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ALLOCATIVE EFFICIENCY AND SUPPLY RESPONSE IN IRRIGATED RICE PRODUCTION

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ECONOMIC EFFICIENCY

In a recent article in this Journal, Sampath (18)† discussed the components of economic efficiency (*i.e.*, price or allocative and technical efficiency) and reviewed the limitations of conventional production function approaches when examining economic efficiency in agriculture. As an alternative, he clearly demonstrated how linear programming techniques may be gainfully applied to compare the economic efficiency of multi-product farm firms, and to explore the causes of differences in performance between groups. The analysis presented was derived from a Farm Management Survey Report for Deoria district of Uttar Pradesh State for 1967-68.

In many situations, researchers may focus on a single crop, or be concerned with farming systems where one crop dominates cropping patterns in a particular season (*e.g.*, rice in the *kharif* or wheat in the *rabi* season). Under such circumstances, the linear programming approach may be less advantageous and models based on variants of the production function techniques continue to have appeal. For example, maximum likelihood procedures have been effectively used to estimate frontier production functions to examine issues of technical efficiency in agriculture (1, 3, 12). However, as pointed out by Lau and Yotopoulos (14), this approach is not well suited to examine questions related to allocative efficiency. Allocative (*i.e.*, price) efficiency cannot be directly measured through production function analysis because prices are not incorporated as exogenous variables, nor does the approach allow for different groups of farms having different endowments of fixed factors (18, p. 20). These limitations can be avoided if profit function analysis is used (14, 22, 24). The method has the added advantage in that input demand and output supply elasticities can be estimated directly from the profit function (14).

The purpose of this paper is to explore the allocative efficiency and supply response of farmers producing modern varieties of rice in the *kharif* season in the irrigated rice of Coimbatore district, Tamil Nadu. The approach used is profit function analysis. One of the rice varieties examined is an *exotic modern variety* (EMV), IR20, bred and named by the International Rice Research Institute (IRRI) in the Philippines in 1969 and released by the All-India Co-ordinated Rice Improvement Project (AICRIP) in the district in 1971. IR20 is moderately resistant to tungro virus and its vector, the green leaf-hopper. We termed other group of rices, ADT-31 and CO-37 the *locally-bred varieties* (LBV). The LBVs are particularly adapted to the area as they were bred at the Aduthurai and Coimbatore Paddy Breeding Stations

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† Figures in brackets denote references cited at the end of the paper.

and selected in particular for their resistance to brown planthopper (BPH), an insect indigenous to southern India, and more recently, of considerable economic importance in Asia (10). ADT-31 was released in 1975, and CO-37, commonly called *Vaigai* in 1974.

The data used in this study were drawn from a larger intensive farm management survey conducted from May 1977 to April 1978 (12). Particular attention was given during the survey to collect farmer-specific prices, and indeed, as necessary in profit function analysis, differences were found in the prices paid and received by different survey participants. These price differences do not imply that competitive markets do not exist in the area or that there were major impediments in the functioning of factor and product markets. Rather, as discussed by Kalirajan (12), the differences in rice and input prices between farmers were largely due to the differences in transport costs to market and to some extent by price movements brought about by the seasonality of demand and supply for goods and services.[1]

THE PROFIT FUNCTION APPROACH

The assumptions inherent in the profit function approach are (11, 14, 25):

(*a*) firms seek to maximize profits;

(*b*) firms are price-takers with respect to prices received for output and prices paid for inputs;

(*c*) the production function which underlies the profit function is concave in variable inputs.

The first of these assumptions, in particular, is tested in the following section. If the underlying production can be represented by a Cobb-Douglas form,[2] then the restricted profit function will be (8, p. 13):

$$\ln \Pi^* = \ln A^* + \sum_{i=1}^{n} \beta_i^* \ln P_i + \sum_{j=1}^{m} \gamma_j^* \ln Z_j \qquad \ldots.(1)$$

where

Π^* is normalized restricted profit;

A^* is a neutral shift parameter for the sampled farms;

P_i are the normalized prices of inputs variable in the production process; and

Z_j are factors fixed in the production process.

The specific form of the productiin function used in the present analysis was:

$$\log \Pi^* = \log A^* + \beta_1^* \ln W + \beta_2^* \ln F + \beta_3^* \ln P + \beta_4^* \ln B + \gamma_1^* \ln L + \gamma_2^* \ln C \qquad \ldots.(2)$$

where

Π^* is restricted profit (current revenue less current variable costs) from the rice crop, normalized by the price received per kg. of paddy;

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[1] Price and Barker (17) similarly found that real agricultural wages varied markedly over the year in response to fluctuating demand for hired labour.

