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Estimating Farm Labor Elasticities To Analyze The Effects Of Immigration Reform

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Abstract

A simultaneous equation model was utilized to help measure the impact of the Immigration Reform and Control Act (IRCA) of 1986 on the U.S. farm labor market. Data from 1948 to 1988 were used in fitting the model to estimate the responsiveness of the farm labor market to changes in economic factors such as farm prices, wages, income, and farm size. Farm labor supply and demand elasticities were derived from two-stage least squares estimates. Results found an elastic (-1.44) relationship between the demand for hired labor and changes in the real wage rate. This means a 10-percent increase in the real wage results in a 14.4-percent decline in the number of hired workers demanded. If the labor supply is restricted by the IRCA, the real wage rate is not expected to rise significantly because farm employers may switch to labor-saving technology or move to less labor-intensive crops to avoid paying higher wages. Furthermore, major labor shortages are not expected in the near future because it will take time for farmworkers, particularly aliens legalized under the program, to leave agriculture to take advantage of opportunities in the nonfarm sector.

Keywords: Immigration reform, farm labor, supply and demand elasticities.

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Introduction

Total employment in farming has fallen substantially in the last 30 years as a result of mechanization, other labor-saving technology, and higher wages in the nonfarm sector. Farms have become fewer and larger. While the decline in farm numbers reduced the number of farm operators and unpaid workers, farm enlargement increased the number of hired workers on larger farms. Operators of labor-intensive farms are concerned with the current supply of affordable hired workers. About 3.8 million persons worked on U.S. farms in July 1989. One third of these were hired workers. Since the farm workforce has been comprised of U.S. workers and illegal immigrants, the Immigration Reform and Control Act of 1986 (IRCA) could significantly reduce the farm labor supply by controlling illegal immigration. The aim of this report is to develop an econometric model to assess the IRCA's effect on the farm labor market.

Immigration Reform and Control Act of 1986

The IRCA attempts to prevent illegal aliens from working in the United States by imposing fines and jail terms on employers who hire them. At the same time, IRCA offered legal U.S. residence status to qualifying illegal aliens who had resided continuously in the United States since before January 1, 1982. Over 1.7 million persons applied before the deadline date of May 4, 1988. As of November 13, 1989, the Immigration and Naturalization Service (INS) had approved almost 1.6 million of these applicants. Approved applicants can eventually become U.S. citizens and some may work in agriculture.

The Special Agricultural Worker (SAW) Program is a provision under the law specifically concerned with the large numbers of illegal aliens working on U.S. farms. Under this provision, illegal aliens may be given legal U.S. resident status and the right to work if they previously did fieldwork in the United States related to "seasonal agricultural services" (SAS). SAS is basically fieldwork performed by hired farmworkers in the production of a wide range of crops. Livestock and livestock products are excluded, however. Illegal aliens who did fieldwork in SAS program crops for at least 90 days between April 30, 1985, and May 1, 1986, could apply to the INS for legal U.S. resident status between June 1, 1987, and November 30, 1988. About 1.3 million persons applied, but INS had approved only 509,000 (40 percent) of these applicants as of November 12, 1989. Approved applicants can eventually become U.S. citizens.

The SAW Program is intended to benefit farm employers who previously employed illegal aliens. However, SAWs are not required to work in agriculture after they become legal residents, and there is no way of knowing how many might leave farmwork or when. If some workers quit working in SAS Program crops, the law requires that a portion of those who quit be replaced by new aliens each fiscal year from 1990 through 1993. These workers are referred to as "Replenishment Agricultural Workers" (RAWs) and must work in SAS Program crops for at least 90 days per year in each of the first 3 years of their U.S. residence to prevent deportation. To qualify for U.S. citizenship, they must work in these crops 90 days each year for 2 additional years. Once they have become permanent residents (after 3 years of farmwork) or citizens (after 5 years of farmwork) they are free to leave agriculture. The purpose of the RAW program is to prevent labor shortages in the SAS program crops. It is the responsibility of USDA and the Department of Labor to determine if any such labor shortages occur between 1990 and 1993.

When the SAW Program ends in fiscal year 1993, the H-2A Temporary Foreign Worker Program will be the only legal source of foreign farmworkers. The H-2A Program is a revision of the H-2 Program for agriculture which allows U.S. farm employers to temporarily employ foreign workers when qualified U.S. workers are not available at the time and place needed. H-2A workers must return to their home countries once the work specified in their contracts is completed. This program has been used sparingly in recent years; in 1987, the U.S. Department of Labor granted foreign worker certifications for fewer than 23,000 farm jobs nationwide. However, the H-2A program has the potential to become more popular after the RAW Program ends, assuming that IRCA is successful at controlling illegal immigration.

