An econometric analysis of the impact of energy development on agricultural labor markets
by Karl Brent Ingebrigtson

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Applied Economics
Montana State University

Abstract:
Energy development in the Northern Great Plains has led to competition for labor services between agriculture and the mining and construction sectors. This competition for resources may have an impact on the viability of marginal agricultural units. In order to determine what, if any, impact this resource competition has on agricultural units, it is necessary to model the market for agricultural labor. The model will quantify the impacts.

A simultaneous equation model, representing the demand and supply of labor, is developed for the analysis. The demand is a function of agricultural wage rate and farm proprietor's income. Supply is a function of the agricultural wage rate, an alternative wage rate (which was either the mining or construction wage rate), population and an employment-to-population ratio.

Bureau of Economic Analysis data from 1969-1977 are utilized for the study. A pooled cross section-time series data set is developed for estimation. Counties which included agriculture, mining and construction in Montana, Wyoming, Utah and Colorado were included in the data set.

Three models are estimated utilizing a full information maximum likelihood technique. Models 1 and 2 contain a first order lagged dependent variable with the alternative wage rates being mining and construction, respectively. Model 3 includes a second order lagged dependent variable with mining as the alternative wage rate.

The estimates indicate that energy development has a very small impact on the market for hired agricultural labor. In the demand equation all models suggested that, in disequilibrium, demanders will overadjust towards equilibrium each year. An upwards-sloping farm labor supply curve is indicated, but the slopes were very steep, suggesting that supply is virtually vertical.

In general, the study indicates that energy development does affect the agriculture labor market. This impact, however, is very small and should, therefore, have very little adverse effect on the viability of agricultural units.

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Date August 3, 1984

Dedication

I dedicate this thesis to my wife, Kari Lynn Ingebrigtson. Without her dedication and support, this work could not have been possible.

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I would also like to thank my parents, Mr. and Mrs. Karl Ingebrigtson for their support during my education. Their encouragement and moral support throughout my education has made this thesis activity possible.

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Energy development in the Northern Great Plains has led to competition for labor services between agriculture and the mining and construction sectors. This competition for resources may have an impact on the viability of marginal agricultural units. In order to determine what, if any, impact this resource competition has on agricultural units, it is necessary to model the market for agricultural labor. The model will quantify the impacts.

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In general, the study indicates that energy development does affect the agriculture labor market. This impact, however, is very small and should, therefore, have very little adverse effect on the viability of agricultural units.

CHAPTER 1

INTRODUCTION

Energy resource development in the Rocky Mountain region has led to several conflicts between the energy production sector and the other sectors of the local economies. The agricultural sector is one sector that competes directly with the energy firms for common resources. These resources include land, water and labor. There has been much discussion concerning the land and water competition, but there has been little debate about the competition for labor services.

The number of agricultural workers in the U.S. has experienced a constant decline since the 1920s. Technological advances in the agricultural production process have been a leading cause of this reduction. Also, industrialization of the entire economy created more alternative employment opportunities for the workers. Much of this alternative employment has been historically located near the urban or suburban areas of the country. The emergence of energy development in rural areas has created alternative employment opportunities near agricultural jobs. Now these alternative jobs are being located in the agricultural areas of the country, thus setting the scene for a conflict between the two sectors.

Jobs in energy production offer much higher wages to the workers than farm jobs. Therefore, there may be an incentive for the farm worker to transfer to a job in the energy sector. Along with the energy jobs in a region, there have been increased opportunities for workers in the construction and service sectors. These increased employment opportunities may create competition for the services of the agricultural workers. Therefore, the development of energy in a region opens jobs directly in the mining and construction sectors, as well as indirectly in all employment sectors of the local economies.

Problem statement. The emergence of large-scale energy development in the Rocky Mountain region over the past decade has produced a conflict between the energy development sector and the agricultural sector. Energy development creates many jobs that agricultural workers can potentially fill: for example, equipment operators, truck drivers and construction workers. If the energy sector, offering relatively higher wages, can attract workers away from the agricultural sector, then agricultural operations may suffer adverse impacts from the development.

Purpose of study. This study will model the market for hired agricultural labor. The relationship between the agricultural worker's market and other employment opportunities (especially energy development) will be identified. The hypothesis tested is that energy development in an area affects the market for hired farm laborers. The impacts will be determined by assessing the influence that wage rates in alternative sectors have on the equilibrium employment and wage levels in the agricultural sector.

For the purposes of this study, two very important assumptions about employment are necessary. First, the direct employment impacts of energy development are assumed to be restricted to the mining and construction sectors. In areas of major energy development the wage rates in the construction and mining sectors exhibit large real growth rates while the wage rates in other sectors did not show large increases (Meale, Ingebrigtson, Branch, 1982). The occurrence of energy development is, therefore, measured by its effects on the wage rates in mining and construction. Second, agricultural employment is assumed to be homogeneous across counties and across different agricultural operations. No differentiation will be made between workers on a grain farm and workers in a ranching operation.

Study organization. The remainder of this study is organized into the following chapters.

2. Conceptual Model
3. Literature Review and Discussion
4. Data
5. Empirical Model Specification
6. Statistical results
7. Conclusions, Problems and Future Research

CHAPTER 2

CONCEPTUAL MODEL

To assess the impact that energy development will have on local agriculture, it is necessary to model the market for hired farm labor. The market for hired farm workers is determined by the supply and demand relationships for labor. Once these supply and demand relationships are estimated, it is possible to investigate how changes in economic conditions will alter the labor market. A change in the supply and/or demand relationship may change the market wage rate and the market employment level in the agricultural sector.

This portion of the study will establish the theoretical framework that will be used to investigate the market for hired farm workers. First, the formulation of the labor demand and supply relationships will be presented. Then a discussion of their dynamic adjustment processes will be presented.

Demand relationship. Labor is a factor of production for individual firms. Therefore, demand for labor, of any form, is an input demand function. When the firm's entrepreneur makes a production decision, he is concerned with how total revenues will be changed with respect to a change in total costs. He will add inputs to production as long as the additions to total revenues from the input will be greater than the additions to total costs. Each firm will employ labor to the point where profits are maximized. The profit maximizing level of the firm is partially determined by the demand for the firm's output. Therefore, the demand for the labor input is derived from consumer demand for the final product produced by the firm.

