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Farmer Education and Farm Efficiency: The Role of Education Revisited

Shahidur Khandker

ECONOMIC GROWTH CENTER

YALE UNIVERSITY

Box 1987, Yale Station
New Haven, Connecticut

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Shahidur Rahman Khandker

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ABSTRACT

If labor market participation for self-employed farm households and family labor use in family farms are decisions determined endogenously, the estimation of production (or profit) functions suffer from a simultaneity bias unless appropriate instruments are used. An agricultural household model that encompasses both the production and consumption decisions of farm operators can motivate the choice of such instruments. A conditional profit function is estimated with an endogenously determined family labor demand function. Differences in production behavior conditional on farm household's participation in the labor market are tested using a two-stage switching regressions model with a criterion function that enables endogenous switching.

Empirical results using farm-level survey data from Bangladesh indicate that endogeneity of family labor demand is indeed statistically significant for farm households who do not participate in the labor market, but is not significant for those who do participate in the labor market. The results further suggest that the effect of education is underestimated when account is not taken of the endogeneity of labor demand. When the productivity gains made from decisions regarding appropriate level and mix of family labor use in farm and off-farm market uses are taken into account, results indicate that farmer education has indeed a productive value to farm efficiency.

FARMER EDUCATION AND FARM EFFICIENCY: THE ROLE OF EDUCATION REVISITED*

Introduction

The role of education in increasing productivity has been recognized as an important form of human capital that may be essential for transforming traditional agriculture (Schultz, 1964). Much research has sought to evaluate the productive role of education for developing agriculture (Yotopoulos, 1967; Lockhead, Jamison, and Lau, 1980; Ram, 1980; Jamison and Moock, 1981). The primary postulate is that education may have productive value to farmers because (1) it helps them to produce larger quantities of output from the same measured quantities of inputs, and because (2) it helps them to choose an optimal bundles of inputs, a more efficient output- mix, and a more appropriate scale.[1]

The approach often used to estimate the contribution of education to agricultural production is to estimate either a production function or a profit function with education as one of several regressors (Lockhead, Jamison, and Lau, 1980). This paper argues that with this approach the contribution of education may not be measured appropriately if the function is subject to simultaneous equation bias. Simultaneity bias may arise if production and consumption decisions of self-employed agricultural households are nonseparable. Nonseparability of production and consumption decisions in turn arise if households use family labor in family farms but do not sell out labor for market work.

The paper is organized in the following manner. First, a brief summary of research using the production function framework for analyzing the contribution of education is presented and its potential bias if nonseparability between production and consumption decisions of farm households arises is discussed. Second, an agricultural household model is developed where participation in the labor market by farm households is endogenous, and behavioral differences between participant and nonparticipant households are emphasized. It is argued that such a framework can provide appropriate instruments which can remove potential simultaneous equation bias. Third, a two-stage regressions model with endogenous switching is suggested for dealing with possible differences in production behavior between farm households which do and do not participate in the labor market. Fourth, an empirical analysis of farm-level data from Bangladesh using a conditional profit function approach is reported which confirm the expected bias. Finally, in order to capture the productivity gains of schooling that may accrue through the allocative role of education in family labor allocation, an unconditional profit function is estimated that shows that education has a significant productive value to Bangladeshi farmers.

The Production Function Model

The contribution of education to agricultural productivity is called the technical efficiency effect, or worker effect, or simply the productivity effect of education. Yotopoulos (1967) were among the first to use a production function to examine the impact of education on agricultural productivity. Subsequent studies (e.g., Lockhead et al, 1980; Ram, 1980; Jamison and Moock, 1981) followed a similar approach to evaluate the impact of education on agricultural production. Given information on gross output of the farm (Q), land under cultivation (T), man-days of family labor (L)[2], quantities of purchased inputs (V), and educational level of the household head (E), one can assess the technical efficiency effect of education in terms of its scale effect on agricultural production. The general functional form of such a production relation may be formally expressed as:

(1) $Q = Q\ (T, L, V, E)$

If we define $\partial Q/\partial E$ as the marginal product of education, specification (1) in Cobb-Douglas or linear form can be used to estimate the worker effect. Within this framework, it is also possible to estimate the allocative effect of education (Welch, 1970).

Estimates from (1), however, can be either incomplete or biased. First, estimating the worker effect is biased due to the well-known simultaneous equations bias caused by endogeneity of variable inputs. Second, estimating the allocative effect in a multiple regression when so many endogenous variables are held constant leaves little "room" for education to improve decision-making which can affect farm production. Third, by focussing only on cost minimization, the production function approach ignores any returns from the changing output mix.

An alternative to the production function approach is to use a restricted profit function that can measure both the allocative and worker effects of education. The restricted profit function[3] corresponding to (1) can be written as

(2) $Y = Y(P_q, P_v, L, T, E)$

where Y is the level of profit defined as gross value of crops less expenditure on purchased inputs, P_q, and P_v are, respectively, the vector of output prices, and the vector of input prices. Since it is a function of all input and output prices and the "fixed" inputs, a restricted profit function also can capture the gains made from choosing a more optimal mix of crops. However, the restricted profit function (although it reduces the simultaneity bias due to endogeneity of purchased inputs) may also be subject to similar simultaneous equations bias, for some of the "fixed" inputs may be endogeneous (Barichello, 1984).[4] Thus, simultaneity bias may arise, even in a restricted profit function, if the functional specification is mis-specified to the extent that farm households' owned inputs such as family labor are endogenously determined.

If farm households sell out labor, and if family and hired labor are perfect substitutes in production, then family labor demand is determined by market prices and factors related only to farmers' production decisions. In this case, endogeneity of family labor demand would not affect the production or profit function estimate of education, given arguments in Zellner, Kmenta, and Dreze (1966).

However, for self-employed farmers, if family labor is not sold out either because of labor market preferences or because family and hired labor are not perfect substitutes in production, it is possible to show that family labor demand is endogenously determined not by production decisions alone, but also by farmers' consumption decisions. This implies that family labor demand is determined by factors that include, among others, an education variable. This clearly produces a simultaneous equation bias. It may serve as a justification for estimating the profit function conditional on family labor in a simultaneous equations framework, while allowing family labor to be determined endogenously. This may also permit the education variable to pick up any returns in variable profit due to education-induced variations in the predicted level of family labor input.

