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THE DEMAND FOR HIRED FARM LABOR

I. Introduction

Total farm employment has considerably declined since World War II, falling from 10.3 million in 1946 to 3.1 million in 1985. This trend is a continuation of the general trend observed since 1910. The total number of family operators and unpaid family members fell from 8.1 million in 1946 to 2.0 million in 1985, while the number of hired farm labor declined from 2.2 million in 1946 to 1.2 million in 1970 and has more or less stabilized since. Table 1 shows U.S. farm employment for selected years from 1946-85.

Table 1

U.S. Farm Employment, 1946-85

	Hired Workers		Family Workers		Total Employment	
Year	Number* (000)	Index 1977=100	Number (000)	Index 1977=100	Number (000)	Index 1977=100
1946	2,189	167	8,106	283	10,295	247
1950	2,329	178	7,597	265	9,926	238
1960	1,885	144	5,172	181	7,057	169
1970	1,175	90	3,348	117	4,523	108
1980	1,303	100	2,402	84	3,705	89
1985	1,098	84	2,017	70	3,115	75

* Includes all persons doing work for pay during the survey week.

Sources: 1) Agricultural Statistics, USDA, (various years)

2) Statistical Abstract of the U.S., (various years)

There was also significant change in the mix of hired and family workers. Hired labor force made up only 21 percent of the total labor force in 1946 but this proportion had increased to 35 percent by 1985. The increase in the proportion of hired farm labor was mainly due to growth in the size of farms and in the amount of farm labor required per farm (Fact Book, 1986).

The 1986 Fact Book of U.S. Agriculture provides a good snapshot of hired farm workers in 1983. Though based on 2.6 million persons who did some hired farm work during the year, it shows that the hired farm workers in that year were predominantly young (50 percent under 25 years), male (78 percent), and lived in non-farm residences (82 percent). The racial mix was 73 percent white, 13 percent Hispanics, and 14 percent blacks and others. Half of the hired farm workers were household heads; the remainder comprised spouses and other family members. Thirty-eight percent of them lived in the South. In the same year, there were 226,000 migrant workers who crossed county lines and stayed overnight to do hired farm work. About 54 percent of these travelled distances of 500 miles or more to reach their farm jobs.

A. Changes in the Quality of Hired Farm Labor

Like most other farm inputs, the quality of the farm labor force has improved over the years. Improvement in the quality of labor comes from improvements in the education and training as

well as in the health and stamina of the labor force. Education and training are acquired through 1) formal education in schools, 2) general or specific on the job training, and 3) work experience that improves skills and social interactions. Though it is difficult to measure all of these quality characteristics, some data are available on the level of formal education of the agricultural labor force (Table 2). Health and stamina are influenced by many factors including nutrition and disease treatment and prevention. However, it is difficult to measure these characteristics (Mabry, 1973) and hence, they cannot be pursued further in the demand analysis.

Table 2

Education of Agricultural Labor Force, 1946-85

	Hired Labor		Family Labor		Total Farm Labor	
Year	Number years*	Index 1946=100	Number years*	Index 1946=100	Number years*	Index 1946=100
1946	7.1	100	8.2	100	8.0	100
1950	7.5	106	8.3	101	8.1	101
1960	8.3	117	8.7	106	8.6	108
1970	9.7	137	10.0	122	9.8	123
1980	11.4	161	11.8	144	11.6	145
1985	11.4	161	11.8	144	11.6	145

*Average number of years in school for those 18 years old and over.

Sources: 1) Statistical Abstract of the U.S. (various years)
2) Manpower Report of the President, 1966
3) Handbook of Labor statistics (various years)

Table 2 shows that there was a gradual increase in the average number of years in school between 1946 and 1980 for both hired and family labor, but that seems to have levelled off after 1980. Improvements in the education of the agricultural labor force improves its quality, and as a result, its productivity. If we assume that education is the only factor that improves quality, we can deflate the number of hired labor by the average number of years in school and obtain a constant quality number of hired labor. Also, the level of education can be introduced as a separate explanatory variable in the analysis of hired farm labor demand in order to separately estimate its influence.

B. Other Changes in U.S. Agriculture

In addition to these dramatic changes in the number, mix and characteristics of the hired agricultural labor force, there were equally dramatic developments in agriculture that have important bearing on the demand for hired farm labor. These include continued structural changes such as increase in farm size and decrease in farm numbers; large expansion in output in the 1970s and contraction in the early 1980s. There were also changes in the economic conditions or forces affecting agriculture such as rapid expansion in farm exports, increase in farm assets, expansion of farm credit, continuing development of new technology, and increased government involvement through farm commodity programs and taxation. These developments have a

profound impact on resource organization in general and hired labor demand in particular. These are what sparked this study.

Though there are several excellent hired farm labor demand studies, most of them did not include these developments in their analysis because the studies were undertaken during or prior to the occurrence of these developments. Therefore, the major goal of this study is to analyze total and quality constant demand for hired labor using the empirical framework of the major previous studies and incorporating more recent data and variables reflecting the recent developments in agriculture. This will give us estimates of structural coefficients and elasticities which will be compared with the results of previous studies to see how sensitive the estimates are to the new developments.

II. Major Forces Affecting the Demand for Farm Labor

Several factors determine the demand for farm labor. Three major sources will be used to identify these forces: (1) economic theory, (2) previous hired farm labor demand studies, and (3) recent agricultural literature. Though the division of these sources is helpful to simplify matters, there are some obvious overlaps between the forces suggested by the three sources.

A. Profit Maximization Model

The basic theory of resource demand is based on the static theory of the competitive firm. A producer's (firm's) demand for production inputs is derived from the demand for its final products. Assuming that the production function (technology) and prices are given, a system of input demand functions can be derived from the first order conditions for profit maximization. The derivation also suitably extends to total demand, the summation of individual demand, since producers are assumed to be identical under perfect competition.

Consider a firm producing one output, Q, and using variable inputs, $X_1, \ldots, X_n$, and a stock of quasi-fixed input, K. The firm's production function can be represented as :

1.1) $Q = f(X_1, \ldots, X_n, K)$ or $Q = F(X, K)$

This is a physical relationship portraying the level of output, the marginal and average productivities of the factors of

production, and the marginal rate of substitution between pairs of factors. The marginal products are

1.2) $\partial F(X, K) / \partial X > 0$

1.3) $\partial F(X, K) / \partial K > 0$

The production function is strictly concave, which implies the law of diminishing returns, i.e.,

1.4) $\partial^2 F(X, K) / \partial^2 X < 0$

1.5) $\partial^2 F(X, K) / \partial^2 K < 0$

1.6) $\partial^2 F(X, K) / \partial^2 X \cdot \partial^2 F(X, K) / \partial^2 K$

$- \partial F(X, K)/\partial X \cdot \partial F(X, K)/\partial K > 0$

The output price P, variable input price W, and quasi-fixed input price, r, are known with certainty. The variable input, X, is chosen after determining K and observing all prices by maximizing the short-run profit function:

1.7) $\text{Max } \pi = P\, F(X, K) - W\, X, \qquad \text{s.t.} \quad X > 0$

Where π is the profit function and the rest are as defined above. The first order necessary condition for profit maximization is:

1.8) $P\, \partial F(X,K) / \partial X = W$

The satisfaction of this condition also satisfies the cost minimization condition:

1.9) $\dfrac{\partial F}{\partial x_i} \cdot \dfrac{\partial F}{\partial x_j} = \dfrac{w_i}{w_j}, \qquad i \neq j$

Condition (1.8) says that the firm should hire current inputs up to the point where the value of the marginal product

from employing one unit of a factor must equal its own price. Assuming the sufficient second order conditions hold, equation (1.8) can be solved to obtain a system of short-run input demand functions as follows:

1.10 $X^* = X^*(W,P,K)$

Where X^* are levels of inputs (such as hired labor) that the firm employs to satisfy conditions equ. 1.8 for any prices. They are homogeneous of degree zero, thus proportional changes in input and output prices do not change input or output levels.