Marginal productivity theory may, in principle, be used to determine the exact amount of labor that will be demanded by each firm. In the short run, capital is fixed so the only variable input will be labor. The additions to total output that occur when one additional unit of labor is employed is the marginal physical product (MPP) of labor. Note that after some quantity of labor has been employed, output will increase at a decreasing rate. This characteristic is called diminishing marginal productivity. The price of the output times the number of units of output produced by the additional unit of labor is the value of the marginal product of labor. The schedule produced from this process is the firm's demand for labor.

In the long run, the demand for labor will be more elastic than in the short run. In the long run, capital is also a variable input; therefore, the firm is able to substitute more capital for labor and vice versa, when the relative costs of the inputs change. This makes the demand for the inputs more responsive to changes in their prices.

Using classical labor theory, it is possible to identify the factors that determine the demand for hired agricultural labor. Given the following generalized profit function:

$$\pi = Pf(L,K) - r_1L - r_2K$$

where:

π = profit

P = price of the final product

L = quantity of labor hired

K = quantity of capital used

r_1 = price of labor

r_2 = price of capital

and f is the production function.

The formulation of the short run input demand function is computed as:

$L = h(P, r_1, K)$

where:

$$\frac{\partial h}{\partial P} > 0, \quad \frac{\partial h}{\partial r_1} < 0$$

It can be seen that the demand for the labor input is a function of:

1. The wage rate of labor
2. The price of the output
3. The capital stock of the firm

Supply relationship. First, the labor-leisure choice of an individual is reviewed, then other factors, which affect supply to a particular industry, are discussed. The supply of labor available to a firm is dependent on the actions of each worker. Each person has some tradeoff between working and leisure. Both income and leisure are desirable for the individual. The individual derives utility from consuming goods that he purchases with his income and by consuming leisure time. Each person will act in a manner that will maximize his or her utility.

The utility of the individual is a function of income and leisure:

$U = g(Z, Y)$

where:

Z = amount of leisure

Y = amount of income

The total amount of time available to each person is T and the amount of work performed by the individual is W. Therefore, by definition:

$Z = T - W$

Note that people will maximize their utility subject to a budget constraint:

$Y = r_1 W + Y_o$

where:

r_1 = wage rate

Y_o = nonlabor income

The utility function becomes:

$U = g(T - W, r_1W + Y_o)$

This function is maximized with respect to W:

$$\frac{dU_1}{dW^1} = -g_1 + g_2r = 0 \quad \text{or,} \quad \frac{-dY_1}{dZ^1} = \frac{g_1}{g_2} = r$$

This indicates that the rate of substitution of income for leisure is the wage rate. The g_i's depend upon the income and the amount of work performed. Since $Y = rW + Y_o$, then $\frac{g_1}{g_2} = r$ contains the variables r and W. When that function is solved for W, the supply function of labor for the ith person is:

$W_i = S_i(r)$

The market supply schedule is the horizontal summation of the individual supply functions. This implies that the market supply of labor to a firm is a function of the wage rate.

This general wage rate can be disaggregated into wages for different sectors or industries. Therefore, the wage rate for hired agricultural labor, as well as the wage rates in other industries, affect the labor supplied to agriculture. The sectors that compete directly with agriculture for laborers will be the only other wages that affect the labor supplied to agriculture.

The likelihood of a person getting a job will affect the decision of whether a person will seek work or not. If the probability of getting a job is small, the individual may not enter the work force.

The composition of this population is also important. If an area has a large population of retired people, the labor force participation rate, as a percentage of total population, may be small in comparison to an area with few retired people.

It can be seen that the supply of labor to an industry is a function of:

1. The wage rate in the industry of study
2. The wage rate in competing occupations
3. The probability of getting a job
4. The size and the composition of the local population

<u>Overall labor market</u>. The previous sections have discussed labor supply and labor demand separately. But in order for a market to be formed, it is necessary to have both supply and demand interact. Therefore, the overall labor market model must include both the supply and the demand functions operating simultaneously. The market wage and

the number of workers will be determined when both the supply and the demand equations are solved simultaneously.

Dynamic adjustment process. The previous discussion has given the basic static model of the demand and supply of labor to an industry. This model will be sufficient for a comparative static analysis of energy development regions. But this study is also interested in the process of adjustments of the demand and supply functions. With this objective in mind, it is important to analyze the dynamics in the agricultural labor market that result from energy development within a region.

When employers and employees react to economic stimuli, they may not respond immediately. The length of time that it takes people to make adjustments is an important factor to consider. People react to economic stimuli with a lagged response for several reasons. First, any change will result in uncertainty for the workers and the employers. Individuals are uncertain as to whether the change is temporary or permanent. This uncertainty will produce a lagged response of the actors. Second, it may also take some time to recognize that a change has taken place. This will result in a longer adjustment process. Third, even if people realize that a change should take place, it will take some period of time for them to make a change. For example, if economic conditions change to an extent that a person should change occupations, the actual job change may take a great deal of time. During any period of time, a stable market that is out of equilibrium will adjust towards an equilibrium state, providing all inputs remain fixed. If the market does not instantaneously return to equilibrium, then a partial adjustment model is suggested.

Assume L* is the desired (equilibrium) level of a linear function for agricultural labor:

$$L^*_t = a + BX_t$$

If the market is out of equilibrium, the actual value is not L^*_t but L_t. A partial adjustment model may be specified as:

$$L_t = \gamma(L^*_t - L_{t-1}) + L_{t-1}$$

where:

$$0 \leq \gamma \leq 1$$

This implies that the actual change of the market in relation to the desired level after one period ($L_t - L_{t-1}$) is a fraction (γ) of the amount needed for the model to reach equilibrium ($L^*_t - L_{t-1}$). The adjustment coefficient (γ) indicates the rate of adjustment of L to L*. L* in equation 1 is substituted into the equation and it is solved for L_t.

$$L_t = a\gamma + B\gamma X_t + (1 - \gamma)L_{t-1}$$

Which states that the position of the agricultural labor market at a moment in time (L_t) is a function at the market position last period. If the market is not in equilibrium, L_t will not equal L_{t-1}. The adjustment factor indicates the speed at which the labor market adjusts towards equilibrium.