Policymakers and employers of agricultural labor are concerned with effects the IRCA might have on farm wages, farm labor availability, farm prices, and the economic competitiveness of farm producers. Development of a farm labor model to address some of these concerns is the main objective of this report. A simultaneous-equation model representing the U.S. farm labor market is the modeling framework. This model will provide elasticity estimates to measure the responsiveness of the farm labor market to changing economic conditions. Obtaining accurate elasticity estimates is important because different ranges of elasticities imply different strategies for implementing government policies such as the IRCA.

Table 1--Summary of demand and supply elasticities from hired farm labor studies

Studies	Time period	Farm wage Short run	Farm wage Long run
		Coefficient	
Demand:			
Schuh	1929-57	-0.12	-0.40
Heady and Tweeten	1929-57	-.26	-.37
Tyrchniewicz and Schuh	1929-61	-.26	-.49
Heady and Tweeten	1940-57	-.48	-.60
Martinos	1941-69	-.55	*
Hammonds, et al.	1941-69	-.85	-1.05
Wang and Heady	1941-73	-1.25	*
This study	1948-88	-1.44	*
Supply:			
Johnson	1929-57	.13	.71
Schuh	1929-57	.25	.78
Tyrchniewicz and Schuh	1929-61	.65	1.55
Hammonds, et al.	1941-69	.24	.82
Wang and Heady	1941-73	.17	1.34
This study	1948-88	.35	.73

*Estimates were unavailable or not statistically significant.

Farm labor elasticity estimates are available from past studies (Hammonds et al.; Tyrchniewicz and Schuh; and Wang and Heady). But the most recent work among them was produced by Wang and Heady whose sample covered the period 1940-73. If farm labor elasticities change over time, then it is important to develop new ones that reflect current conditions. Hammonds et al. concluded that the elasticity of demand for hired farm labor has been increasing since the 1930's and by 1970 had entered an elastic phase. As it turns out, the results of this study are consistent with Hammond's conclusions. Comparisons in table 1 show that the wage elasticity of demand increased from -0.12 in the Tyrchniewicz and Schuh study based on data from 1929 to 1957 to -1.44 in this study based on data from 1948 to 1988.

Conceptual Model And Data

The econometric model used in this study specifies two types of farm labor: hired labor and family labor. Family labor includes operator labor and other nonwage earners, typically family members. The statistical model chosen to represent the farm labor market is defined by the following system of equations.

Hired labor market:

$$Y_1 = \alpha_1 + \beta_1 Y_2 + \beta_2 Y_3 + \beta_3 X_1 + \beta_4 X_2 + \beta_5 X_3 + \beta_6 X_4 + \mu_1 \quad \text{(demand)}$$

$$Y_1 = \alpha_2 + \beta_7 Y_2 + \beta_8 Y_3 + \beta_9 X_1 + \beta_{10} X_5 + \mu_2 \quad \text{(supply)}$$

Family labor market:

$$Y_2 = \alpha_3 + \beta_{11}Y_1 + \beta_{12}Y_4 + \beta_{13}X_2 + \beta_{14}X_3 + \beta_{15}X_4 + \beta_{16}X_6 + \mu_3 \quad \text{(demand)}$$

$$Y_2 = \alpha_4 + \beta_{17}Y_1 + \beta_{18}Y_4 + \beta_{19}X_5 + \beta_{20}X_6 + \mu_4 \quad \text{(supply)}$$

where

Y_1 = hired farm labor employment, USDA, National Agricultural Statistics Service (NASS), estimates of number of workers in July.

Y_2 = family labor including operators and unpaid workers, USDA, NASS, estimates of number of workers in July.

Y_3 = real hired farm wage rate, USDA, NASS, estimates of hourly wage rate for all farmworkers in July. Deflated by consumer price index.

Y_4 = real wage for family farm labor. Two variables were used to approximate the price of family labor: (1) USDA estimates of wage rates for all farmworkers in July deflated by the consumer price index; and (2) net farm income per family labor, deflated by the consumer price index (USDA, Economic Research Service).

X_1 = hired farm labor employment, lagged 1 year.

X_2 = index of prices received by farmers, all products deflated by index of prices received by farmers for production items excluding labor.

X_3 = number of farms (USDA, Economic Research Service).

X_4 = trend variable (1948=1, 1942=2, ··· 1988=41).

X_5 = index of adjusted nonfarm wage rate deflated by consumer price index (U.S. Department of Labor). See Wang and Heady for adjustment formula.

