The Effect of Technological Change on the Demand and Supply of Hired Farm Workers in the United States

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Abstract: *This paper investigates the effect of technological change on the demand for, and supply of, hired farm workers in the United States for the period 1950 to 1992. Particular attention is given to the proxy for technological change. We have used total expenditures, both by public and private sectors, for research and development in the field of agriculture. We find that technology has a negative impact on the hired labor demand after the second and third year of initial investment. Our results show that technology is labor saving. The demand and supply elasticities were found to differ from other studies. We also derive elasticities of adjustment and draw some policy conclusions. The paper also presents a dynamic-in-period simulation of the estimated model.*

Key Words and Phrases: *Elasticity, hired workers, technological change, total expenditures.*

The number of farms in the United States has declined by nearly 3.6 million, from 5.6 million farms in 1950 to 2.0 million in 1992 (Jones and Canning). The trend toward fewer, but larger, farms accelerated during the 1950s and 1960s, but slowed in the 1970s. The latest census data (U.S. Department of Commerce) show that the long-term structural trend of declining farm numbers, decreasing land in farms, and increasing farm size continued throughout the 1980s. Farms have become fewer and larger, and the decline in the number of farms has reduced the number of farm operators and family workers. The number of hired farm workers has declined as well, but not as much as the number of family workers.[1] The United States agricultural production sector remains heavily dependent on hired farm workers, even in a period of farm consolidation and at a time when more farm operators and their family members are depending upon off-farm work as an income source (Mishra).

Hired farm workers accounted for about 25% of annual average farm[2] employment in 1910. During the 1980s and 1990s this percentage remained constant at 35%, with exceptions in 1986 and 1987, when it increased to its highest level of 36% (Whitener; Oliveira and Cox). In addition, the percentage of hired farm workers, employed for more than 250 days per year increased from about 11% in 1971 to approximately 19% in 1991. During the same period, the percentage of casual workers, those working for

Table 1.
Distribution of Hired Farm Workers by Duration of Farm Work, 1946-1991

Year	Total Workers (000)	Less Than 25 Days	25-74 Days	75-250 Days	Greater Than 250 Days
		-------------Percentage	-------------		
1946	2770	29.50	27.00	23.50	19.90
1951	3274	34.10	28.30	20.80	6.80
1956	3575	41.90	25.70	20.00	12.40
1961	3488	45.90	24.30	18.20	12.20
1966	2763	40.90	26.00	19.90	13.30
1971	2488	46.70	25.40	16.70	11.20
1976	2767	41.40	23.60	23.00	12.00
1981	2492	38.80	21.60	23.70	15.90
1986	2577	37.40	20.10	24.70	17.80
1991	2463	34.75	20.42	26.19	18.94

Sources: Coltrane; Whitener; Oliveira & Cox; Runyan (1994); Runyan (1997).

less than 25 days per year, decreased from approximately 47% to 35% (Table 1). The trend toward relatively greater participation in the farm labor force by hired farm workers, as opposed to farm operators and their families, may be related to farm consolidation, crop specialization and the emergence of new technologies that have made these structural changes feasible (Emerson; Coltrane; Holt).

Many researchers recognize the importance of hired farm workers in U.S. agriculture and note the declining trend in the use of labor (Duffield and Coltrane; Gunter; Holt; Huffman; Gardner; Gallasch; Gallasch and Gardner; Tyrchniewicz and Schuh; Wallace and Hoover; Gisser). Holt associates this decline in labor usage with the increasing capital intensity of agriculture and the rapid adoption of new technology. How technology affects the demand and supply of hired farm labor has implications for the structural change in agriculture. Wallace and Hoover, extending the work of Gisser, were the first to examine how technological change impacts the demand for hired labor. Using cross-sectional data, they proxied technological change by expenditures of Agricultural Experiment Station Research and Cooperative Extension Services (R+E) and used this measure as an additional variable in a demand function for hired labor.[3] Their findings showed a positive coefficient on the variable for R+E, which indicates that the demand for labor increases with technology.

However, the positive association between R+E and the demand for labor was shown to become negative upon including a known demand function for output.

It should be noted that the Wallace and Hoover study was limited in at least two ways. First, because of the cross-sectional nature of the data, product prices were held constant. Second, their data on research and development did not include private expenditures on research and development. It should be noted that "private R & D" involves money spent by private firms to produce better machines and farming equipment, better fertilizer and better pesticides and insecticides.