<u>Summary</u>. The conceptual model for this study will include a simultaneous determination of the demand and the supply of agricultural laborers. The model will also include the methodology to account for the adjustment process that will take place in the labor market.

The basic conceptual model is a set of equations:

$L = f(P, r_1, r_2, t)$, demand

$L = g(r_1, r_3, U, N)$, supply

where:

L = the amount of labor supplied or demanded in the agricultural sector

P = the price of agricultural products

r_1 = the wage rate for agricultural laborers

r_2 = the cost of other inputs of agriculture

r_3 = the wage rate of occupations that compete for agricultural laborers

t = a measure of technology

U = the employment opportunities in a region, possibly the local unemployment rate

N = the population of the region

These two equations should be solved simultaneously, which assumes that the labor market will clear in the short run. A lagged structure should also be added to these equations to account for the adjustments that workers and entrepreneurs have to make over time.

CHAPTER 3

LITERATURE REVIEW

The purpose of this study is to investigate the impact of energy development on the market for hired agricultural labor. This chapter presents past studies on the subject.

Most of the farm labor market studies of the past two decades have made use of the methodology developed by Schuh (1962) to estimate the structural demand and supply relations for the hired labor components of the agricultural labor force. The supply of hired farm labor is a function of: 1) real wages of hired farm labor, 2) a measure of the income earned in nonagricultural employment, 3) the amount of unemployment in the economy (which affects the availability of alternative income opportunities), and 4) the size of the civilian labor force. The demand for hired farm labor is a function of: 1) the real wage rate of hired farm labor, 2) an index of the prices of agricultural products, 3) an index of the prices of other inputs, and 4) a measure of technology.

The long-run and short-run supply and demand elasticities are estimated using the distributed lag approach developed by Nerlove (1958). The dependent variable is lagged one period and is added as an additional independent variable in the supply or demand equation. The estimate of the parameter on the lagged dependent variable is utilized to compute the coefficient of adjustment, which identifies the relationship between the short-run and the long-run elasticities.

The complete statistical model includes the long-run demand relation, the long-run supply relation, and two adjustment equations, one for the demand adjustments and one for the supply adjustments. The statistical model for estimation consists of short-run demand and supply equations in two endogenous variables:

$$S\ L_1 = \alpha_1 + B_1 r_1 + B_2 X_1 + B_3 X_3 + B_4 X_4 + u_1$$

$$D\ L_1 = \alpha_2 + B_5 r_1 + B_6 X_2 + B_7 X_3 + B_8 X_5 + u_2$$

where:

L_1 = hired agricultural employment

r_1 = index of composite wage rate in agriculture, deflated by the Consumer Price Index

X_1 = "corrected" nonfarm income deflated by the Consumer Price Index

X_2 = index of the prices received by farmers, all products, deflated by the index of prices paid by farmers for items used in production, excluding labor

X_3 = hired agricultural employment lagged one year

X_4 = size of the civilian labor force

X_5 = index of technology

The price of farm labor and the quantity of labor employed are mutually determined endogenous variables. In order to avoid biased and inconsistent estimators, it is necessary to estimate the equation using a simultaneous equation method.

The equations are specified in order to facilitate estimation. A partial adjustment specification is applied to the model. The respecified equations are:

$L_1 = a_1 + b_1 r_1 + dX_{10} + S_1 X_3 + 1X_4 + u_1$, supply

$L_1 = a_2 + b_2 r_1 + eX_2 + S_2 X_3 + pX_5 + u_2$, demand

where:

$a_1 = \alpha_1 \gamma_1$ and $b_1 = B_1 \gamma_1$ etc.

$S_1 = (1 - \gamma_1)$, $S_2 = (1 - \gamma_2)$

The coefficients of adjustment for supply and demand are γ_1 and γ_2, respectively. Both equations are overidentified by one.

A trend variable is introduced into each equation as a partial guard against specification bias in the coefficient of adjustments. It was pointed out by Brandow (1958), Halvorson (1958), and Griliches (1959) that the coefficients of adjustment are subject, to a greater extent than the other parameters, to specification bias due to omitted variables. The trend variable should pick up the effects of the omitted variables that are correlated with time and, therefore, eliminate part of any specification bias.

Schuh computes both the supply and the demand elasticities with the model. The elasticities are computed at two points: the sample mean of the variables and the level at the end of the sample. The data set was a time series of national wage rate data for the period 1929 to 1957. Therefore, the elasticities calculated at the end point are more relevant because they most closely reflect the current state of the labor market. This is important for an analysis of the sectoral decline in employment and the rise in agricultural wages. However, elasticities calculated at the extreme point of a linear relationship have lower statistical reliability than those calculated at the sample mean.

Schuh used farm labor and wage data provided by the Farm Labor publication of the USDA. The employment figures are expressed in year-equivalents rather than the number of people employed. Schuh felt that because the study is investigating labor aggregates and farm work is highly seasonal, the year-equivalent data is appropriate. The wage data for the study is a USDA estimate of annual expenditure on hired farm labor divided by employment. The nonfarm wage rate was constructed by use of data on total compensation to nonfarm employees. The unemployment rate is included in the supply model to correct for nonfarm income. Average nonfarm income only measures the true income alternative if jobs are available in other sectors. Nonfarm income opportunities decrease as unemployment increases. To get a corrected alternative income, the measure of nonfarm income is multiplied by the average employment rate of the labor force. This methodology provides an average income for both employed and unemployed members of the labor force.

Estimation of the supply function yields a coefficient of adjustment of 0.32. This means that 32 percent of the difference between equilibrium and actual employment is eliminated in a one-year period. At this level, it will take eight years to eliminate 95 percent of a given amount of disequilibrium. The coefficient also implies a long-run elasticity about three times larger than the short-run elasticity.

The short-run supply elasticity with respect to agricultural wage is 0.25 at the means. The short-run elasticity with respect to corrected nonfarm income is -0.36. This implies that suppliers of labor are more responsive to nonfarm income potential than to farm income potential.

