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Examining Labor Substitution: Does Family Matter for U.S. Cash Grain Farmers?

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The substitution of capital for labor and new labor-saving technologies has reduced the labor required for farming, yet many farms today depend on hired labor in some form. Common in the literature is the assumption of perfectly substitutable farm labor. This has implications for the operator's off-farm labor decision. Intuitively, different forms of farm labor have different impacts on production. We use the Agricultural and Resource Management Survey to estimate the elasticity of substitution between hired and family labor. The results provide little evidence to support the popular homogeneity assumption and find labor can be unitary and complimentary under certain scenarios.

Key Words: cash gains, family, farm labor, heterogeneity, hired labor, homogeneity, labor, seemingly unrelated, substitution

JEL Classifications: D13, J22, J23, Q12, Q18, R38

Agricultural labor can largely be divided into two groups: hired labor without farm ownership claims and family labor, having ownership claims. According to the Farm Labor Survey of the National Agricultural Statistics Service (NASS), hired labor makes up one-third of all those working on farms with the remaining two-thirds being self-employed, farm operators, and their family members. The majority of hired labor is found on the nation's largest farms, those with sales over $500,000.

In the past, family labor and hired labor worked side by side on cash grain farms with similar productivity. The degree of differentiation between family and hired labor was traditionally the result of the impacts of managerial and supervisory duties by the family worker. However, things have changed. Increasingly family workers (operator and spouses) tend to work off-farm where they are more productive, receive higher income, and receive fringe benefits like health insurance and retirement income. In the absence of family labor, hired labor is left to perform major tasks on the farm with reduced productivity.

Employment in farm production as a whole has declined significantly in the United States. Significant contributors to this trend have been technical change and improved capital productivity. These trends have resulted in increased labor productivity, reduced numbers of farm households and operators, and larger average

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farm size. Some farm operators have left farming altogether, giving way to large farms or increased development outside agriculture. On other farms, labor has been absorbed in off-farm markets such as off-farm employment and "pluri-activity" (Mishra et al., 2002) leaving a more concentrated number of large farms producing a larger share of agricultural output. Although employment on farms has declined as a result of the substitution of capital for labor and the adoption of other new labor-saving technologies, many farms today depend on hired labor in some form (Kendel, 2008). This is particularly true for large farms.

Taylor (2010) shows a reduction in the supply of migrant workers, who work as hired labor in the United States, as a result of booming economies back in their home countries and also to immigration reform. They further conclude that U.S. agriculture is especially impacted. The reduced supply of migrant farm workers (or hired labor) implies that U.S. growers must look for substitutes or increase wage rates at a time of rapidly increasing prices for other inputs. As farm size grows and family members increasingly work away from the farm, it will be increasingly important to balance these divergent trends through technological change, hired labor (domestic or immigrant), or a combination thereof that allows the operator to more efficiently manage the farm.

From an agricultural policy perspective, if family and hired labors are homogenous, then farm operators and spouses can easily use decoupled government payments to hire replacement workers on the farm.[1] The operator and spouse can then work higher earning jobs off-farm or simply enjoy greater hours of leisure. Aside from the profit maximization of off-farm labor, farm households may be attracted to less variability in off-farm wages (Mishra and Holthausen, 2002) or other fringe benefits associated with off-farm employment (D'Antoni and Mishra, 2013).

The development economics literature provides a different explanation for the differentiation of hired and family labor. This literature indicates that hired and family labor are less than perfect substitutes in the presence of missing markets (Eswaran and Kotwal, 1986; Fafchamps and Quisumbing, 1999; Feder, 1985; Singh, Squire, and Strauss, 1986; Taylor and Adelman, 2003). However, little guidance is provided on assessing the degree of substitutability in the presence of government policies that alter the labor allocation decision of family labor. Johnston and Leroux (2007) report for instance that, for farmers, family labor can be more efficient than hired labor because it is assumed to be better incentivized and less likely to shirk (see also Binswanger and Rosenzweig, 1986).

The farm household model (Singh, Squire, and Strauss, 1986) states that family and hired labor are assumed perfect substitutes and can be added directly. This assumption implies that each additional unit of family and hired labor has an identical impact on production, costs, and profits. The objective of this article is to test the hypothesis of farm labor homogeneity while making no *a priori* assumptions as to the substitution relationship between hired and family labor. More simply, we test the assertion by Schultz' (1999) that family and hired labor may exhibit different levels of productivity and may deserve to be treated as separate inputs.

A locally flexible cost function approach is used, thereby allowing the data to reveal the true relationship between hired and family labor. Specifically, we use farm-level data from the Agricultural Resource Management Survey (ARMS) to jointly estimate a translog cost function with factor share equations through iterative seemingly unrelated regression (ITSUR). Our study focuses on cash grain farms of differing size and production regions as defined by the Economic Research Service (ERS) of the U.S. Department of Agriculture. Regionally, the results provide little evidence to support the homogeneity assumption and further indicate

[1] Decoupled payment is defined as an income transfer to farm households that is not tied to production. There is considerable evidence in the literature that agricultural policy, in the form of decoupled and coupled farm payments, has an impact on the hours of off-farm work or decision to work off the farm by farm operators and spouses (Ahearn, et al., 2004; Ahearn, El-Osta, and Dewbre, 2006; Dewbre and Mishra, 2007).

that the elasticity of substitution can be unitary or even complimentary under some scenarios. Controlling for farm size, we find that hired and family labor is slightly more substitutable on the largest farms while more complementary on the smallest farms. This evidence weakens the narrative that decoupled payments subsidize hired on-farm labor and operator/spouse off-farm work.[2]

