TECHNICAL EFFICIENY OF RICE PRODUCTION IN EAST AND WEST JAVA, INDONESIA.

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Data from the PATANAS survey conducted by the Indonesian Government for the year 1983/84 were analysed. Frontier and ordinary least square production functions were estimated for *sawah*[1] rice production by farmers from eight villages in East and West Java. The results indicated that farmers from the same village, as well as farmers within the same agroclimatic zones of East or West Java, were technically efficient in rice production for that year.

1. INTRODUCTION

The analysis reported in this paper is part of a multidisciplinary study of draught animals in Indonesia. The major species of draught animals used are cattle and buffaloes although horses are used on some of the Outer Islands. It is generally acknowledged that these animals serve many purposes on the farm such as providing meat, being a relatively liquid form of capital, as well as providing draught power. In this paper we concentrate on the last of these services because a major objective of the study is to identify biological and economic constraints on the use of animal power and the farming systems in which draught animals are used. In attempting to identify such constraints an issue of interest is the technical efficiency with which farmers use draught power in combination with their other inputs to produce commodities for sale or consumption.

Technical efficiency is concerned with the efficiency of the input to output transformation; that is, the technically efficient farm's output should lie on the envelope curve, or production curve, which traces out the maximum quantities of output from varying quantities of

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[1] levelled ricefields for wet rice production

inputs under a given technology. Within the context of multidisciplinary research it is useful to concentrate on technical efficiency[2] because a major function of biological or technical research is to shift the production function upwards. If farmers were found to be technically and/or allocatively inefficient, the research options need to be evaluated against the extension or education strategy of trying to improve farmers' efficiency under the current technology. In practice, of course, mixed strategies involving both research and extension are often employed.

The hypothesis to be tested, therefore, is that farmers are technically efficient in their use of inputs, including draught power. It must, of course, be remenbered that any measures of technical efficiency or inefficiency are based on observed practices within the sample of farms. In this sense they are relative measures rather than 'absolute' measures as might be derived from biological or engineering theory. If this hypothesis were supported then there is no simple extension of current technology option to be evaluated. The hypothesis was tested using farm data from four villages in East Java and from four villages in West Java. Using these observations, production functions were estimated for rice production.

The difficulty in testing for technical efficiency is to estimate the production function which accords with the above-given theoretical definition. Regression methods which use ordinary least squares (OLS) with the assumption of a normally distributed disturbance do not usually provide such a function. Recent advances in the theory and

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[2]Allocative efficiency is the degree to which a farmer combines inputs on the envelope curve to achieve the greatest financial gain.

practice of estimating stochastic 'frontier functions' by maximum likelihood estimation (MLE) methods have brought empirical estimates of production functions much closer to their theoretial definition of envelope curves or frontier. Estimation of the frontier production function in this study is based on the model proposed independently by Aigner, Lovell and Schmidt (1977) and by Meeusen and van den Broeck (1977).

2. RECENT STUDIES OF RICE PRODUCTION, ANIMAL POWER AND EFFICIENCY

Soekartawi and MacAulay (1982) compared technical efficiency in rice production between tenant farmers and owner farmers for one village in East Java. Using OLS they fitted Cobb-Douglas production functions to observations from these two groups of farmers. By comparing the intercept terms of the two equations, Soekartawi and MacAulay tentatively concluded that tenants may have greater technical efficiency than owners. Labour inputs, the amount of land, and seasonal effects, were significant in explaining the variation in output from tenants' farms. For owner-operated farms land area, animal power and seasonal effects were found to be significant in explaining the variation in output. According to Soekartawi and MacAulay, land owners generally had a 'higher financial capacity' to own and maintain animals.

Nehen (1983) studied the effects of tractor, animal and manual cultivation on rice yield per hectare for 197 *sawah* farms in West Java, during the 1979/80 wet season and the 1980 dry season. Using a linear production function and OLS Nehen found that extra tractor cultivation increased rice yield by about 470 kg/ha and land preparation by extra draught power increased rice yield by about 345 kg/ha, as compared to using manual land preparation in the dry season. Results for the wet season were not as clear cut.