The objective of this paper is to examine the factors affecting the demand for and supply of hired farm workers in the United States during the 1950 to 1992 period. Particular attention is given to the role of technological change in determining demand for, and supply of, hired farm workers. The analysis uses the three stage least squares (3SLS) estimation procedure to evaluate the empirically specified simultaneous equation model.[4] Elasticities (both short-run and long-run) are determined that enable the derivation of valuable information regarding policy changes, such as government price support programs (that are being phased out of the agricultural sector); the effects of trade agreements, such as the North American Free Trade Agreement (NAFTA); and, finally, the effect of immigration policy on the market of hired farm workers.

Background

Previous studies (e.g., Schuh; Tyrchniewicz and Schuh; Wallace and Hoover; Gardner; Gunter) investigating factors affecting the demand and supply of hired farm workers support the hypothesis that the demand for, and supply of, hired farm labor depend on farm wage rates, nonfarm wage rates, price of farm products and other factors. Many researchers in the late 1960s and early 1970s examined the effects of the agricultural minimum wage on the demand for, and supply of, hired farm workers (see, for example, Gardner; Gallasch; and Gallasch and Gardner). The first empirical research that treated hired farm workers as a separate market was conducted by Schuh. Later studies by Tyrchniewicz and Schuh econometrically analyzed the regional and demographic submarkets of hired farm workers. Other studies investigated the effect of U.S. immigration reform on the hired farm labor market (Gunter et al., Duffield and Coltrane). Duffield and Coltrane investigated the disequilibrium in the hired farm workers market caused by the Immigration Reform and Control Act (IRCA) of 1986. Their study suggests that the hired labor market is efficient and labor is not misallocated. A study by Gunter et al., on the other hand, concludes that because of IRCA there has been an increased supply of agricultural workers coming to the United States. However, Gunter et al. point out that these workers are likely to take jobs in other sectors of the economy, resulting in a shortage of farm laborers. A decrease in labor supply is shown to have a small effect on fruit and vegetable production (a labor-intensive operation).

Using micro-level, cross-sectional data from Georgia, Gunter analyzed factors affecting pricing of regular hired farm labor. The study concludes that farm wages are impacted by local labor market conditions, farm characteristics and human capital differences among workers. Perloff, using 1988 Current Population Survey data, studied the wage rate differential between agriculture and other sectors and found that it does not take large wage increases to encourage workers to switch from other sectors to agriculture.

The impact of technological change on farm labor demand was examined by Heady and Tweeten using time as a proxy for technological change. Using Ordinary Least Squares (OLS), they obtained a significant negative coefficient for technological change in explaining agricultural labor demand. Tyrchniewicz and Schuh, using a similar measure of technology and the 2SLS estimation procedure, found a statistically significant negative effect of time on the demand for hired farm workers. However, the time trend was included to account for the secular shifts in preferences on the part of employers and institutional, and other changes in the economy. Hammond, et al. used agricultural productivity as a proxy for technological change and concluded that it has a positive impact on the demand for hired farm workers. While studies have concentrated on cross-sectional analysis and on studying the effect of various issues (immigration, minimum wage) on the demand and supply of hired farm workers, it is worth noting that little attention has been given in the literature to adequately modeling and examining the effects of technological change on the demand for hired farm workers.

Model Specification

The econometric model is based on the standard theory of demand for, and supply of, labor in a competitive market. Marginal productivity is used as a guide for specifying the demand for hired farm workers. Using the theory of perfect competition in both factor and product markets, input demand by the firm is obtained from the individual firm's first-order conditions for profit maximization (Heady; Hamermesh; and Tyrchniewicz and Schuh). As a result, the input demand function is a function of input prices, prices of output and level of technology. The aggregate input demand function is obtained by summing individual firms' input demand functions (Hamermesh).

An individual's labor supply is derived from the first-order conditions of the individual's utility maximization. The market supply of labor is obtained by summing all individuals' labor supply functions (Killingsworth). Therefore, supply of labor is partly a function of the wage rate available to the worker. It follows that the market supply of hired farm workers should be a function of the farm wage rate, alternative wage rates (nonfarm wages), and other factors such as contractual obligations and changing economic conditions.