Literature Review

Prior research has attempted to measure the elasticity of substitution between hired and family labor. The studies have largely been limited to estimation of production functions for farm output, generally using a Cobb-Douglas functional form as in Deolalikar and Vijverberg (1983, 1987). These two studies analyzed the substitutability of farm labor in India and Malaysia. Deolalikar and Vijverberg (1983) estimated a Cobb-Douglas production function for farm outputs as a function of farm labor and other farm inputs. The farm labor input was then represented by a second production function nested within the farm production function. Using data from 268 districts in India (1970–1971), the authors estimated the aggregate output of 22 major crops. The best-fit production model, as determined by a standard F-test, included a nested Constant Elasticity of Substitution (CES) production function for farm labor, which was restricted to a Cobb-Douglas specification. Deolalikar and Vijverberg (1987) extended the 1982 study to include farms in both India and Malaysia. A Cobb-Douglas production function was once again used for farm outputs, whereas a generalized quadratic production function was used to represent hired and family labor. A sample of 476 Indian and 100 Malaysian farm households, for 1974–1975 and 1976–1977, were used in the estimation of aggregate output. In both of these studies, perfect substitutability of hired and family labor was rejected.

Huffman (1976) demonstrated a similar result using a cross-section of aggregate county data from the 1964 Census of Agriculture. Specifically, Huffman used data for 276 counties in Iowa, North Carolina, and Oklahoma and estimated the ratio of hired labor (L_H) and farm husband or wife (L_{Op}). The elasticity of substitution, σ_{ij}, between hired labor and farm wives was 1.152. However, the elasticity of substitution was much lower between hired labor and farm husbands (0.682); therefore, the rate at which farm husbands can be replaced by hired labor is relatively lower than that of farm wives. In an absolute sense, both farm husbands and wives do not exhibit perfect substitutability with hired labor.

There are several weaknesses to the mentioned studies. First, the studies are small in scope and regionally focused. Second, some models have imposed *a priori* relationships regarding the elasticity of substitution between family and hired farm labor. The current research has the advantage of an improved methodological approach and more recent farm-level data. We use a large, nationwide data set comprising farms of different economic sizes across the United States.

Theoretical Considerations

In their foundational work on farm household models, Singh, Squire, and Strauss (1986) state that family and hired labor are assumed perfect substitutes and can be added directly. This assumption implies that each additional unit of family and hired labor has an identical impact on production, costs, and profits. This notion continues in more recent research (Blanc, Cahuzac, and Elyakime, 2008a) with the added acknowledgment that family and hired labor may impact production processes differently (Deolalikar and Vijverberg, 1983, 1987; Huffman, 1976).

Consider the farm household model as proposed by Blanc, Cahuzac, and Elyakime (2008a, 2008b) and derived from Dawson (1984), where the decision to allocate labor to off-farm work

[2] Note this article takes one channel to examine the effect of government payments on degree of substitutability between hired and family labor. Other channels (such as slippage, changes in land rental payments, or scale effects for farmers who either cannot or do not wish to borrow) that can be used to examine the same effect but would require panel data, which is beyond the scope of this article.

and hire farm labor is separated into four regimes assuming hired and family labor are perfectly substitutable. The farm household is expected to follow a utility maximization framework where U denotes utility. The utility is a function of leisure ($L_{ei}\,(L_F, L_O)$) and income ($I(L_F, L_O)$). Both farm household income and time devoted to leisure are a function of time devoted to farm labor (L_F) and off-farm labor (L_O).

$$\text{(1)}\qquad Max\, U = U(L_{ei}\,(L_F, L_O), I(L_F, L_O))$$

$$s.t.$$

$$\text{(2)}\qquad L_{ei} + L_F + L_O - T = 0$$

$$\text{(3)}\qquad w_O L_O + \pi_F + V - I = 0$$

$$\text{(4)}\qquad L_{ei}, L_F, L_O \geq 0$$

Utility maximization in equation (1) is subject to the total available hours (T) allocable to leisure, farm labor, and off-farm labor (equation [2]), the full income constraint (equation [3]), and nonnegativity constraints (equation [4]). The full income constraint is defined as the sum of income from off-farm labor ($w_O L_O$), farm profits (π_F), and other household nonlabor income (V) minus total income (I). Farm profits are further defined as the value of farm production minus the input costs. Specifically,

$$\text{(5)}\qquad \pi_F = P_f f\,(L(L_F, L_H), X_f) - w_f\, X_f - w_H\, L_H$$

where P_f is the price of farm outputs, $f(.)$ is the farm production function, w_f is a vector of prices for inputs X_f, and w_H is the wage paid to hired labor L_H.