[2] The Cobb-Douglas form was used because of its simplicity and for the ease with which elasticities can be estimated. While others (*e.g.*, 14, 21, 24) have also used this functional form with success, its limitations must also be clearly recognized (2).

W is the wage per day normalized by the price of paddy;
F is the price of fertilizer per kg. normalized by the price of paddy;
P is the price of pesticide per kg. normalized by the price of paddy;
B is the normalized cost per bullock day estimated in a similar manner as W, F and P above;
L is the area grown to rice in acres;
C is the capital flow calculated as the sum of depreciation, maintenance and opportunity cost of capital stock.[3]

The restricted profit function defined by equation (2) is in terms of exogenous variables: normalized (or real) prices and fixed factors of production, and as such, does not enable the associated levels of variable inputs, x_i, to be derived. The levels of variable inputs are estimated from the implied factor demand functions which are derived by differentiating the normalized restricted profit functions with respect to the normalized price for that factor by using Sheppard's Lemma (8, 20, 25).

For the logarithmic profit function specified by equation (2), the variable factor demand functions are estimated as (8, p. 13):

$$\begin{array}{ll} \text{for labour} & \frac{-Wx_1}{\Pi^*}=\beta_1^* \\ \text{fertilizer} & \frac{-Fx_2}{\Pi^*}=\beta_2^* \\ \text{pesticides} & \frac{-Px_3}{\Pi^*}=\beta_3^* \\ \text{bullocks} & \frac{-Bx_4}{\Pi^*}=\beta_4^* \end{array} \qquad \ldots.(3)$$

where

x_1 is the total number of man-days used;
x_2 is the total chemical fertilizer used, in kg.;
x_3 is the total pesticide use, in kg.;
x_4 is the total bullock pair days

applied to the rice crop.

The restricted profit function [equation (2)] and the factor demand functions [equation (3)] were empirically estimated from the farm survey data for the *kharif* rice crops. Since β_i^* appears in both functions the two sets of equations are estimated jointly by imposing the condition that the β_i^*'s are equal in both the profit and relevant factor demand function. The restricted Aitken estimation model proposed by Zellner (26) and elaborated by Byron (4) was used to simultaneously estimate the parameters of equations (2) and (3).[4]

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[3] Depreciation was calculated by the straight line method and opportunity costs were derived by multiplying the stock by 12 per cent, the lending rate of the local co-operative societies in the district at the time of the survey. Junankar (11) discusses a number of issues involved when estimating the normalized prices of variable inputs and when calculating the cost of capital.

[4] Unlike the approach used by Lau and Yotopoulos (14), this formulation of the restricted Aitken estimators has the advantage of estimating the Lagrange multipliers, λ_i (together with their standard errors) for each restriction imposed on the model. Thus, the significance of λ_i so derived can be tested, and the equality of the β_i^* between the equations evaluated.

EMPIRICAL RESULTS

The mean levels of resources used by the sample farmers to produce the *kharif* rice crop in Coimbatore district irrigated area in 1977 are shown in Table I. Of the 91 sample farmers, 50 grew the LBV and 41 the EMV; both groups of farmers were found to use similar levels of productive inputs. In each case, the mean level of fertilizer applied was greater than the recommended level of 40-20-20 kg./hectare of N-P-K for *kharif* season rice, but the levels of insecticides applied were consistent with extension recommendations (13). The average yield of the LBV, however, was 0.8 ton higher than for the EMV, significant at the one per cent level. Thus, with similar levels of productive inputs, farmers growing the more recently released LBVs appeared to be realising higher crop yields.

TABLE I—MEAN INPUT LEVELS APPLIED TO EXOTIC MODERN VARIETY (EMV) AND LOCALLY-BRED VARIETY (LBV), COIMBATORE IRRIGATED AREA, KHARIF SEASON, 1977

Input	Variety		t-value[a]
	EMV	LBV	
Labour (man-days)	209	181	1·83ns
Pesticides (Rs./acre)	119	112	0·61ns
Fertilizers			
N (kg./acre)	46	50	0·66ns
P (kg./acre)	23	21	1·27ns
K (kg./acre)	21	21	0·44ns
Seed (Rs./acre)	53	55	1·12ns
Other inputs (Rs./acre)	264	279	0·90ns
Yield (tons/acre)	1·57	2·37	9·56**
Sample size (Number)	41	50	

a. To test for differences between means.
** Significant at 1 per cent level.
ns=Not significant.