The elasticity with respect to the civilian labor force is 1.21. This high value is thought to be a result of several factors: the differential rates of entry into the labor force among industries, the relatively high birth rate in the agricultural population, and a tendency for first employment to be in agriculture. An elasticity greater than one is a reflection of the continual over-supply of labor in agriculture, which may be a justification for continual transfers of labor out of agriculture.

The long-run elasticities are about three times higher than they are in the short run. The elasticities are 0.78 with respect to the agricultural wage rate, -1.11 with respect to corrected nonfarm income, and 3.78 with respect to the civilian labor force.

In the short run, the demand elasticity with respect to the agricultural wage rate is -0.12, with respect to the real farm prices 0.15, and with respect to technology -0.14. The coefficient of adjustment is 0.30, which implies that 30 percent of the difference between equilibrium and actual employment will be eliminated in one year by the employers of hired farm labor. The coefficient also implies that the long-run elasticities will be about three times as large as the short-run elasticities. The long-run demand elasticities are -0.40 with respect to the agricultural wage rate, 0.52 with respect to real farm prices, and -0.45 with respect to technology.

The model does explain much of the variation in the dependent variable. The R^2 of the model is around the 0.97 level and the coefficients on the independent variables, with the exception of the trend variable, are significant at the 5 percent level.

Schuh tested the residuals for serial correlation by use of the Durbin-Watson test. The null hypothesis of no serial correlation was not rejected.

One weakness of Schuh's results is his use of the Durbin-Watson test to test the null hypothesis, i.e., that there is no correlation. As stated by Kmenta (1971), the Durbin-Watson test is not applicable in a regression that has a lagged dependent variable as an independent variable. This implies that the test that Schuh used and the results of that test may have been in error. If this is the case, then the model, which is not corrected for serial correlation, may not be the "best" model. The estimates provided by the model may be biased as the result of the serially correlated residuals.

The formulation of the Schuh model led to further study of the demand and the supply of hired farm labor. Trchniewicz and Schuh (1968) used essentially the same model to determine the regional supply and demand relationships for farm labor. Their study was conducted to test two hypotheses: 1) that members of the hired farm labor force respond to economic stimuli with a distributed lag, and 2) that the hired farm labor force participates in a national rather than a regional labor market.

The study was conducted on five multi-state regions in the U.S. Time series data from 1929-1957 for each region were utilized for the estimation. The results of the study indicate that the labor market does respond with a distributed lag. The model with a distributed lag gives a higher R^2 than the models without the distributed lag. The coefficient on the lagged variable is significant to the 5 percent level in all the study areas. It was noted that the distributed lag models will usually give a higher R^2 value than models without the lagged dependent variable, but it was still felt that the distributed lag model offers the best explanation of the farm labor market.

It was noted that the test for serial correlation, with the lagged model, is weak. The lagged dependent variable may be removing the serial correlation from the residuals for the wrong reason. If this is the case, then the lack of serial correlation in the test on the residuals does not give concrete evidence that the distributed lag hypothesis holds. Even with the above stated precautions, it was concluded that the distributed lag model gives a better interpretation of the actions of the hired farm labor force.

The study also concludes that hired farm workers respond to a national labor market. That is, the supply of hired agricultural labor offered is responding to economic stimuli outside of the region, as well as to nonfarm economic stimuli in the region. This result implies that workers in agriculture may tend to leave their occupation for jobs in other sectors outside of the local region.

The same weakness exhibited by the initial Schuh model exists in this model. The model is not corrected for possible serial correlation of the residuals. If there is indeed serial correlation, then the estimate provided by the model may be biased.

Other studies have directly analyzed the impacts that energy development, particularly mining, will have on the local farm labor market. Conklin, Adams, and Menkaus (1978) used a variation of the Schuh model to estimate the intersectoral linkages of agricultural employment and coal development employment. It was noted that the mining wages in the region of study (Wyoming) are significantly higher than the agricultural wage rate in the same region. It was hypothesized that this large wage differential may create an incentive for workers to transfer out of agriculture into a mining occupation.

The statistical model used has two equations, much like Schuh's model, but it does not have the lagged dependent variables. It appears as:

$$L = B_0 + B_1 r_1 + B_2 X_{t1} \; B_3 X_{t2} + u_{t1}$$

$$r_1 = \alpha_0 + \alpha_1 L_1 + \alpha_2 X_{t3} + \alpha_3 X_{t4} + u_{t2}$$

Where:

L = Wyoming total agricultural employment in year t.

r_1 = Wage differential in year t, (hourly mining wage - hourly agricultural wage).

X_{t1} = First difference in Wyoming civilian labor force in year t.

X_{t2} = Ratio of the index of prices received by farmers over the index of prices paid by farmers.

X_{t3} = Wyoming mining employment in year t.

X_{t4} = Man-days lost due to work stoppages in Wyoming in year t.

u_{t1} = Random disturbance.

u_{t2} = Random disturbance.

Time series data for Wyoming from the period 1955-1974 were utilized for the estimation. The results of the model suggest that the difference in the wage rates between the two sectors creates a transfer incentive for the farm workers. The results indicate that agricultural employment was becoming more responsive to the wage differential over time. The results also indicate that the change in size of the civilian labor force has little effect on employment in the agricultural sector. It was also concluded that the difference in the wage between mining and agriculture was not, at least partially, due to the unions present in the mining sector. This conclusion was reached because the estimate of the parameter on the work stoppage variable, which was a proxy for union presence in the region, was not significant, and therefore, was rejected as an explanatory variable to the wage differential. The overall conclusion of the study is that there is an increasing incentive for workers in agriculture to move into occupations in the mining sector.

Unlike the models previously discussed, this model was corrected for serial correlation when it was estimated. The model, even though it is a static representation of the labor market, exhibited serial correlation. Therefore, the adjustment for serial correlation was the correct specification. The major shortcoming of the model is the specification of one of the independent variables. In particular, the use of the first difference of the civilian labor force as an explanatory variable. The study did not present any reason for adopting this as an explanatory variable. The conclusion concerning the impact that unions have on the wage differential is questionable. The work stoppage variable may not necessarily represent the presence of the union. Even if it does measure union presence, if there has been no work stoppages during the time series it will not be a good explanatory variable. The variable measuring union presence and its effects may need to be modified.