Kasryno (1985) used estimates of Cobb-Douglas production functions to assess the allocative efficiency of rice farming in Java during the wet seasons of 1976/77 and 1982/83. Kasryno used panel data obtained from the Agro-Economic Survey, pooled the observations of eight villages (two from East Java and six from West Java), and used dummy variables for location (East versus West) and a dummy variable for the two time periods (1976/77 versus 1982/83). All of the variables, namely labour, animal power, tractor power, fertilizers, pesticides and area, significantly influenced the yield of rice. Interestingly, however, the coefficients on animal power had a negative sign in most of the models that Kasryno formulated.

The above-mentioned studies are the only such studies which have focussed on the role of animal power as one of the determinants of rice production in Indonesia. All have shown that animal power is a significant variable, though in one case the use of extra animal power was found apparently to depress rice production. It is difficult to judge whether the variability of the response for draught animal power across both time and space is the true situation or whether it is the result of statistical aberrations, such as the choice of functional form or the omission of important variables. These studies, except for the restricted analysis of Soekartawi and MacAulay, are evidence that little attention has been given to the question of technical efficiency in Indonesian rice production. One study in which technical efficiency was considered in a framework similar to that used here is Siregar's (1987). However, Siregar did not include a drought power variable in his estimated Cobb-Douglas function. He considered only the quantities of preharvest labour, total fertilizers and the area of rice as determinants of rice output per farm. Using observations from 63 farms in two villages on the north coastal plain of West Java and the technique of corrected ordinary least-squares (COLS), Siregar found a marked degree of technical inefficiency of production amongst the farmers in his sample. To some extent this finding is probably a result of the COLS method which 'corrects' the intercept of the OLS equation until no residual is positive and one of them is zero. Nevertheless, Siregar (1987) found that participation in the BIMAS[3] intensification program was a highly significant determinant of measured efficiency. In a similar, though non-Indonesian study, Kalirajan and Flinn (1983) found considerable technical inefficiency amongst farmers producing rain-fed rice in the Bicol region of the Philippines. In a study of rice production in Sri Lanka, Ekanayake and Jayasuriya (1987) drew mixed conclusions about technical efficiency, depending on the location of farms in an irrigation system or on the estimation methods used.

3. THE DATA

This study uses cross-sectional survey data of a single year of *sawah* rice farms from eight villages (four from East Java and four from West Java) and panel data for *sawah* rice farms from one village in East Java. The PATANAS survey gathered information from a total of 40 villages (25 villages from East Java and 15 villages from West Java) and in each village data was collected from 50 sample households

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[3]A government loan program of physical production inputs.

which were selected using proportional random sampling from 200 sample households. Four rounds of interviews had been performed for East Java and two rounds of interviews were carried out for West Java. This meant that whilst the analysis was on a per season basis for East Java it was on an annual basis for West Java. Also, it was possible to derive panel data for one village in East Java.

The major quantifiable inputs in the production of rice are area and the type of land used (for example, irrigated *sawah*, rain-fed *sawah*, or dry land), type and amount of land preparation (manual, mechanical or draught power), timing of seed transplanting and seeding rate, quantities and the timing of chemicals and fertilizer applications, number of weedings, and amounts of pre-harvest labour which are used.

To estimate production functions for rice from this bank of data it was necessary to aggregate some specific types of inputs into broader classes. Aggregation of inputs implies that all of these inputs are either perfect substitutes or perfect complements, which may not be the case. It was necessary also to select observation on rice plots that had complete information about the physical inputs and outputs of rice production. Then, the results from all such plots operated by an individual farmer were added, giving an estimate of the total input-output relationship for rice production for individual whole farms for either (a) on a per season basis for East Java or (b) on an annual basis for West Java.

