of the farm wage-rate coefficient indicates that as the wage-rate has risen, there has been an accompanying net return of labor to farms. Similarly, the coefficient of the composite nonfarm wage-rate indicates that as this variable increased in the previous year, there was an accompanying net migration from farms. The signs of the regression coefficients were "consistent" for all but one of the variables. The sign of the parity ratio was negative, indicating that as the parity ratio increased in the previous year, there was an accompanying net departure from the farm. The time periods in which the parity ratio increased were similarly periods when nonfarm employment opportunities increased most rapidly.

The results of the migration analysis do not alter the conclusions from the analysis of supply functions for family labor. The farm wage-rate and the nonfarm wage-rate variables had "consistent" signs in both sets of equations; the standard errors also being large relative to the regression coefficients.

THE SUBSTITUTION OF FARM LABOR AND MACHINERY

Functions including the price of farm machinery were not presented in the foregoing analysis of labor demand because of inconsistent empirical

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52/ The regression coefficients are as defined under equations 1 and 2, with the notation of the significance levels as defined under table 5. The dependent variable, \( \hat{y}_{2t} \), is the annual net migration from farms, United States. The deflator of \( x_{1t} \), \( x_{2t} \) and \( x_{6t-1} \) is the index of prices paid by farmers for production expenses.
results where this variable was included in the estimating equations. Since substitution between labor and machinery inputs is difficult to estimate quantitatively, the phenomena involved is discussed in some detail in this section. Also, regression equations are presented which include both the farm wage-rate and machinery prices as independent variables, either singly or as ratios of the two.

Relationship of the Farm Labor and Farm Machinery Markets

The substitution of labor and machinery is affected by four factors which can be measured in national statistics: the price and availability of labor and the price and availability of machinery. The relationship of these several variables to the demand for labor has not yet been empirically established. It has been suggested that the "push-pull" migration hypothesis applies, but that the main force in off-farm migration is generated by farm-nonfarm relative wages subject to off-farm employment opportunities. Mechanization must increase as the number of workers decline. A simultaneous determination of labor supply and demand and machinery demand may thus appear appropriate in establishing the basic structural relationships involved. However, as this study indicates the extremely great multicollinearity among major variables relating to machinery and labor demand makes these estimates highly difficult, and perhaps impossible with degree of refinement. Several of the important "determining variables" of farm labor (table 2) have changed simultaneously over time. As farm wage-rates and farm machinery prices have increased, 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 which have increased the productivity of machinery relative to machinery prices; (2) farm wage-rates rather than value productivity of labor in agriculture; and (3) farm machinery prices have followed steel and industrial product prices—with all of these variables coinciding closely with the trend in national price level and the shift of most major industries to a more highly mechanized and capital-intensive structure. Structural relationships between farm labor and farm machinery have been changing constantly within this realm of simultaneous forces. Cromarty postulated that the earning power of a farm machine is dependent not only on price, but also on the changes in technology in farm machinery and farm production methods. See references cited in footnote 44.


Cromarty, op. cit.
Farm labor and machinery on a firm level are, in one sense, complementary resources. If a new tractor is added, an additional man must be hired to operate the machine on typical farms. This situation perhaps best applies to areas of agriculture which are already well-mechanized. Too, substitution of labor and machinery may represent a "one-way" relationship. As labor leaves the farm, machinery is introduced to replace it. To reverse this process and accommodate labor returning to the farm, machinery must be sold or left idle. Machinery will be sold only under the unlikely circumstances that its marginal value product is less than its salvage value, and even then it has salvage value mainly on other farms. These aspects of the farm labor machinery relationship suggest reasons why the interaction of machinery and labor demand cannot be isolated from the relatively simple national statistics available on price and quantity of the two resources.

Empirical Demand Functions Containing a Machinery Price Variable

In face of the likely difficulties discussed above, four equations have been estimated which are based on the specification of two different demand models for hired labor, and farm machinery investment, with farm machinery price included as a variable. 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 for hired labor is the same as used in previous sections of the demand for hired labor. The series for farm capital and expenditures is an aggregation of farmer expenditures on tractors, trucks, automobiles for farm business use, and other machinery and equipment. The explanatory variables which contain the price of farm machinery and the farm wage-rate are presented both separately and as a ratio of the two variables.