Adams and Menkaus (1980) attempted to expand on their previous work. They studied the effect that mining will have directly on the agricultural labor market for the entire Northern Great Plains. This study used the Schuh model to determine the elasticities of the demand and supply relationships for hired agricultural labor. The Schuh model is modified to facilitate the examination of the specific impact that mining has on the labor market. The model was also estimated assuming serial correlation of the residuals, unlike the original Schuh model.

It was hypothesized that the introduction of mining into the region will stimulate economic activity. This added activity, particularly rising wages, may have some impact on the agricultural sector in the regional economy.

The empirical model is:

$$L_t = B_0 + B_1 r_1 + B_L X_{1t} + B_3 X_{2t} + B_4 L_{t-1} + u_{1t}$$

$$L_t = \propto_0 + \propto_1 r_1 + \propto_2 XY_{3t} + \propto_3 X_{4t} + \propto_4 X_{5t} + \propto_5 L_{t-1} + u_{2t}$$

Where:

L_t = Agricultural hired labor force for Montana, North Dakota, and Wyoming in year t.

r_1 = Average of Montana, North Dakota, and Wyoming agricultural hourly wage in year t, deflated by the Consumer Price Index.

X_{1t} = Ratio of the index of prices received over the index of prices paid by U.S. farmers in year t.

X_{2t} = Farm productivity index of output per unit of input for the Northern Great Plains in year t.

X_{3t} = Average of Montana, North Dakota, and Wyoming hourly mining wage in year t, deflated by the Consumer Price Index.

X_{4t} = First difference of the civilian labor force in Montana, North Dakota, and Wyoming.

X_{5t} = Time trend variable.

u_{1t} = Random disturbance.

u_{2t} = Random disturbance.

B_4 = $1-\gamma_1$ where γ_1 = the coefficient of adjustment for demand.

$\alpha_y = 1-\gamma_2$ where γ_2 = the coefficient of adjustment for supply.

The data were from a three-state region for Montana, North Dakota, and Wyoming for the period 1964-1978. The variables in the demand equation had greater statistical significance and the R^2 of the demand equation was higher than in the supply equation. The coefficient of the lagged dependent variable is significantly different from zero, which implies that adjustments are occurring over time. In the supply equation, the lagged value is not statistically significant. In the supply equation, the mining wage is statistically significant, which implies that the mining wage does appear to have some impact on the supply of hired labor in agriculture. The trend variable in the supply equation is also significant. This supports the hypothesis that the variable may be an important shifter of the supply of labor. That is, the supply of labor may be influenced by factors such as tastes, education and industrial structure and not strictly wages.

This model did assume serial correlation in the residuals. Thus, the parameter estimates should not be biased because of the serial correlation. Once again, the first difference of the civilian labor force was used in the model. The rationale for using this variable is that the actual value of the labor force in year t is highly collinear with agricultural and mining wages. Therefore, they took the first difference of the variable to eliminate the collinearity. This methodology for correcting for collinearity is not correct, and may have detrimental consequences for the results. However, the first difference may be appropriate as a measure of rapid growth: a large positive first difference indicates a "boom" economy.

All of the labor market studies reviewed used a simultaneous equation system to model the supply and demand relations. Many of the models used a distributed lag approach to aid in the explanation of the adjustment process that the market must go through. It appears that these two methods are the most prevalent means of analyzing the adjustment process of the agricultural labor market as it is affected by energy development.

These model specifications do appear generally consistent with the conceptual model specification discussed in the previous chapter.

CHAPTER 4

DATA

Data Formulation. The data used in the model is comprised of Bureau of Economic Analysis (BEA) county level statistics for the years 1969-1977. With the short time series available, it is necessary to combine several counties in a four state area in order to get a large sample size. The pooled cross section-time series data base comes from counties in a four state area. The states of Montana, Wyoming, Colorado, and Utah are sampled because these states have experienced rapid energy development over the past decade.

Several variables are created from the BEA data. These variables are:

1) Wage and salary agricultural employment - number of wage and salary workers in agriculture.
2) Average annual income for hired agricultural labor - difference of agricultural income minus farm proprietorship income divided by the number of wage and salary farm workers.
3) Farm proprietorship income - Total farm proprietor income divided by the total number of farm proprietors.
4) Mining employment - Total employment figures from the mining sector.
5) Average annual mining income - Total mining income divided by total number of mining employment.
6) County population.

7) Employment/population ratio - Total wage and salary employment divided by total county population.

8) General construction employment - Total employment in the construction sector.

9) Average annual construction income - Total construction income divided by total construction employment.

All income variables are deflated to 1967 dollars using the G.N.P. Implicit Price Deflator.

After all the variables are formed for each county in the four state region, selection criteria are established to limit the sample size. There are two factors that are necessary for a county to be included in the sample. These are: (1) hired agricultural workers must be existent in the county, and (2) some form of energy development or mining employment must also be existent in the county. The exact selection criteria, for every year from 1969-1977, are:

1) Mining employment is greater than 0.

2) Mining income is greater than 0.

3) General construction employment is greater than 0.

4) General construction income is greater than 0.

5) Farm wage and salary employment is greater than 3.

The selection criteria produced a sample set of 85 counties. Non-agricultural counties were eliminated, as well as counties with no mining or construction employment. Several major growth (energy development) counties were included in the set. These included such counties as Rosebud, Montana; Sheridan, Wyoming; and Garfield, Colorado.

This data set is substantially different than the time series data utilized in all previous studies. The other studies utilized strictly yearly state or national average wage rates and income for a specified time period. No attempt was made to model county-specific relationships between mining and agriculture. This data set also utilizes a time series approach but it also incorporates (pools) the time series over 85 counties, thus forming a pooled cross-section/time series data set. By utilizing the selection process outlined above, only counties with both energy development (mining or construction) employment and agricultural employment were included in the data set. Those counties eliminated were always included in the state or national average wage and income values utilized in the previous studies. This inclusion may possibly dilute the relationships between energy development and agriculture that may exist in many counties. The data set for this study eliminates that possibility of diluting the relationship. Therefore, the data used should identify any direct relationship between mining/construction and agriculture.