4. THE MODEL

The linear production function was chosen even though production functions of agricultural activities can be expected usually to follow the law of diminishing returns. A Cobb-Douglas production function, which would capture the diminishing returns effect, could not be used because not all farmers used all inputs. Including a zero in the input-matrix of a Cobb-Douglas function leads to incorrect results, and the approach which is sometimes used, that of substituting a small number instead of zeroes into the function, introduces an unmeasureable degree of bias (Johnson and Gordon, 1971, p.120-124). Linear functions have constant marginal product of inputs and the elasticity of production of an input approaching one as the input level increase. The empirical work for East Java is based on the linear model as follows:

$$Y_i = \beta_{oi} + \sum_{k=1}^{k=5} \beta_k X_{ki} + \beta_6 X_{6i} + \mu_i \qquad (1)$$

The empirical work for West Java is based on the linear model:

$$Y_i = \beta_{oi} + \sum_{k=1}^{k=5} \beta_k X_{ki} + \mu_i \qquad (2)$$

where, for both models:

i = 1,2...n

k = 1,2...5

Y_i = [Rice] output of unprocessed rice (in kilograms).

X_{1i} = Area of land sown to rice (in hectares).

X_{2i} = Pre-harvest labour for East Java and pre-harvest plus harvest labour for West Java . This includes all classes of labour without differentiating by sex or age used in land preparation, planting, weeding, and fertilizing (in hours).

X_{3i} = Animal power. It was not possible to distinguish between the sources of animal power, that is whether buffaloes or cattle were used (in hours).

X_{4i} = Urea applied per season for East Java or amount purchased for the whole year for West Java (in kilograms).

X_{5i} = TSP (trisulphur phosphate) applied per season for East Java, or amount purchased for the whole year for West Java (in kilograms).

X_{6i} = Dummy variable which takes the value of 0 for the wet season and the value of 1 for the dry season for East Java.

μ_i = a disturbance term.

The frontier regression model applied in this work is the stochastic frontier production function model proposed independently by Aigner, Lovell and Schmidt (1977) and by Meeusen and van den Broek (1977). The stochastic frontier regression is a regression with a nonnormal asymmetric disturbance. The linear model may be represented in matrix form as follows:

$$Y = X\beta + X\gamma + \epsilon_i \qquad (3)$$

where $\epsilon_i = \nu_i + \mu_i$

Y is the maximum output obtained from X, a vector of stochastic inputs and β and γ are the vectors of unknown parameters to be estimated. The error term is subject to two random disturbances, of different characteristics. The component ν_i represents the random disturbance and is assumed to be independently and identically distributed as $N(0, \sigma^2_\nu)$. Thus the frontier can be stochastic with ν_i greater than or less than zero, due to unfavourable events such as bad weather, and measurement errors. The error component, μ_i is assumed to be distributed independently of ν_i, and μ_i is non-positive.

This non-positive disturbance is derived from a normal distribution truncated above at zero, with variance σ^2_μ, whereby each farm output must lie on or below its frontier, and these deviations are believed to be under the farmer's control, and may be the result of technical inefficiencies.

The frontier regression model was estimated using the LIMDEP statistical package of Greene (1986). The parameters estimated are β, λ and σ^2 (where $\lambda = \sigma_\mu / \sigma_\nu$ given that $\sigma^2 = \sigma^2_\mu + \sigma^2_\nu$). In practice ν_i and μ_i have unknown variances, but from the value of λ, it can be decided whether the disturbances are due to random or non-positive errors. For example, when $\lambda^2 \rightarrow 0$ it implies that either $\sigma^2_\nu \rightarrow \infty$ and/or $\sigma^2_\mu \rightarrow 0$, in this case the random error dominates in determining of value of ϵ_i. Likewise, when $\lambda \rightarrow \infty$ the non-positive errors becomes the dominant source of the disturbance (Aigner et al., 1977, p.26).

5. EMPIRICAL RESULTS

5.1 EAST JAVA ANALYSIS

Results of the Breusch-Pagan test confirmed the presence of heteroscedastic errors in the data set of village 7. From the correlation matrix and Klein's test multicollinearity was present for the cross-sectional data and panel data sets of village 24. In both cases the variables, preharvest labour and area were highly correlated. By excluding the preharvest labour variable from the input-matrix, multicollinearity was no longer a problem, and the estimated regression coefficient for area then explained the influence of both the area and preharvest labour variables towards rice production (Koutsoyiannis, 1978, p.236).