The question that arises then is, what are appropriate instruments that can be used to obtain consistent estimates of the education variable? An agricultural household model that combines both the production and consumption decisions of farm operators who are producers and consumers of their own products may motivate the choice of appropriate instruments.

There is an additional problem, moreover. Even if endogeneity of family labor in the restricted profit function is corrected by using instruments provided by the farm household model, farm households' self-selection regarding labor market participation can produce sample selection bias in the regression equations. Since labor market participation is a choice variable, family characteristics including education, among other factors, may influence this decision-making process. Correcting sample selection bias may mean reducing the influence of these family characteristics on the productive role of farmer education. Consequently, the resulting estimates may, indeed, show the causal impact of education on farm efficiency.[5]

An Agricultural Household model

The essential characteristic of an agricultural household model is that it encompasses both production and consumption decisions of farm operators who supply family labor to their agricultural operations and derive income for consumption from such activities. However, production and consumption decisions may be studied separately under the assumptions that perfect substitutablity between family and hired labor exists in production and that there is a fixed agricultural wage rate determined by the market. The interdependence between production and consumption flows from production to consumption decisions but not the other way around, since income influences consumption decisions, and any excess (or shortage of) family labor can be sold (or bought) at the fixed market wage rate (Strauss, 1984).

There may exist another source of dependency between production and consumption decisions which, unlike the other case, makes production and consumption decisions nonseparable for either of two reasons: the labor market is imperfect or it does not exist in the first place. While the first condition is not typically thought to be important in agricultural household modelling, the second factor is often emphasized (Strauss, 1984). Thus, for self-employed farmers, if family and hired labor are imperfect substitutes in production and no family labor is sold out, we get a case where the household faces a "virtual" or shadow wage rate to equate demand for family labor with its supply. Such a wage rate is thought to depend on all the variables the household takes as given, affecting either production or consumption, thereby making the two sets of decisions nonseparable. The agricultural household model being developed here is such a case where production and consumption decisions are nonseparable. Production or profit function estimation cannot capture the true productivity effect of education unless it is estimated along with a labor demand function that is determined endogenously by the household's production and consumption behavior.

Assume that agricultural households supply family labor to family farming. In addition, if the households wish, they can supply family labor to market work for cash income. Market work may consist of agricultural and non-agricultural wage employment. Assume further that there is no fixed market wage for supply of family labor to market activities. Instead, the members of a household unit (if they decide to participate in the labor market) face a market wage schedule which is a positive function of education. However, if there is imperfect substitutability between family and hired labor, or if family labor cannot be marketed for labor market preference, we get a case where family labor supply to market work is zero.[6]

Thus, the maximization problem of a self-employed farm household unit facing self-selection regarding labor market participation of its members may be operationalised in the following way.

Farm households are assumed to maximize the objective function given by 3(i) subject to the constraints 3(ii) through 3(vi), where

C = Consumption of non-farm consumer goods

M = Consumption of leisure

Q = Agricultural output

R = Consumption of own agricultural produce

P_q = Price of agricultural output

P_c = Price of non-farm consumption goods

L = Family labor used in farming

S = Family labor used in market work

E = Education characteristics

T = Farm size

W = Per period income received from market work

Ω = Total working hours available to the household unit.

3(i) $U = U(M, C, R)$

3(ii) $P_c C = P_q (Q - R) + WS$

3(iii) $W = f(E), f' > 0, f'' < 0$

3(iv) $Q = Q(L, E, T)$

3(v) $\Omega = L + S + M$

3(vi) $S \geq 0$

Here equation 3(i) is the familiar utility function, 3(ii) is the budget constraint, 3(iii) is the wage function for market work, 3(iv) is agricultural production function[7], 3(v) is the household time constraint for working hours, and 3(vi) is the binding constraint for self-employed farmers who do not use family labor for market work. After necessary substitutions, we can form the following Lagrange function:

$$(4) \quad \delta = U\Big[(\Omega - L - S),\ C,\ R\Big] + \lambda_1\Big[P_qQ\ (L,E,T) + WS - P_qR - P_cC\Big] - \lambda_2 S$$

where λ_1 is the marginal utility of income and λ_2 is the marginal disutility of family labor use in market work and both are positive. However, λ_2 is zero for those households who supply family labor to market work and thus 3(vi) is not binding for them.

The first-order conditions for maximization yield the following equations:

$$5(i) \quad \partial\delta/\partial L = -\ \partial U/\partial M + \lambda_1 P_q \partial Q/\partial L = 0$$

$$5(ii) \quad \partial\delta/\partial S = -\partial U/\partial M + \lambda_1(W - \lambda_2/\lambda_1) = 0$$

$$5(iii) \quad \partial\delta/\partial C = \partial U/\partial C + \lambda_1(-P_c) = 0$$

$$5(iv) \quad \partial\delta/\partial R = \partial U/\partial R + \lambda_1(-P_q) = 0$$

$$5(v) \quad \partial\delta/\partial\lambda_1 = P_qQ + f(E)S - P_cC - P_qR = 0$$

$$5(vi) \quad \partial\delta/\partial\lambda_2 = -S = 0$$

Equations 5(i) and 5(ii) yield the optimal condition for family labor allocation between farming and leisure (or to market work) which may be expressed as:

(6)(i) $P_q \partial Q/\partial L = (W - \mu) = W^*$, for non-participant households;

(6)(ii) $P_q \partial Q/\partial L = W$, for participant households;

where μ is equal to λ_2/λ_1. The equilibrium condition for family labor allocation for farm households who decide to participate in the market work is the equality between returns from two activities, family farming and market work. For those who decide not to participate it is the equality between the return from farming and what may be called the "reservation" or "virtual" price of family labor, W^*. However, W^*, unlike W, is endogenously determined by parameters affecting either the household's production or consumption decisions, since it depends on λ_2 and λ_1, which are endogenous variables in the system. Thus, even if W is fixed by the market and not determined by the household characteristics, such as the endowment of education, there is a possibility that production and consumption decisions become non-separable for those households who decide not to participate in the labor market. This is, however, not the case for those who decide to sell out family labor for market work. [8]

In order to examine the effects of education on labor demand in agriculture as well as on the shadow wage, W^*, for non-participants farm households, assume that μ is fixed. Total differentiation of the first-order equations in the system of equations (5) with respect to change in E will yield the following system of equations in matrix form given by (7).