A total of nine years of data was available which, when pooled with the 85 counties selected, produced 765 initial observations. Models 1 and 2 (discussed below) utilize a one period lag and are also corrected for serial correlation. Therefore, only 7 years of data are available, reducing the total to 595 actual observations. There are 168 county dummy variables and 12 structural parameters in the equation system leaving 1,020 degrees of freedom.

Model 3 utilizes a 2 year lag and is corrected for serial correlation, hence only 6 years of data are available. Therefore, there are 510 observations per equation. The county dummy variables and 14 structural parameters leave 848 degrees of freedom for the system.

Data Problems. BEA employment and income numbers are the most readily available time series data. The use of that data set, however, does pose some concerns.

The primary data uncertainty is caused by the computation of "true" wage rate and employment levels for each sector. The measured wage rate in each sector is the total income of that sector divided by the employment in that sector. The total employment includes both full- and part-time workers in each sector. Therefore, when average wage rates are computed for each sector, the net effect is a lowering of the overall income average for that sector. Also, other factors that are portions of a wage package such as pension, insurance, and room and board, are not included in these wage estimates. For example, farm laborers often receive room and board along with their salary, but room and board is not included in the wage rate, so the wage rate used in the model estimation may understate the "real" wage rate of that sector. These costs are included in the net proprietor's income variable, but they are not explicitly identified as a wage rate.

Another problem with the data is the presence of proprietors in the emloyment data. Only in the case of agriculture can proprietors be readily separated from hired labor. In the other sectors the actual number of proprietors cannot be readily determined, so the total employment figures utilized may overstate the wage & salary employee count for the sector due to the existence of proprietors. This problem is more likely to occur in the construction sector than the mining sector due to the size requirement of a typical mining business. Most of those businesses are usually incorporated and are, therefore, not included as proprietors.

The implications of these potential data faults are discussed at length in the final chapter. But, in general, the statistical results received from the model estimation may be biased due to data problems.

CHAPTER 5

ECONOMETRIC SPECIFICATION

Specification. As shown in the conceptual model chapter and the literature review, the most desirable model of the agricultural labor market is a simultaneous equation model. The model should make use of the supply and the demand functions for hired farm labor. It should also have a lagged structure that will be used to determine the dynamics of the labor market. The following model is specified for each county i: (Note: A model with a second order lag on hired labor is considered subsequently.)

$$L_{1i} = \alpha_{1i} + a_1 L_{2i} + b_{11} X_{1i} + b_{15} X_{5i} + W_{1i}$$

$$L_{1i} = \alpha_{2i} + a_2 L_{2i} + b_{22} X_{2i} + b_{23} X_{3i} + b_{24} X_{4i} + b_{25} X5_{5i} + W_{2i},$$

where:

L_{1i} = quantity of hired agricultural labor

L_{2i} = agricultural wage rate

X_{1i} = farm proprietor's income

X_{2i} = wage rate for the mining (or other alternative) sector

X_{3i} = population

X_{4i} = employment/population ratio

X_{5i} = quantity of hired agricultural labor lagged one year (L_{1it-1})

W_{1i}, W_{2i} are random disturbances.

Note that the constant terms (α_{1i}, α_{2i}) are permitted to vary across counties. Assumptions about the random disturbances are discussed below.

In matrix notation the simultaneous system is written as:

(1) $AL_i + B_iX_i = W_i$,

Where:

$$A = \begin{bmatrix} 1 & -a_1 \\ 1 & -a_2 \end{bmatrix} \qquad B_i = -\begin{bmatrix} \alpha_{1i} & b_{11} & 0 & 0 & 0 & b_{15} \\ \alpha_{2i} & 0 & b_{22} & b_{23} & b_{24} & b_{25} \end{bmatrix}$$

$L_i = (L_{1i}, L_{2i})$, $X_i = (1, X_{1i}, \ldots, X_{5i})'$, $W_i = (W_{1i}, W_{2i})'$

The disturbances W_i are assumed to follow a first order autoregressive process:

(2) $W_i = RW_{it-1} + S_i$,

Where: $R = \begin{bmatrix} \rho_1 & 0 \\ 0 & \rho_2 \end{bmatrix}$,

W_{it-1} = lagged valve of the disturbance W_i,

$S_i \sim N(0, \Sigma)$, and the S_i are independent across counties and time periods.

To obtain the reduced form, use (1) and (2) to write:

(3) $L_i = -A^{-1}B_iX_i + A^{-1}RW_{i+1} + A^{-1}S_1$.

Lag equation (1) one period to obtain:

(4) $AL_{i+-1} + B_iX_{i+1} = W_{i+-1}$,

and then substitute (4) into (3):

(5) $L_i = -A^{-1}B_iX_i + A^{-1}RAL_{i+1} + A^{-1}RB_iX_{i+-1} + V_i$

Where $V_i = A^{-1}S_i$.

Equation (5) is the reduced form of (1) and (2); only predetermined variables appear on the right hand side and the disturbances V_i are not serially correlated. The reduced form county-specific constant terms, (π_{1i}, π_{2i}) say, are given by:

$$i = \begin{bmatrix} \pi_{1i} \\ \pi_{2i} \end{bmatrix} = A^{-1}(R-I) \begin{bmatrix} \alpha_{1i} \\ \alpha_{2i} \end{bmatrix}$$

<u>Estimation</u>. The parameters in (5) could be directly estimated by Full Information Maximum Likelihood (FIML). However, the 170 distinct constant terms makes FIML extremely cumbersome. Instead the following two step procedure is employed: (1) Estimate each of the equations in (5) by ordinary least squares (without imposing the restrictions implied by the structural model). The regressors include 84 dummy variables corresponding to each of the counties but one, as well as the usual intercept. Suppose there is no dummy variable for the first county. Then the coefficients of the remaining dummy variables are the differences between the constant terms for the remaining counties and the constant terms for the first county, $\pi_{ji} - \pi_{j1}$ $j = 2, \ldots, 85$. The OLS estimators of these differences are consistent.