The conceptual model discussed above and the data availability allow us to specify the demand for hired farm workers as:

$$FWA_t = \alpha_0 + \alpha_1 Y_t + \alpha_2 PRF_t + \alpha_3 PPF_t + \alpha_4 PLB_t + \alpha_5 Y_{t-1} + \sum_{i=0}^{2} \alpha_6^i (RADEXP)_{t-i} + u_t \quad (1)$$

and the supply of hired farm workers as:

$$Y_t = \beta_0 + \beta_1 FWA_t + \beta_2 NFW_t + \beta_3 MINW_t + \beta_4 TREND_t + \beta_5 Y_{t-1} + e_t, \quad (2)$$

where:

Y_t	=	Number of hired farm workers (in millions),
FWA	=	Real farm wage rate ($ per hour), deflated by the GNP deflator (1982=100),
NFW	=	Nonfarm manufacturing wage rate ($ per hour), deflated by the GNP deflator (1982=100),
PPF	=	Index of prices paid by farmers for other material inputs (index, 1982=100),
PLB	=	Price of land and buildings, deflated by the GNP deflator (1982=100),
PRF	=	Index of prices received by farmers for farm output (index, 1982=100),
MINW	=	Minimum wage rate ($ per hour),
$RADEXP_{t-i}$	=	Total expenditures, both public and private on research and development for the current period (i=0) and for the past two years (i=1 and i=2), as proxy variable for technology.

Note that the demand equation is specified in the price-dependent form and the supply equation is specified in the quantity-dependent form. Both left hand side variables are endogenously determined and, also, wages enter as an argument in the production function. Furthermore, it should not make a difference in convergence if one uses the same instruments. This empirical specification is consistent with the work of Gardner, and Wallace and Hoover.

Data

Annual observations covering the period from 1950 to 1992 are used in this study.[5] The variable Y_t represents hired farm workers (in millions) and is obtained from various issues of the *Economic Report of the President*. The number of hired farm workers is the annual average employment of hired farm workers.[6] In making the decision to enter the hired farm labor market, a worker considers farm wages and nonfarm wages. Hourly nominal farm wage rates in dollars per hour are converted to real farm wage rates (FWA) by the GNP deflator.[9]

An hourly real nonfarm wage (NFW) in dollars per hour is included in the supply function to reflect the alternative wage received by workers in other markets. NFW is measured by the annual average hourly earnings of production workers on manufacturing payrolls.[10] Data on nominal nonfarm wage rates were obtained from *Employment and Earnings* (U.S. Department of Labor, various). These nominal wages, adjusted for unemployment, were deflated by the GNP deflator.[11] The variables PPF and PLB are included in the model to investigate the effect of nonlabor (other material inputs, land and capital) inputs on the demand for hired farm workers. The data for both variables were obtained from *Agricultural Statistics* (U.S. Department of Agriculture, various). The minimum wage variable (MINW) is treated essentially as a dummy variable; it is zero before 1967 and 1 thereafter because on February 1, 1967, the agricultural labor force of the United States became covered, for the first time, by federal minimum wage laws and other statutes of the Fair Labor Standards Act (U.S. Department of Labor, 1970). The index of prices received (PRF) by farmers is included in the demand function to account for the farm size effect and also the price support programs. Data for this variable were obtained from *Agricultural Statistics* (U.S. Department of Agriculture, various). A trend variable (TREND) is included in the supply function to account for any changes in tastes and preferences for employment in other industries (as pointed out by Tyrchiewicz and Schuh); the effect of age; and the effect of increased schooling or experience on mobility. The variable may also account for working conditions (Ballerby) in other industries such as shorter working hours, fringe benefits (McCarthy and Morrison), improved transportation (Bennett and Gade), and changes in communication systems.