The OLS estimates of the parameters of model (1) for villages 11, 12 and 24 are reported in Table 1. Results from Table 1 indicate that different variables were significant to rice production in the different villages. As well, the size of the coefficients varied greatly between each village. However, there were sufficient similarities between the coefficients of villages 11 and 12 to enable the information from these two villages to be pooled at the 1 per cent level of significance. Villages 11 and 12 are from similar agroclimatic zones (Zone C) as classified by Oldeman (1987).

Crop area was a significant variable explaining variations in rice production between farmers within each village. Preharvest labour was a positive significant variable for farmers from village 11. Animal power and urea were positive significant variables for farmers from villages 12 and 24. TSP was not a significant variable for production in any village and farmers in village 12 did not use any TSP. The dummy variable for season was a significant, negative variable for villages 11 and 24. This implies that the yield from the dry season crop was lower than the yield from the wet season crop.

The results of panel data analysis for village 24 are reported in Table 2. The results showed that the area (preharvest labour variable was omitted) coefficient was a significant variable in explaining the variation in rice production between farmers in this village. From F tests ~~the null~~ hypothesis that farm dummies can be pooled across a village was accepted at the 5 per cent level of significance. This result suggests that farmers within this village are operating at similar input-response levels.

TABLE 1: Linear Production Functions of Rice for the Year 1983/84 in 3 Villages of East Java.

	Village 11	Village 12	Village 24
constant	-668.720** (209.4)	-144.39 (157.4)	447.994** (174.1)
Dummy for Season D1=1 for the dry season	-648.246** (281.3)	32.71 (153.5)	-375.46* (208.2)
Area (ha)	4643.48** (719.6)	2689.83** (405.1)	1179.14** (388.5)
Preharvest Labour (hr)	1.712* (0.884)	-0.056 (0.4684)	-
Animal (hr)	-1.863 (3.174)	15.697* (8.185)	1.928** (0.976)
Urea (kg)	0.996 (2.437)	3.[illegible]19** (1.3[illegible]9)	3.85** (1.215)
TSP (kg)	1.195 (3.673)	-	1.09 (2.374)
adj R^2	0.95	0.89	0.70
F statistic	129.01**	71.77**	21.14**
Durbin-Watson statistic	2.103	2.538	2.36
Breusch-Pagan 'Q' statistic	0.83	10.82	5.23
$\chi^2_{0.05}$ (p-1)	12.59	11.07	11.07
No of obs.	44	45	44

standard errors in parentheses
** significant at the 5 per cent level
* significant at the 10 per cent level
The quantity $Q = ESS/2$ is, under the null hypothesis, asymptotically distributed as χ^2 (p-1). Thus if $Q > \chi^2_{0.05}$ (p-1) one would reject the null hypothesis of homoscedasticity at the 5 per cent level.

TABLE 2: Linear Production Function for Village 24 in East Java for the Wet Seasons of 1983/84 and 1984/85

	Coefficient	standard error
Area	2339.960*	796.5
Animal (hr)	0.869	1.44
Urea (kg)	2.39	1.87
TSP (kg)	2.36	3.65
Number of farms	28	
adj R^2	0.76	
Significance of regression	F(31,24)=6.78**	$F_{0.05}$=1.94
Analysis of Covariance	F(27,24)=1.25	$F_{0.05}$=1.94

** significant at the 5 per cent level

The estimates for village 24 shown in Table 2 is for two seasons, hence the size of the coefficient for the area variable is greater than that shown in Table 1. This can be due to the higher yield obtained in the wet season of 1984/85 (4231 kg/ha) as compared to the yield of the wet season of 1983/84 (3639 kg/ha).

5.2 WEST JAVA ANALYSIS

Results of the Breusch-Pagan test confirmed the presence of heteroscedastic errors in the data set of village 15. Observation of the correlation matrix and Klein's test showed that for village 11, urea and TSP were highly correlated, with a correlation coefficient of 0.99 and evidence of multicollinearity. By excluding TSP from the regression of model (2) the effects of multicollinearity were reduced, and the coefficient for urea then explains the effects of both urea and TSP in the rice production process (Koutsoyiannis, 1978, p.236). The OLS estimates of the parameters of model (2) for villages 9, 11, and 14 are reported in Table 3.