Two equations predicting the demand for hired labor for the period 1910-57 are presented first. A linear equation utilizing the farm wage-


rate and the price of farm machinery as a ratio was estimated as follows:\(^{58}\)

$$\overline{Y}_{lt} = 25.66 + .0169X_{lt} + .2054X_{lt} - .0588X_{lt} - .8570\overline{Y}_{l t-1}$$

\(\cdot (0.0320)_{lt} (0.1115)_{st} (0.0401)_{lt} (0.0727)_{lt-1}\)

The coefficient of determination for equation 72 is .982. On theoretical grounds, we expect the coefficient of \(X_{lt}\) to be negative. Though insignificant, the empirical estimate of the coefficient is positive. A parallel equation in logs, with the machinery price and wage-rate entered as single variables is: \(^{59}\)

$$\overline{Y}_{lt} = .7923 - .0994X_{lt} - .1375X_{lt} - .0094X_{lt} + .8470\overline{Y}_{l t-1}$$

\(\cdot (0.031)_{lt} (0.139)_{st} (0.016)_{lt} (0.053)_{lt-1}\)

The coefficient of determination for equation 73 is .985. The regression coefficient for the index of machinery prices is significant and has a negative elasticity of -.1375. Were the time variable, \(X_{st}\), entered in the equation so as to be more statistically significant, the \(X_{st}\) coefficient may not have been significant.

Two predictions are made for capital expenditures on farm machinery: equation 74 with observations in logarithms and equation 75 with observations in linear form:\(^{60}\)

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\(^{58}\) The regression coefficients are as defined under equations 1 and 2, with the notation of the significance levels as defined under table 5. The farm wage-rate, \(X_{lt}\), is deflated by the index of farm machinery prices, United States. The variable, \(X_{lt}\), is the ratio of the farm wage-rate to the index of prices received by farmers for all commodities, United States.

\(^{59}\) The regression coefficients are as defined under equations 1 and 2, with the notation of the significance levels as defined under table 5. The variables \(X_{lt}\) and \(X_{st}\) are deflated by the index of prices paid by farmers for living expenses, United States. Time is in exponential form in equation 58.

\(^{60}\) The regression coefficients are defined under equations 1 and 2, with the notation of the significance levels as defined under table 5. The dependent variable, \(\hat{y}_{lt}\), is defined as the aggregate farm capital expenditure on farm machinery and equipment, United States. The variable, \(X_{lt}\), is deflated by the index of farm machinery prices, United States and the variable \(X_{lt}\), is the annual average number of hired farm workers, United States.
In neither of the equations was the coefficient for the variable "ratio of wages to machinery prices" significant at the 5-percent level, although the values were greater than the corresponding standard errors.

These equations suggest several implications for the analysis of the machinery labor substitution of relationships. First, the results for equations 74 and 75 indicate that the data have not been entered in such form and variables have not been specified to clearly indicate the effect of prices for the two resources on their substitution. Cromarty indicates 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."\(^{61/}\)

As mentioned earlier in this section and illustrated in table 3, wage-rates, machinery prices, and machinery purchases have increased simultaneously while the labor force has decreased. This multicollinearity gives rise to the estimational difficulties mentioned earlier. Finally, the substitutability of labor and machinery, and the variables used to express it, cannot be measured apart from changes in crop production methods and other technological changes affecting the relative marginal productivity of labor and machinery. The four estimated equations are of interest, however, because they explain the dependent variables in terms of "what has transpired in the past" in accordance with the aggregative data used. To adequately specify and measure the substitution of labor and machinery, two characteristics probably need to be expressed in the model: (1) inclusion, along with the price of machinery, of quality changes in machinery; and (2) de-aggregation of the data and analysis on the basis of smaller areas and/or crops, so that specific instances of machinery labor substitution can be expressed.

### PREDICTIONS OF THE FARM LABOR FORCE

In the preceding sections, empirical demand and supply functions for farm labor were presented and analyzed to extend information on the structure of the farm labor market, particularly as it has existed in the past. The test of a demand function lies in its predictive accuracy.