Now, let the farm production function $f(L(L_F, L_H), X_f)$ be a Cobb-Douglas production function of the following form:

$$\text{(6)}\qquad f(L(L_F, L_H), X_f) = AL^{\beta_1} \prod_{i=1}^{n} x_i^{\beta_i}$$

where X_f is a vector of farm inputs and $L(L_F, L_H)$ describes the farm labor input as a function of hired and family labor. The Lagrangian ($\mathcal{L}$) can be constructed for the outlined maximization problem with the following first-order conditions:

$$\text{(7)}\qquad \begin{aligned} &U(L_{ei}(L_F, L_O), I(L_F, L_O)) \\ &\quad + \lambda(L_{ei} + L_F + L_O - T) \\ &\quad + \delta(wL_O + \pi_F + V - I) \\ &\frac{\partial \mathcal{L}}{\partial L_O} = -\frac{\partial U}{\partial L_{ei}} + w_O \frac{\partial U}{\partial I} = 0 \rightarrow \\ &\quad w_O = MRS_{L_{ei},I} \end{aligned}$$

$$\text{(8)}\qquad \begin{aligned} \frac{\partial \mathcal{L}}{\partial L_F} &= -\frac{\partial U}{\partial L_{ei}} + \left(\frac{\partial U}{\partial I}\right)\left(\frac{\partial I}{\partial \pi_F}\right) \\ &\quad \times \left(\frac{\partial \pi_F}{\partial f(L(L_F, L_H))}\right)\left(\frac{\partial f(L(L_F, L_H))}{\partial L(L_H, L_F)}\right) \\ &\quad \times \left(\frac{\partial L(L_F, L_H)}{\partial L_F}\right) = 0 \end{aligned}$$

$$\text{(9)}\qquad MRS_{L_{ei},I} = \left(\frac{\partial L(L_F, L_H)}{\partial L_F}\right)(VMP_L)$$

where VMP_L is equal to the value marginal product of farm labor and $MRS_{L_{ei},I}$ is equal to the marginal rate of substitution between leisure and Income.

Let us now consider two alternative definitions for $L(L_F, L_H)$. The common approach to the farm household model, which assumes perfect substitution between labor inputs, is represented by L^O:

$$\text{(10)}\qquad L^O(L_F, L_H) = \alpha_1 L_F + (1 - \alpha_1)L_H$$

Alternatively, the relationship can be characterized by a quadratic function where the elasticity of substitution between hired and family labor is nonconstant.

$$\text{(11)}\qquad \begin{aligned} L^{'}(L_F, L_H) = \alpha_0 + \alpha_1 L_F + \alpha_2 L_H + b_1 L_F^2 \\ + b_2 L_H^2 + b_3 L_F L_H \end{aligned}$$

From the first-order conditions described by equations (8) and (9), we can derive four labor regimes from our utility maximization framework (Blanc, Cahuzac, and Elyakime, 2008a). The value of ϕ in the following regimes is dictated by our choice of functional form for $L(L_F, L_H)$ and the resulting marginal physical product of family labor $\left(\frac{\partial L(L_F, L_H)}{\partial L_F}\right)$.

$$\text{(12)}\qquad \begin{aligned} &w_O < MRS_{L_{ei},I} < \alpha_1 VMP_L + \phi VMP_L \rightarrow \\ &\quad L_O = 0 \text{ and } L_H = 0 \end{aligned}$$

$$\text{(13)}\qquad \begin{aligned} &w_O = MRS_{L_{ei},I} < \alpha_1 VMP_L + \phi VMP_L \rightarrow \\ &\quad L_O > 0 \text{ and } L_H = 0 \end{aligned}$$

$$\text{(14)}\qquad \begin{aligned} &w_O < MRS_{L_{ei},I} = \alpha_1 VMP_L + \phi VMP_L \rightarrow \\ &\quad L_O = 0 \text{ and } L_H > 0 \end{aligned}$$

$$w_O = MRS_{L_{ei},I} = \alpha_1 VMP_L + \phi VMP_L \rightarrow L_O > 0 \text{ and } L_H > 0 \tag{15}$$

If we assume perfect substitution between labor inputs, then $L^O(L_F, L_H)$ is the labor input included in the farm production function (equation [6]), which results in a very simplistic representation of our labor regimes where $\phi = 0$. Under the case of perfect substitutability, $VMP_L = w_f = w_H$, which implies a single wage for farm labor and thereby a shared demand curve for hired and family labor.

Alternatively, if farm labor is represented by equation (11), then $\phi = (2b_1L_F + b_3L_H)$ and there is not a single wage or single demand curve for farm labor. If $\phi = (2b_1L_F + b_3L_H) > 0$, then as hired and family labor become highly substitutable ($\phi \rightarrow 0$), the number of hired workers will increase. The more highly substitutable farm labor is, the more freely the farm operator and spouse will change labor allocations to maximize income and leisure. The inverse is also true: as ϕ increases, the hours of labor from hired workers will fall. This implies that the lower the rate of substitution between hired or family farm labor, the less likely decoupled payments will be to subsidize increase of hired labor.

Empirical Model

The locally flexible translog function is well established in the literature (Berndt and Wood, 1975; Bigsby, 1994; Binswanger, 1974; Diewert and Wales, 1987; Greene, 2008). It allows for estimation with an unrestricted substitution relationship between factors of production.

$$\begin{aligned} \ln(\mathrm{C_k}) = {} & a_0 + a_Y \ln(Y_k) + \frac{1}{2}a_{YY}ln(Y_k)^2 \\ & + \sum_{i=1}^{5}\beta_i ln(P_i) \\ & + \frac{1}{2}\sum_{i=1}^{5}\sum_{j=1}^{5}\beta_{ij}ln(\mathrm{P_i})\ln(\mathrm{P_j}) \\ & + \sum_{i=1}^{5}d_{iY}ln(P_i)ln(Y_k) + a_T T \\ & + \frac{1}{2}a_{TT}T^2 + \sum_{i=1}^{5}g_{iT}ln(P_i)T \end{aligned} \tag{16}$$

The variable Y_k represents the respective quantities of all cash grains and cash grains excluding corn outputs. Cash grain farms tend to receive significant farm program payments and be less reliant on labor as a result of the increasing use of specialized machinery (White and Hoppe, 2012). Additionally, empirical evidence shows that the operators and spouses of cash grain farms have a higher likelihood of participating in off-farm work (Ahearn, El-Osta, and Dewbre, 2006).