By inserting the input demand functions back into the production function, the output supply function can be obtained from which the optimum level of output can be obtained as a function of output price, input wages, and the quasi-fixed factor:

1.11) $Q^* = F(X^*(P,W,K) = Q^*(P,W,K)$

Since the input demand functions are homogeneous of degree zero, so is the output supply function (Intriligator, 1971). The response of the optimal levels of input X^* and output Q^* to changes in W, P, and K can be obtained by first inserting the input demand function (equ. 1.9) into the first-order necessary condition (equ. 1.8) and the supply function (equ. 1.11) into the production function (equ. 1.1) to obtain the following n+1 identities:

1.12 a) $P\ \partial F(X^*(P,W,K))/\partial X = W$

and

1.12 b) $X^* = X^*(P,W,K)$

1.13) $Q^*(P,W,K) = f(X^*(P,W,K))$

The sensitivities of X^* and Q^* are obtained by differentiating these identities with respect to the n+1 parameters P, W, and K. Details of the derivations can be found in Intriligator (1971). The results on the input side are;

1) $\frac{\partial X^*}{\partial W}$ negative definite and symmetric matrix.

Negative definite means that the elements along the principal diagonal are negative, i.e., $\partial X_i / \partial W_i < 0$, $i = 1, \ldots, n$, which means that the input demand curves always slope downward. Thus an increase in the price of an input will lead to decrease in the demand for that input. Hence, in equation 1.10, a negative relationship is expected between X_i and W_i.

The symmetry condition,

1.14) $$\frac{\partial X_i^*(P,W,K)}{\partial W_j} = \frac{\partial X_j^*(P,W,K)}{\partial W_i}$$

shows that the effect of change of W_j on the demand for X_i^* is the same as the effect of change of W_i on the demand for X_j^*. However, the maximization model does not imply whether the signs of

$\frac{\partial X_i^*}{\partial W_j}$, $i \neq j$, will be positive or negative.

2) A priori one can say nothing definite about the signs of individual $\partial X/\partial P$ since an increase in P, through its effect

on output, can lead to an increase (if superior) or decrease (if inferior) in the use of the inputs. What can be ruled out is that all cannot be negative simultaneously. However, one can generally assume that all inputs are superior and expect a positive relationship between X_i and P.

In the above model, the level of the stock of quasi-fixed input, K, is fixed in the short-run. However, K can be varied in the long-run and hence, the wealth of farmers is used to represent this phenomena in the next section.

Limitations of the Above Theory

The static theory of profit maximization discussed above is a good starting point for the understanding of the basic forces that determine the demand for variable farm inputs such as hired farm labor. However, static input demand functions estimated strictly from the above derivations may not be satisfactory for several reasons. First, the derived static demand functions are constrained by the assumptions of the profit maximization model. Three of the constraints are particularly important here:

1) The model assumes that producers make immediate adjustments to quantity demanded in response to changes in relative prices, unhindered by market information and/or supply lags. This is unrealistic because producers may not be able to make instantaneous adjustments due to physical, psychological, technological and institutional factors. Hence, several time

periods may elapse before full adjustments are made in response to a new set of relative prices and other factors. This is addressed by using dynamic demand models as discussed in the next section.

2) The assumption that output and input prices are known and given at the time of planning production should also be questioned because product prices are not observable at the time production decisions are made. Agricultural production decisions are based on expected rather than actual prices; therefore, the output price has to be modified so that the expected price rather than the actual product price is used.

3) The unconstrained profit maximization model implies that capital funds required for production purposes are unlimited. This assumption is also unrealistic because most farmers have to borrow from commercial banks and government credit institutions in order to finance the purchases of production inputs. Thus, credit limits are reasonable constraints to be placed in the optimization model. The interest rate paid by farmers on non-mortgage loan is taken to represent the ease with which credit can be obtained.

The second reason that static input demand functions are unsatisfactory is that the derived functions are "vague in that the constraints on the production process are unknown and regarded as given and constant during the period of analysis" (Bohi, 1981). For example, the models assume that technology is

known and fixed, some inputs are of limited availability in the short-run, and some inputs are indivisible or lumpy because of the lack of continuous technology (Bohi, 1981). Though these constraints may be necessary to simplify the models, they may not be realistic in the analysis of demand involving dated data. For example, technology can be changed and some fixed inputs can be increased or decreased over time. Because of the limitation of data and the need for simplifying the analysis, only changes in technology will be considered in the analysis.

The third reason for dissatisfaction is that, the input demand functions derived from the theoretical models don't include explanatory variables other than input and product prices. However, review of earlier hired farm labor demand studies and recent agricultural literature show that factors such as agricultural exports, wealth of farmers, acreage diverted from crop production, and changes in farm numbers and sizes could have affect the demand for farm inputs.

In addition to these, though labor is generally classified as a variable input, it has some element of fixity because of the fact that it is not an inanimate resource and cannot be shunted abruptly out of agriculture in immediate response to relative price changes. It has many sociological attributes which relate to its mobility (Heady and Tweeten, 1963). Also the employment of labor usually involves contractual obligations; requires hiring, training, and dismissal costs; and involves non-wage

fixed costs that introduce elements of fixity into the use of the input. Thus, labor tends to be a border line case between variable and fixed inputs. Also, the supply condition of hired farm labor is different from that of other variable inputs. Because people do not always offer to work more when wages rise due to the trade-off between work and leisure. Hence, the demand and supply sides should be looked at the same time.

Therefore to make the demand functions of hired labor more realistic the demand functions derived above have to be modified and estimated simultaneously with the supply function. These modifications, however, don't change the basic estimation methods used in previous input demand studies, which form the basis for this study.

B. Previous Hired Farm Labor Demand Studies

Depending upon what the researcher seeks to find out, the demand functions for farm inputs can be estimated directly from time series data (Griliches (1958), Heady and Tweeten (1963), and Olson (1979)), from cost (Binswanger, 1974) and profit (Antle, 1984) functions based on duality theory, from production functions using experimental data (Tweeten and Heady, 1962), and from observations on prices and quantities obtained from farm surveys (Carman and Heaton, 1977). Since our analysis involves only time series data, the review will be limited to the major time series studies of hired farm labor.

There are a large number of single equation and simultaneous equation hired farm labor demand studies. Only a few important ones will be reviewed here. Heady and Tweeten (1963) estimated several static and dynamic demand models using single equation OLS, simultaneous equation models estimated in reduced form by the Theil-Basmann technique, and autoregressive least squares method. They estimated the models in original observations and in logarithmic forms using data for the periods 1910-57, 1920-39, 1929-57, and 1940-57. The number of hired laborers used was specified as a function of the average farm wage rate, the prices received for agricultural products lagged one period, the stock of farm machinery and equipment, a time trend variable, and the lagged dependent variable. Only the farm wage rate and the lagged price received for agricultural products were found to be the principal determinants of hired labor demand. The lagged dependent variable was significant in some of the equations but was reduced when a time variable was included.

Schuh (1962) estimated the demand and supply of hired farm labor using simultaneous equation model and data for the period 1929-57. The quantity of hired labor demanded was specified as a function of the real farm wage, the prices received for agricultural products, the prices of other inputs, a measure of technology, a time trend variable, and the lagged dependent variable. The supply of hired labor was specified as a function of real farm wage, income earned in nonagricultural employment,

the unemployment rate in the general economy, and the size of the civilian labor force. Static and dynamic models were estimated using the Theil-Basmann technique. Also a single equation least squares estimate was made in order to verify the validity of the assumption of simultaneous determination of quantity hired and the wage rate.

The statistical results show that both the static and dynamic simultaneous equation procedures were acceptable but the single equation was not because OLS consistently failed to obtain a parameter estimate for agricultural wage in the supply equation that was significantly different from zero. The major determinants of demand were the real farm wage rate, the price received, and the lagged dependent variable where applicable. The time trend variable was also significant in the static simultaneous equation model. All the variables in the supply functions were highly significant.