$$
(7)\quad
\begin{bmatrix}
(U_{MM} + \lambda_1 P_q \partial^2 Q/\partial L^2) & U_{MM} & -U_{MC} & -U_{MR} & P_q \partial Q/\partial L & 0 \\
U_{MM} & U_{MM} & -U_{MC} & -U_{MR} & (W - \mu) & -\lambda_1 \\
-U_{CM} & -U_{CM} & U_{CC} & U_{CR} & -P_c & 0 \\
-U_{RM} & -U_{RM} & U_{RC} & U_{RR} & -P_q & 0 \\
P_q \partial Q/\partial L & W & -P_c & -P_q & 0 & 0 \\
0 & -1 & 0 & 0 & 0 & 0
\end{bmatrix}
\begin{bmatrix}
dL \\ dS \\ dC \\ dR \\ d\lambda_1 \\ d\mu
\end{bmatrix}
=
\begin{bmatrix}
-\lambda_1 P_q \; \partial^2 Q/\partial L \partial E \\
-\lambda_1 f' \\
0 \\
0 \\
-(f'S + P_q \partial Q/\partial E) \\
0
\end{bmatrix}
dE
$$

Thus, solving the above system (7) for $\partial L/\partial E$ and $\partial \mu/\partial E$, we get

$$
(8)\quad \partial L/\partial E = (\lambda_1/\Delta) \Big[-(f'S + P_q \partial Q/\partial E)(D_2) + \lambda_1 P_q \partial^2 Q/\partial L \partial E \; (2U_{CR} P_c P_q - U_{CC} P^2{}_q - U_{RR} P^2{}_c) \Big]
$$

$$
(9)\quad \partial \mu/\partial E = (\lambda_1/\Delta) \Big[(\Delta_{11}) P_q \partial^2 Q/\partial L^2 - (f' - P_q \partial^2 Q/\partial L \partial E)(\mu D_2 + D_1) \Big]
$$

where Δ is the bordered Hessian determinant of left-hand matrix of equation (7), Δ_{11} is the cofactor of elements in the first row and first column of the matrix formed by the Cramer's rule, and

$$D_1 = \begin{vmatrix} -U_{MC} & -U_{MR} & (W - \mu) \\ U_{CC} & U_{CR} & -P_c \\ U_{RC} & U_{RR} & -P_q \end{vmatrix}$$

$$D_2 = \begin{vmatrix} U_{MM} & -U_{MC} & -U_{MR} & (W - \mu) \\ -U_{CM} & U_{CC} & U_{CR} & -P_c \\ -U_{RM} & U_{RC} & U_{RR} & -P_q \\ W & -P_c & -P_q & 0 \end{vmatrix}$$

Second-order conditions for constrained maximization with two constraints restrict that Δ is positive and Δ_{11} is negative, while for a constrained utility maximization case, $(2U_{CR}P_cP_q - U_{CC}P^2{}_q - U_{RR}P^2{}_c)$ is positive. Even after assuming that cross- and direct-derivatives in the utility function are, respectively, positive and negative, it is not possible to sign the determinants, D_1, and D_2. However, if, for simplicity, one assumes that both D_1 and D_2 are less than zero, then, assuming diminishing marginal productivity of labor in agricultural production, one can get the following results:

(10) $\partial L/\partial E > 0$ iff $P_q\partial^2Q/\partial L\partial E \geq 0$ or $\partial L/\partial E$? if $P_q\partial^2Q/\partial L\partial E < 0$

(11) $\partial\mu/\partial E > 0$ iff $(f' - P_q\partial^2Q/\partial L\partial E) \geq 0$ or $\partial\mu/\partial E$? if $(f' - P_q\partial^2Q/\partial L\partial E) < 0$

Equation (10) suggests that for a household which sells no labor to the market, an increase in education will increase the demand for family labor in agriculture so long as the increase in the level of education has a non-negative effect on marginal productivity of labor. If education has a negative effect on marginal productivity of labor, its effect on labor demand is indeterminate. Note that this effect of E on labor demand crucially depends on what happens to marginal productivity of labor in agriculture and not on the relative returns between two income earning activities. This is caused by the assumption that family labor supply to market work is zero.[9]

The effect of E on μ (i.e., the difference between market and farm wage) is important to know because it affects the virtual wage rate, W^*, by the following condition:

$$(12)\quad dW^*/dE = f' - d\mu/dE$$

By using results in (11) one can assert that education's effect on the virtual wage rate is in general ambiguous. In other words, if education has a positive effect on the difference between market and farm wages, an increase in education will have an indeterminate effect on the shadow wage of the family labor. However, if education has a negative effect on this wage difference, an increase in education leads to an increase in the virtual wage for family labor.

The effect of education on family labor demand for farm households who supply family labor to market work in addition to family farming can be shown by totally differentiating the optimal condition, 6(ii), for family labor allocation with respect to education, E.[10] Thus, for $S > 0$, the effect of education on family labor demand, L, is:

$$(13) \qquad \partial L/\partial E = 1/D\ [f' - P_q \partial^2 Q/\partial L \partial E],$$

where $D = P_q \partial^2 Q/\partial L^2$. Since $\partial^2 Q/\partial L^2$ is negative by assumption, it follows that

$$(14) \qquad \partial L/\partial E \gtrless 0 \text{ as } f' \lessgtr P_q \partial^2 Q/\partial L \partial E.$$

This suggests that the effect of education on family labor demand in agriculture for households selling out family labor for market work depends on the relative returns of labor in two income earning activities. This further implies that even though non-separability between production and consumption decisions does not arise for households who sell out family labor for market work, education may influence family labor demand in farming if education affects labor productivity in both activities.

According to what is known as the "screening hypothesis," "Education does not make workers more productive; it merely identifies those who were more productive to begin with" (Jamison and Moock, 1981; p. 5). Thus, if we further assume that education affects neither farm labor productivity nor the market yield on labor (if supplied) so that $f' = P_q \partial^2 Q/\partial L \partial E = 0$, equations (10) and (11) show that even then education has a positive effect on both the shadow wage of family labor and on the family labor demand in agriculture. This implies that for a self-employed farm operator who does not sell out his family labor, even if education does not affect his family labor productivity in agriculture, an increase in educational endowment will increase the "virtual" wage rate for his family labor and also will increase the demand for family labor in family farming. This suggests that even under the screening hypothesis, family labor demand in agriculture becomes endogenous for households who do not sell out labor in the market.