The input prices for hired labor, family labor, capital, land, and fertilizer, chemical, pesticide expense are represented by the variables (P_i, P_j) in equation (16). Also included in the model are the constant (a_c) and time trend (T). The parameters $a_0, a_Y, a_{YY}, a_T, a_{TT}, \beta_i, \beta_{ij}$, g_{iT}, and d_{iY} are estimated with particular attention given to the interaction term (β_{ij}) for hired labor and family labor. The cost function is estimated jointly with $(n - 1)$ factors of production. By dropping one share equation (equation [17]), the system becomes nonsingular and can be estimated by ITSUR (Greene. 2008).

$$\begin{aligned} S_i = \frac{\partial \ln(\mathrm{C_k})}{\partial \ln(P_i)} = \frac{X_iP_i}{C_k} = {} & \beta_i \\ & + \sum_{i=1}^{5}\beta_{ij}\ln(P_i) + d_{iY}\ln(\mathrm{Y_k}) + g_{iT}\mathrm{T} \end{aligned} \tag{17}$$

In ITSUR, we make two key assumptions, i.e., exogeneity (reduced form) of each separate equation and correlation between the error terms across equations. Separate reduced form cost share equations for different inputs were used. Homogeneity restrictions (equations [18] and [19]) are included to ensure a proportional change in all factor costs results in a proportional change in production. This assumption also maintains that a change in all factor prices will not change the relative quantities of each factor used in production (Bigsby, 1994).

$$\sum_{m=1}^{3} a_m; m = constant, Y, YY \tag{18}$$

$$\sum_{i=1}^{5}\beta_{ij} = \sum_{i=1}^{5}g_{iT}\mathrm{T} = \sum_{i=1}^{5}d_{iY} = 0 \tag{19}$$

From the cost share equations (17) and the interaction effect (β_{ij}) of the estimated cost function, the Allen partial elasticity of substitution can be calculated using the following equation:

$$(20) \qquad \sigma_{ij} = \frac{\beta_{ij}}{S_i S_j} + 1$$

If β_{L_H,L_F} is positive and significant, then as σ_{L_H,L_F} approaches infinity, the assumption of perfect substitution between hired and family labor is increasingly justified. If β_{L_H,L_F} is insignificant, then $\sigma_{L_H,L_F} = 1$ and the substitution relationship between family and hired labor is unitary. We also include a variable for time to control for any time specific effects from pooling.

Data

The data used in this research is pooled from the 2006–2008 ARMS. ARMS is conducted annually by ERS and the NASS. The survey collects data to measure the financial condition and operating characteristics of farm businesses, the cost of producing agricultural commodities, and the well-being of farm operator households.

ARMS has a complex stratified, multiframe design where observation in ARMS represents a number of similar farms when using the provided expansion factors. The expansion factors are most useful in univariate applications, when the full survey is used, or when the goal of the research is making generalizations about the population of farms. The recommended procedure in this scenario is the delete-a-group jackknife recommended by Dubman (2000; National Research Council 2007). However, there is not clear or unanimous support for the jackknife approach when using subsets of the data or complex, multivariate analyses. In fact, Goodwin and Mishra (2006) argue that it is not clear whether stratification alters the likelihood function beyond the simple weights and whether it is appropriate to apply the predefined jackknife replicate weights to subsamples of the ARMS data. Similar to El-Osta (2011), then, we use a bootstrapping technique rather than the jackknife procedure for remedying the sample design issues in our subsample.[3]

Data on production cost, input prices, and output quantities were taken from ARMS for farms engaged in cash grain farming. The cash grains included in this study are corn, soybean, wheat, sorghum, and barley. We estimate models with and without corn to determine whether there is a structural difference between corn and the remaining cash grains. The sample data are restricted to family farms only, which account for approximately 98% of all U.S. farms (Table 1). Additionally, 85% of total production and nearly 90% of all cash grain production can be attributed to family farms (Hoppe et al., 2007).

Large and very large family farms also specialize in cash grains more than any other agricultural commodity and tend to employ the majority of hired farm workers. The share of work hours accounted for by hired labor on large and very large family farms amounts to 21.8% and 55.5%, respectively. Therefore, controls for farm size are included in the model to capture the scale effects. Farms with sales less than $250,000 are considered small, those with sales between $250,000 and $499,999 are considered large, and farms with sales of $500,000 or more are considered very large.

ERS Resource Regions (Figure 1) are used to determine financial, economic, and resource-related issues affecting farmers and are characterized by similar farm attributes, commodities produced, physiographic, soil, and climate conditions (Isserman, 2002). Approximately half of all hired farm labor is located in the western and southwestern United States. The Northeast is the most populated region in the

[3] Although enumerators query farmers on all questions in the ARMS, farmers may refuse to answer a particular question—leading to missing information. However, missing information is computed through a multiple imputation method by statisticians at the NASS. The method generally takes into account survey design, type, size, and location of the farming operation (see Dubman, 2000, for details). As such, multiple-imputation methods provides unbiased estimates and increase the efficiency of the regression estimates (Gedikoglu and Parcell, 2013; Robbins, Ghosh, and Habiger, 2013).