A similar study was made by Hammonds, et. al. (1973) for the U.S. and Oregon using 1941-69 and 1951-70 data, respectively. Simultaneous equation models were specified and estimated by two stage least squares method. The results show that the major determinants of demand were the real farm wage rate, the real price received for agricultural products, and a measure of technology. The determinants of supply were non-farm income corrected for unemployment, the unemployment rate in the general

economy, and the lagged dependent variable. The real farm wage rate and a time trend were not important in the supply equations.

Olson (1979) specified the demand for hired labor as a function of the farm wage rate, the price of fuel and oil, the price of farm machinery, the prices received for farm goods, the number of family workers, the number of farms, the average farm size, the national net farm income, the variation in income, expenditure for and stock of farm machinery, and slow changing variables grouped together in a time trend variable. Several static and dynamic single equation models of demand were estimated within a system of equations using modified limited information maximum likelihood estimation procedure. The models were estimated in original observations and logarithmic forms using data from 1946 to 1977. The results show that the dynamic specification was not supported and the factors that determine demand were the farm wage rate, the price of farm machinery, the price received for farm goods, and the number of family workers.

Finally, Wang and Heady (1980) estimated the demand and supply of hired labor using single equation least squares, two stage least squares simultaneous equation method, and autoregressive two stage least squares method. The variables used and results obtained were similar to those of Hammonds, et. al. above.

From the review of the above literature, the most significant studies having been cited, it is apparent that

several factors other than input and output prices suggested by economic theory determine the demand for hired farm labor. These factors include expected net farm income, an index of technology, the debt-equity ratio, the interest rate, and time representing slowly changing variables. Other factors suggested in the more recent agricultural economics literature that may affect the demand for farm inputs but not included in the earlier studies will be briefly explored in the next section.

C. Emerging Forces Affecting the Demand for Hired Labor

The theoretical framework reviewed above suggests that the demand for hired farm labor is determined by the price/wage of hired labor, prices of related inputs, and the price of the product. However, the review of previous hired labor demand studies, recent agricultural literature and the various limitations of the basic theoretical model discussed above suggest that more explanatory variables should be included in the demand functions in order to make the estimates more meaningful. The additional variables to be included in this study are addressed as emerging forces, and how these forces affect the demand for hired farm labor are explored below.

a. Farm Product Exports

Agricultural exports, both commercial and non-commercial, have increased considerably over the decades. In nominal

dollars, the value of agricultural exports from the U.S. increased from $2,857 million in 1946 to $43,780 million in 1981 but declined to $31,187 million in 1985. After adjusting for inflation, the value of exports increased three-fold between 1946 and 1981. This increase can be viewed as a phenomenon arising from external shocks that shift the demand curve for agricultural products. This kind of shift in the 1970s led to increased product prices in the short-run and to increased output in the long-run. To meet the growing demand, farmers increased their productive capacity and used more variable inputs.

The impact of agricultural exports on the demand for hired farm labor can be captured by incorporating the variable in the demand equations. Increases in exports are expected to increase the demand for hired farm labor with a time lag.

b. Increased Wealth of Farmers

There was a gradual increase in the wealth of farmers up to the early 1970s, a sharp increase in the 1970s, and a marked decline in the early 1980s. Since most of the wealth of farmers is in the form of land, the fluctuation largely followed changes in farmland values. Changes in the wealth of farmers have impact on the demand for farm inputs, particularly capital inputs. Increase in liquid farm assets such as cash and bonds will directly provide the funds required for investments and the purchase of other inputs. Also increase in asset values will

increase the willingness of lending institutions to extend credit for the purchase of inputs.

Increased asset values can also be a measure of the farm firm's ability to withstand unfavorable outcomes. If a farm's equity is high, a relatively small financial loss may cause little concern; whereas if the equity is low, the same loss may increase liabilities above the value of owned assets and cause bankruptcy. The ratio of the farmer's debt to outstanding liabilities is a measure of this influence on input demand both psychologically for the farmer and actually for outside credit sources (Heady & Tweeten, 1963).

The debt-equity ratio can also serve as a proxy variable to measure past incomes. It will be used to represent the influences of wealth on the demand for farm inputs. A positive relationship is expected between quantity demanded of hired farm labor and the debt-equity ratio.

c. Production Credit and Interest Rate

There has been considerable expansion in the use of credit for the purchase of farm inputs. Total farm debt increased from $8.3 billion in 1946 to $207 billion in 1983, but declined to $188 billion in 1985. Interest payments on these debts increased from $402 million in 1946 to $18.7 billion in 1985, becoming the single most important farm expense and surpassing the

expenditures for fertilizer, livestock and poultry, feed purchased, and hired labor.

The increased availability of credit allows farmers to purchase more inputs than they would be able to do otherwise. On the other hand, increases in interest rates increase the cost of borrowing and that would lead to reduced use of inputs. This is because producers will equate the marginal value product of the input to the cost of the input plus the cost of credit used to buy the inputs (Heady and Dillon, 1961).

However, there are considerable debates as to the role of real balances on aggregate production functions and agricultural production functions. Also, there are no investigations as to the role of interest rates in the demand for variable inputs (Kimble, et. al.). Traditionally, the interest rate was used as an explanatory variable only in the analysis of the demand for durable inputs. It seems that the first attempt to include interest rate (credit) in the demand for variable inputs was made by Kimble, et. al. (1988). They suggested that operating and mortgage credit can enter the production function as non-physical inputs and estimated several variable input demand functions incorporating interest rate as a separate explanatory variable. They found out that the majority of the inputs are substitutes with operating credit and complements with mortgage credit.

In the demand for hired labor, interest rate on non-mortgage credit will be used to represent the ease with which

credit is available and the cost of borrowing. It should be noted that the introduction of interest rate in the hired labor demand functions implies a relaxation of the assumption of no credit constraint in the profit maximization model.

d. Government Farm Programs and Policies

i. Acreage Diversion from Crop Production

There are two major categories of government commodity programs, withholding cropland from production and support of prices and incomes. Acreage diversion directly places a constraint on the production function by limiting the availability of land. That leads to the reduction of other complementary factors of production. The size of cropland withheld from production ranged from zero in 1946-55, 1980 and 1981 to 78 million acres in 1983. Acreage diverted from crop production will enter the demand functions for hired farm labor as a separate explanatory variable.

The price and income support programs include direct price support programs; commodity storage, handling, disposal and surplus removal; international commodity agreements; special food assistance programs; and marketing orders and agreements. Most of these programs are more or less concerned with supply management and are directly or indirectly reflected in the product prices and farm incomes and need not be represented independently in the demand functions.

e. Technical Change

The processes and effects of technological change have been addressed at length elsewhere (Binswanger, Hayami & Ruttan, Kislev and Peterson). In short, technological change in the form of new and/or better quality machinery, fertilizers, pesticides, hybrid seeds, better trained labor, livestock disease controlling drugs, etc., result in new production coefficients, alter the relative prices of inputs and outputs, and contribute to increased production efficiency. Increased efficiency results in the shift of the production function upward at every level of input. Technical change can be incorporated into the production function by relaxing the assumption of known and fixed technology and by dating the production function and the inputs.

If the production surface is lifted upward parallel to itself with no change in its shape, then the marginal productivity and marginal rates would remain unchanged. Mathematically, this simple parallel shift in the isoquant can be represented by the following production function:

1.15 c) $Q_t = a_t + f(X_1, X_2, \ldots, X_n)$

If the extra output , $a_t - a_{t-1}$, can be sold at the same price as before, there would be no change in the use of inputs or remunerations and the owners will receive large residual profits. This is a neutral technical change with respect to the relative use of factors of production (Brown, 1970).

However, most technical changes will increase the marginal productivity of all or of some of the inputs. If one assumes that the marginal productivity, $\partial f/\partial X_i$, increase in the same proportion, say, κ, the relative marginal productivity and hence, the marginal rate of substitution will remain the same. In that case, technical change can simply be accounted for by renumbering the isoquants, say, from q to κq. This kind of neutral technical change can be represented by the production function;

1.16 d) $Q_t = a_t f(X_1, X_2, \ldots, X_n)$

Under this condition, for any given factor price, the relative use of factors will be left unaltered by the technical change, if output advances at the same rate as a_t (Brown, 1970).