X_6 = family labor, lagged 1 year.

The supply and demand equations across labor markets are jointly dependent. Unlike the Tyrchniewicz and Schuh model, which assumed a negative relationship (substitution) between hired and family labor, the interaction between labor types is expected to be positive in this study. Although the Tyrchniewicz and Schuh results supported substitution between labor types from 1929-61, a later study by Wang and Heady found no such empirical evidence in the 1940 to 1973 sample period. These conflicting results are probably related to the different time periods sampled. Substitution effects found in the earlier study may be related to the large-scale farming trend that began in U.S. agriculture during the 1940's. Since that time, farms have become fewer and larger, and the decline in farms reduced the number of farm operators and family workers. But farm enlargement increased the number of hired workers needed on the bigger farms. This resulted in a substitution of nonfamily labor for family labor over time. The decline in farm numbers began leveling off in the 1960's as would labor substitution which may explain why Wang found no statistically significant relationship between family and nonfamily employment. More recent data show a constant relationship between family and nonfamily labor use. Total hours worked on U.S. farms declined slightly from 1982 to 1986, and the proportion of total hours worked in agriculture attributed to family and nonfamily workers remained about the same (USDA).

Previous studies have included technology indexes to identify its role in labor markets (Tyrchniewicz and Schuh; and Wang). However, these attempts failed to find any significant relationship between change in technology and change in labor use. In this study, USDA's yearly estimate of the number of farms in the United States was included as an instrumental variable in the demand equations. Changes in this variable reflect the adoption of large-scale technology that has taken place in agriculture over the past few decades. Farm numbers diminished as average farm size increased to accommodate these new technologies. As discussed above, the demand for family workers is expected to fall as the number of farms decline. But, the demand for hired workers per farm increases as farms become larger.

Family workers do not receive a fixed wage or salary but are compensated by sharing the total labor return to the farm. Data on the labor return to each family member are not available. Therefore, in this study, two variables were evaluated as proxies for the price of family labor: (1) the net farm income per family worker, and (2) the hourly wage rate paid to hired workers.

Farmworkers and operators often work off the farm in various other industries. In an attempt to measure the effect of off-farm employment opportunities, this study included a nonfarm wage in the supply equations. The hourly wage rate of production workers on manufacturing payrolls was used as a proxy for the alternative labor wage in the nonagricultural sector since most farmworkers are not employed as managers or professionals (Oliveira). This variable was adjusted for unemployment using a calculation first suggested by Johnson and later modified by Wang. It is assumed that when the unemployment rate of the economy reaches 20 percent, no off-farm employment opportunities exist.

Nerlove-type distributed lags were introduced into each equation by lagging the dependent variable one time period, resulting in the independent variables X_1 and X_6. The purpose of this variable is to measure the time required for workers and employers to adjust to changes in the system. Participants in the labor market are often unable to respond immediately to economic forces. For example, contractual obligations or imperfect information about the future could cause a lagged response in the demand or supply of labor. Lack of training or education is an often-cited reason why farmworkers do not instantaneously adjust their labor supply to lower wages paid in the farm sector compared with higher wages in the nonfarm sector.

Nerlove's partial adjustment hypothesis can be stated as:

$$y_t^* = \sum_{i=1}^{p} \alpha_1 x_{t1} \quad , \qquad (1)$$

where y_t^* represents the longrun equilibrium quantity demanded, x_{t1}, $(i=1,2,\cdots,p)$ are the independent variables and α_1 are the estimated regression coefficients. The observed variable, y_t, may exhibit a partial adjustment from the current to the longrun equilibrium level. Nerlove postulated that this relationship between the observed quantity and the equilibrium quantity demanded at time t to be given by the following difference equation:

$$y_t - y_{t-1} = \gamma(y_t^* - y_{t-1}) + \mu_t \qquad 0 < \gamma < 1, \qquad (2)$$

where γ is the elasticity of adjustment, y_{t-1} is the observed quantity demanded lagged one period, and μ_t is a disturbance term. The basic idea of this model is that only some fixed fraction (γ) of the desired adjustment is accomplished in one period. Substitution of equation (1) into equation (2) results in a statistical model in which all variables are observable.

The elasticity of adjustment measures the relationship between the longrun equilibrium level and the current level and is obtained by subtracting the estimated regression coefficient of y_{t-1} from 1 when the data are expressed in logarithms. When the coefficient is small, the elasticity of adjustment will be close to 1, indicating a relatively swift adjustment from the shortrun to the longrun equilibrium. Subtracting a large coefficient from 1 gives a low elasticity of adjustment, indicating a slow adjustment of current to longrun equilibrium. It is undesirable to have an elasticity of adjustment outside the range $0 < \gamma < 1$ because it is difficult to interpret using economic rationale.

