Labor Heterogeneity and Rice Production in Malaysia

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ABSTRACT

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Estimates of an unrestricted translog production function are used to test whether a consistent aggregate exists for male and female labor in rice production in the Muda river valley of Malaysia. It is shown that the production function is of the Cobb Douglas form and that a consistent aggregate of male and female labor may be obtained by the use of geometric indices with weights proportioned to the elasticities of the inputs. At the same time the results cast doubt on production function estimates obtained by means of the simple addition of all types of labor.

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On utilise la forme estimée d'une fonction de production translog libre pour découvrir s'il existe un aggrégat établi pour la main d'oeuvre masculine et féminine employée à la production du riz dans la vallée de la Muda en Malaisie. Il est démontré que la fonction est de la forme Cobb-Douglas et qu'on peut obtenir un aggrégat connu au moyen d' indexes géométriques pondérés d'aprés les élasticités des intrants. En même temps, les résultats mettent en doute les estimations de fonction de production obtenues par l'addition simple de tous les genres de main d'oeuvre.

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LABOR HETEROGENEITY AND RICE PRODUCTION IN MALAYSIA

Introduction

Berndt and Christensen (1974) have recently introduced a method of testing for the existence of a consistent aggregate index of different types of labor (or any other factor) used in production function analysis. In their empirical application, Berndt and Christensen demonstrate that a consistent aggregate index for blue and white collar workers in U.S. manufacturing does not exist. Such a conclusion is of major significance for development economics since it points to the possibility that much of the empirical research on agricultural production functions may involve errors of specification. That is, estimates of production functions based on an undifferentiated labor variable may lead to errors in the measurement of labor's marginal product if different types of labor (for example, male-female, busy season-slack season, hired-family) have been aggregated incorrectly or have been aggregated when in fact no consistent aggregate index exists.[1/]

In the development literature, few authors have considered the possibility that labor is heterogeneous, and, in the few instances where the possibility has been considered, the existence of a consistent aggregate has been accepted unquestioningly and the form of the aggregation has been specified *a priori*.[2/] In this paper we apply the procedure developed by Berndt and Christensen to test whether a consistent aggregate exists for male and female labor in rice production in the Muda river valley of Malaysia. Unlike the Berndt and Christensen results, it is shown that such an aggregate index does exist in this case and that the correct form of aggregation happens to be that chosen arbitrarily by Nath and by

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1/ See Nath (1974) for the case of seasonal labor inputs and Brown and Salkin (1974) for the case of family and hired labor inputs.

2/ Two inputs are separable if the marginal rate of substitution between the two inputs remains unaffected by changes in the quantities of other factors used in production.

Brown and Salkin for their studies. Finally, estimates of labor's marginal product are obtained from a correctly specified production function and are compared with those obtained when the production function is estimated using a labor input aggregated by simply adding together disparate labor types.

Empirical Method

The test procedure consists of the estimation of a general production function, the translog function, which, under various restrictions on the estimated parameters, can be interpreted as an approximation to various arbitrary production functions with characteristics of interest. For instance, if given restrictions are met the translog becomes an approximation to the class of production functions with constant returns to scale (CRTS). In addition, by testing the critical restrictions on the estimated coefficients it is possible to establish whether or not factors of production are separable[1/] and therefore whether or not a consistent aggregate exists.

The production function to be estimated is of the form:

$$\ln Q = \ln\alpha_o + \alpha_A \ln A + \alpha_M \ln M + \alpha_F \ln F + 1/2\ \gamma_{AA}(\ln A)^2 + 1/2\ \gamma_{MM}(\ln M)^2 + 1/2\ \gamma_{FF}(\ln F)^2 + \gamma_{AM}\ln A.\ln M + \gamma_{AF}\ln A.\ln F + \gamma_{MF}\ln M.\ln F \qquad (1)$$

where:

Q = quantity of output

A = area cultivated

M = male labor

F = female labor.

For constant returns to scale to exist, it is necessary and sufficient that the following relations are satisfied:[2/]

1/ Two inputs are separable if the marginal rate of substitution between the two inputs remains unaffected by changes in the quantities of other factors used in production.