In contrast, under the same hypothesis, labor endogeneity in the production or profit function does not arise for households who participate in the market by selling part of its family labor pool. This is evident in equation (13) above.

The optimal values of endogenous variables generated in the framework of an agricultural household model may be expressed in the reduced-form equations as follows:

15(i) $L^* = L^* (\Omega, E, T, P_q, P_c)$

15(ii) $S^* = S^* (\Omega, E, T, P_q, P_c)$, if $S>0$ or else $S^* = 0$, when $S=0$

15(iii) $C^* = C^* (\Omega, E, T, P_q, P_c)$

15(iv) $R^* = R^* (\Omega, E, T, P_q, P_c)$

where the asterisks refer to optimal values of the variables.

By plugging 15(i) into the agricultural production function 3(iv), we get the agricultural output function as

16(iv) $Q^* = Q^* (L^*, E, T)$

where family labor demand is endogenously determined. Note that variables Ω, P_q, P_c enter into the labor demand equation, 15(i), or modified production function equation, 16(iv), as instruments only if non-separability between production and consumption decisions holds for the farm operators. If the decisions are separable, these variables will be irrelevant instruments in either equation.

Thus, family labor endogeneity is a relevant issue only when nonseparability between production and consumption arises in the event that farm households do not sell out family labor for market work. Alternatively, labor endogeneity may not be a crucial problem and, hence, estimates of education variables will tend to be unaffected if family labor is sold out for market work. Thus, one needs to test for labor endogeneity for both types of households, those who sell out family labor and those who do not.

A Switching Regression Model

Farm households' participation in the labor market is an endogenously determined variable. One may use a procedure that utilizes information on farm households' labor market participation and then examine its impact on underlying differences in their production behavior. This has been called a two stage regressions model with endogenous switching (Akin et al., 1985; Kenny et al., 1979; Maddala, 1983).

We have two types of sample households producing agricultural output who sell and do not sell family labor to market work. This leads us to the following two regimes:

(17) $$Y_{1i} = X_i\beta_1 + \mu_{1i}$$

(18) $$Y_{2i} = X_i\beta_2 + \mu_{2i}$$

where Y_{1i} is the level of restricted profit (value of gross output less expenditure on purchased inputs) of the ith farm household, given that the household sells family labor to market work; Y_{2i} is the level of restricted profit of the ith farm household, given that the household does not sell labor to market work; X_i is a vector of explanatory variables including family labor and education of the ith household; β_1 and β_2 are unknown coefficient vectors; and μ_{1i} and μ_{2i} are unknown disturbances. The system of equations (17) and (18) allow farm households who sell out labor to be behaviorally different (i.e., in terms of output production and farm profit) from those who do not.

Alternatively, one can write the above specification as follows:

$$(19) \qquad Y_i = X_i\beta_2 + \alpha I_i X_i + \mu_i^*$$

where Y_i is the level of farm profit and I_i is a dummy variable, 1 for household who sells out labor, and 0 otherwise. Equation (19) allows for interaction effects of labor market participation with other explanatory variables. If $E(\mu_i^*) = 0$ in (19), one can examine the expected effect of labor endogeneity on production and farm profit:

$$(20) \qquad E(Y_i/I_i=0) = X_i\beta_2$$

$$(21) \qquad E(Y_i/I_i=1) = X_i(\beta_2 + \alpha) = X_i\beta_1$$

However, the problem that emerges is that selling out labor to market work is endogeneous. This can be modelled as follows:

(22) $I_i^* = Z_i\gamma + \varepsilon_i$

where $I_i = \begin{cases} 0; & I_i \leq 0 \\ 1; & I_i > 0 \end{cases}$

Here Z_i are exogenous variables, γ is a vector of unknown coefficients, and ε is a disturbance term.

Now, we assume that the three error terms, μ_{1i}, μ_{2i}, and ε_i, follow a multivariate normal distribution with mean vector zero, and covariance matrix $\sum$ where:

$$\sum = \begin{matrix} \sigma_{11} & \sigma_{12} & \sigma_{1\varepsilon} \\ \sigma_{21} & \sigma_{22} & \sigma_{2\varepsilon} \\ \sigma_{\varepsilon 1} & \sigma_{\varepsilon 2} & \sigma_{\varepsilon\varepsilon} \end{matrix}$$

The criterion function (22) enables endogenous switching in the two regimes (17) and (18) (Maddala, 1983). Households self-select into equations (17) and (18) as long as $\sigma_{\varepsilon 1}$ and $\sigma_{\varepsilon 2}$ are non-zero. Although OLS cannot be used to estimate (17) and (18) because the expectations of the disturbances are non-zero, it is possible to estimate them by OLS under the following conditions as shown by Lee (1976):

(23) $E(\mu_{1i}/I_i=1) = -\sigma_{1\varepsilon}\left[\phi(Z_i\gamma)/\Theta(Z_i\gamma)\right]$

(24) $E(\mu_{2i}/I_i=0) = \sigma_{2\varepsilon}\left[\phi(Z_i\gamma)/(1-\Theta(Z_i\gamma))\right]$

where ϕ is the standard normal density function and Θ is the corresponding distribution function.

We define $W_{1i} = \phi(Z_i\gamma)/\Theta(Z_i\gamma)$, and $W_{2i} = \phi(Z_i\gamma)/(1-\Theta(Z_i\gamma))$ which enables us to rewrite (15) and (16) as

(25) $$Y_{1i} = X_i\beta_1 - \sigma_{1\varepsilon}W_{1i} + \varepsilon_{1i}$$

(26) $$Y_{2i} = X_i\beta_2 + \sigma_{2\varepsilon}W_{2i} + \varepsilon_{2i}$$

where the residuals $\varepsilon_{1i} = \mu_{1i} + \sigma_{1\varepsilon}W_{1i}$; and $\varepsilon_{2i} = \mu_{2i} + \sigma_{2\varepsilon}W_{2i}$.

Since ϕ and Θ are a function of $Z_i\gamma$, we have a two-step method of estimating the restricted profit functions. As a first step, because we have assumed that the three error terms follow normal distributions, (22) can be estimated using the probit procedure with the normalization $\sigma_{11} = 1$. Then ϕ and Θ are estimated and are used to construct the inverse of Mills' ratios, W_{1i} and W_{2i}. Ordinary least squares may then be used to estimate (25) and (26). This procedure will be used to estimate the restricted profit functions conditional on family labor using data from Bangladeshi farm households.