The variable RADEXP represents a measure of technological change. This variable is the sum of the expenditures (in million dollars, deflated by GNP deflator, 1982=100) on Experiment Station Research, Cooperative Agricultural Extension work, and private expenditures on research and development in the agricultural sector (firms making tractors, combines or farm equipment). The data on expenditures on Experiment Station Research and Cooperative Agricultural Extension work were obtained from Huffman and Evenson. Data on private expenditures in research and development were obtained from Statistical Abstract of the United States. In modeling technological change, the Almon polynomial distributed lag approach was used. The reason for a lagged approach is that the actual expenditures are observed over subsequent years as plans are finalized, materials and labor are engaged in the project and construction is carried out. Thus, it is expected the effects of current research and development (RAD) expenditures will be "distributed" over the current and future periods until the projects are completed. Furthermore, since a certain amount of "start-up" time is required for any investment project, it is expected that major effects of the investments are delayed for several periods. Since current expenditures are distributed in the current and future periods until the projects are completed, we may equivalently model the effect of RAD expenditures on the demand for hired labor as a distributed lag structure.

A partial adjustment specification is introduced into each equation with the use of the lagged value of hired farm workers variable (Nerlove). This specification allows us to measure the length of time workers and employers need to adjust to changes in the system. Nerlove shows that only a fixed fraction of the desired adjustment is accomplished in one period. This measurement is called the elasticity of adjustment and shows the relationship between the long-run equilibrium level and the current level, and takes a value between 0 and 1. In the supply function, it is obtained by subtracting the estimated coefficient of the lagged hired farm workers from 1. In the demand function, the elasticity of adjustment is obtained by first solving the demand equation with respect to the hired farm labor variable (Y_t) and then by subtracting the calculated coefficient of the lagged hired farm workers from 1 (Duffield and Coltrane).

Results and Dynamic In-Period Simulation

The three-stage least squares (3SLS) procedure provides consistent estimates for a dynamic simultaneous equation system when the equations are over-identified and the errors are assumed to be independent. Given that lagged dependent variables have been included in each equation, one should test for autocorrelated errors. The Durbin-Watson test or Durbin's h statistic, which is usually used for detecting autocorrelation, is not appropriate for testing dynamic simultaneous equation systems. Godfrey developed a large-sample test for autocorrelation to use in place of the Durbin-Watson test; this test was used to test the present model. No evidence of autocorrelation was present in either equation (1) or (2).

Equations 1 and 2 are estimated as a system of equations by using the three-stage least squares (3SLS) estimation technique. System variables were expressed in natural logarithms. The parameter estimates and the summary statistics of the models are presented in Table 2. Regression results support the econometric specification of the model and most of the estimated parameters are significant at the 0.10 level or greater. The slope of the inverse demand function is negative and statistically significant

Table 2.
3SLS Estimates of Demand and Supply Equations for Hired Farm Labor, 1950-1992

Independent Variable	Regression Coefficients Demand	Regression Coefficients Supply
Intercept	2.8291 (1.4958)*	14.2996 (5.1330)**
Farm Wages		0.3645 (0.1792)**
Nonfarm Wages		-0.2389 (0.0910)**
Number of Workers (Y_t)	-1.4951 (0.4463)***	
Number of Workers (Y_{t-1})	-0.7988 (0.3753)***	0.7973 (0.1323)***
Prices Paid by Farmers	-0.2819 (0.3161)	
Prices Received by Farmers	0.4523 (0.1406)***	
Price of Land and Buildings	0.4532 (0.1623)***	
Minimum Wages		-0.0375 (0.0573)
Trend		-0.00063 (0.0021)***
Expenditures on R&D (t)	0.1746 (0.1145)	
Expenditures on R&D (t-1)	-0.0796 (0.0433)**	
Expenditures on R&D (t-2)	-0.3338 (0.1617)**	
Sample size	43	43
R^2	0.81	0.98
Adjusted R^2	0.78	0.96

Note: Standard errors are in parentheses. The single, double and triple asterisks indicate significance level at 10%, 5%, and 1%, respectively.

(α_1<0), as economic theory suggests. The coefficient of the price of the farm products variable is positive and significant (α_2>0), indicating that a general increase in farm prices stimulates farm labor demand.

The coefficient of the price of material inputs is negative but statistically insignificant (α_3 <0), indicating that the demand for farm workers is not affected by price variation of material inputs. The coefficient of the price of land and buildings is positive and statistically significant (α_4 >0), suggesting that an increase in the prices of land and building stimulates the demand for farm labor. This shows that land and labor are complements. This result is consistent with the findings of Gallasch and Gardner.