In both the above types of neutral technical change, the effect of technology can be captured by the use of a smooth linear or exponential time trend variable in the production function. The derived input demand function will also have the time trend variable as a working approximation for technical change.

The type of technical change observed in U.S. agriculture is, however, the non-neutral type whereby some marginal productivities are affected more than others (Binswanger, Hayami and Ruttan, Kislev and Peterson). In that case, the functional form of f_t (shape of the isoquant), or its parameters, or both can be affected. That introduces changes in relative factor use

(substitution) even without changes in relative factor prices. Hence, the use of factors whose marginal productivities have increased relative to others will increase as farms minimize costs. In actuality both the marginal productivity and relative prices have changed over time. Thus, increase in the use of farm machinery and fertilizer and decrease in the use of labor observed in U.S. agriculture are the outcomes of these phenomena.

Over time, both neutral and non-neutral technical changes will be experienced in agriculture. The outcome of this is that, the production function and the associated input demand functions will be affected accordingly. However, as indicated in some studies (e.g. Tomek, 1981), it is difficult to isolate and measure the impacts of technical change from that of other forces affecting the production function. To circumvent the problem, the agricultural productivity index is chosen as a proxy for both neutral and non-neutral technical change. Also hired farm labor will be adjusted for quality (educational) changes in order to account for part of the effect of technical change.

f. Increase in Farm size

One of the major structural changes that has occurred in U.S. agriculture is change in farm size. Average farm size increased from 193 acres in 1946 to 446 acres in 1985. The effects of changes in farm size on the demand for farm inputs have gained increased attention in recent years. Most previous

hired farm labor demand studies didn't include farm size in their analysis. However, Olson (1979) used this variable and found out that farm size is not an important determinant of hired farm labor demand. However, the issues of farm size, economies of scale, and related subjects are still under debate. It is hoped that the inclusion of average farm size in the demand functions of hired farm labor will provide additional evidence.

h. Decrease in Farm Number

Farm numbers have declined from 5.9 million in 1946 to 2.3 million in 1985, but the decline was not uniform during this period. Farm numbers declined at an annual rate of 2.0 percent between 1946 and 1973 but slowed down to 0.9 percent thereafter. Despite the decrease in the number of farms, total acreage in farms changed little, from 1145 million acres in 1946 to 1014 million acres in 1985. Also, the number of crop acres remained fairly constant during the same period. That was because as the number of farms decreased, the remaining farms increased their holdings and raised the average farm size. As a result, total farm input use didn't decline but the demand for some inputs, particularly labor, declined partly because of the displacement of owner-operators and hired labor as farms were consolidated.

Thus, it is difficult to tell a priori the impact of farm numbers on the demand for hired farm labor. Farm number will enter the demand functions as a demand shifter.

i. Unemployment Rate in the General Economy

The rate of unemployment in the general economy is a good indicator of the employment opportunity available for both hired and family labor. Though it is possible to have limited employment opportunities in some geographic areas, education fields, and certain types of skills at the same time there is excess supply in the general economy, the unemployment rate can give a fairly accurate picture of the overall employment opportunity at any one time. The lower the rate of unemployment in the general economy, the easier it will be for family and hired farm workers to leave agriculture and seek non-farm employment, hence, decreasing the supply of hired and family labor to agriculture.

III. Empirical Framework

As stated in the objectives, this study is primarily an extension of previous hired farm labor demand studies and hence, essentially uses the same estimation framework (primarily simultaneous equation but also some single equation) used in most previous hired farm labor demand studies. The major difference from the earlier studies will be the incorporation of additional explanatory variables and refinement of the estimation methods whenever alternatives are available. However, in the update of some of the results of the previous studies, the same models and estimation techniques used in the original studies will be used directly. In the following paragraphs, only the simultaneous equation estimation framework and the associated estimation problems will be briefly discussed.

A. Simultaneous Equation Estimation

The simultaneous equation estimation technique enables the estimation of a complete system of equations that are related to each other. Consider two structural equations of demand and supply models for hired farm labor:

1.17) Demand: $Y_{1t} = \beta_0 + \beta_1 W_1 + \beta_2 X_1 + U_1$

1.18) Supply: $Y_{2t} = \alpha_0 + \alpha_1 W_1 + \alpha_2 X_2 + U_2$

Where Y_1, Y_2, and W_1 are endogenous variables determined within the system and X_1 and X_2 are predetermined variables. The application of OLS estimation concerns the likely correlation of

U_1 with X_1 in Equ. 1.17 and U_2 with X_2 in Equ. 1.18 which lead to biased and inconsistent parameter estimates. Single equation limited information estimation techniques that can give unbiased and consistent parameter estimates are indirect least squares (ILS), instrumental variables (IV), two stage least squares (2SLS), and limited information maximum likelihood (LI/ML). Because of its ease and applicability to both just and over-identified equations, the 2SLS technique will be employed to estimate the structural parameters of the simultaneous equation models.

In 2SLS, a proxy or instrumental variable $\bar{W}_1$ is constructed which is highly correlated with W_1, but not with U_1 and U_2. The 2SLS technique then consists of replacing W_1 by $\bar{W}_1$, which is purged of the stochastic element and then performing an OLS regression of Y_i on $\bar{W}1$ and X_i.

In dynamic simultaneous equation estimation with independent errors, the 2SLS is asymptotically efficient. However, it is not a consistent estimator when the error terms are correlated because the lagged endogenous variables are correlated with the residuals. If the errors are positively correlated, the coefficient of the lagged dependent variable will be upward biased and as a result, the corresponding adjustment coefficient will be downward biased and the associated long run elasticities will be inflated. Also, the usual formula of the covariance matrix of the 2SLS estimator will be a biased

estimator of the asymptotic covariance matrix of the estimator parameter, hence, the t and F statistics are biased (Wang and Heady, 1980). In this case, the presence of autocorrelation is detected by the use of Durbin-h statistics. The problem is corrected by the use of autocorrelated 2SLS (A2SLS) discussed in detail by Fair (1980). The A2SLS is a consistent estimator, it is an efficient estimator in a class of limited information estimators if each equation has the same autocorrelation coefficient. The small sample properties of A2SLS have been studied by means of Monte Carlo study (Wang and Heady, 1980); and the results suggest that it performs reasonably well in the dynamic simultaneous equation model with alternative assumptions of error structure.

B. Other Empirical Considerations

a. Functional Forms

The choice of functional forms can be based on criteria such as 1) consistency with the regression method and the underlying production function, 2) ease of estimation including fewness of the estimated coefficients, 3) consistency with maintained hypothesis as to the way in which demand is related to the explanatory variables 4) conformity with the data as evidenced in the statistical results (t test, R^2, DW-statistic, etc), and 5) the reasonableness of the implied elasticities (Griffin (1984), Tomek and Robinson (1981)). Though these

criteria are important in the selection of functional forms, the functional forms used in previous input demand studies are maintained in this study for reasons explained earlier. These functional forms are linear and log-linear.

The linear form is the simplest functional form where the explanatory variables appear as additive elements:

1.19) $Y_{it} = \beta_0 + \beta_1 X_{1t} + \ldots + \beta_k X_{kt} + U_t$

where the β_i are the slopes and are constant over the entire range of the data. The elasticity of demand implied by the form is;

1.20) $\epsilon_i = \beta_i \ (X_i \ / \ Y_i)$

where $\beta_i = \partial \ Y_i / \partial \ X_i$. Thus for each one unit change in X, Y will change by β_i. The elasticity can be estimated at any price and input level, it is variable. In most of the previous studies the elasticities were estimated at the mean of the observations.