Data and Its Characteristics

The data used in this paper were collected for a separate study (Khandker, 1985) by drawing a sample of 500 households from seven districts of Bangladesh. The sample comprises households both from farming populations and non-farming populations. The seven districts were selected from regions north, east, and west of Dhaka as well as a central part of Bangladesh. The sample included information on inputs and outputs of individual farms from several communities across Bangladesh, which provides a unique opportunity to test the effect of education on farm efficiency. However, data from only 364 farm households were used in this paper, because these households have no missing values for the variables used in the empirical implementation of the model. These 364 sample households belong to six districts, which are, respectively, Rangpur, Bogra, Sherpur, Tangail, Comilla, and Dhaka. Data on input and output were collected on an individual crop basis during a single data collection period. Data used in this paper are gross values of outputs, and inputs which were valued at the observed farm-level prices.

Households use family as well as hired labor in family farming. However, out of 364 households, only 130 households sell out family labor to market work, which consists of both agricultural and nonagricultural activities. Some of the households which do not sell out labor for market work use family labor both in family farming and family nonfarming activities. A small amount of female and child labor was used by both types of households (Table 1). Thus, family labor mostly consists of household male members' labor.

The dependent variable is the farm profit which is calculated as gross value of outputs less expenditure on purchased inputs. The explanatory variables in the restricted profit function are family labor, land owned, education level of the household head who is often a male, education level of spouse, and average schooling of other household members working. The instruments used in family labor demand function are variables such as family size, consisting of economically active members (age 10 and above but less than 65), community-level agricultural wage paid to hired adult male worker, and the age of the household head. The means and standard deviations of the variables by nonparticipants and participants households are shown in Table 1.

Table 1. Mean and Standard Deviation (S.D) of Variables

Variable name	Non-participants (Sample 234)		Participants (Sample 130)	
	Mean	S.D.	Mean	S.D.
Profit (Taka)[a]	18399.45	19438.93	16445.15	16415.06
Land owned (hectare)	1.28	1.13	1.39	2.03
Family adult male(mandays)	150.56	166.63	115.96	149.51
Family female (mandays)	38.45	31.93	30.59	35.31
Family child labor	2.75	10.24	1.25	8.24
Family labor (mandays)[b]	186.56	171.37	141.76	159.34
Hired labor (mandays)	146.11	131.82	160.32	165.24
Family size[c]	6.24	2.60	6.15	2.25
Schooling of household(HH) head (years)	3.93	3.97	7.40	5.26
Age of HH head (years)	46.81	12.44	44.02	13.42
Schooling of spouse(years)	1.53	2.45	4.33	4.46
Spouse's age (years)	37.23	10.78	35.38	11.89
Average schooling of household members working	3.04	2.24	5.10	4.98
Average age of household members working	22.52	8.13	26.83	10.67
Percentage of HH heads work in off-farm work	0	0	0.58	0.49
Actual wage of heads(Taka)	0	0	39.58	16.08
Percentage of spouses work in off-farm work	0	0	0.31	0.46
Spouse's wage (Taka)	0	0	29.07	13.07
Percentage of other members work in off-farm work	0	0	0.35	0.48
Members' wage (Taka)	0	0	27.61	10.66

a Profit is defined as gross value of crops grown over the year 1983-1984 less expenditure on purchased inputs.

b Family labor is calculated as family adult male labor plus female and child labor adjusted by the differences in the community-level wage rates of three categories of labor. The community wages of three categories of labor are, respectively, Tk. 17.95, 8.40, and 9.22.

c Family size is defined as the number of family members of the household unit who belong to age group 10-65. This is what in Bangladesh called the economically active population.

Empirical Results

The parameter estimates for the probit procedure of farm households' participation in the labor market are shown in Table 2. Most of these estimates are of the expected sign. Landholding has a negative effect on the probability of farm households selling out of family labor to market work, presumably working as an income effect on family labor supply. Community-level agricultural wage rate for casual hired labor decreases the probability of selling out family labor to market work, perhaps indicating that an increase in wage for casual hired labor will reduce (increase) the supply of family labor to off-farm (farm) work, thereby substituting family labor for hired labor. On the other hand, family size increases the probability of selling out family labor to market work, suggesting that the larger the number of working members in the household, the more likely that family labor is sold out for market work. Furthermore, all the education variables have significant positive effects on the probability of household members' participation in the labor market, mostly in nonfarm activities. The chi-square ratio which tests whether coefficients on all regressors except the intercept are zero indicates that the model predicts well household member's labor market participation in off-farm work. This also suggests that the households' selling out of family labor to market work is an endogenously determined decision.

A restricted profit function, conditional on family labor, can be derived from a Cobb-Douglas production function using duality theory (Jamison, and Lau, 1982).[11] It is a function of land, family labor, schooling of three categories as described earlier.[12] The dependent variable, profit (calculated as gross value of crops less expenditure on purchased inputs) and explanatory variables, land and family labor, are in logarithmic values.

Table 2. Probit Maximum Likelihood Estimates of Labor Market Participation

Explanatory Variables	Coefficients	t - Statistics
Intercept	-1.152	-2.05**
Landholding	-0.075	-1.93**
Family size of active members in the family	0.027	0.83
Community wage for casual hired agricultural labor	-0.011	-0.36
Schooling of household head (male)	0.038	1.62***
Schooling of spouse	0.104	3.30*
Schooling of other working household members	0.074	2.34**
(-2.0) x Log Likelihood Ratio	63.099	
Number of observations (N)	364	

Notes: Dummy dependent variable = 1, if any member of the household unit works for market work, 0 otherwise (participant households = 130, nonparticipant households = 234). *, **, and *** denotes, respectively, 1%, 5%, and 10% levels of significance. Other working members include both children and non-children members working for the household and living with the household.