The second step is to subtract the OLS estimates, $\pi_{ji} - \hat{\pi}_{j1}$ from the corresponding dependent variables to obtain new variables, $\hat{L}_{ji}$ say:

$$\hat{L}_{ji} = L_{ji} - (\hat{\pi}_{ji} - \hat{\pi}_{j1}), \; j = 1,2 \; j \; i = 2, \ldots, 85.$$

Then estimate (5) by the FIML procedure, with L_{ji} replaced by $\hat{L}_{ji}$ and all of the constant terms constrained to be equal across counties. If the $\hat{\pi}_{ji} - \hat{\pi}_{j1}$, were the true values rather than estimates, the two step procedure would yield asymptotically efficient estimators of the structural parameters. Since only consistent estimates rather than the true values are available, the two step procedure is only guaranteed to produce consistent estimators of the structural parameters. [The use of estimates for the first stage also implies a modification to the covariance matrix of the estimators in the second stage. However, this complication is ignored; standard errors are computed as if the first stage estimates were the true values.]

CHAPTER 6

STATISTICAL RESULTS

This chapter presents the statistical results determined when the structural equation models were estimated. Models 1 and 2 utilize 1 period lags of the dependent variable. Model 1 assumes that the alternative wage rate is the mining wage. The construction wage rate is the alternative wage in Model 2. Model 3 utilizes a two period lag structure and assumes that the alternative wage rate is the mining sector wage rate. The structural parameter estimates elasticities, and reduced form elasticities are presented separately in this section. Prior to the specific equation and model discussion, some general results and conclusions are presented.

General Results. Table 1 presents the parameter estimates for each model specification. In all model specifications, the parameter estimate on the agricultural wage rate variable in the supply equation is negative. This sign is not consistent with standard economic theory which usually assumes a positive relationship between the quantity supplied and the price of a good. The coefficient estimate is significantly different from zero at the 95 percent confidence level only in Model 2.

The coefficient estimate on the lagged dependent variable in the demand equation for Models 1 and 2 is negative, which is not the expected sign. In both cases, the t-statistic indicates that the estimate is significant at the 95 percent confidence level. The implied

TABLE 1
Parameter Estimates
(t-statistics in parentheses)

Parameter	Model 1 Demand	Model 1 Supply	Model 2 Demand	Model 2 Supply	Model 3 Demand	Model 3 Supply
Constant	2,100	129	1,106	142	1,224	206
	(6.2)	(5.5)	(9.2)	(10.7)	(8.2)	(3.0)
Agricultural Wage	-.452	-.005	-.233	-.008	-.242	-.013
	(5.7)	(1.3)	(8.1)	(3.0)	(7.2)	(.8)
Proprietors Income	.004	0	.002	0	.002	0
	(3.9)		(4.4)		(4.0)	
Alternative Wage	0	-.001	0	-.009	0	-.001
		(3.8)		(7.1)		(0.5)
Population	0	.001	0	.001	0	.001
		(6.9)		(11.0)		(7.5)
Employment/Population Ratio	0	-37.8	0	11.9	0	-32.0
		(2.0)		(1.0)		(1.3)
First Order Lag	-.802	.212	-.549	.366	-.313	.063
	(10.7)	(2.1)	(11.3)	(14.3)	(0.5)	(1.0)
Second Order Lag	0	0	0	0	-.570	-.363
					(9.9)	(7.2)
Serial Correlation	.476	-.036	.437	-.285	.483	.379
	(41.5)	(.3)	(30.6)	(5.5)	(38.5)	(9.1)

Notes: 1. Dependent variable is quantity of hired farm labor.
2. For Models 1 and 3, alternative wage is mining wage
3. For Model 2, alternative wage is construction wage.
4. First order lag is the dependent variable lagged 1 year, second order lag is the dependent variable lagged 2 years.

adjustment coefficient is one minus the parameter estimate, so the negative sign of the parameter estimate will yield an adjustment coefficient greater than one. This means that the incremental adjustment of the demand for labor in a disequilibrium situation overshoots the equilibrium value each year. The tests for stability of the models indicate that they are both stable and, therefore, will adjust towards the equilibrium. The adjustment process of the market in disequilibrium will cause the market to oscillate around the equilibrium value until it converges at the equilibrium.

The structural elasticities of the systems are, in general, quite small. The only exception is the elasticity with respect to the agricultural wage rate in the demand equation in both Models 1 and 2. Therefore, the systems are not very susceptible to forces that change the independent variables of the models' equations. The reduced form elasticities are also quite small.

The remainder of the chapter presents and discusses the actual parameter estimates for each equation system, as well as the structural elasticities and reduced form of each system.

<u>Structural Parameter Estimates and Elasticities</u>. This section discusses the structural coefficient estimates and the structural elasticities that were determined when the equations were estimated. Table 1 presents the parameter estimates along with the t-statistics associated with each estimate. Tables 2 and 3 present the structural elasticities for each function. The elasticities are evaluated at the mean values of the data.

TABLE 2

Structural Elasticities
Demand

Model	Agricultural Wage		Farm Proprietor's Income		Coefficient of Adjustment
	Short	Long	Short	Long	
1	-5.13	-2.85	0.06	0.03	1.80
2	-2.53	-1.64	0.03	0.02	1.55
3	-2.79	-1.48	0.04	0.02	1.88

TABLE 3

Structural Elasticities
Supply

Model	Agricultural Wage		Alternative Wage		Population		E/P Ratio		Coefficient of Adjustment
	Short	Long	Short	Long	Short	Long	Short	Long	
1	-0.06	-0.07	-0.04	-0.05	0.04	0.05	-0.04	-0.05	0.79
2	-0.09	-0.15	-0.15	-0.24	0.03	0.04	0.01	0.02	0.63
3	-0.15	-0.12	-0.01	-0.01	0.05	0.04	-0.04	-0.03	1.30

In all three cases, the parameter estimates for agricultural wage rate in the demand equation were significantly different from 0 at the 95 percent confidence level. All the coefficients are negative, which implies an inverse relationship between the quantity of labor demanded and the wage rate. This relationship is consistent with standard economic theory. The slope of the demand equation in Models 2 and 3 is approximately twice as steep as it is in Model 1. This indicates that the quantity of labor demanded in Model 1 is more responsive to the wage rate than it is in Models 2 and 3. The elasticity values were greater than 1 for all models, indicating that the quantity demanded of labor is very responsive to wage rate changes. The elasticity values for Model 1 indicate that the quantity of labor demanded is twice as responsive to wage rate changes than it is in Models 2 and 3. (See Table 2.)