Table 1. Share of U.S. Farms Belonging to Each Organization Typology

	Share
Small family farms	90.28%
Low sales	18.78
Medium sales	6.32
Residential/lifestyle	39.73
Retirement	16.07
Limited resource	9.38
Large family farms	7.49%
Large	4.08
Very large	3.40
Nonfamily farms	2.23%

Source: Hoppe et al., 2007.

United States yet employs the fewest number of hired farm laborers. According to ERS (2000), the Fruitful Rim region accounts for the largest share of large and very large family farms, whereas the Northern Great Plains region has the largest of all U.S. farm operations. Hence, analysis presented here controls for region and to determine whether the heterogeneous product mix and/or labor market conditions in alternative regions influence the substitutability of farm labor.

The wages paid to hired labor (P_{L_H}) is defined as *WAGERATE* in the ARMS data set. This is the NASS average wage rate for hired labor, including Social Security taxes for the year. The wage paid to family labor (P_{L_F}) is calculated as (*OPPD* + *SPPD*)/(*OPHRS* + *SPHRS*), where *OPPD* is the amount paid to the principal operator for farm work, *SPPD* is the amount paid to the spouse for farm work, and *OPHRS* and *SPHRS* are the total annual hours worked on the farm by the operator and spouse.

In the ARMS questionnaire, the question of operator and spouse earnings is posed "Of the total cash wages, how much was paid out to you (the principal operator) and your (principal operator) spouse" as two separate responses. The questionnaire also asks the principal operator to provide, "On average, for each three month period during the year, about how many paid and unpaid hours per week did you and your spouse work on the farm?" The mean was taken to provide an average number of hours worked on farm for the operator and spouse each year. Other family members such as children and siblings devoting labor to the farm are omitted from the family farm wage calculation as a result of data limitations.

Our calculation of the wage for family farm labor was necessitated by limited data on actual wage data for farmers, but estimates the hourly wage in closest proximity to how many family-owned farm businesses perform. For example, the operator and spouse generally receive periodic wages throughout the year to pay for living expenses. After the crop has been harvested and sold, the family receives an owner's draw from the business profits. A large portion of their annual compensation depends on these profits. It is then reasonable to calculate the wage as described previously.

The price of land (P_{Land}) is represented by cash rents per acre. Cost of capital (P_K) is calculated as the ratio of total interest expense to total farm debt. The fertilizer, lime, and chemical expense[4] per acre (P_{Chem}) is included in the model. The farm expenses related to interest payments and fertilizer/chemical/pesticides are reported directly by farmers in the ARMS survey. Total costs (C) are assumed to be variable; therefore, total cash operating expense is used as the dependent variable in the cost function. The cost function is estimated for two groups (K) of farm products: all cash grains and cash grains excluding corn. The output (Y_K) of each product group is included in the cost function for the respective models.

Cost share equations are estimated for four of the five variable inputs to permit estimation of the system of equations. The cost shares included are for capital, hired labor, family labor, and fertilizer/chemical/pesticide expense. The reported value for each of these expenses was divided by total operating expenses to obtain cost shares. Specifically, the cost share for hired farm labor (S_{L_H}) was calculated as the sum of hired labor expense, contract labor expense, and labor fringe benefit expenses divided by

[4] Ideally, price of fertilizers and pesticides would be price per unit of ingredient instead of cost per acre. We believe the variables we included serve as an appropriate proxy.

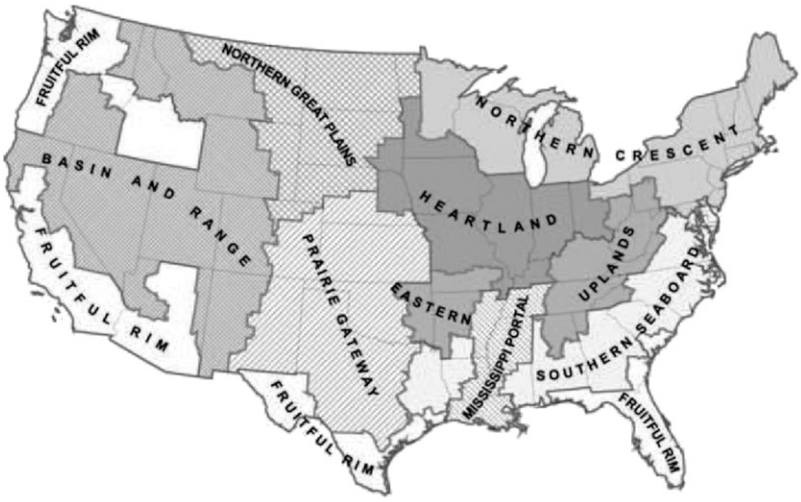

Figure 1. USDA Farm Resource Regions (Source: ERS, 2000)

total operating expenses. This definition fully accounts for the farm expenses attributable to hiring farm labor. The cost share for family labor (S_{L_F}) was calculated as the total amount paid to operators and spouses divided by the total operating costs.

Our data set is pooled from 2006–2008; therefore, a time trend is included in the model with linear, squared, and interaction terms between time and each input price. The primary goal of the time variables is not to make strong conclusions regarding changes in technology over this short period, but rather the interaction effects between time and the labor input variables will determine whether Hicks neutrality can be assumed. This information is important when considering the proper specification of $L(L_F, L_H)$.