The log-linear functional form is as follows:

1.21) $\ln Y_{it} = b_o + b_1 \ln X_{1t} + \ldots\ldots + b_k \ln X_{kt} + U_t$

This form provides directly estimates of elasticities since slope and elasticities are the same, i.e.,

1.22) $$\epsilon_i = \beta_i = \frac{\partial \ln Y_i}{\partial \ln X_i} = \frac{\partial Y_i}{\partial X_i} \frac{X_i}{Y_i}$$

This functional form places some undesirable restrictions on the estimated elasticities. First, it implies that the elasticities will remain constant (while the slope is not constant) over any range of values which the explanatory

variables take on; this is contrary to a variable elasticity suggested by economic theory (Bohi, 1981). Second, it imposes a symmetry condition, i.e., the adjustment to quantity demanded whether price increases or decreases is the same. This is in line with the results of the static theory discussed above but may not be realistic under real world conditions. Because there are lags in adjustment due to technology, psychological preparedness, credit constraints, etc. the quantities may not be adjusted at the same rate when prices increase and decrease. Third, demand functions of this form are consistent with profit maximization only if the production function is log-linear. This would require that the elasticities of substitution among inputs in production be constant and equal (Bohi, 1981).

Though these restrictions may seem stringent, the major concern which is constant elasticity is not necessarily good or bad, rather, the point is that the implications of the mathematical properties of the function relative to the logic of the behavioral and economic relations must be recognized (Tomek and Robinson, 1981).

2. Identification Problem

This is a mathematical problem arising from the simultaneous equation system. Details of this problem can be found in any standard econometrics textbook (Johnston, Intriligator). In this excercise, the equations will be

identified by the order condition for identification through the use of zero restrictions. This condition requires that the number of excluded exogenous variables be greater than or equal to the number of included endogenous variables less one.

C. Source of Data

Aggregate time-series data for U.S. agriculture will be utilized. The data will cover the period 1946 to 1985. The major sources of data are various USDA publications and other sources based on USDA information. Some of these sources are Agricultural Statistics, Economic Indicators of the Farm Sector, 1986 Fact Book of U.S. Agriculture, and Statistical Abstract of the United States.

D. Definition of Variables

Definitions of variables used in the analysis are as follows:

Dependent Variables

LH_t = Hired farm workers employed, estimated by USDA and measured in numbers (thousands)

QLH_t = Hired farm workers employed adjusted for level of education obtained (quality) and calculated as follows:

a) $ILEH_t = \frac{LEH_t}{LEH_{77}} \times 100$

b) $QLH_t = LH_t \times ILEH_t$

where LEH is the median number of years in school

FW_t = The index of wage paid for hired farm labor

RFW_t = The index of wage paid for hired farm labor (1977=100) deflated by the consumer price index (1967=100).

Independent Variables

DLW_t = Real average hourly wage rate of non-agricultural labor.

UN_t = Percent civilian unemployment rate in the general economy.

LEH_t = Median number of years in school for those hired farm workers 18 and over.

LW_t = Average hourly wage rate of non-farm civilian labor force.

RLW_t = Average hourly wage rate of non-farm civilian labor force adjusted for unemployment and deflated by CPI, 1967 = 100 (Wang & Heady).

a) $K_t = LW_t\ (1 - 5.\ UN_t)$

b) $KK_t = K_t / K1977\ .\ 100$

c) $RLW_t = KK_t / CPI\ 1967{=}100$

Where LW_t is the average hourly wage of non-agricultural workers, UN_t stands for the unemployment rate in the general

economy, and CPI is the consumer price index. As indicated by Wang and Heady (1980), the variable RLW_t reflects the appeal of the real wage earned adjusted for employment opportunities in the non-farm sector. This formulation is based on the assumption that when the unemployment rate reaches 20 percent in the economy, there are no off-farm employment opportunities. And as a result, RLW_t has a zero effect on the supply of labor.

CLW_t = LW_t $(1-UN_t)$/CPI 1967=100

DPP_t = The index of prices received by farmers for all agricultural products (1977=100) deflated by the producer price index (1967=100).

DPM_t = Real prices of farm machinery, i.e., index of price paid for farm machinery (1977=100) deflated by the producer price index (1967=100).

RY_t = Net farm income in billions of dollars deflated by the producer price index (1967=100).

E_t = the ratio of U.S. farmers total equities to their outstanding liabilities for farming purposes

RZ_t = The value of agricultural exports deflated by the producer price index (1967 = 100)

R_t = Average interest rate on non-real estate loans outstanding on December 31.

D_t = Acreage diverted from crop production under various government programs.

N_t = Number of farms in the U.S. on January 1 of the current year.

A_t = Average farm size of U.S. farms in acres on January 1 of the current year.

TE_t = Index of agricultural productivity (1977=100), representing technical change.

T = Time represented by the last two digits of the current year. Used as a proxy for mobility and alternative employment opportunities.

E. Estimation Models

Because of the various conditions that give rise to lags in demand and supply of hired farm labor mentioned above, all demand and supply models will be specified using the Nerlove partial adjustment process. The simultaneous equation models will be estimated by two stage least squares. Also single equation models of hired labor demand functions will be estimated to see if simultaneity assumption is truly necessary.

Model A

This is a basic model of hired labor market which is similar to the one used by Wang and Heady (1980). The main feature of this model is that the real non-farm wage rates (DLW_t) and the unemployment rate (UN_t) are entered as separate explanatory variables in the supply function.

Demand

1.23) $LH_t = a_1 + a_2RFW_t + a_3DPM_t + a_4DPP_t + a_5TE_t + a_6LH_{t-1} + U_t$

and

Supply

1.24) $LH_t = b_1 + b_2RFW_t + b_3DLW_t + b_4UN_t + b_5LH_{t-1} + U_t$

Equations (1) and (2) are estimated by two-stage least squares regression, treating LH_t and RFW_t as endogenous variables.

Model B

Model B is the same demand function as model A but uses adjusted non-farm wage rate (RLW_t) instead of DLW_t and UN_t:

Demand

1.25) $LH_t = a_1 + a_2RFW_t + a_3DPM_t + a_4DPP_t + a_5TE_t + a_6LH_{t-1} + U_t$

Supply

1.26) $LH_t = b_1 + b_2RFW_t + b_3RLW_t + b_4LH_{t-1} + U_t$

Here the supplier of labor looks at the non-farm wage rate and the employment opportunity as related decision variables.

Model C

This model includes additional explanatory variables on the demand side. A lot of experimentation will be made here until theoretically and statistically sound models can be developed. Correct sign of coefficients, serial correlation, and

multicollinearity, and other concerns will be addressed. The additional explanatory variables are 1) interest rate on non-mortgage loans, b) price of land, c) farm income, d) agricultural exports, e) acreage diverted from crop production, f) farm numbers and g) average farm size.

Model D

In this model, the median number of years in school (LEH_t) will be introduced as a separate explanatory variable into both the demand and supply equations. This will enable to measure the impact of education separately in the demand and supply equations.

Demand

1.27) $$LH_t = a_1 + a_2RFW_t + a_3DPM_t + a_4DPP_t + a_5TE_t + a_6LH_{t-1} + a_7LEH_t + U_t$$

Supply

1.28) $$LH_t = b_1 + b_2RFW_t + b_3DLW_t + b_4UN_t + b_5LEH_t + U_t$$

Model E

This is a quality constant model whereby instead of using LEH_t as a separate explanatory variable, the number of hired labor employed, i.e., the dependent variable is adjusted for quality improvements (education):

Demand

1.29) $QLH_t = a_1 + a_2RFW_t + a_3DPM_t + a_4DPP_t + a_5TE_t + a_6QLH_{t-1} + U_t$

Supply

1.30) $QLH_t = b_1 + b_2RFW_t + b_3DLW_t + b_4UN_t + b_5QLH_{t-1} + U_t$

Model F

This is a single equation demand function for hired farm labor. It is hypothesised that hired farm labor demand is a function of real farm wage rate, real prices of substitute and complementary inputs, real prices received by farmers for all agricultural products, and other demand shifters. The assumption that quantity demanded and farm wages are determined simultaneously in the market place is dropped here.

1.26) $LH_t = a_1 + a_2RF_t + a_3DPM_t + a_4DPP_t + a_5TE_t + a_6LH_{t-1} + U_t$

This and other variations of this model are estimated and reported in Table 3.

F. Estimation Results

Table 3 presents the results of dynamic single and simultaneous equation estimations. The data period and the estimation techniques are shown in columns 2 and 3, respectively. The estimated equations are not exactly those presented in Models A to E but are slightly modified to avoid statistical problems

Table 3. Structural Coefficients of the Demand Functions for Hired Farm Labor.