The restricted profit function is estimated by OLS separately for participant and nonparticipant households using the Mills-ratio estimate associated with the self-selected subsample. If the unmeasured characteristics influencing sample selection and farm efficiency are jointly normally distributed, then the influence of the selectivity associated with labor market participation can be "taken out" of the restricted profit function estimates by including the Mills-ratio estimates. Thus, the "corrected" estimates of restricted profit function yield the estimates solely as a function of occupational selectivity. Thus, the inclusion of the Mills-ratio variable in the restricted profit function not only purges out selectivity effects, but also its coefficient provides a consistent estimate of the covariance between the unmeasured characteristics in the profit function and the participation equation (Heckman, 1979). Moreover, estimates of the conditional profit function are also corrected for possible endogeneity of family labor using two-stage least squares (2SLS) for both the participants and nonparticipants farm households. In the two-stage least square procedure a family labor demand function is fitted first on the basis of a two-stage switching regressions model to ascertain whether differences exist in household behavior regarding family labor use in own farming. The instruments used in the estimation of the family labor demand function include community-level wages for casual hired labor, age of household head, and family size. Table 5 presents the estimates of family labor demand functions for both types of households. These estimates are used to predict family labor use in family farming which in turn are used in the second stage of the 2SLS estimation of the conditional profit function. Table 3 shows both OLS and 2SLS regression estimates of the conditional profit function for labor market participant households, while Table 4 reports similar

Table 3. Two-stage Switching Regression Estimates of a Restricted Profit Function for Participant Households
(sample 119)

Explanatory Variables	OLS estimates	2SLS estimates
Intercept	10.439 (8.41)*	10.402 (6.45)*
Landholding	0.613 (5.95)*	0.607 (3.39)*
Family labor	0.152 (1.88)***	0.160 (0.68)
Schooling of household head (male)	-0.058 (-1.93)***	-0.058 (-1.93)***
Schooling of spouse	-0.029 (-0.65)	-0.029 (-0.63)
Schooling of other working household members	-0.003 (0-06)	-0.003 (-0.07)
Mills ratio	-1.339 (-1.79)***	-1.339 (-1.79)***
R^2	0.537	0.531
SSE	52.782	52.787
degrees of freedom	112	112
F ratio	21.68*	21.16*

Note: t-statistics are in parentheses. *, **, and *** denotes 1%, 5%, and 10% levels of significance respectively. The dependent variable is profit which, and the explanatory variables, land and family labor, are in log values.

Table 4. Two-stage Switching Regression Estimates of a Restricted Profit Function for Non-Participant Farm Households
(sample 229)

Explanatory Variables	OLS estimates	2SLS estimates
Intercept	8.165 (14.29)*	8.579 (10.35)*
Landholding	0.664 (8.70)*	0.691 (5.77)*
Family labor	0.254 (2.38)**	0.175 (1.77)***
Schooling of household head (male)	-0.010 (-0.55)	0.006 (0.32)
Schooling of spouse	-0.042 (-0.80)	-0.038 (-0.73)
Schooling of other working household members	-0.015 (-0.45)	-0.011 (-0.32)
Mills ratio	0.685 (0.84)	0.570 (0.71)
R^2	0.617	0.619
SSE	64.615	62.076
degrees of freedom	222	222
F ratio	59.47*	60.14*

Note: t-statistics are in parentheses. *, **, and *** denotes, respectively, 1%, 5%, and 10% levels of significance. The dependent variable is profit which, and the explanatory variables, land and family labor, are in log values.

Table 5. Two-stage Switching Regression (OLS) Estimates for Family Labor Demand Functions in Agriculture

Explanatory Variables	Participant group	Non-participant group
Intercept	4.846 (1.93)***	3.211 (2.86)**
Landholding	0.471 (4.11)*	0.527 (7.23)*
Community-level agrl. wage	-0.264 (-0.50)	0.921 (3.02)**
Family size	1.030 (3.72)*	0.721 (4.38)*
Age of the household head	-0.661 (-1.87)***	-0.392 (-1.79)***
Schooling of household head (male)	0.044 (1.20)	0.054 (2.16)**
Schooling of spouse	-0.015 (-0.27)	0.119 (1.52)
Schooling of other working household members	0.045 (0.85)	0.054 (1.16)
Mills ratio	0.805 (0.92)	-2.354 (-1.97)***
R^2	0.464	0.494
SSE	63.456	85.414
degrees of freedom	110	220
F ratio	11.92*	26.88*

Notes: t-statistics are in parentheses. The dependent variable is log of family labor use in farming and explanatory variables such as landholding, community-level agricultural wage for male worker, family size, and age of the household head are also in log values. *, **, and *** denote, respectively, 1%, 5%, and 10% levels of significance.

estimates for the farm households who do not sell out family labor for market work.

Using Hausman's (1978) test for endogeneity of family labor (Tables 3 and 4), it can be shown that endogeneity is relevant for farm households who do not sell out family labor for market work, while it is not for those who participate in the labor market. This implies that when family labor demand is endogenously determined, appropriate instruments are necessary to correct for such simultaneous equation bias. The results in Table 4 also confirm that, because of such simultaneous bias, education's impact on farm efficiency may be underestimated when family labor endogeneity is not corrected.

Both land and family labor have positive effects, as expected, on farm productivity for both types of farm households. However, there exists significant differences in production behavior of these two types of households. The Mills ratio estimates in the profit function indicate that farm households who sell out family labor have less than average farm productivity, while the households who do not sell out family labor have larger than average farm productivity. Moreover, the Mills ratios for family labor demand function (Table 5) indicate that farm households who participate in off-farm work have larger than average family labor demand in farming, while the households who do not participate in off-farm market work have less than average family labor demand in own farming.

Although education influences family labor demand in agriculture, it has no effect in farm efficiency. The negative effect of household head's education on farm efficiency (Table 3), although inconceivable, is, however, evident in some other studies (Jamison and Moock, 1981).[13]

There are several reasons why the true productive value of education in agriculture may not be properly measured in our estimation of the conditional profit function. First, the Cobb-Douglas specification of the model may impose fewer options for education to play which may produce incomplete measures of the true productive value of schooling, because of its greater restriction on the feasible farm technology (Barichello, 1984). Second, the conditional profit function has an omitted variables problem because of its exclusion of price variables such as prices of output and purchased inputs.[14] Finally, the family labor input may reflect measurement error because it ignores any direct reference to labor supplied by different members of the family. Thus, any gains to be accrued from using the appropriate level and mix of family labor in agriculture, as well as family labor allocation between farm and off-farm market, uses is not captured in our model.

Although the first two problems cannot be dealt with in this paper, the third problem is pursued below. Since information on the time allocation of each member of the household is available from the survey, one can use such information to predict wage offers for family members who use their time in the family farm as unpaid workers on the basis of the wage earned by those who work off-farm.[15] The profit calculated as gross value of crops less expenditure on purchased inputs is further netted out by excluding the predicted wage bill for family labor and then estimate a functional form that uses this net profit as the dependent variable and the predicted wage rates, among others, as regressors. This functional specification captures the gains from schooling in family labor allocation of different categories between farm and off-farm uses.