\(^{61/}\) Cromarty, \textit{op. cit.}, p. 40.
In this section, predictions of the size of the farm labor force for 1965 and 1975 are presented. Short-run predictions based on previously discussed demand functions are presented first. Second, 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 Employment

Several labor demand functions were utilized, including separately the demand for hired, family and total farm employment, in predicting size of the farm labor force or employment. The term "short-run" is used to indicate a time period of such duration that a firm is unable to vary the quantity of some resources used. For the purpose of this study based on time series data, the time periods are definitionally determined as consisting of yearly periods varying in span from 1 to 5 years, or up to 1965.

To present forecasts for 1965, projections of the independent variables were constructed. Basically, they are simple extensions of trend, since 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 31 of table 5; (2) family labor, equation 54 of table 8; and (3) total farm employment, equation 64. Predictions from these equations are summarized in table 9. The term $Y$ in table 9 refers to actual numbers of workers while $Y_p$ refers to the predicted number of workers. As expected, the computed trend in the demand for farm labor is downward over time. The demand function for total farm employment was estimated from data covering the period 1910-57, and was not as sensitive to changes in 1958 and 1959 as were the demand functions for family and hired workers estimated with data from shorter periods. The demand function for family labor, estimated over a shorter period, 1940-57, was slightly closer to the actual data than were the other estimates. The best fit was for hired labor over the period 1929-57 in which autoregressive least-squares equations were employed.

For 1965 a total farm employment of from 6.4 to 6.75 million workers is predicted from equation 64. Separated into component sectors on the basis of equations 31 and 54, demand for family workers is estimated at 4.8 million while demand for hired labor is predicted at 1.6 million. The total of the separately estimated 4.8 and 1.6 million

<table>
<thead>
<tr>
<th>Year</th>
<th>Total farm employment</th>
<th>Family workers</th>
<th>Hired workers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ya</td>
<td>Yp</td>
<td>Ya</td>
</tr>
<tr>
<td>1958</td>
<td>7,525</td>
<td>8,100</td>
<td>5,570</td>
</tr>
<tr>
<td>1959</td>
<td>7,384</td>
<td>7,800</td>
<td>5,459</td>
</tr>
<tr>
<td>1965</td>
<td>---</td>
<td>6,750</td>
<td>---</td>
</tr>
</tbody>
</table>

(In thousands of workers)
workers closely approaches the estimated total of 6.75 million workers from equation 64. This total of 6.75 million workers in 1975 would represent a decline of 33 percent in employment from the 1947-49 number of farm workers.

The following section includes estimates of long-run or 1975 demand for farm labor.

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 studies have been compiled in the last few years which estimate the future course of agriculture and present informal estimates of the long-run demand for farm labor. These predictions have been made by Daly and Barton, Bonnen and Black, The President's Materials Policy Commission, Koffsky, Cochrane and Lampe, Ruttan, and Clark.62/ A common method in these informal predictions is: to assess consumer needs for and projected supplies of agricultural products. Employment predictions are then based on these projections, the labor force assessments relating to a rigid set of conditions. For example, Bonnen and Black63/ state the following assumptions: (1) a continued high level of employment; (2) no all-out war; (3) no basic change in the tax structure; (4) "average" weather; and (5) a specific size of the future population. Given these restrictions, factors affecting the


63/ Bonnen, op. cit.
rate of food consumption were 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 future foreign trade is difficult to determine.

Population predictions used for the United States in 1975 have varied according to the year of the written report because estimates of the fertility rate have changed almost between years. For instance, some of the population estimates were, in millions of persons: Clark, 234; Koffsky, 210; Paley Commission, 193.6; Daly, 215.8 to 243.9. Given a population prediction, and adjusting for income and price elasticities and foreign trade, estimates of the consumer needs of agricultural products are then made. Estimates of future production are then computed.

Finally, the estimates of the size of the farm labor force, such as for 1975, are calculated: to furnish the manpower needed either to fulfill the production estimates, or to meet consumer needs. Among the predictive methods used were "educated guesses," as in Black, and extensions of linear trends as utilized by Clark. A comparison of predictions of the agricultural labor force for 1975 are: Daly, 5.5 million workers; Black, a decrease of 10 percent in the labor force from 1950, or about 8.4 million workers; Clark, 2 million workers (or approximately 3.5 million workers on a comparable scale with the other estimates).