A trend variable is often added to distributed lag models to reduce specification error. It provides a test for secular changes in the labor market over time that are difficult to quantify and are not explicitly taken into account by the other variables in the model, such as changes in the quality of the labor force, increased levels of education in farm areas, and changes in tastes and preferences for agricultural employment versus other industries. Secular improvements in communication and transportation are other variables that are difficult to quantify and their effects on the labor market may be picked up by a trend variable. Considering these factors, this study included a trend variable in the demand equations.

The National Agricultural Statistics Service (NASS) of USDA conducts the Quarterly Agricultural Labor Survey (QALS) to estimate farm wage rates, the number of farmworkers, and hours worked. USDA has collected farm employment information since 1910. USDA's 1910-1974 estimates were based on panels of volunteer farmers who reported their employment and wages each month. In 1974, the QALS was converted to a probability survey and was conducted quarterly. The 1981 survey was cut back due to budget reductions. The survey has recently been restored, but quarterly employment data in the early 1980's is incomplete (Martin). However, the survey was conducted in July during the cutback years, with the exception of 1981, so there are comparable wage and employment estimates for the month of July throughout most of the QALS reporting history. Hence, Y_1, Y_2, and Y_3 in the above model represent farm labor employment and wages in July. Values for 1981 are estimates based on the trend of the time series.

Results and Economic Interpretations

Two-stage least squares (2SLS) parameter estimates are provided in this section. A description of 2SLS and the appropriateness of using it when autocorrelation is present and the right hand side of the equation includes the dependent variable lagged is discussed in the appendix. An alternative set of estimates was derived from a procedure called feasible generalized least squares (FGLS) which corrects for autocorrelation. The FGLS estimates were very similar to the uncorrected 2SLS estimates. See table 2 and appendix table 1.

The 2SLS estimates of the demand and supply functions for hired and family labor are given in table 2. The t-statistics for the estimated parameters are provided in parentheses. The regression results generally supported the economic theories used in specifying the equations. The hypothesis of labor substitution was rejected because the model gave evidence of positive interdependence between hired and family labor. This suggests that labor substitution has become less common as total labor supply declined and farm production became concentrated on large farms. It may no longer be a question of individual producers' choosing between hired and family labor. Rather, it is the availability of hired and family labor in a local area that most likely determines the labor mix. At an aggregate level, the two labor components respond to many of the same economic forces and have a tendency to move in the same direction in response to economic shocks.

A negative sign on the wage coefficient in the hired labor demand equation indicated that an increase in the real farm wage decreases the demand for hired labor. The model did not provide a good measure of the effect of wages on the demand for family labor. Quantitative data that represents a wage to family workers is difficult to obtain. Most studies, including this one, consequently use some form of farm income to represent payments to family labor. Complicating matters more is the assumption of a negative sloping demand curve for family labor. If the wage of hired workers increases, all else constant, farm operators are expected to reduce the demand for hired labor. But, if farm income increases, the farm operators may demand more of their own labor services, implying a positively sloping demand curve. In an attempt to alleviate this problem, this study used

Table 2--2SLS estimates of supply and demand equations for hired and family labor, 1948-88

Independent variable	Hired labor Demand	Hired labor Supply	Family labor Demand	Family labor Supply
	Regression coefficients			
Constant	9.970* (2.47)	0.053 (.109)	-3.048 (-.271)	-2.369* (-2.94)
Real farm price	0.341 (1.18)		0.051 (.059)	
Lagged dependent	0.230 (.937)	0.512* (4.00)	0.730* (2.68)	0.947* (7.38)
Number of farms	-1.442* (-2.41)		0.227 (1.56)	
Trend	-0.078 (-1.29)		0.029 (.632)	
July wage rate	-1.447* (-2.21)	0.358* (1.92)		
Family labor income			0.082 (.210)	0.103* (2.35)
Adjusted nonfarm income		-0.178* (-2.24)		-0.029 (-.574)
July family labor	0.977* (2.78)	0.427* (4.25)		
July hired labor			0.274 (.519)	0.159 (.816)

*Statistically significant at a 0.10-level of significance.
T-tests appear in parentheses.

the real wage for hired workers as an opportunity cost to family labor, but with no greater success.