2/ See Berndt and Christensen (1974).

$$\alpha_A + \alpha_M + \alpha_F = 1 \tag{2}$$
$$\gamma_{AA} + \gamma_{AM} + \gamma_{AF} = 0$$
$$\gamma_{AM} + \gamma_{MM} + \gamma_{MF} = 0$$
$$\gamma_{AF} + \gamma_{MF} + \gamma_{FF} = 0$$

For all of the inputs to be mutually separable (global separability) it is sufficient that:

$$\gamma_{AM} = \gamma_{AF} = \gamma_{MF} = 0 \tag{3}$$

If this relation holds the production function is of the Cobb-Douglas form. Finally,[1/] if global separability is rejected it is still possible that two of the three inputs are separable. For M and F to be separable from A (denoted FM - A) it is sufficient that the following relation be satisfied:

$$\gamma_{AF} = \gamma_{AM} = 0 \tag{4a}$$

Similarly for FA - M the critical relation is

$$\gamma_{MF} = \gamma_{AM} = 0 \tag{4b}$$

and for MA - F the critical relation is:

$$\gamma_{AF} = \gamma_{MF} = 0 \tag{4c}$$
[2/]

1/ The tests we set forth above are for <u>linear</u> separability. Other tests are possible for nonlinear separability and for the conditions under which the production function is of the CES (constant elasticity of substitution form). See Berndt and Christensen (1974), and the refinements of the Berndt and Christensen tests made by Denny and Fuss (1977). However, since the linear separability relations are special cases of the nonlinear relations and since the Cobb-Douglas is a special case of the CES function it is sufficient to test for the linear and Cobb-Douglas cases first, then if these cases are not rejected, no further tests are necessary.

2/ Only two of the three relations, 4a-4c, are independent.

DATA

The region from which the data are drawn is in the extreme northwest of Peninsular Malaysia and comprises the State of Perlis and four administrative districts in the State of Kedah. Padi cultivation is the main occupation of over 50,000 families in the area which contains about 30% of the padi land in Malaysia and accounts for almost 50% of total padi output. The recent switch from single- to double-cropping as a result of new irrigation facilities (the Muda River Project) has been accompanied by a significant increase in output from 227,000 tons in 1965 to 678,000 tons in 1974.

The data are for individual farm households and were collected in 1973 as part of the FAO/IBRD cooperative program. For the purposes of our analysis, we have concentrated on those households which have been double-cropping for one or more years and which operate non-acid land. This concentration ensures a relatively homogeneous sample: it omits those operating on the qualitatively inferior acid soils (8% of the original sample) and those who were in the process of switching from single- to double-cropping during the period of observation (20% of the original sample). The remaining sample was then further adjusted to exclude (i) all households which failed to report labor usage for land preparation, planting, harvesting or threshing; and (ii) all households which failed to report padi output. The final sample size is 386.

Becuase the survey commenced in the middle of the first crop production period, our study is confined to the second crop, that is, that crop which relies on irrigation water. The labor variable for our estimates is measured in hours and is disaggregated according to sex (male/female). The labor of household members less than 15 years of age was not included as information obtained from the survey indicated that the use of child labor is essentially nil. Area operated is measured in relong and the dependent variable is the quantity of harvested padi output, measured in gantang, which was produced in the second crop season.[1/]

1/ A relong equals 0.287 hectares and a gantang equals 2.41 kilograms.

Estimation and Results

One method of estimating equation (1) would be to derive the three first order conditions for profit maximization and then estimate the three equations using, say, two stage least squares to avoid simultaneous equations bias. This is, in fact, the method used by Berndt and Christensen. The disadvantage of this procedure is that it requires observations on input prices - which are not apt to vary substantially over a cross section taken from a small geographic area and which in any case we lack for male and female labor - and assumes profit maximization. Since the production function is a technological concept and free of institutional assumptions it is preferable to estimate the function directly without imposing the first order conditions. Given the lag between input and output decisions which occurs in agriculture, we apply ordinary least squares which can be expected to yield unbiased direct estimates of the production function.[1/]

Given the estimated production function we first test for CRTS (relations (2) above). If constant returns to scale is not rejected we proceed to use restricted squares to impose CRTS as a maintained hypothesis and test for global separability (relation (3)). If CRTS is rejected we test for global separability without first imposing the CRTS relations. Finally, in either case, if global separability is rejected we procede to test separability for pairs of inputs (relations 4a-4c). In conducting the tests an overall significance level of .09 is used and .01 is allocated to each of the nine F - tests of joint hypothesis (four restriction in relation (2), three in relation (3) and two in (4a-4C)). Table 1 gives the critical F values for the tests.