Technological change was modeled as an Almon polynomial distributed lag of RAD expenditures. The estimated results indicate that a two-period, one-degree polynomial yielded the best statistical results. The results show that current RAD expenditures do not have any significant effect on the demand for farm labor. However, one and two years lagged RAD expenditures have negative and significant effects on the demand for hired farm labor (α^1_6<0 and α^2_6<0). Note also that the effect of the two years lagged RAD expenditures on the inverse demand for hired farm labor is stronger than the one year lagged. The coefficient of the lags can be interpreted as follows. An increase of 10% in RAD expenditures in the present time will not affect the inverse demand for farm labor in the current year but will result in a decrease in the inverse demand for farm labor by 0.80% in the next year, and in a decrease by 3.34% in the third year.

Results from this analysis indicate that technological progress as presented in this model tends to decrease farm labor demand over time. The empirical results presented by Gallasch, and Tyrchniewicz and Schuh, show a negative effect on the demand for hired farm workers of the variables used as proxies for technological change, while the empirical results obtained by Wallace and Hoover, and Hammond et al. suggest a positive effect.[10, 11]

The slope of the supply function is positive and significant (β_1 > 0), as economic theory predicts. The coefficient of the nonfarm wage rates variable (β_2<0) has a negative and statistically significant coefficient, indicating that hired workers work less on the farm and more off the farm when the nonfarm wage increases. The results support the negative and statistically significant effect of nonfarm (manufacturing) wage rates on the supply of hired farm workers. The presence of a minimum wage rate (β_3) does not appear to have any statistically significant effect on the supply of hired farm workers. One explanation could be the small portion of farm workers covered by minimum wage. Note that under the 1967 amendment to the Fair Labor Standards Act (FLSA), farm workers are paid minimum wages when certain conditions are met.[12] Gallasch points out that only a small percentage of farm workers are covered, indicating that in aggregate data the effect of the minimum wage may be

Table 3.
Goodness-of-Fit Obtained from Dynamic-In-Period Simulation

Goodness-of-Fit Tests	Statistics
Wage Rates of Hired Farm Workers	
Mean Error	0.0006
Mean % Error	0.0210
RMS Error[a]	0.0330
RMS % Error	1.0264
MSE[b]	0.0011
Theil U1[c]	0.0101
Theil U2	0.0051
Number of Hired Farm Workers	
Mean Error	0.0000
Mean % Error	0.0028
RMS Error[a]	0.0359
RMS % Error	0.5027
MSE[b]	0.0013
Theil U1[c]	0.0050
Theil U2	0.0025

[a]RMS Error represents the Root Mean Square Error.
[b]MSE represents Mean Square Error.
[c]Theil U1 represents the Theil Forecast Error Statistics.

difficult to detect. The author also notes that the minimum wage was set below the market wage rate for farm workers.

With respect to the supply function, the effect of time is negative and statistically significant ($\beta_4<0$), indicating that the supply of hired farm labor is decreasing through time. The empirical results of Tyrchniewicz and Schuh show a negative effect of time on the supply of hired farm workers. However, it should be noted that the time variable was used in their study as a proxy for technological change. In contrast, the results of Wallace and Hoover; Gardner; and Gallasch suggest a positive time effect. With our results, we can conclude that, over time, farm workers are moving out of the farming sector. If the working conditions in nonfarm activities such as shorter hours, improved transportation to urban areas, and communication systems, improve over time, then farm workers will likely leave the farm and work in the nonagricultural sector.

The impact of NAFTA on hired farm workers cannot be measured precisely because NAFTA is only one of the many political, social and economic forces affecting this market in the United States. A recent report released by the U.S. Department of Agriculture (USDA) (1997) shows that U.S. agricultural employment due to the NAFTA increased by only 0.01% compared to 0.39% in Mexico and 0.36% in Canada. In the United States the greatest increase was experienced in livestock and meat-related industries and other food products industries. However, experts believe that employment in the agricultural sector, particularly in the hired farm labor market will not change as a result of strict immigration policy (IRCA). Strict immigration policy is likely to decrease the number of farm workers. A decrease in the number of farm workers is going to have some impact in the labor-intensive operations, when taking into consideration the elasticity of output demand and labor share in revenue (Gunter et al.), but it will have a very small impact in the production of other commodities.