The coefficient of the lagged dependent variable in the hired demand equation was less than 1, indicating a positive coefficient of adjustment, although it was not statistically significant. The lagged dependent variable was the only estimated coefficient significantly different from zero in the family labor demand equation. These low significance levels may be related to collinearity among the independent variables in the demand equations. The correlation between the lagged dependent variable and the quantity of family labor in the hired labor demand equation was 0.91. Large correlation coefficients for hired labor, real price, lagged family labor, and real family wage suggest a strong chance of multicollinearity in the family labor demand equation.

The real price coefficient in the hired labor demand equation had a positive sign as expected, but it was statistically insignificant. The insignificant price estimate in the hired demand equation is disappointing since farm prices are considered to be an important factor in the demand for labor. The problem may be associated with the price index that was used to represent real prices received by farmers. This index was developed for all crops and may be too general for labor-intensive crops. Another possible explanation is that as farms became bigger and more specialized, they also became less responsive to some economic signals such as product price.

The estimated coefficient for the number of farms, as expected, had a positive sign for hired labor demand and a negative sign in the family labor demand equation. This coefficient reflects structural changes in agriculture related to technological changes. As farms become fewer and larger to accommodate new technologies, the number of family workers and operators declines, but the demand for hired workers increases on larger farms. The trend variable was insignificant in both the hired labor and family labor demand equations.

Estimates in the hired labor supply equation supported a positive relationship between the supply of hired and family labor, but this relationship was not evident in the family labor supply equation. The insignificant hired labor coefficient in the family labor equation may have been caused by multicollinearity. The correlation coefficient between lagged family labor and the quantity of hired labor is 0.97. This high degree of collinearity may have produced high variances for the 2SLS estimated parameters.

Hired and family workers are willing to supply more labor as wages or income increases. The model showed that hired workers reduce farmwork in favor of off-farm work when the nonfarm adjusted wage increases. But the number of family workers did not respond significantly to the nonfarm adjusted wage. This may be the result of using the number of workers instead of the hours worked to represent the quantities of labor. Family workers probably adjust their work hours to relative wage changes, but their attachment to the farm prevents them from leaving farmwork entirely. This may also be true for part-time operators who use nonfarm earnings as a supplement to their farm income.

Elasticity Estimates

The elasticity of adjustment, γ, measures the relation among the shortrun and the longrun elasticities and was derived by subtracting the 2SLS estimated coefficient of the lagged dependent variable from 1. Dividing the coefficients of the independent variables by the estimate of γ provides the longrun elasticities. Since the data were converted to natural logarithms, the shortrun elasticity estimates are the coefficients of the independent variables.

The estimated elasticities and elasticities of adjustment for the hired and family labor markets are given in table 3. The elasticities of adjustment ranged from 0.76 in the hired labor demand equation to 0.05 in the family labor supply equation. However, the estimated coefficient of the lagged dependent variable in the hired labor demand equation was not significantly different from zero. Therefore the 0.76 elasticity of adjustment value is not significantly different from 1 because the elasticity of adjustment is determined by subtracting 0 from 1. This also means that the shortrun and longrun elasticities are statistically the same since the longrun elasticity is calculated by dividing the shortrun elasticity by the elasticity of

Table 3--Elasticities of adjustment and shortrun and longrun elasticities

Variable	Hired labor		Family labor	
	Demand	Supply	Demand	Supply
	Coefficient			
Elasticity of adjustment	0.769*	0.487	0.269	0.052
Price of labor:				
Short run	-1.44	0.358	***	0.103
Long run	-1.87	0.735	***	1.952
Real farm price:				
Short run	***		***	
Long run	***		***	
Adjusted nonfarm wage:				
Short run		-0.178		***
Long run		-0.364		***
Interaction variable:				
Short run	0.977	0.427	***	***
Long run	1.270	0.873	***	***

*Not significantly different from 1.
***The estimated coefficient corresponding to this elasticity was not statistically significant at a 0.10-level of significance.

adjustment. This suggests that employers of hired workers are very quick to adjust their hired labor demand when the price of labor changes. On the other hand, the demand for family labor had a small elasticity of adjustment, indicating a long period between the shortrun and the longrun equilibrium level. The hired labor market also had a larger elasticity of adjustment on the supply side when compared with the family labor market. The shortrun elasticity for the price of hired labor was about twice the size of the longrun elasticity. It would take 4-5 years before the supply of hired labor fully adjusted to a wage change. Family labor supply, which had the lowest elasticity of adjustment, responds much more slowly to wage changes. Only about 5 percent of the difference between equilibrium and actual employment is accounted for each year by suppliers of family labor. The longrun elasticities are about 20 times greater than the shortrun elasticities in the family labor supply equation. This corresponds to over a 50-year adjustment period from the time of the initial disequilibrium to equilibrium.