A Long-Run Predictive Model for Farm Labor

The more formal models discussed earlier are used in this section for making projections of farm employment in 1975. One difficulty in

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64/ Clark, Colin, op. cit.
65/ Koffsky, op. cit.
67/ Daly, op. cit.
68/ These estimates generally assume that farmland will remain constant and that farm employment will decrease while agricultural output per man-hour will increase. Factors tending to increase output per man-hour are taken as: (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.
69/ Bonnen, op. cit.
70/ Clark, Colin, op. cit.
71/ Daly, op. cit.; Bonnen, op. cit.; Clark, Colin, op. cit.
extending trends, and the "determining variables must be thus estimated," is that they soon cause labor employment to approach zero and become negative. However, complex estimational procedures also may lead to projections which depart from reality and upcoming structural transformations. We do, however, employ our estimating equations to make projections to 1975. Projections thus are provided which can be compared with the less formal predictions which have been made in the studies cited earlier.

The model used for long-run prediction in this paper is a growth model similar to that proposed by Hicks.\textsuperscript{12} Hick's model is:

\begin{equation}
E_n = E_0 (1 + g)^n
\end{equation}

where \(g\) = the growth rate, \(E_0\) = equilibrium output in period 0, and \(n\) = the \(n\)-th time period. This model was one with a constant growth rate and the function changes at an increasing rate. To predict farm labor force size for the United States, the equation was altered so that the function decreases at a decreasing rate, as follows:

\begin{equation}
M_n = M_0 (1 - p)^n
\end{equation}

where \(M_n\) = man-hour requirements of agricultural labor in the year \(n\), \(M_0\) = 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, estimated change in total United States population was added to the model as follows:

\begin{equation}
M_n = M_0 (1 - p)^n (1 + g)^n
\end{equation}

where \(g\) = the yearly average change in population in the United States, and the other parameters are the same as explained above.

The advantages of a model of this type are: (1) projections are a function of farm man-hours in the present or some base year; (2) the equation may be modified as man-hour productivity changes; (3) the model can consider growth in the consumer sector; and (4) algebraically, the model allows "slow" convergence to some lower asymptote, zero, with

the rate of convergence subject to estimated productivity and population changes. Our 1975 projections are for man-hour requirements in agriculture, following the FERD data explained earlier. They are not for labor employment or work force as measured by AMS data.

A convenient method used in estimating \( p \), the change in farm productivity, was to determine the average yearly rate of change in farm man-hour requirements for the last few years utilizing FERD data.\(^{73/}\)

Thus, we let \( M_0 = 76 \), 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, the estimate of \( p \) for 1956 is:

\[
72 = 76(1 - p)^1(1 + g)^2
\]

where \( g \) is estimated to be .0172. Taking the logarithms of both sides and solving, we have \( p = .068 \). Similarly, the values of \( p \) for 1957 and 1958 were determined, and an average value for \( p \) was .067. In order to predict, the value of \( p \) was substituted into the equations for 1965 and 1975, using 1958 as the base period. The resultant point estimates are in index form, based on the 1947-49 average of man-hour requirements. The United States farm man-hour "needs" in 1965 are thus estimated to be 45.7 percent of the 1947-49 average, while the farm labor "needs" in 1975 are estimated to be 27.1 percent of the 1947-49 average. Estimates from the equation are plotted and compared with a linear trend in fig. 11. Roughly, the 1975 man-hour requirements in fig. 11 correspond to employment of 5 million under projections from equation 78 and 3 million farm workers from extension of the linear trend. The two series, paralleling AMS and FERD data, are not directly comparable, however. Man-hour requirements may decrease considerably more than the number of farm workers. With increasing technology and greater labor productivity, 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, thus is recommended in use of projections such as those above.

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 percent, respectively, of the 1947-49 average. For policy purposes, these estimates indicated 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 percent and by 1975 to 40 percent of the 1957-58 average requirements.

\[\text{73/ U.S. Department of Agriculture. Changes in farm production and efficiency, op. cit., p. 18.}\]
Fig. 11. A prediction of agricultural man-hour requirements and an extension of linear trend, 1957-75.
APPENDIX

Sources of data used in the study are:


A computed index of the value of farm machinery: A starting point was taken for 1930 and deflated. For succeeding years, net additions to farm machinery are deflated and added to the previous year's total. U. S. Department of Agriculture. Agricultural Marketing Service. Farm income situation. July 1959.