The results of dynamic in-period simulations for the model are presented in Figure 1.[13] In addition, several goodness-of-fitstatistics are presented in Table 3 to assess the models' simulation abilities. Initial values are specified for the first observation of the endogenous variables (i.e., wage rates and number of workers). The model is then allowed to produce all succeeding values of wage rates and numbers of workers endogenously, given the values of the exogenous variables. In general, the simulation results (Table 3 and Figure 1) show that the simulation closely follows the actual values of the endogenous variables. More analytically, the Mean Error and the Mean % Error (Table 3) for the wage rates and the number of workers are very close to zero in all models, suggesting that the model simulates the historical values without any significant bias. The rest of the goodness-of-fit statistics presented in Table 3 (i.e., Root Mean Square Error (RMS Error), RMS % Error, Mean Square Error (MSE), Theil U1 and Theil U2) are very close to the ideal values of zero, which indicates that the model simulates the actual data quite well.

Elasticity Estimates and Policy Implications

On the basis of the results of this study, we can now discuss the economic implications of the elasticities obtained and evaluate government policies designed to solve some of the income problems in agriculture. The discussion will center around the coefficient of adjustment, elasticities of the variables, the effect of technological progress, immigration policies and price support programs on hired farm workers.

Table 4 presents the elasticity of adjustment as well as the short- and long-run demand and supply elasticities. Note that the model estimates a price-dependent