Equ.	Data Period	Est. Method	Depend. Var.	C	RFW_t	FW_t	RY_{t-1}	Y_{t-1}	LH_{t-1}	QLH_{t-1}	RZ_{t-1}	Z_{t-1}	R_t	TE_t	PR_t	D_t	N_t	A_t	LEN_t	CLW_t	LW_t	LU_t	T	AR(1)	R^2	$\bar{R}^2$	dW	h	g
1.32	1946-85	OLS,O	LH	1932.82		-2.72		10.00*	.50*			.02*	-76.92*					-2.67*							.96	.96	1.80	.94	.50
						(2.45)		(3.06)	(.12)			(.007)	(38.55)					(.85)											
1.33	>>	>>	>>	1558.93	-18.06*		9.65**		.58*		.03*			-6.03**											.95	.94	1.93	.62	.42
					(7.81)		(5.81)		(.15)		(.01)			(3.48)															
1.34	>>	>>	>>	2003.09	-17.32*				.51*		.03*			-8.06*		-1.19									.95	.94	1.87	1.16	.49
					(7.85)				(.15)		(.01)			(3.01)		(.83)													
1.35	>>	>>	>>	1874.24	-36.82*		8.33**		.43*		.03*			-10.98*					128.57*						.96	.95	2.11	-.98	.57
					(10.90)		(5.13)		(.15)		(.01)			(3.88)					(55.95)										
1.36 D	>>	2SLS,O	>>	1940.90		-2.97		10.00*	.49*			.02*	-72.22**					-2.72*									1.79		.51
						(2.93)		(3.03)	(.12)			(.01)	(39.29)					(.85)											
S	>>	>>	>>	2823.03		8.40			.43*												-90.04	5087.74*	-36.41*				2.30		.53
						(6.40)			(.13)												(130.02)	(1419.78)	(8.75)						
1.37 D	>>	A2SLS,O	>>	2311.71		-1.88		10.22*	.41*			.02*	-93.52*					-3.24*						.17			1.99	.23	.59
						(3.31)		(3.29)	(.20)			(.01)	(45.41)					(1.33)						(.27)					
S	>>	>>	>>	2541.00		8.18			.49*												-94.55	5135.49*	-33.12*	-.23			2.07		.51
						(6.21)			(.14)												(127.92)	(1332.91)	(9.56)	(.20)					
1.38 D	>>	2SLS,O	>>	2091.57	-25.95*		10.14**		.45*		.04*			-6.58**													1.70		.55
					(11.86)		(5.56)		(.21)		(.01)			(3.54)															
S	>>	>>	>>	905.80	22.95*				.80*											-71.36		6010.36*	-26.30*				2.28		.20
					(11.16)				(.15)											(47.58)		(1532.81)	(5.85)						

Table 3. (Continued)

Equ.	Data Period	Est. Method	Depend. Var.	C	RFW_t	FW_t	RY_{t-1}	Y_{t-1}	LH_{t-1}	QLH_{t-1}	RZ_{t-1}	Z_{t-1}	R_t	TE_t	PR_t	D_t	N_t	A_t	LEH_t	CLW_t	LW_t	LU_t	T	AR(1)	R^2	$\bar{R}^2$	dW	h	g
1.39 D	>>	A2LS,O	>>	3363.51	-38.20*		12.32**		.12		.05*			-10.35*										.42*			1.94		.88
					(12.83)		(7.42)		(.27)		(.02)			(4.83)										(.20)					
S	>>	>>	>>	737.99	22.23*				.84*											-65.63		5924.83*	-24.46*	-.19			2.00		.16
					(10.27)				(.14)											(48.58)		(1440.50)	(5.60)	(2.18)					
1.40 D	>>	2SLS,O	LH	2759.36	-27.60*				.34		.04*			-9.26*		1.31											1.55		.66
					(12.82)				(.23)		(.02)			(3.11)		(.85)													
S	>>	>>	>>	721.86	29.16*				.86*												-86.52	5999.49*	-28.30*				2.13		.14
					(14.50)				(.18)												(54.83)	(1635.46)	(6.80)						
1.41	>>	OLS,O	QLH	2958.38				12.92*		.50*			-42.59**		.68*		-.21	-5.04*							.80	.76	1.95	.23	.50
								(3.46)		(.12)			(25.40)		(.25)		(.25)	(2.40)											
1.42	>>	>>	>>	1249.88		-1.47		11.17*		.45*		.02*	-70.25**					-1.13*							.80	.76	1.66	2.18	.55
						(2.62)		(3.14)		(.14)		(.007)	(39.06)					(.56)											

* = significant at 5% level.
** = significant at 10% level.
Numbers in parentheses are the standard errors.

encountered during estimation. Equations 1.32 to 1.35 are single equation total hired labor demand and equations 1.41 and 1.42 are total hired labor demand on constant quality basis and all were estimated by OLS. The rest are simultaneous equation models and were estimated by 2SLS and A2SLS.

Definitions of explanatory variables are as given above and additional definitions are provided at the bottom of the relevant tables, when needed. In all the equations estimated by 2SLS and A2SLS, all the equations were just or over-identified based on the necessary condition for identification (Johnston, 1984). That is, the number of variables that do not appear in a given equation is equal or greater than the number of endogenous variables in a given equation less one. The Durbin-Watson (dw) statistic and the Durbin-h statistic are reported for all the single equation OLS estimates. However, only the h-statistic is meaningful in those models where the lagged values of the dependent variables are included among the regressors. The dw statistic is also reported for the 2SLS estimates as a matter of information despite the fact that the statistic was designed for single equation regression models where all the explanatory variables are exogenous (Wang and Heady). R^2 and $\bar{R}^2$ are reported only for the single equation estimates since they are meaningless in simultaneous equation context.

Now focusing on the empirical results in Table 3, the R^2 are all high. Based on Durbin-h statistic, only equations 1.37

and 1.39 had auto-correlated disturbances and were estimated by A2SLS. The coefficients of real farm wage (RFW_t) are negative as expected and significant. However, the coefficients of the undeflated wage rate (FW_t) are negative but not significant, implying that nominal wages are not important determinants of hired labor demand. The price received for agricultural products was not significant in most unreported equations and hence, it was not included in the equations. The lagged net farm income (RY_{t-1}), used as a proxy for the wage of family labor, has positive coefficients and is significant at the 10 percent level in equations 1.33, 1.35, and 1.38 and 1.39. Also the undeflated lagged farm income, Y_{t-1} has positive and highly significant coefficients. These results suggest that hired and family labor are close substitutes.

The coefficients of agricultural exports lagged one period, RZ_{t-1} and Z_{t-1}, are positive and significant, suggesting that increases in agricultural exports increase the demand for hired labor with a time lag. Non-mortgage interest rate is negatively related with hired labor demand and is significant. Thus, an increase in interest rate will lead to reduced demand for hired labor in the same period.

The agricultural productivity index, TE_t, used as a proxy for technical change, has negative coefficients and is mostly significant at the 5 percent level. This implies that improvements in technology decrease the demand for hired farm

labor by allowing the substitution of capital for labor. This result is consistent with the general decline in the use of labor observed in Table 1. Acreage diverted from crop production, farm numbers, and average farm size have negative coefficients, but only average farm size was significant. Thus the models suggest that increase in the average farm size decreases the demand for hired labor. This may be due to the substitution of smaller machinery by larger machinery as the farm size increases which in turn leads to fewer machinery operators.

The educational level attained by hired labor force, represented by the average number of years in school (LEH_t), was introduced into model 1.35 and its coefficient is positive and significant. Since the effect of education, at least in the short-run, is to increase productivity, i.e., increase the marginal product of labor, it pays to use more hired labor as its quality increases so long as wages are not proportionately increasing and/or output is increasing, ceteris paribus. In the long-run, the improved education would make it easier for agricultural workers to transfer to alternative occupations.

Models 1.41 and 1.42 were estimated on quality constant basis by correcting the quantity of hired labor employed by the average number of years in school as explained earlier. In both equations, the R^2 was 0.80 and the magnitude of the coefficients of the explanatory variables were very close to those of the other models.