The model is estimated through ITSUR. Choosing the iterative method over the traditional SUR methods avoids variation in results related to which equation we choose to drop from the system (Kmenta and Gilbert, 1968). Furthermore, Kmenta and Gilbert (1968) demonstrate that ITSUR and maximum likelihood estimates do not differ. To avoid simultaneity, the cost share equation we choose to omit from the system is land. This equation was chosen because the definition of land price as a variable input cost was least tenable.

The hypothesis tests for parameter significance were performed using both z tests and t tests because of the relatively small samples for some trials. There was no significant difference in results between the two tests in our estimation, so we present z values based on theoretical considerations. To understand this decision, it is important to recall the context in which we are estimating the cost function. Recall, the null hypothesis of farm labor homogeneity rests primarily on the magnitude and significance of the interaction parameter (β_{L_H,L_F}), which is the numerator of our elasticity of substitution measure. Considering the goal of this study is to disprove the notion of homogeneity of labor, the z test serves as a more conservative procedure with respect to the hypothesis of our research while simultaneously being the more aggressive measure for testing the significance of the parameter values. Given this choice, conservatism was chosen with respect to the overall purpose of the study rather than the regression.

Results and Discussion

Our results for cash grain farms, both including and excluding corn, show little evidence to support the notion of perfectly substitutable labor (Table 2). This is consistent with prior findings domestically, internationally, and in the developmental economics literature (Benjamin, 1992; Deolalikar and Vijverberg, 1983; Eswaran and Kotwal, 1986; Frisvold, 1994; Huffman, 1976) demonstrating heterogeneity of labor

Table 2. Elasticity of Substitution, Cost Shares, and Estimated Interaction Effect for Hired and Family Farm Labor on Cash Grain Farms by Regions

Economic Research Service Resource Regions	Including Corn					Excluding Corn				
	No.	β_{ij}	$\hat{S}_{HL}$	$\hat{S}_{FL}$	σ_{ij}	N		$\hat{S}_{HL}$	$\hat{S}_{FL}$	σ_{ij}
Heartland, Northern Great Plains, Prairie Gateway, and Fruitful Rim	1081	0.058 (0.034)	11%	3%	17.8	983	0.120 (0.038)	11%	3%	38.0
Heartland, Northern Great Plains, Prairie Gateway, and Basin and Range	1049	0.088 (0.037)	10%	3%	27.6	958	0.172 (0.040)	10%	3%	57.0
Heartland, Northern Great Plains, Prairie Gateway, Fruitful Rim, and Basin and Range	1133	0.068 (0.033)	11%	3%	20.5	1034	0.127 (0.036)	11%	3%	39.0
Prairie Gateway, Fruitful Rim, and Basin and Range	355	0.075 (0.054)	12%	2%	1.0	329	0.119 (0.056)	12%	3%	38.2
All regions	1577	0.084 (0.029)	12%	3%	22.7	1374	0.159 (0.032)	12%	3%	44.8

inputs in agrarian production.[5] Very broadly, it appears that removing corn from the group of cash grains results in an increase in the substitutability of labor. With the high degree of mechanization and dominance of corn in terms of row crops, it is surprising that the rate of substitution does not increase when including corn.

Table 2 also shows that the range of estimates across both cash grain classifications for elasticity of substitution is from one to 57.0. Interestingly, we find that the highest measures of elasticity of substitution occur in the ERS region groups where the Fruitful Rim is omitted for both cash grains including and excluding corn. This is notable twofold because of the predominance of labor as an input to production in this region but also as a result of the crop mix grown in this region. The high labor use in this region is generally needed to support vegetable and fruit production rather than cash grains. Comparing the regional groupings further, the "All Regions" or national estimate was lower than the trial of Heartland, Northern Great Plains, Prairie Gateway, and Basin and Range. Along with the discussed impact of including the Fruitful Rim in the national group, this also reflects the expected trend that elasticity of substitution declines as the labor market area expands. In Borjas, Grogger, and Hanson (2011), they find that the elasticity of substitution between high school dropouts and graduates was 7.4 in the national Current Population Survey (CPS) data, 14.5 at the state level, and 41.7 at the Metropolitan Statistical Area (MSA) level. This reflects the notion that there are increased linkages and commonalities between people in the same community rather than divergent communities aggregated.

Testing for heterogeneity of farm labor across farm sizes resulted in three test groups for each output (Table 3). Results indicate that the scale of operation did have an impact on substitutability of farm labor. Interestingly, labor on cash grain farms including corn exhibited a complimentary relationship for the smallest farms. Perhaps this reflects the relationship between farm profits and the family wage. For example, as the quantity of hired labor declines, a farm's operating costs decline. Holding revenue constant, this results in greater farm profits. As farm profits increase, we would also expect higher farm household wages.

For cash grains including corn, the elasticity of substitution was 55.71 for large farms and

[5] Similar results were obtained by Jacoby (1993) in the case of Peruvian farm households and Fafchamps and Quisumbing (1999) in the case of Pakistani farm households.

Table 3. Elasticity of Substitution for Hired and Family Farm Labor Controlling for Farm Size

Farm Size	Cash Grains Including Corn	Cash Grains Excluding Corn
Small	−41.61***	1.00
Large	55.71***	1.00
Very large	60.83***	45.63**

*** Significant at 1%; ** significant at 5%; * significant at 10%.

increased to 60.83 for very large farms. However, when excluding corn, the elasticity of substitution was unitary for both small and large farms. Very large farms exhibited much higher substitutability of labor with an elasticity of 45.63. For both classifications of cash grains, the largest farms exhibited the highest degree of substitutability between hired and family labor. Considering the increasing degree of mechanization and standardization of tasks as farm size grows, laborers require much less farm specific knowledge and more training in specific, repeatable tasks.