The elasticities of adjustment show that the hired labor market adjusts faster than the family labor market. It is not surprising that the adjustment coefficient is largest for the demand for hired labor since hired help receives a regularly scheduled monetary payment. Furthermore, farmers view hired labor as a marginal input in the production process and one that can be readily adjusted to changing economic conditions. Conversely, family labor demand is less responsive to economic shocks because of its attachment to the farm and flexible form of wage payment.

On the supply side, family labor might be more resistant to economic shocks than the supply of hired labor because nonfarm earnings can supplement farm income enough to allow family members to continue living on the farm. However, as suggested earlier in the case of nonfarm wages, the response of family labor supply would probably be greater if the quantity of labor were measured in hours instead of number of workers.

The hired labor market was much more responsive to wage changes than family labor, particularly on the demand side where the shortrun family price of labor elasticity was not significantly different from zero. The shortrun demand elasticity estimate for the price of hired labor was -1.44. This indicates that a 10-percent increase in the price of hired labor would result in a 14.4-percent decrease in the quantity of hired labor demanded, other things being equal. Shortrun supply elasticities with respect to the price of labor were 0.35 for hired labor and 0.10 for family labor.

The elasticities with respect to the price of labor continued to be elastic (-1.8) for hired labor in the long run. On the supply side, the longrun wage elasticity for hired labor was 0.73. The wage elasticity for family labor was 1.95. This suggests that family labor supply is responsive to wage changes in the long run. However, the large difference between the shortrun and longrun elasticity indicates that it takes family labor much longer than hired labor to adjust from the short run to the long run.

With respect to nonfarm wage, the supply of hired labor has a shortrun elasticity of -0.17 and a longrun elasticity of -0.36. This means that a 10-percent increase (decrease) in the nonfarm wage would result in a 1.7-percent decrease (increase) in the supply of hired labor in the short run. In the long run, the nonfarm wage elasticity for hired labor is about twice as high as the shortrun elasticity and it would take 4-5 years before the supply of hired labor fully adjusted to a change in the nonfarm wage, ceteris paribus. The nonfarm wage elasticity for family labor was not significantly different from zero. Again, this supports the postulate that family labor is much less responsive than hired labor to nonfarm influences.

The interaction variables in table 3 describe the supply and demand relationships between hired and family labor. The number of family workers is the interaction variable in the hired labor equations and the number of hired workers is the interaction variable in the family labor equations. The interaction elasticities for hired labor demand were 0.97 in the short run and 1.2 in the long run. This implies that a 10-percent increase (decrease) in the demand of family labor would be accompanied by a 9.7-percent increase (decrease) in demand of hired labor in the short run. The small difference between the shortrun and longrun elasticities indicates that the change in the demand of hired workers in response to a change in the number of family workers would happen very quickly. On the supply side, a 10-percent increase (decrease) in the supply of family labor would associated with a 4.2-percent increase (decrease) in the supply of hired workers. It would take 4-5 years before the longrun equilibrium was reached.

The interaction variables in the family labor market were not statistically significant. This suggests that the relationship between hired and family labor is not symmetrical. However, it is likely that multicollinearity between lagged family labor and the quantity of hired labor caused estimation difficulties in the family labor demand equation.

Positive signs on the hired labor interaction elasticities imply that the supply and demand of the two labor types move together with changes in economic conditions. This does not necessarily contradict the Tyrchniewicz and Schuh model, which provided evidence of substitution between labor types over the time period they sampled (1929-61). The substitutability between the labor types may have changed over time suggesting that these inputs are only substitutes over certain ranges of combinations. Since the numbers of hired and family workers have declined considerably since 1961, perhaps the size of the total workforce has diminished to a point where hired labor is no longer an available substitute for family labor and vice versa.

Policy Implications

Estimates of shortrun wage elasticity with respect to hired labor demand from previous studies ranged from -0.12 to -1.25, with the absolute values of these estimates getting larger over time (table 1). The -1.44 shortrun wage elasticity estimated in this study suggests that the shortrun elasticity for hired labor demand is continuing to strengthen as predicted by Hammonds. An elastic labor demand implies a shift in the supply curve will have a greater impact on the quantity of hired labor used than on the wage rate.

If the IRCA restricts the number of illegal immigrants, the effect on the labor supply can be represented by an upward shift in the supply curve. The elastic demand for hired labor found in this study suggests that producers will make adjustments, even in the short run, to avoid paying higher wages. Producers may shift away from hired labor by adopting labor-saving technology to produce crops they currently produce with less labor or switch to more capital-intensive crops. This impact on the labor supply will intensify in the long run when supply relationships become more elastic.