Table II shows the parameter estimates for the normalized profit functions. As the acceptability of a profit maximizing objective is subject to debate (*e.g.*, 5, 11, 15 vs. 9, 19) an examination of the acceptability of the assumption in the present situation is appropriate before proceeding with the interpretation of the results. Lau and Yotopoulos (14, p. 15) show that this assumption can be examined by determining if the elasticities of the variable inputs are equivalent when derived from the profit function and from the corresponding factor demand function. The hypothesis implied by this assumption is directly examined by testing if the Lagrange multipliers for the equality constraints are significantly different from zero. If they are, the assumption of profit maximization, relative to that input, is rejected.

TABLE II—JOINTLY ESTIMATED PARAMETERS OF NORMALIZED PROFIT FUNCTION AND VARIABLE FACTOR DEMAND FUNCTIONS FOR RICE, COIMBATORE, KHARIF 1977

Variable	Parameter	Estimated values, restricted GLS[a]	
		EMV	LBV
Profit function—equation 1			
Constant	lnA*	6·5316**	6·8003**
		(1·3723)	(1·3102)
N labour wage[b]	β_1^*	—0·5715†	—0·4583**
		(0·2901)	(0·1149)
N fertilizer price	β_2^*	—1·2019†	—0·7735**
		(0·6290)	(0·1971)
N pesticide price	β_3^*	—0·0672ns	—0·0613**
		(0·0491)	(0·0278)
N bullock price	β_4^*	—0·1210ns	—0·0667**
		(0·0886)	(0·0303)
Land	γ_1^*	0·9518**	0·9301**
		(0·1462)	(0·0113)
Capital	γ_2^*	0·0501*	0·0604*
		(0·0235)	(0·0263)
Factor demand functions—equation 2[c]			
Labour	β_1^*	—0·5715†	—0·4583**
		(0·2901)	(0·1149)
	λ_1	0·4638ns	1·6659ns
		(0·3437)	(1·3485)
Fertilizer	β_2^*	—1·2019†	—0·7735
		(0·6290)	(0·1971)
	λ_2	1·7783ns	1·2047ns
		(1·4750)	(1·3857)
Pesticides	β_3^*	—0·0672ns	—0·0613**
		(0·0491)	(0·0278)
	λ_3	4·1499**	1·9275ns
		(0·8653)	(1·5346)
Bullocks	β_4^*	—0·1210ns	0·0667**
		(0·0886)	(0·0303)
	λ_4	0·3543ns	1·8595ns
		(0·4786)	(1·7902)

a. Figures in parentheses are standard errors of estimates.

* Significant at 5 per cent level; ** Significant at 1 per cent level; † Significant at 10 per cent level; ns=Not significant.

b. N represents normalized price, *i.e.*, $P_i^* = \frac{P_i}{P_y}$.

c. The Lagrange multipliers are related to the restriction that β_i^*'s are equal when derived from the profit and factor demand equations.

In the case of the LBVs, none of the Lagrange multipliers, λ_i, are significant (Table II). Thus, the hypothesis that farmers growing LBVs attempt to maximize profit cannot be rejected. By implication, farmers growing LBV are judged to be allocatively efficient. But in the case of EMVs, the Lagrange multiplier for the pesticide (λ_3) is significantly different from zero, implying that farmers were not equating the marginal value product and marginal cost of pesticides with IR20.[5] In the case of other variable inputs, farmers appear allocatively efficient for the EMV.

By implication, the assumption that the sample farmers in the irrigated area of Coimbatore district are profit maximizers with respect to their *kharif* rice crop does not appear unduly restrictive. Among the reasons for accepting that profit maximization is a reasonable proxy for utility maximization in this case (which implies, *inter alia*, that risk considerations may not be of dominant importance) is that the district is regarded as one of India's most progressive and favourable rice-growing areas (16). Factors that contribute to this position include the area's assured and well-controlled supply of irrigation water for two rice crops a year, a low risk climate (*i.e.*, a lack of hazard due to typhoons, droughts or floods), and an active co-operative movement that distributes production inputs. In aggregate, these factors tend to minimize production risk. Likewise, price risk is minimal; farmers have a ready market for paddy because the region is a substantial rice importer (12, 16). In consequence, for decision-making purposes, farmers' price expectations are reasonably based on market prices, and the costs of marketing and transport are well established and widely known. Thus, the price coefficient was accepted as a proxy of 'price responsiveness' of the sampled farmers.