Several of the above models were also estimated in log-linear form, unfortunately, incorrect signs and non-significant coefficients and very low R^2 were encountered. Also other independent variables such as the price and stock of farm machinery and the ratio of farmers' equities to their outstanding liabilities were incorporated into some of the models, but again, the results were not satisfactory for the same reasons. In general, both the single equation and simultaneous equation models with deflated explanatory variables performed relatively better. Particularly models 1.33, 1.34 and 1.38 performed well on the basis of expected signs and significance of the coefficients, level of R^2, absence of serial correlation, etc.

On the supply side, the real farm wage had positive coefficient and was significant. But the nominal wage was negative and not significant. Other significant explanatory variables with expected signs were the lagged dependent variable, the unemployment rate in the general economy, and the time trend variable. Thus, when the unemployment rate in the general economy increases, the supply of hired labor to agriculture will increase. On the other hand, when opportunities for mobility and alternative employment increase, as represented by the time trend variable, then the supply of hired labor to agriculture will fall. This result is consistent with those of Schuh (1962) and Wang and Heady (1980) but not with Hammonds, et. al. (1973).

Non-farm wage rate adjusted for unemployment (DLW_t) and unadjusted for unemployment (LW_t) have negative coefficients as expected, but both were not significant. A probable explanation for such a result is that, since labor has some element of fixity due to costs of mobility and preference for work, the variables may not be appropriate to depict alternative wages. Although not attempted here, an alternative to this may be to use the expected value of non-farm earnings (Schuh, 1962).

G. Elasticities of Hired Farm Labor Demand

The elasticities of demand of hired labor with respect to the major explanatory variables are presented in Table 4. The short-run elasticities were estimated at the mean of the observations and the long-run elasticities were derived from the short-run elasticities using the adjustment coefficient.

The short-run elasticity of demand with respect to the real farm wage ranges between -.47 and -1.00 and the long-run elasticity between -.90 and -1.70. Thus a 10 percent increase in the real farm wage will reduce hired labor demand by 4.7 to 10.0 percent in the short-run and by 9.0 to 17.0 percent in the long-run. Demand is not responsive to agricultural exports both in the short and long run with a 10 percent increase in agricultural exports leading only to about one to two percent increase in demand in the short-run and by about 3 percent in the long-run.

Table 4

Elasticities of Demand of Hired Farm Labor

	Short-run				Long-run				
Equation	RFW_t	RZ_{t-1}	TE_t	A_t	RFW_t	RZ_{t-1}	TE_t	A_t	g
1.32	-	-	-	-.55	-	-	-	-1.10	.50
1.33	-.47	.14	-.32	-	-1.12	.33	-.76	-	.42
1.34	-.46	.14	-.42	-	-.94	.29	-.86	-	.49
1.35	-.97	.14	-.58	-	-1.70	.25	-1.02	-	.57
1.36	-	-	-	-.56	-	-	-	-1.22	.46
1.37	-.68	.19	-.35	-	-1.24	.35	-.63	-	.55
1.38	-1.00	.23	-.54	-	-1.14	.26	-.61	-	.88
1.39	-.73	.19	-.49	-	-.90	.29	-.74	-	.66

g = adjustment coefficient

Similarly, the elasticity of hired labor demand with respect to the index of technology is between -.32 and -.58 in the short-run and between -.61 and -1.02 in the long-run, which are generally inelastic. However, relatively speaking, demand is more responsive to technology than to most variables due to its dynamic role in facilitating the substitution of inputs. As put forth by Schuh (1962), to the extent that technology has been an exogenous force in the labor market, it has acted to reduce the quantity of labor demanded by allowing capital to be relatively less expensive than labor and increasing high-paying off-farm employment opportunities.

Finally, the elasticity of hired labor demand with respect to average farm size is between -.55 and -.56 in the short-run and between -1.10 and -1.22 in the long-run. A possible reason why it is inelastic in the short-run but elastic in the long-run is that as farm size increases, it may not be possible to substitute hired labor by mechanical and chemical inputs immediately because of contractual obligations involved in hiring labor and due to the need for credit to purchase substitute inputs. Also, land is usually used as a collateral to secure credit, thereby increasing the time lag between increase in the farm size and the securing of loans to buy the inputs that will be substituted for hired labor.

H. Update of Selected Previous Hired Farm Labor Demand Estimates

Selected estimates of selected previous hired farm labor demand studies were updated using data for the period 1946-85. The results of the original estimates and the updates are presented in Table 5. In Heady and Tweeten's original model 8.9 (equ. 1.43), the R^2 was .98 in the original and .94 in the update (equ. 1.43'). The real farm wage (RFW_t) was negative and significant at the 10 percent level in the original, but in the update it is still negative but not significant. The coefficients of the lagged dependent variables are almost equal in magnitude and significant in both the original estimate and the update. Contrary to the negative coefficients reported in Table 3, the time trend variable has positive coefficients, though not significant. Also, this result is not in agreement with the generally declining trend in hired labor utilization observed over the period 1946-85.

In Heady and Tweeten's original model 8.12 (equ. 1.44) of the same study, the R^2 declined from .98 in the original to .95 in the updated estimate (equ. 1.44'). The farm wage rate deflated by the price paid index, PFW_t, was negative and not significant in both the original and the updated estimates. All the other variables had similar signs for the coefficients. The average price received by farmers, DPP_t, was insignificant in the original estimate but significant in the update. Also the

Table 5. Update of Selected Previous Hired Farm Labor Demand Estimates.

Equation	Study	Data Period	Est. Method	Dept. Var.	C	RFW_t	PFW_t	DPP_t	MPP_t
1.43	Heady & Tweeten (Model 8.9)	1910-57	OLS,O	LH	27.89	-.10* (.06)			.05 (.03)
1.43′	Update	1946-85	>>	>>	164.00	-1.31 (8.39)			1239.82 (896.74)
1.44	Heady & Tweeten (Model 8.12)	1910-57	>>	>>	23.86		-.05 (.06)	.05 (.06)	
1.44′	Update	1946-85	>>	>>	2020.61		-586.82 (452.05)	2.51* (1.24)	
1.45	Hammonds D	1941-69	2SLS,O	>>	1927.77	-16.99* (4.25)		8.35* (2.41)	
	S	>>	>>	>>	1112.09	4.88 (4.88)			
1.45′	Update D	1946-85	>>	>>	218.40	-3.01 (9.21)		194.66 (206.78)	
	S	>>	>>	>>	1282.21	10.24 (11.16)			
1.46	Wang & Heady D (Model 24&25)	1941-73	2SLS	>>	1968.78	-16.85* (7.77)		7.73* (3.76)	
	S	>>	>>	>>	88.11	5.00** (2.99)			
1.46′	Update D	1946-85	>>	>>	301.21	-4.90* (9.25)		207.26 (207.37)	
	S	>>	>>	>>	442.09	6.85 (13.70)			

Table 5. (Continued)

Equation	Study	LH_{t-1}	RLW_t	CLW_t	LU_t	TE_t	T	R^2	$\bar{R}^2$	dW	h	g
1.43	Heady & Tweeten (Model 8.9)	.83* (.07)					.18 (.12)	.98				.17
1.43′	Update	.81* (.13)					.11 (6.52)	.94	.93	2.09	-.48	.19
1.44	Heady & Tweeten (Model 8.12)	.85* (.07)					-.24* (.11)	.98				.16
1.44′	Update	.49* (.15)					-14.03* (6.93)	.95	.94	2.04	-.36	.51
1.45	Hammonds D	.19 (.21)				4.70 (3.36)						.81
	S	.70* (.23)		-24.95* (6.90)	24.70* (13.00)		5.67 (6.30)					.30
1.45′	Update D	.83* (.16)				-.67 (3.07)				2.05	-.86	.17
	S	.69* (.14)		-40.34 (44.96)	6032.61* (1405.76)		22.19* (5.56)			2.41		.31
1.46	Wang & Heady D (Model 24&25)	.21 (.34)				4.39 (4.80)				.47		.79
	S	.98* (.10)	-5.91* (1.11)				-7.00* (3.50)			1.94		.02
1.46′	Update D	.80* (.16)				-.35 (3.08)				1.98		.20
	S	.88* (.16)	-1.00 (3.13)				-7.92 (5.73)			2.05		.12

PFW_t = Wage of hired labor deflated by the index of prices paid by farmers for production expenses.