Once participants under the SAW Program become citizens, they may choose to leave farmwork. Results from this study suggest that some of them will eventually go to higher paying jobs in the nonfarm sector. The model showed that hired workers responded only slightly to nonfarm wages but this response is likely to get stronger, particularly in the long run if the IRCA is successful at restricting the supply of alien farmworkers. Illegal alien workers are less responsive to nonfarm influences because they probably have less access to nonfarm jobs and fewer marketable skills than their legal counterparts. In the past, if these workers acquired the information and skills needed to obtain nonfarm jobs, they were replaced by new illegal aliens, having a stabilizing effect on farm labor supply. Now, under the IRCA, employers will be less willing to hire illegals because of employer sanctions and as workers leave farmwork they may become more difficult to replace.

Both hired and family labor use have decreased over the years as farm numbers declined, but the need for hired workers has increased on larger farms. If immigration reform reduces the supply of workers in the hired labor market, larger farms that depend on large amounts of hired labor will be most affected. It is unlikely that these farms will be able to replace hired farm labor with family labor. Family members have an attachment to their own farms and, according to the results of this study, are not available substitutes for hired labor. Substitution of inputs is more likely to occur between hired labor and capital if wages begin to increase significantly.

The full impact of the IRCA will not be felt immediately. People in the farm labor market do not respond instantly to changes in government policy. If changes in the labor supply influence the wage rate and the demand for labor, it will take some years before the effects of the initial shock are fully realized. It will take time before new citizens working in agriculture adjust to their legal status and begin to respond to conditions in the nonfarm sector. This suggests a low probability of a major labor shortage occurring during the course of the RAW program and the number of replenishment agricultural workers entering the country will be limited. In fact, for the first year of the RAW program, fiscal year 1990, no national shortage was determined by USDA and the Department of Labor. However, there may be some localized labor shortages, but these happened before the IRCA.

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Appendix: Statistical Procedures

The model was developed on the premise that hired and family labor markets can each be described by a supply and demand equation with the level of employment and price of labor determined simultaneously. These markets are assumed to be jointly dependent, resulting in a four-equation simultaneous system. The structural model has four endogenously determined variables and six exogenous variables including the dependent variables lagged one period. The dependent variables are lagged in each equation to capture the dynamic adjustment from the current to the longrun equilibrium level. Each equation is just identified by the rank conditions.

Two-stage least squares (2SLS) provides consistent estimates for a dynamic simultaneous equation system when the equations are just identified and the errors are independent. In addition, Monte Carlo studies have shown 2SLS to have small-sample properties superior to other estimation techniques (Kennedy). Using matrix notation, the first equation in a set of simultaneous equations is:

$$y = Y_1\gamma + X_1\delta + \epsilon \tag{3}$$

where the matrix X_1 contains observations on all of the exogenous and lagged endogenous variables in the entire system of structural equations. Y_1 contains observations on the endogenous variables included in the first equation and γ and δ are the corresponding estimates of the structural parameters of Y_1 and X_1. The ϵ vector contains the error terms. The 2SLS estimator of γ and X_1 is the instrumental variables estimator with X_1 serving as its own instrument and the instrument for Y_1 is:

$$\hat{Y}_1 = X(X'X)^{-1}X'Y_1 \tag{4}$$

Then:

$$\hat{\beta} = [Z_1'X(X'X)^{-1}X'Z_1]^{-1}Z_1'X(X'X)^{-1}X'y \tag{5}$$

is the 2SLS estimator where $Z_1 = [Y_1\ X_1]$. The asymptotic covariance matrix of β can be estimated by:

$$\hat{\Sigma}(\hat{\beta}) = \hat{\sigma}_{11}[Z_1'X(X'X)^{-1}X'Z_1]^{-1} = \hat{\sigma}_{11}[Z_1'QZ_1]^{-1} \tag{6}$$

where $Q = X(X'X)^{-1}X'$ and $\hat{\sigma}_{11} = (y - Z_1\hat{\beta})'(y - Z_1\hat{\beta})/T$ (7)

is a consistent estimate of the variance of the disturbance vector ϵ and T is the number of observations.

Caution should be taken when lagged dependent variables are used as regressors because if the error terms are autocorrelated, 2SLS does not provide consistent estimates of β and the usual formula of the asymptotic covariance matrix is invalid (Pindyck and Rubinfeld; and Godfrey).