Figure 1.
Dynamic-in-Period Simulation of Number of Farm Workers and Wage Rate

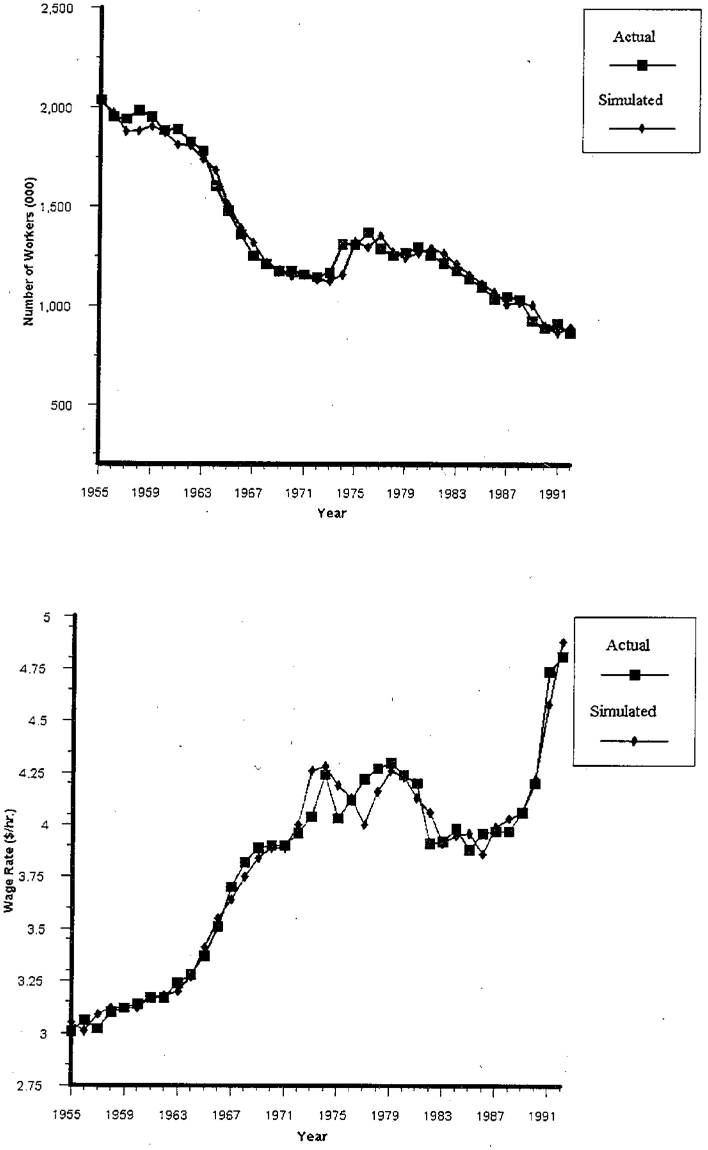

Table 4.
Elasticity of Adjustment and Short-Run and Long-Run Elasticities

Variable		Demand	Supply
Elasticity of Adjustment		0.4657	0.2027
Farm wages:	Short-Run	-0.6688	0.3645
	Long-Run	-1.4361	1.7981
Nonfarm Wages:	Short-Run		-0.2388
	Long-Run		-1.1782
Trend:	Short-Run		-0.0062
	Long-Run		-0.0308
Minimum Wages:	Short-Run		-0.0374
	Long-Run		-0.1847
Prices Paid by Farmers:	Short-Run	-0.1886	
	Long-Run	-0.4049	
Prices Received by Farmers	Short-Run	0.3025	
	Long-Run	0.6495	
Price of Land and Building:	Short-Run	0.3031	
	Long-Run	0.6510	
Expenditures on R&D (Year T):	Short-Run	0.1168	
	Long-Run	-0.3428	
Expenditures on R&D (Year T-1):	Short-Run	-0.0532	
Expenditures on R&D (Year T-2)	Short-Run	-0.2233	

demand equation (or inverse demand). As a result, the estimated coefficients of the inverse demand are presented in Table 2 and they represent price flexibilities. Inverses of the price flexibilities are then used to generate own-price demand elasticity estimates. The elasticity of adjustment measures the relationship between short-run and long-run elasticities. The elasticity of adjustment is 0.20 in the supply equation and 0.47 in the demand equation. Adjustment values, both in the demand and supply function, are significantly less than 1, indicating a long period between the short-run and long-run equilibrium levels. These values are lower than those obtained by Tyrchniewicz and Schuh (0.42 and 0.53, respectively). However, our elasticity of adjustment for demand (0.47) of hired farm workers is higher than those obtained by Duffield and Coltrane (0.44).

The short-run response to farm wage is inelastic in both the demand (−0.67) and the supply side (0.36). Both these elasticities increase in the long-run, with a -1.44 value on the demand side and 1.80 on the supply side. Given the inelastic nature of the demand and supply curves in the short run, any economic force that shifts either curve will have a significant effect on the wage rate but a small impact on the quantity of labor used. In the long run, when the demand and supply are elastic, the major impact of changing economic forces would be on the quantity of labor rather than on wages. Consequently, in the short run the impact of farm price support programs would be to shift the demand curve for labor to the right, resulting in a higher wage rate but not much additional employment. In the long run, however, the price support program would tend to raise wage rates only slightly but would lead to a higher level of agricultural employment. Price support programs that lead to higher farm prices result in an increase in the demand for labor,[14] other things being equal. The empirical results (Table 4) show that a price support program that increases the farm price by 10% will increase the demand for labor by 3.03% in the short run and by 6.49% in the long run, other factors held constant.

The supply of hired labor has a short-run elasticity of -0.24 and a long-run elasticity of -1.18 with respect to nonfarm wages. This implies a high response rate to nonfarm wages, especially in the long run. For example, a 10% increase (decrease) in the nonfarm wage would result in a 2.4% decrease (increase) in the supply of hired farm labor in the short run and a 11.78% decrease (increase) in the supply of hired farm labor in the long run. This result indicates that immigration policies that increase restrictions on farm workers gaining entry or legal status (IRCA) in the United States, will reduce the supply of farm labor and eventually put upward pressure on farm wages.

The long-run effect of technological change on the demand of labor is equal to -0.34, indicating that a 10% increase in the RAD expenditures will decrease the demand for labor by 3.43% in the long run. The short-run effect of RAD expenditures is given by the short-run elasticities of RAD expenditures at time t, t-1 and t-2. Note that from the estimated coefficients presented in Table 2, the effect of the RAD expenditures at time t is not statistically significant compared with the RAD effects at t-1 and t-2. The elasticities of the lagged RAD expenditures show that an increase in the RAD expenditures by 10% will decrease the demand of hired labor by 0.53% the next year and by 2.23% the year after. Thus, our results show that agriculture shifts away from hired labor with the use of labor saving technology.

The time trend variable coefficient in the supply function is negative and indicates that, over time, less labor is being supplied to agriculture, other factors held constant. One explanation for this might be that farm workers have become better educated, qualifying them for better paying nonfarm jobs. Older farm workers might be induced to seek less physically demanding nonfarm employment or reduce their hours working on the farm. Another interpretation might be that, over time, farm workers become more aware of potential health hazards associated with pesticide and insecticide use and wish to avoid these problems. Finally, the time trend variable might be picking up such aspects of industrialization as better working conditions (less physically demanding, shorter working hours and fringe benefits); improved transportation systems to reach nonfarm work sites; and improved communication of nonfarm job opportunities available in other industries.