1/ This is demonstrated by Zellner, Kmenta, Dreze (1966).

Table 1: SIGNIFICANCE LEVELS FOR RESTRICTIONS ON THE TRANSLOG PRODUCTION FUNCTION

Test	Significance Level	Restrictions	Degrees of Freedom	Critical Value of F
CRTS	.01	4	372	3.36
Complete Global Separability	.01	3	369	3.83
Three Linear Separabiltiy Tests	.01	2	369	4.66

The estimated parameters for the unconstrained translog production function are given in column one of Table 2.[1/] The F statistic for the constant returns to scale and linear homogeneity restrictions (equations (2)) is 0.7043. Since the null hypothesis of CRTS cannot be rejected we conduct the remaining tests under a maintained hypothesis of CRTS; column two presents the translog production function estimated under the restrictions given by equations (2).

The F statistic for the test of complete global separability is 2.8231 and the null hypothesis that the production function is of the Cobb-Douglas form cannot be rejected at the .01 significance level. We conclude that the inputs are separable and a consistent linear aggregate of male and female labor exists.

Interpretation of Results

Our results confirm very strongly the existence of a consistent linear aggregate of male and female labor in Malaysian padi production and thus differ sharply from those of Berndt and Christensen for blue and white collar workers in U. S. manufacturing. If male and female labor are introduced into the production function as separate inputs, we have shown that the production function is of the Cobb-Douglas CRTS form. This

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1/ The regressions reported in Table 2 were examined for a heteroscedastic relationship between the residuals and area. Using the Spearman Rank Correlation test the hypothesis of homoscedasticity was not rejected at a 5% significant level.

Table 2:[1/] Parameter Estimates of the Translog Production Function

Parameter	Unconstrained	CRTS Imposed	CRTS and Global Separatability Imposed	Undifferentiated Labor Variable
α_A	-1.280 (0.695)	-1.256 (0.515)	0.688 (0.064)	0.691 (0.067)
α_M	0.916 (0.470)	1.303 (0.266)	0.281 (0.051)	- -
α_F	0.817 (0.602)	0.953 (0.386)	0.030 (0.056)	- -
γ_{AA}	-0.925 (0.251)	-0.925 (0.240)	- -	- -
γ_{MM}	-0.281 (0.117)	-0.242 (0.112)	- -	- -
γ_{FF}	-0.214 (0.165)	-0.175 (0.154)	- -	- -
γ_{AM}	0.536 (0.135)	0.496 (0.129)	- -	- -
γ_{AF}	0.392 (0.196)	0.429 (0.181)	- -	- -
γ_{MF}	-0.173 (0.117)	-0.254 (0.097)	- -	- -
α_L	-	-	-	0.324 (0.069)
α_0	2.770 (1.557)	1.145 (0.547)	3.123 (0.138)	3.123 (0.138)
SSE	84.457	85.089	89.097	91.708
$\bar{R}$	.67	.67	.66	.65

1/ Standard errors in parenthesis.

implies that a consistent aggregate of male and female labor may be obtained by the use of geometric indices with weights proportional to the elasticities of the respective inputs.[1/]

Our results, therefore, lend some support to the procedure adopted by Nath (1974) and by Brown and Salkin (1974) whereby disparate labor inputs are introduced immediately, without any prior testing, into a Cobb-Douglas specification as separate inputs. At the same time, however, they cast doubt on the vast majority of production function estimates which are based on an aggregate labor index obtained by means of simple addition of all types of labor. It is of some interest, therefore, to compare the estimated coefficients of the production function and the implied marginal products obtained when the labor variable is correctly specified with those obtained when an aggregate labor variable is used and the aggregation is achieved by means of arithmetic addition. The results of this comparison are reported in columns three and four of Table 2.

Column 3 of Table 2 presents the parameter estimates for the translog production function with constant returns to scale. Column 4 contains an estimate of the production function in which labor is treated as a single homogeneous factor of production (L = M + F). This comparison suggests that the bias introduced by incorrect aggregation (simply summing male and female labor) of the labor inputs may be relatively small. With regard to the constant and the coefficients on land and labor, the two estimates produce remarkably similar results. In each case land is the most important input having an elasticity of 0.69, while the elasticity of output with respect to labor is 0.32 if labor is incorrectly aggregated compared to 0.31 when labor is correctly aggregated.[2/]

1/ See Griliches (1957).