Conclusions

Family and hired labor are sources of labor in production agriculture. Over the past several decades productivity gains have gradually reduced the total agricultural labor force, yet hired labor continues to play an important role in this industry. Large farms still employ most of the hired labor, particularly cash grain farms. Additionally, with increased reliance on off-farm income, most family members are working off the farm; the reliance on hired labor is more important for producers and policymakers. This brings us to the issue of labor homogeneity and substitutability. A key element required to empirically evaluate this is the substitutability of farm labor. As the degree of substitutability between hired and family labor increases, farm operators and spouses can more easily hire replacement workers on the farm. The farm household can then allocate more hours to off-farm labor or simply enjoy more hours of leisure with little detriment to farming operations.

Our results indicate that the differentiation between hired and family workers on cash grain farms differs as the definition of cash grain farm changes, the geographic area changes, and farm size changes. As farm size increases, labor tends to become highly substitutable as a result of greater specialization and mechanization, but these increases are far below the infinite rate of substitution implied by homogenous farm labor. We also find that as the geographic region increases, the degree of differentiation between workers increases as well. Additionally, the Fruitful Rim appears to exhibit a unique relationship between hired and family workers relative to the remaining ERS regions. The "uniqueness" in this regard is a topic of future of research we intend to explore. Finally, we find that including corn farms in our definition of cash grains reduces the substitutability between family and hired workers. This was surprising considering the scale and mechanization of corn farming, but perhaps this reflects the notion that family members have a higher incidence of managerial positions on these farms and therefore are not equally substituted with the hired workers they manage.

These findings are important for policymakers. As the next Farm Bill debate ensues, talks surrounding the elimination of decoupled government payment will likely increase. It will be crucial to accurately assess the impact of this policy change on farm households. Under the foregoing narrative of off-farm labor subsidization, it would be expected that large declines in government payments would have significant impacts on the flow of labor into the farm sector. In light of the current results, we might expect a more muted response from farm households with regard to the number of hours worked on-farm. Therefore, the impact of government payments might fall more heavily on hired farm labor than farm operators and spouses with regard to income from farming. Together with recent increases in minimum wages for H-B1 visa workers, the impact of decreasing payments could significantly affect hired laborers. Finally, with shortage of migrant workers and rising input cost, policymakers may have to design an effective immigration policy that best suits farmers and production agriculture.

The relevance of labor substitutability also extends beyond off-farm labor allocation. With the aging of the farm population, it will become even more important for operators to decrease their responsibilities on the farm without negatively impacting the operation. Future changes may include increased adoption of technology innovations. Precision technologies and global positioning satellite guidance may decrease the specialized knowledge needed to operate farm machinery and allow the farm operator to track the exact movements of machinery in the field. As the cost to adoption declines, this may allow farm operators to increasingly hire labor to fulfill their responsibilities without detriment to production.

This research also has extensions to more specific types of agricultural labor. The substitutability of domestic and nondomestic labor is important to understand, especially when considering increased minimum wages. The analysis can also be expanded to include the substitutability of labor from the operator's children with other forms of farm labor. Both are significant extensions that will be the focus of future research.

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References

Ahearn, M.C., H. El-Osta, and J. Dewbre. "The Impact of Coupled and Decoupled Government Subsidies on Off-Farm Labor Supply." *American Journal of Agricultural Economics* 88(2006):393–408.

Ahearn, M.C., D. Harrington, R. Hoppe, and P. Korb. "Decoupled and Coupled Payments Alter Household Labor Allocation." *Decoupled Payments in a Changing Policy Settings*. M.E. Burfisher and J. Hopkins, eds. Washington, DC: USDA, ERS, Agricultural Economic Report No. 838, 2004.

Benjamin, D. "Household Composition, Labor Markets, and Labor Demand: Testing for Separation in Agricultural Household Models." *Econometrica* 60(1992):287–322.

Berndt, E., and D. Wood. "Technology, Prices, and the Derived Demand for Energy." *The Review of Economics and Statistics* 57(1975):376–84.

Bigsby, H. "Production Structure and the Australian Sawmilling Industry." *Australian Journal of Agricultural Economics* 38(1994):271–88.

Binswanger, H.P. "A Cost Function Approach to the Measurement of Elasticities of Factor Demand and Elasticities of Substitution." *American Journal of Agricultural Economics* 56(1974):377–86.

Binswanger, H.P., and M.R. Rosenzweig. "Behavioural and Material Determinants of Production Relations in Agriculture." *The Journal of Development Studies* 22,3(1986):503–39.

Blanc, M., E. Cahuzac, and B. Elyakime. "Demand for On-Farm Permanent Hired Labour on Family Holdings." *European Review of Agriculture Economics* 38,4(2008a):493–518.

———. "Demand for On-Farm Permanent Hired Labour on Family Holdings: A Rejoinder." *European Review of Agriculture Economics* 38,4(2008b):609–12.

Borjas, G.J., J. Grogger, and G.H. Hanson. "Substitution between Immigrants, Natives, and Skill Groups." Working paper in School of International Relations and Pacific Studies, University of California, San Diego, 2011.

D'Antoni, J.M., and A.K. Mishra. "Welfare Implications of Reduced Government Subsidies to Farm Families: Accounting for Fringe Benefits." *Agricultural Economics* 44,2(2013):72–77.

Dawson, P. "Labour on the Family Farm: A Theory and Some Policy Implications." *Journal of Agricultural Economics* 35(1984):1–19.