The negative sign on the parameter estimates of the agricultural wage rate in the supply equations is not expected. The parameter estimate is only statistically significant in Model 2. In all three cases, the value of the estimates is quite small. Therefore, even if the sign is not expected, the actual slope of the supply equation is almost vertical. The vertical slope implies that the quantity of agricultural labor supplied is not responsive to wage rate changes in that sector. In general, the elasticity results show that the quantity of labor supplied is not highly responsive to changes in the agricultural wage rate. Model 3 exhibits the highest responsiveness to wage rate changes in the short run. It is about 3 times as responsive to changes than is Model 1. The long run responses, however, do not hold the same pattern. Model 2 has the greatest long run response to wage rate changes than does either Model 1 or 3. (See Table 3.)

The parameter estimates on the proprietors' income in the demand equations are approximately twice as high in Model 1 as in Models 2 and 3. This means that the demand for labor in Model 1 is more responsive to farm proprietors' income than are Models 2 and 3. In all three models, the t-statistics show that the values are significant at the 95 percent level. The positive signs on the estimates are consistent with the hypothesized values. Therefore, as farm proprietors' income increases, the demand function for farm labor can be expected to shift outward so more labor will be demanded at any given price. The elasticity values less than 1 indicate that the demand function for farm labor is not responsive to changes in the proprietor's income. As is the case in the agricultural wage rate, the elasticity is greater in Model 1 than it is in the other two specifications. Therefore, the demand function is more highly influenced by proprietor income changes in the specification of Model 1 than in the other two specifications. The long run elasticities reveal the same relationships. (See Table 2.)

The estimates of the alternative wage parameters are statistically significant in Model 1 and 2, but not in Model 3. In all cases, the estimates are of the expected sign: as the alternative wage increases the supply of agricultural labor will decrease. The coefficient estimate in Model 2 is the largest, which suggests that the agricultural supply is more responsive to changes in the construction wage rate than in the mining wage rate, which are Models 1 and 3. The elasticity values also indicate that the supply of agricultural labor is more responsive to changes in the construction wage rate than it is to the mining wage rate (see Table 3). This means that the construction sector offers greater competition for the agricultural laborer than does the mining sector. The long run structural elasticities demonstrate the same relationships as the short run elasticities.

The positive signs on the population variable estimates is expected. As population increases in a county, the supply of labor can be expected to increase. All of the parameter estimates are statistically significant. The elasticity values indicate that population changes have the greatest effect in the short run in Model 3 but in the long run the population influences Model 1 the most. (See Table 3.)

The negative sign on the employment/population ratios in Models 1 and 3 is consistent with the expected sign. Therefore, as the e/p ratio increases (the labor market becomes more "tight"), the supply of that labor will likely decrease. Since high growth energy development counties are characterized by high e/p ratios, this provides some evidence that growth affects the supply of labor to agriculture. The elasticities indicate that supply in Model 1 is most responsive to changes in the e/p ratio, being almost three times more responsive than Model 3 in the short run. (See Table 3.)

The parameter estimates on the first and second order lagged dependent variables determine the adjustment coefficient for the models. For Models 1 and 2 the adjustment coefficients are one minus the first order lag parameter estimate. In Model 3, the adjustment coefficient is a function of both the first and second order lag parameter estimates. The adjustment coefficients are utilized to identify the difference between short run and long run structural elasticities. Short run elasticities are produced by the model estimation, while the long run elasticities are determined by dividing the short run elasticities by the adjustment coefficients.

The parameter estimates for the first order lag on the demand equation for all models are negative. This negative sign will, therefore, produce an adjustment coefficient greater than 1 in all three demand equations. These adjustment coefficients greater than 1 will produce long run elasticities smaller than short run elasticities. Therefore, in the models, demanders of farm labor will overadjust to a disequilibrium condition, caused by a changing agricultural wage, in the short run. The systems are, however, stable so a new equilibrium will eventually be obtained. During each period in disequilibrium, the system comes closer to reaching the new equilibrium level. In models 1 and 2 the system oscillates around the new equilibrium value each year until the new level is reached. But on Model 3 it oscillates every third year around the new equilibrium value.

The parameter estimates on the first order lagged dependent variable in the supply function are positive in all three models. Therefore, the adjustment coefficients for Models 1 and 2 are less than 1, which is expected. The value for the parameter estimate for the second order lag in Model 3 is negative, therefore the adjustment coefficient in Model 3 is greater than 1. This implies that in Model 3 the suppliers of agricultural labor will overadjust in the short run to a change in the agricultural wage rate. In Models 1 and 2 the new equilibrium value of the system to disequilibrium will be reached asymptotically. In Model

3, the new equilibrium value will be reached like the demand function -- by oscillating around the new level until it is reached. This oscillation occurs every third year.

The serial correlation parameter estimates in the demand equations are all positive, which is the expected sign. These estimates provide evidence that the equations are serially correlated and the adjustment was proper and justified.

The serial correlation estimates in the supply function are negative in Models 1 and 2, which is not expected. Model 3 has the expected positive sign on the serial correlation estimate. The correlation in Models 2 and 3 is much larger than in Model 1.

The parameter estimates for the demand equations of the three models in general were statistically significant. In all three cases, the coefficients on the lagged variables were negative thus producing an adjustment coefficient greater than 1. The demand function in Model 1 was more responsive to agricultural wage rate and proprietor income changes than was either of the other two models. All short run demand elasticities are greater than the long run elasticities, indicating an overadjustment process in disequilibrium. The models are all stable so an equilibrium level will eventually occur.

The estimates on the agricultural wage rate in all three supply functions are not the expected sign, but the values indicate an almost vertical supply function. Overall, the parameter estimates and the statistical significance of the estimates are best in Model 2, indicating that the alternative wage specification, i.e. the construction wage rate, provides the most effective specification of the supply response.