From F-tests it was shown that the slopes of the linear production surfaces for villages 9, 11 and 14 were not significantly different. In other words, there were sufficient similarities between the marginal products of this particular bundle of inputs across these three villages to enable observations from these villages to be pooled. These three villages were in the same agroclimatic zones (Zone B) as classified by Oldeman (1987). The pooled linear production function of villages 9, 11 and 14 is given in Table 4.

TABLE 3: Linear Production Function of Sampled Rice Farms

for Villages of West Java for the year 1983/84

	Village 9	Village 11	Village 14
Constant	-654.39 (447.4)	-613.42** (237.4)	-69.73 (129.4)
Area (ha)	882.65 (1425)	3,438.39** (1157)	7,300.03** (1436)
Labour (hr)	0.30 (0.548)	0.16 (0.128)	0.48* (0.283)
Animal (hr)	23.64** (9.22)	11.05** (3.45)	-4.77 (7.82)
Urea (kg)	10.59** (4.35)	7.68** (2.41)	0.35 (2.10)
TSP (kg)	5.55 (4.71)	-	1.52 (2.90)
adj R^2	0.87	0.98	0.94
F statistic	39.15**	470.14**	100.87**
Durbin-Watson statistic	2.57	1.70	2.34
Breusch-Pagan 'Q'	2.78	0.61	7.44
Critical Value $\chi^2_{0.05}$ (p-1)	11.07	9.48	11.07
No. of Farms	29	25	31

standard error in parentheses
**significant at the 5 per cent
*significant at the 10 per cent
The quantity $Q = ESS/2$ is, under the null hypothesis, asymptotically distributed as χ^2 (p-1). Thus if $Q > \chi^2_{0.05}$ (p-1) one would reject the null hypothesis of homoscedasticity at the 5 per cent level.

TABLE 4: Linear Production Functions of Annual Rice Production of Pooled Data of Villages 9, 11 and 14 in West Java

	Coefficent	standard error
constant	-102.48	186.0
Dummy 1 (village 11)	-645.57**	257.5
Dummy 2 (village 14)	362.82*	207.3
Area (ha)	2765.92**	751.2
Labour (hr)	0.14	0.11
Animal (hr)	10.39**	2.15
Urea (kg)	8.30**	2.10
TSP (kg)	3.56	2.82
adj R^2	0.97	
Durbin Watson	2.48	
F statistic	356.33**	
Number of farms	85	

** significant at the 5 per cent level

* significant at the 10 per cent level

From Table 4 it can be seen that the important significant variables to rice production in these villages were area, animal hours and urea. The marginal product of an extra hectare of land in these villages was 2766 kg of rice, an extra hour of draught animal power had a marginal product of 10 kg of rice, and an extra kilogram of urea added 8 kg of rice.

5.3 FRONTIER ANALYSIS

For each village the OLS estimates were not significantly different from the MLE of the frontier regression. Thus, for all the villages analysed all the sampled farmers within any one village were operating at production levels which were equal to, or insignificantly away from, the levels of technical efficiency implied by the estimated frontier production function for each village.

For the pooled samples (villages 11 and 12 in East Java) and (villages 9, 11 and 14 in West Java) the OLS estimates were not significantly different from the MLE of the frontier regression. These results would imply that farmers within these pooled samples were technically efficient.

6. DISCUSSION

In this study production of rice from one year was analysed. Rice production is the only output considered. Output in this study was measured in terms of quantity and not quality. Technical efficiency is assessed only in terms of the conversion of a selected bundle of measurable inputs to output. That is, there are inputs such as management, fixed and working capital, rainfall and applied water which are not included in the analysis. These inputs affect output and conclusions regarding technical efficiency of production must be circumscribed. If management is a factor which contributes to output, and it is not included in some way in the estimated production function, then the marginal productivity attributed to the factors which are included will be higher than is truly the case. Whilst farmers may be technically efficient or inefficient with this bundle of measurable inputs, they may or may not be efficient in the use of the other factors involved in production, but which are not included in the estimated production function. More complete analysis would require a more detailed specification of the inputs used, outputs produced, and operation of each farm than has been possible from the data source (PATANAS)[4] which was used.