2/ Although we have estimated the production function with separate labor inputs, given our previous results, this is equivalent to estimating the function when labor is correctly aggregated and introduced as a single input. The correct aggregate is $(M^{\alpha M}F^{\alpha F})^{\frac{1}{\alpha_F + \alpha_M}}$ and the corresponding coefficient is $\alpha_F + \alpha_M$, which, for our study, equals 0.31.

It follows that some policy conclusions drawn from an estimated production function based on an incorrect aggregation of the labor input may not be subject to large errors. For example, tests of allocative efficiency with respect to land are not affected by incorrect aggregation. On the other hand, tests of allocative efficiency with respect to labor may be biassed since the true marginal product of labor in any given situation will depend on the proportions of male and female labor involved. In fact, use of the aggregate labor variable will only produce a true measure of labor's marginal product if the proportion of male labor withdrawn from production is λ and the corresponding proportion of female labor is $(1-\lambda)$ where:

$$\lambda = \frac{MPL_L - MPL_F}{MPL_M - MPL_F}$$

If we write π as the proportion of male labor in total labor (and not marginal labor) and $(1-\pi)$ for the corresponding female proportion, we obtain:

$$\lambda = \frac{\pi[(1-\pi)\alpha_L - \alpha_F]}{(1-\pi)\alpha_M - \pi\alpha_F} \tag{5}$$

Using the mean value of $\pi(=0.48)$ and the values of the coefficients in Table 2, we calculate λ to be 0.50 which is very similar to the mean value of π. That is, in this case, the use of an agggregate labor variable will only produce the correct value of labor's marginal product if equal quantities of male and female labor are withdrawn from production.

The explanation of this result is not difficult to find. Table 2 shows that the coefficient on the female labor variable is not statistically different from zero.[1/] Accordingly, if λ_F is set equal to zero in equation 5, the equation collapses to:

$$\lambda = \pi\alpha_L/\alpha_M$$

which, given $\alpha_L \doteqdot \alpha_M$, implies $\lambda \doteqdot \pi(=0.48)$.

1/ These results bear some resemblance to those obtained by other researchers. Thus, Nath (1974) finds that the coefficient on slack season labor is not statistically different from zero, while Brown and Salkin (1974) find that the coefficient on family labor is not statistically different from zero.

Clearly, however, there is no technological reason why λ should equal 0.50. More generally, therefore, we can say that the error in the estimate of labor's marginal product varies from $\left(\frac{\pi\alpha_L - \alpha_M}{\alpha_M}\right)$ 100%

if $\lambda = 1$, to zero if λ is given by equation 5, to $\left(\frac{(1-\pi)\alpha_L - \alpha_F}{\alpha_F}\right)$ 100%

if $\lambda = 0$. That is, the error is -45% if only male labor is withdrawn from production; zero if male and female labor are withdrawn in equal proportions; and 462% if only female labor is withdrawn.[1/]

An explanation of why the elasticity of output with respect to female labor is not statistically different from zero is more difficult to find. One possibility is that male and female labor are used for different tasks and output is only responsive to the male tasks. In fact, there is a sharp division of tasks by sex in the Muda River Valley: male labor is used almost exclusively for land preparation, supervision and threshing, while female labor is confined to transplanting and harvesting activities. A second possibility is that an active labor market may exist for male but not for female labor during the crop cycle so that the relevant opportunity cost of female labor is determined in relatively low productivity tasks in the household. This, however, is not a particularly convincing explanation since the Muda River Valley apparently possesses a very active labor market throughout the year for both males and females. In any case, our analysis does not allow us to distinguish between these possibilities.

It may be concluded that, at least in the case of Malaysian rice production, estimates of the marginal product of land are not biassed by incorrect aggregation of the labor variable but that estimates of labor's marginal product are subject to error. In particular, we have shown that, because the elasticity of output with respect to female labor is not statistically different from zero, estimates of the marginal product of labor treated as a homogeneous input can be considerably greater or smaller than the true value depending on the proportions of male and female labor actually withdrawn from production.

1/ If the coefficient on female labor is interpreted as zero, the error is, of course, infinite.

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