The Durbin-Watson test or Durbin's h statistic which are usually used for detecting autocorrelation are not appropriate for dynamic systems. Godfrey and Guilkey have developed large sample tests for identifying autocorrelation in dynamic simultaneous equation models. But the sample used in this study may not be large enough for these tests to be meaningful (Guilkey). Since autocorrelation is often present in time series data, an alternative procedure to 2SLS was also used in this study. First, it was assumed that the errors were generated by a stable first-order autoregressive process. After applying 2SLS to the system, each equation was then estimated using the feasible generalized least squares (FGLS) estimator (Fomby, Hill, and Johnson). This method is described below.

The first-order autoregressive process for the t^{th} observation can be represented by:

$$\epsilon_t = \rho\epsilon_{t-1} + \nu_t \qquad (8)$$

where the current disturbance ϵ_t depends on the error in the previous period, ϵ_{t-1} and on another error, ν_t. The autoregressive parameter ρ is unknown and was estimated from the 2SLS residuals:

$$\hat{\epsilon} = (y - Z_1\hat{\beta}) \qquad (9)$$

and $$\hat{\rho} = \sum_{t=3}^{T}\hat{\epsilon}_{t-1}\hat{\epsilon}_t / \sum_{t=3}^{T}\hat{\epsilon}^2_{t-1} \qquad (10)$$

A transformation matrix called P is formed using $\hat{\rho}$ and then applying this matrix to y, X, and Z_1 transforms the data to y^*, X^*, and Z_1^* resulting in a new disturbance vector with independent errors. Least squares regression on the transformed observations generates the FGLS estimator

$$\hat{\hat{\beta}} = (Z_1^* Q^* Z_1^*)^{-1}\ Z_1^{*\prime} Q^* y^* \qquad (11)$$

The asymptotic covariance matrix of $\hat{\hat{\beta}}$ is given by:

$$\Sigma(\hat{\hat{\beta}}) = \hat{\hat{\sigma}}(Z_1^* Q^* Z_1^*)^{-1} \qquad (12)$$

where $\hat{\hat{\sigma}} = (y - Z_1^*\hat{\hat{\beta}})'(y - Z_1^*\hat{\hat{\beta}})/T$

FGLS was used in conjunction with the Cochrane and Orcutt iterative procedure to estimate β and ρ for each equation. A search routine was used to find an efficient starting value for the iterative procedure and to help locate a global minimum (Johnston). The FGLS estimates are consistent, but they are not asymptotically efficient in the presence of lagged dependent variables and autocorrelated errors (Fomby, Hill, and Johnson). Maddala shows that FGLS estimates do not achieve the efficiency of the generalized least squares estimator if P is unknown. An asymptotically efficient estimator has been developed by Hatanaka for single-equation estimation called the two-step Aitken method. The method can be extended to the two-step estimation of the simultaneous equation model. However, a computer algorithm for the simultaneous equation method is not readily available and the time and expense involved in developing one exceeds the scope of this paper.

In summary, when serial correlation is present with lagged dependent variables, the 2SLS estimator is inconsistent and although FGLS is consistent it is not efficient. Without an adequate test for serial correlation, it is unclear as to which procedure is appropriate. Results from the FGLS procedure are given in appendix table 1. The estimated parameters are very similar to those derived from 2SLS given in table 2. Relaxing the zero autocorrelation restriction had little effect on the estimated structural parameters or the estimated covariance matrix. This implies that serial correlation is not a factor and nothing is gained from using the more complicated FGLS procedure.

Appendix table 1--FGLS estimates of supply and demand equations for hired and family labor, 1948-88

Independent variable	Hired labor		Family labor	
	Demand	Supply	Demand	Supply
	Regression coefficients			
Constant	9.703* (2.28)	-0.278 (-.677)	-2.349 (-.241)	-2.500* (-2.33)
Real farm price	0.332 (1.33)		0.148 (.174)	
Lagged dependent	0.293 (1.24)	0.484* (4.06)	0.717* (3.34)	0.993* (6.80)
Number of farms	-1.600* (-2.54)		0.215 (.680)	
Trend	-0.148 (-1.24)		0.022 (.149)	
July wage rate	-1.420* (-2.67)	0.507* (3.06)		
Family labor income			0.037 (.094)	0.113* (2.50)
Adjusted nonfarm income		-0.281* (-3.35)		-0.060 (-.887)
July family labor	0.953* (2.66)	0.486* (4.93)		
July hired labor			0.210 (.355)	0.105 (.500)

*Statistically significant at a 0.10-level of significance. T-tests appear in parentheses.

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