The procedure is carried out here in the following way. Family labor is classified under three categories: household head, his spouse, and other members, including economically active children. A probit procedure is carried out (Table 6) for each category of members according to whether or not a person in a particular group participates in off-farm work. A wage equation is estimated for the subsamples who participate in the labor market by including age and education of the person as well as the Mills ratios calculated by using the probit results reported in Table 6. These estimates, which are reported in Table 7, are then used to predict wages for three categories of family labor of all samples which in turn are used to calculate the wage bill for unpaid family labor.[16] The profit net of the family labor wage bill is then taken as the dependent variable and the Cobb-Douglas specification of a profit function is estimated for all samples by including, among others, three types of predicted wage offers (Table 8).

Furthermore, in case results suffer from possible selectivity bias due to Cobb-Douglas specification of the model, a quadratic profit function is estimated that utilizes all samples. The results of the quadratic profit function are also reported in Table 8.

The exercise carried out through Tables 6 to 8 indicate that the household head's education has a positive significant value to farm efficiency. This result was not apparent when schooling-induced variations in household decision-making regarding family labor allocation between farm and off-farm market uses were not taken into consideration. Thus, the allocative role of farmer education in family labor allocation was not captured when a profit function, conditional on family labor, were estimated.

Table 6. Probit Maximum Likelihood Estimates of Labor Market Participation by Different Members of Farm Household
(Sample 364)

Explanatory Variables	HH head	Spouse	Other members
Intercept	-0.458	-3.649	-2.095
	(-0.72)	(-4.67)*	(-2.94)*
Landholding	-0.241	-0.047	-0.118
	(-2.27)**	(-0.82)	(-1.37)
Family size (age 10-65)	-0.069	-0.024	0.141
	(-2.46)**	(-0.48)	(3.68)*
Community agrl. wage	-0.024	0.241	-0.011
	(-0.76)	(2.92)*	(-0.30)
Schooling of household head (male)	0.112		
	(6.85)*		
Schooling of spouse		0.155	
		(6.07)*	
Schooling of other working household members			0.094
			(2.52)**
(-2.0) x Log Likelihood Ratio	67.986	65.463	23.483

Notes: Dummy dependent variable = 1, if household head works for market work (76), or spouse works for market work (40), or any member other than household head and his spouse works for market work (46), 0 otherwise. t-statistics are in parentheses. *, **, and *** denote, respectively, 1%, 5%, and 10% levels of significance.

Table 7. Estimates of Wage Function for Different Members Working Off-farm

Explanatory Variables	HH head	Spouse	Other members
Intercept	11.028	47.438	8.424
	(0.79)	(2.79)**	(0.73)
Age	0.279	0.109	0.249
	(1.66)***	(0.59)	(1.59)
Education	2.028	-0.282	1.077
	(2.86)**	(-0.29)	(2.99)**
Mills Ratio	-0.120	-15.655	2.250
	(-0.08)	(-2.37)**	(0.43)
F Ratio	13.59*	14.02*	5.45*
Degrees of freedom	72	62	40

Notes: t-statistics are in parentheses. *, **, and *** denote, respectively, 1%, 5%, and 10% levels of significance.

Table 8. Estimates of Restricted Profit (Gross Revenue Less of Purchased Input Costs Less of Wage bill for Family Labor) Function

Explanatory Variables	Cobb-Douglas function	Quadratic function
Intercept	22.061 (4.38)*	225566.50 (3.98)*
Landholding	0.887 (7.04)*	13890.67 (7.90)*
Landholding squared		-592.825 (-1.86)***
Pred. wage for HH head	-1.837 (-1.37)	-1854.16 (-1.11)
Pred. wage (head) squared		24.136 (0.99)
Pred. wage for wife	-0.533 (-1.76)***	-1519.19 (-3.22)*
Pred. wage (wife) squared		43.716 (3.75)*
Pred. wage for members	-1.962 (-2.64)**	-14057.7 (-3.45)*
Pred. wage (memb) squared		253.458 (3.17)*
Schooling of household head (male)	0.143 (1.69)***	845.920 (1.64)***
Head's schooling squared		-83.260 (-0.91)
Schooling of wife	0.003 (0.09)	301.361 (0.65)
Wife's schooling squared		-122.0 (-1.59)
Schooling of other working household members	0.019 (0.50)	-157.792 (-0.19)
Members' schooling squared		0.722 (0.08)
R^2	0.369	0.417
degrees of freedom	192	349
F ratio	16.06*	17.98*

Note: t-statistics are in parentheses. *, **, and *** denotes 1%, 5%, and 10% levels of significance respectively. The dependent variable is profit which, and the explanatory variables, land, and three categories of predicted wages are in log values for the Cobb-Douglas specification.

Conclusions

The production or profit function approach often used to study the impact of education on agricultural efficiency is potentially a misspecified functional form if family labor is endogenously determined. Labor endogeneity may occur if family labor is not sold out either because of labor market preferences or because family and hired labor are imperfect substitutes in production. This makes the production and consumption decisions of farm operators nonseparable. An agricultural household model that encompasses both decisions may be employed to motivate the choice of appropriate instruments. Instrumental variables can be used in a restricted profit function to properly study the impact of education on agricultural productivity, which otherwise will be underestimated.

An agricultural household model is developed to show under what conditions family labor demand may be endogenous. Self-selection into labor market participation is endogeneously determined by the farm household's family characteristics as well as other factors. It produces a sample selection bias if differences in production behavior conditional on labor market participation of farm households are not explained. This is an argument for using a two-stage switching regressions model for estimating a restricted profit function conditional on family labor.

An empirical implementation of such a procedure with data from Bangladesh suggests that family labor demand is indeed endogenous when households do not participate in the labor market. Moreover, it is found that the production behavior of farm households who participate in the labor market is different from those who do not participate in the labor market. Since labor market participation is endogeneously determined, this may suggest that correcting for this form of sample selection bias in the restricted profit function reduces the impact of family background characteristics on the productive capacity of farmers and, hence, the education coefficient may indeed measure the causal impact of farmer education on farm efficiency.