MPP_t = Index of prices received by farmers deflated by the index of farm machinery prices.

Numbers in parenthesis are the standard errors.

coefficient of the lagged dependent variable has become smaller and within the range estimated for the single equation models reported in Table 3. The time trend variable has a negative sign and is significant both in the original and the updated estimate and this agrees with the results reported earlier in Table 3.

In the simultaneous equation model of Hammonds, et. al., estimated by 2SLS (equ. 1.45), all the corresponding variables other than the index of technology, have the same signs in the original and the update (equ. 1.45′) and there was no serial correlation problem. The real farm wage and the real price received by farmers were significant at the 5 percent level in the original estimate but only the lagged dependent variable was significant in the update. Also, the magnitude of the lagged dependent variable increased over four-fold in the update, thus substantially decreasing the adjustment coefficient. There are two major concerns with this model. First, the lagged dependent variable was not significant in the original estimate and hence, a dynamic model wouldn't have been appropriate. Second, all the explanatory variables other than the lagged dependent variable were insignificant in the update, which implies that the demand for hired labor is determined by demand in the past period. These problems seem to be the result of multicollinearity arising from high collinearity between the lagged dependent variable and

the price variables and severely limit the usefulness of the model.

Finally, in Wang and Heady's original models (24) and (25), i.e., updated as equation 1.46', all the coefficients other than that of the index of technical change (TE_t) have similar signs in both the original and the update. The sign of TE_t changed from positive to negative in the demand equation, although it was not significant in both. In the original demand estimate, RFW_t and LH_{t-1} were significant but in the updated estimate, only LH_{t-1} was significant. Again this lack of significance is suspected to be due to the same problems discussed above in conjunction with Hammonds' model.

The updating of the above three previous estimates leads to the following two generalizations. First, of the four models updated above, only Heady and Tweeten's original model 8.12 performed well in terms of high R^2, correct signs of coefficients, and significance of three out of four coefficients. In two of the remaining three models, only the lagged dependent variable was significant. Second, the adjustment coefficient of the updated estimates varied from .17 in Hammonds' model to .51 in Heady and Tweeten's model 8.12, thus giving widely differing adjustment speeds. Of these models, only the adjustment coefficient of the update of model 8.12 approximates those of the current study reported in Table 3. This again shows that Heady

and Tweeten's original model 8.12 is a better model specification given the new set of data.

A summary of the elasticities of hired labor demand and supply with respect to real farm wage of selected previous demand studies and their updates is provided in Table 6. Both the short-run and long-run wage elasticities greatly vary within each study and among the studies due to differences in data periods, estimation techniques, and statistical problems discussed in detail in the respective studies. However, certain general patterns are discernible from the table. If we look at the original estimates, the short-run wage elasticity increased over time from -.03 in Heady and Tweeten's study to close to unit elasticity in Hammonds, Olson, Wang and Heady, and the current study. The long-run wage elasticity also exhibits a similar pattern and is already in the elastic range.

On the supply side, the short-run wage elasticity is highly inelastic, with the current study having much larger values. The pattern of the long-run wage elasticity is not clear due to big differences in the sizes of the adjustment coefficients obtained in these studies. An explanation why the short-run wage elasticity is so inelastic may be due to the fact that most of the mobile labor force has already moved out of agriculture and the remaining small force is partly under some sort of contractual obligation that may not allow them to take new

Table 6

Elasticities of Demand and Supply of Hired Farm Labor with Respect to Real Farm Wage of Previous and Updated Estimates

Study	Data Period	Estimation	Demand		Supply	
			Short-run	Long-run	Short-run	Long-run
Heady & Tweeten (Model 12)	1910-57	OLS	-.03	.17	-	-
" Update	1946-85	OLS	-.29	-.57	-	-
Heady & Tweeten (1963, all)	1910-57	OLS	-.03 to -.10	-.17 to -.91	-	-
Hammonds et. al.	1946-85	2SLS	-.85	-1.05	.24	.82
" Update	1946-69	2SLS	-.08	-.47	.27	.87
Schuh (1962)	1929-57	Theil-Basmann	-.12	-.40	.25	.78
Olson (1979)	1946-77	OLS	-.60 to -.90	-	-	-
Wang & Heady (All)	1941-73	2SLS	-.33 to -1.33	-.84 to -1.35	.002 to .77	.007 to 1.30
Current Study	1946-85	OLS, 2SLS	-.46 to -1.00	-.90 to -1.70	.58 to .77	3.00 to 5.00

employment when available. Also the relatively low wages in agriculture may not be able to attract labor from other sectors of the economy.

IV. Summary and Conclusions

The single equation dynamic models, equ. 1.32 and 1.35 performed well with R^2 of 0.95 or better and the coefficients had the expected signs and were mostly significant at the 5 percent level. All the coefficients of the lagged dependent variable were highly significant implying that dynamic models are appropriate for the analysis. However, as discussed in detail above, the dynamic specifications seem to contribute to specification problems arising from the lagged dependent variables picking up the effects of left out variables. Two single equation models estimated on quality constant basis, equations 1.41 and 1.42, gave R^2 of .80, which is comparatively low, though most of the variables had the expected signs and were significant. Since this is probably the first study of constant quality hired labor demand, the results are encouraging.

The simultaneous equation models 1.36 to 1.40 estimated by 2SLS also performed quite well yielding estimates comparable to those of the single equation models. In models 1.36 and 1.38, serial correlation was suspected and the equations were re-estimated by A2SLS and reported as models 1.37 and 1.39, respectively. However, the results were not much different from those of 2SLS and the autocorrelation coefficients were not statistically significant. In general, both the single equation and simultaneous equation models performed satisfactorily and are appropriate for hired labor demand analysis. However, this doesn't help to strongly support the assumption of simultaneous

doesn't help to strongly support the assumption of simultaneous determination of quantity demanded and farm wage.

The empirical estimates of labor demand showed that real farm wage had the expected sign and was significant. The short-run real wage elasticity was between -.46 and -1.00 and the higher side favorably compares with the results of the relatively recent studies such as those of Hammonds (1973), Olson (1979), and Wang and Heady (1980). The long-run real wage elasticity was between -.90 and -1.72, which is elastic, showing that farmers will adjust the size of the hired labor force given sufficient time to adjust the use of other inputs. Also, a comparison of this result with those of previous hired labor studies shows that the real farm wage elasticity is increasing over time. This trend is also consistent with the findings of the studies mentioned above.

The other major determinants of hired labor demand are the lagged real farm income, agricultural exports, interest rate, the index of technical change, average farm size and the level of education. Lagged real farm income, used as a proxy for the wage of family labor, has positive coefficient and is significant showing that hired and family labor are substitutes. The results do not support that acreage diverted from crop production and farm numbers are determinants of hired labor demand.

On the supply side, the real farm wage has a positive and significant coefficient. The short-run wage supply elasticity is between .58 and .77 and the long-run elasticity is between 3.00

and 5.00. The long elasticity is quite large and outside the range estimated in the previous studies. The problem seems to originate from specification bias arising from left out variables which would bias the coefficient of the lagged dependent variable upward, thereby making the adjustment coefficient small. The other major determinant of the supply of hired labor are the unemployment rate in the general economy and the time trend variable.

Though the findings of this study generally agree with those of the previous studies, the update of selected models of some of the previous studies, using data for the period 1946-85, didn't give good results, i.e., insignificant coefficients, unexpected signs of regressors, and widely differing magnitudes of coefficients were encountered. On the other hand, as shown above, the same set of data, estimation methods, and functional forms but with different model specifications, gave quite good results. From these we can deduce that most of the models used in previous studies are not appropriate to analyze current hired labor demand with different sets of data and varied economic conditions.

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