Conclusion

This paper evaluates the effects of technology and other factors on the hired farm labor market in the United States during the period 1950 to 1992. The model here differs from previous research in the specification of technological change. Specifically, the study uses the total expenditures by public (expenditures of Agricultural Experiment Station Research and Cooperative Extension Services) and private firms as a proxy for technology. The results of the dynamic in-period simulations of the model suggest that the model simulates historical values quite well. The graphical validation and the goodness-of-fit statistics obtained from the dynamic simulations indicate that models' overall simulation performance is good.

Changing technological conditions, along with other structural changes, have had, and are continuing to have, a great impact on labor utilization in agriculture. These effects do not occur instantaneously, but are spread over time. Results provide evidence that technology is negatively correlated with the demand for hired farm workers and reduces the demand for these workers in the second and third year after the initial investment in research and development. Our results show that agriculture production can shift away from hired labor with the use of labor-saving technology. Farm and nonfarm wages continue to play an important role in the decisions of farm workers to work on the farm or move to the nonfarm sector. The elasticities of adjustment obtained from this study are lower, indicating a slow rate of adjustment, and are within the range previously reported in the literature.

Our results indicate that farm support programs that lead to higher farm prices would result in an increase in the demand for hired farm workers. The free movement of factors of production under NAFTA would increase the size of the farm labor force. Assuming that immigration policy is relaxed, this will result in higher employment and lower wages in the agricultural sector.

Notes

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1. Family labor tends to hold supervisory positions. Hired farm workers include persons who manage farms for employers on a paid basis, supervisors of farm workers, and farm and nursery workers.

2. This is defined as average number of persons employed at any time during the year on a farm.

3. This variable was first suggested by Griliches, who studied the effect of technological change on the aggregate production function.

4. In the past, researchers have used the 2SLS estimating procedure. However, in this study we will use 3SLS. Greene explains the advantages of the 3SLS estimation procedure over the 2SLS.

5. Data are from the 48 contiguous states of the United States.

6. Seasonality of employment is predominant in the agricultural labor market. In this study we use annual average employment of hired farm workers. The annual average employment means average number of people who said their primary occupation during the survey week was hired farm work. These respondents were also asked the number of hours they worked at their primary occupation that week. This is reported in various issues of the *Agricultural Statistics* (U.S. Department of Agriculture, various), *Statistical Abstracts of the United States*(U.S. Department of Commerce) and the *Economic Report of the President* (U.S. Council of Economic Advisors).

7. These farm wage rates are for workers without room and board. The data (nominal) were obtained from the *Agricultural Statistics* (U.S. Department of Agriculture, various). Again, we take an annual average of hourly wage rates without room and board as reported by the USDA.

8. When farm workers leave the farm, they go to various industries other than manufacturing. Empirically, however, the hourly wage rate of production workers on manufacturing payrolls proved to be the best proxy for the alternative labor wage in the nonagricultural sector.

9. The nonfarm wage rate is multiplied by 1 minus the average unemployment rate of the country and then deflated by the GNP deflator (1982=100). It is assumed that when the general unemployment rate reaches 20%, no off-farm employment opportunities exist. See Wange and Heady for adjustment formula.

10. Gallasch used expenditures on Experiment Stations research and Cooperative Agricultural Extension programs (same data as used by Wallace and Hoover). The model used this expenditure both in the demand and supply equations. Gallasch used OLS estimation procedure to estimate the model.

11. Tyrchniewicz and Schuh used time trend as a proxy for technological change. Also, they used OLS and 2SLS estimation procedures.

12. See Lianos and Gallasch for detailed discussions on the minimum wage and FLSA.

13. Note that dynamic instead of static simulation was chosen because solved values of the endogenous variables obtained from the simulated model were used to calculate lagged values of the endogenous variables.

14. However, as one reviewer noted, caution should be exercised when interpreting the relationship between price support programs and hired farm labor demand because some farm programs have shifted acreage into less labor intensive crops.

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