Deolalikar, A.B., and W.P. Vijverberg. "The Heterogeneity of Family and Hired Labor in Agricultural Production: s Test Using District Level Data from India." *Journal of Economic Development* 8(1983):45–69.

———. "A Test of Heterogeneity of Family and Hired Labour in Asian Agriculture." *Oxford Bulletin of Economics and Statistics* 49(1987):291–305.

Dewbre, J., and Mishra, A. "Impact of Program Payments on Time Allocation and Farm Household Income." *Journal of Agricultural and Applied Economics* 39(2007):489–505.

Diewert, W., and T. Wales. "Flexible Functional Forms and Global Curvature Conditions." *Econometrica* 55(1987):43–68.

Dubman, R. *Variance Estimation with USDA's Farm Cost and Returns Surveys and Agricultural Resource Management Study Survey.* Washington, DC: Economic Research Service, U.S. Department of Agriculture, 2000.

Economic Research Service. *Agricultural Information Bulletin Number 760*. Washington, DC: U.S. Department of Agriculture, 2000.

El-Osta, H. "The Impact of Human Capital on Farm Operator Household Income." *Agricultural* *and Resource Economics Review* 40(2011):95–115.

Eswaran, M., and A. Kotwal. "Access to Capital and Agrarian Production Organization." *The Economic Journal* 96(1986):482–98.

Fafchamps, M., and A.R. Quisumbing. "Human Capital, Productivity, and Labor Allocation in Rural Pakistan." *The Journal of Human Resources* 34(1999):369–406.

Feder, G. "The Relationship between Farm Size and Farm Productivity: The Role of Family Labor, Supervision and Credit Constraints." *Journal of Development Economics* 18(1985):297–313.

Frisvold, G. "Does Supervision Matter? Some Hypothesis Tests Using Indian Farm-Level Data." *Journal of Development Economics* 43(1994):217–238.

Gedikoglu, H., and J. Parcell. "Implications of Survey Sampling Design for Missing Data Imputation." Paper presented at the 2013 AAEA & CAEA Joint Annual Meeting, Washington, DC, August 4–6, 2013.

Goodwin, B.K., and A.K. Mishra. "Are 'Decoupled' Farm Program Payments Really Decoupled?: An Empirical Evaluation." *American Journal of Agricultural Economics* 88(2006):73–89.

Greene, W.H. *Econometric Analysis*. Upper Saddle River, NJ: Pearson Prentice Hall, 2008.

Hoppe, R.A., P. Korb, E.J. O'Donoghue, and D.E. Banker. *Structure and Finances of U.S. Farms: Family Farm Report*. Washington, DC: Economic Research Service, U.S. Department of Agriculture, 2007.

Huffman, W.E. "The Productive Value of Human Time in U.S. Agriculture." *American Journal of Agricultural Economics* 58(1976):672–83.

Isserman, A. *Defining Regions for Rural America*. Kansas City, KS: Federal Reserve Bank of Kansas City, 2002.

Jacoby, H.G. "Shadow Wages and Peasant Family Labor Supply: Application to the Peruvian Sierra." *The Review of Economic Studies* 60(1993):903–21.

Johnston, D., and H. Leroux. "Leaving the Household Out of Family Labour? The Implications for the Size-Efficiency Debate." *European Journal of Development Research* 19(2007):355–71.

Kendel, W. *Profile of Hired Farmworkers, A 2008 Update*. Washington, DC: U.S. Department of Agriculture, Economic Research Service, Economic Research Report # 66, 2008.

Kmenta, J., and R.F. Gilbert. "Small Sample Properties of Alternative Estimators of Seemingly Unrelated Regressions." *Journal of the American Statistical Association* 63(1968):1180–200.

Mishra, A., M. Morehart, H. El-Osta, J. Johnson, and J. Hopkins. *Income, Wealth, and Well-being of Farm Operator Households*. Washington, DC: U.S. Department of Agriculture, Economic Research Service, Agricultural Economics Report # 812, 2002.

Mishra, A.K., and D.M. Holthausen. "Effect of Farm Income and Off-Farm Wage Variability on Off-Farm Labor Supply." *Agricultural and Resource Economics Review* 31(2002):187–99.

National Research Council. *Understanding American Agriculture: Challenges for the Agricultural Resource Management Survey*. Washington, DC: National Academies Press, 2007.

Robbins, M., S. Ghosh, and J. Habiger. "Imputation in High-Dimensional Economic Data as Applied to the Agricultural Resource Management Survey." *Journal of the American Statistical Association* 108(2013):81–95.

Schultz, T.P. "Women's Role in the Agricultural Household: Bargaining and Human Capital." Center Discussion Paper No. 803. New Haven, CT: Yale University: Economic Growth Center, 1999.

Singh, I., L. Squire, and J. Strauss. *Agricultural Household Models: Extensions, Applications, and Policy*. Baltimore, MD: The John Hopkins University Press, 1986.

Taylor, J.E. "Agricultural Labor and Migration Policy." *Annual Review of Resource Economics* 2(2010):369–93.

Taylor, J.E., and I. Adelman. "Agricultural Household Models: Genesis, Evolution, and Extension." *Review of Economics of the Household* 1(2003):33–58.

White, T.K., and R.A. Hoppe. *Changing Farm Structure and the Distribution of Farm Payments and Federal Crop Insurance*. Washington, DC: Economic Research Service, U.S. Department of Agriculture, 2012.