A conditional profit function, although permits the education variable to pick up any returns in variable profit due to schooling-induced variations in the predicted level of family labor when family labor becomes endogenous, yet may not measure the true productive value of schooling in agriculture. This is partly due to the fact that such functional specification does not permit education to pick up any returns that may accrue due to the allocative role of education in family labor allocation between farm and off-farm uses. It serves as an argument for using a profit function unconditional on family labor by subtracting the predicted wage bill for family labor from the profit on the basis of wage estimates for those who work off-farm for wage. This procedure when followed indeed confirms that farmer education has a productive value to farm efficiency in Bangladesh.

Footnotes

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1 Welch (1970) describes the productivity effect as the "worker effect" and the allocative efficiency effect as "allocative effect" of education. He defines worker effect as the "increased output per change in education, holding other factor quantities constant", while "allocative" effect helps increase farm operators' "ability to acquire and decode information about costs and productive characteristics of other inputs" (Welch, 1970; p. 342) Welch argues with supporting evidence that allocative effect of education is much more important than the worker effect, which subsequently confirmed by other findings (Huffman, 1977).

2 Family labor may constitute heterogenous units such as adult male, adult female, and child labor so that L in specification (1) is a vector of these different heterogenous labor inputs. In South Asian countries, for example Bangladesh, limited wage employment exists for certain categories of family labor such as female and child labor outside family farm (Binswanger and Rosenzweig, 1984).

3 When the production function (1) is well-behaved and farms face fixed prices and maximize profits, by duality theory, a restricted or variable profit function exists that relates variable profit to the prices of outputs, prices of variable inputs, and quantities of the fixed inputs.

4 Barichello (1984) argued that the level of fixed inputs, such as capital, which is fixed for reasons of shortrun adjustment costs, is likely to be influenced by the management skills, or schooling, of the farm operator. Using Canadian agricultural data, Barichello reported that endogeneity of the level of capital inputs makes estimates of education variables underestimated.

5 Jamison and Moock (1981) introduced some family background factors such as age and occupational status of farm household head as instrumental variables, while estimating production function for Nepalese farmers to correct what they called "over-estimated effect of education". Effect of education in a production function may be over-estimated since family background factors might potentially influence the productive capacity of farmers, and, thus, education, which is highly correlated with these factors, may proxy for them. The motivation for using instruments in this paper is, however, derived from the model which argues that self-selection in occupation can produce endogeneity of family labor demand, which may be determined endogenously by, among others, family background factors. Thus, correcting sample selection bias, in addition to simultaneity bias, may give consistent estimates of education variable, which may reflect causal effect of education on farm efficiency.

6 If family labor is a vector of heterogenous labor inputs, then L will be a vector of such heterogenous family labor inputs. Accordingly, leisure, M, market wage, W, education characteristics, E, total working hours, Ω, and family labor supply to market work, S, will also be vectors. Moreover, if some components of family labor are sold out but others are not, then the model developed in this paper needs to be qualified accordingly.

7 Assume that there are no purchased inputs involved in production. Alternatively, Q is gross value of crops less expenditure on purchased inputs, in which case equation 3(iv) is a restricted profit function. In thes latter case, labor purchased from market is unskilled and imperfect substitutes for family labor.

8 If farm households sell out family labor (S>0), the optimal condition for family labor allocation is

$$P_q \partial Q/\partial L = W = f(E).$$

For a particular household with a given education endowment, the market wage is fixed, and thus, production and consumption decisions for such household are separable. In this case, the household's utility maximization boils down to two sub-maximization problems. The first is to maximize income, I, for any work effort of the household in own farm and market work. Given this income, and supply of effort, the household then maximizes utility which determines optimal amount of leisure and consumption of other goods. That is to say,

maximize

$$I = P_q Q, \quad \text{subject to}$$

$$L^* = L + S, \text{ and}$$

$$Q = Q(L, E, T)$$

in the first step, which will lead to optimum level of income as a function of given effort, L^*, E, T, and P_q. In the second stage, the problem is to maximize,

$$U = U(C, M, R)$$

subject to

$$P_c C + P_q R = I(L^*, E, T, P_q) + WS$$

$$\text{and, } \Omega = L^* + M .$$

Thus, maximization in step one determines I as a function of given effort, L^*, where the effort is itself determined by the maximization problem in step two which, of course, displays an income-leisure trade-off.

9 It is shown latter that if S > 0, the effect of education on family labor demand in agriculture depends on the relative returns of labor in two income earning activities (i.e., family farming versus market work).

10 This way of showing the effect of education on family labor demand is possible because the production and consumption decisions are separable for farm households who participate in the market work for wage income.

11 The Cobb-Douglas functional form is likely to be an overly restrictive characterization of the actual farm technology, and hence, may restrict the opportunity for education to profitably exploit the technology (Barichello, 1984). This is perhaps the case due to the homogeneity restriction that is imposed on the Cobb-Douglas production function. Despite its drawbacks, the Cobb-Douglas specification is widely applied to describe farm technology and to measure the productive value of schooling in farming. Thus, consistent with this tradition, the results of a Cobb-Douglas functional form are reported here.

12 Because price variables are not included (which are not available) in the conditional profit function, conditional on family labor, such function may better be called a value-added production function rather than a profit function.

13 When a quadratic profit function, quadratic in education variables, was estimated (results are not shown here), it shows a non-linear role of education in farm production (see also Jamison and Moock, 1981). The non-linear effect of education implies that education has a payoff for higher level of farmer education.

14 The left-out price variables such as prices of outputs and inputs may not create severe problem for estimation in the context of Bangladesh. Given the aggregate valued-added production or profit function, aggregate prices (i.e, yearly) of both outputs and inputs are required which, according to one study, do not vary across regions (Khandker, 1983)

15 The procedure adopted here essentially is to estimate earnings for the subsample of different household members working in the off-farm work for wage income, and on this basis predict a wage offer for those who work in the family farm as unpaid family workers. This procedure is due to Heckman (1974, 1979) and is being widely used by researchers. One should, however, note that this method will generate inconsistent parameter estimates if the two subsamples differ in unmeasured characteristics.

16 The mean predicted wages for three categories of labor for all 364 samples are, respectively, Taka 33.43 for household head, Taka 19.42 for household head's spouse, and Taka 24.19 for other members as against the actual mean wages, Taka 39.58, Taka 29.07, and Taka 27.61, for those who work outside farm for wages.

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