The findings of technical efficiency in rice production by farmers within villages or within the same agroclimatic zones of either East or West Java derives from finding that no significant variation existed between the sampled farmers in their use of the selected bundle of resources for the production of rice. Importantly, and in contrast to Siregar's (1987) finding, the results obtained here were from a mixture of farmers: some who were participating, and others who were not participating in the BIMAS programs conducted out in each village. An implication of the finding is that farm size did not prevent farmers from achieving technically efficient production. Farm sizes in the study ranged from 0.02 hectares to 2.7 hectares and the average being 0.34 hectares. Land size, however, was the dominant variable when it came to increasing total output. One possible reason for all farmers being technically efficient producers of rice may be that farm sizes are small enough, relative to the supply of key inputs, to enable all the necessary tasks to be done sufficiently well and on time, to achieve maximum levels of output. Another reason could be that timeliness of operation is not sufficiently critical relative to available resources, to prevent all farmers from 'getting it right' and growing a good crop. As well, the findings of technical efficiency, if valid, also might imply that all farmers are able to get command over sufficient resources of various substitutable types, despite the reality

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[4] This is being attempted through an intensive study of a sample of farmers in each of two other villages in *kabupaten* Subang in West Java (see Basuno and Perkins, 1988).

that farmers differ in their access to credit for working capital, have differences in their access to, and types of, services of fixed capital.

However, our finding of technical efficiency may be incorrect because some of these above-mentioned factors are not included in the analysis. That is, the observed technical efficieny might be due to failure to account for the effects of the fixed inputs to production. Also, our finding could be the result of statistical aberrations including our choice of a linear function and omitted variables.

7. CONCLUDING COMMENTS

Results from this study suggests that variation in rice output between farms in these Indonesian villages is due to random disturbances rather than technical inefficiency. This result stands in contrast to Siregar's earlier finding for West Java and studies in other rice-producing countries. The finding of technical efficiency in production using this technique is not unique. Aigner et al. (1977) attained a similar result for gross agricultural output per farm in the US and also for the US primary metal industry.

The second main finding was that for each village different variables explained the variation in rice yields amongst farmers and the sizes of the coefficients were also different. However, F tests confirmed that, the slopes of response functions across different villages within East or West Java could be pooled when villages were in the same agroclimatic zones. Unfortunately, the possibility of pooling information of similar agroclimatic zones across East and West Java was not tested because the input-matrices for East and West Java were different.

If producers of rice in these villages are technically efficient, and if the technology is being correctly and appropriately applied, than there is not much scope for increasing the level of production with this given level of technology. There may, of course, be scope to increase output by introducing new technology into the existing farming system, and this knowledge can come about through research. A relevant question might be, does this analysis indicate areas on which technical research ought to focus? Some inputs have been shown to be significant to rice production, namely, land, labour and/or animal power and fertilizers. While it cannot be assumed that these inputs will be significant on some improved production function, these inputs would seem to offer some guide to areas in which technological development might have promise for shifting the production function upwards. In this regard work on draught power could offer some promise of rewards to research, but given the importance of other inputs, particularly land, it is doubtful if the rewards to concentrating on animal power alone can be great.

Finally, what can be said about agricultural development from the standpoint of this investigation? The agricultural environments of Indonesia are many and varied leading to a diversity of farming systems and input-output responses. In such circumstances allocating government research and extension efforts to the right tasks in the right places is difficult. The techniques used in this study offer an opportunity to improve decision making within and between such agencies. Thus we note that villages of the same agro-climatic zones were operating at similar response surfaces. Thus, if our results is correct, there could be a lower priority on technical extension within these villages relative to the northern coastal plain - if Siregar's result is correct. Neither study can be definitive about the allocation of biological research effort or economic extension services aimed at improving allocative efficiency. It is, however, a useful starting point to know if farmers are technically efficient in the use of current technology.

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