The intercept terms of the normalized profit functions (log A*) indicate similar technical efficiency of the EMV and LBV producers.[6] The sums of the elasticities of the fixed factors (land and capital) indicate that constant returns to scale prevail in both cases. Of more interest, however, are the output supply and factor demand elasticities derived from Table II and reported in Table III.

The output elasticities show that rice supplies in the irrigated area of Coimbatore are quite sensitive to changes in rice prices, with the EMV (1.96) being somewhat more price elastic than the LBV (1.32). The farmers' demand for inputs, particularly for fertilizer and labour, are also sensitive to changes in rice prices, whereas the demand for pesticide and bullock inputs are less sensitive to price changes. The price elasticities (the diagonal elements) for the variable factors show that the demand for these inputs are price elastic. Of the variable inputs, the demand elasticities for fertilizer

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[5] The differences in pest management efficiency between the LBV and EMV is probably due to the latter crop's comparative susceptibility to BPH. Thus, while the farmer's control of BPH is effective in the case of the less resistant EMV, whose later maturity also coincides with the natural build-up of the pest in the wet season (13).

[6] Readers will appreciate that the concept of allocative efficiency used in the profit function model differs from Farrell's (7) in the sense that a farmer can still be allocatively efficient, given his production function, which may not be the most technically efficient technology of production.

TABLE III—OWN AND CROSS-PRICE ELASTICITIES OF VARIABLE INPUTS AND ELASTICITIES WITH RESPECT TO FIXED INPUTS IN RICE PRODUCTION, COIMBATORE, KHARIF SEASON, 1977*

Input	Price of rice	Normalized price of Labour	Fertilizer	Pesticide	Bullocks	Fixed Land	Capital
(*a*) Exotic modern variety							
Rice response ..	1·96	−0·57	−1·20	−0·07	−0·12	0·95	0·05
Labour	2·96	−1·57	−1·20	−0·07	−0·12	0·95	0·05
Fertilizer	2·96	−0·57	−2·20	−0·07	−0·12	0·95	0·05
Pesticides	2·96	−0·57	−1·20	−1·07	−0·12	0·95	0·05
Bullocks	2·96	−0·57	−1·20	−0·07	−1·12	0·95	0·05
(*b*) Locally-bred variety							
Rice response ..	1·32	−0·46	−0·73	−0·06	−0·07	0·93	0·06
Labour	2·32	−1·46	−0·73	−0·06	−0·07	0·93	0·06
Fertilizer	2·32	−0·46	−1·73	−0·06	−0·07	0·93	0·06
Pesticides	2·32	−0·46	−0·73	−1·06	−0·07	0·93	0·06
Bullocks	2·32	−0·46	−0·73	−0·06	−1·07	0·93	0·06

* Lau and Yotopoulos (12, pp. 15-16) show how these elasticities are derived from the restricted profit function. The nature of the Cobb-Douglas profit functions results in the equality of the cross-price elasticities for each input.

TABLE IV—INDIRECT ESTIMATES OF THE INPUT ELASTICITIES OF THE RICE PRODUCTION FUNCTIONS, COIMBATORE, KHARIF SEASON, 1977

Factor	Indirect elasticities EMV	LBV
Labour	0·1930	0·1942
Fertilizer	0·4058	0·3278
Pesticides	0·0227	0·0260
Bullock power	0·0409	0·0283
Land	0·3214	0·3941
Capital	0·0169	0·0256
Sum of elasticities	1·0007	0·9960

(1.7 and 2.2) and labour (1.5 and 1.6) are somewhat more price elastic than for pesticides and bullock power. The cross-price elasticities between the variable inputs are negative, implying that the variable inputs are complements as opposed to substitutes.

The supply elasticities for rice approach unity for land, but are small (less than 0.1) with respect to capital for both EMV and LBV. Thus, within the range of farm sizes studied, an increase in the irrigated area grown to paddy in the *kharif* season (allowing for adjustments in the levels of use of variable inputs) will, predictably, have a far greater impact on changes in farm profits than changes in capital intensity for a given farm size.

The partial regression coefficients in Table II also enable indirect estimates of the production elasticities of the underlying production function to be derived (24, p. 338). These are reported in Table IV for the EMV and LBV. The indirect production elasticities suggest that fertilizer is the most important input factor influencing changes in rice supply in the Coimbatore irrigated area, followed by land and labour. Bullocks, capital, and pesticides have low production elasticities in these irrigated rice production systems.

SUMMARY AND CONCLUSIONS

Profit function and the associated factor demand schedules were fitted to a sample of farms producing EMV and LBV in the irrigated area of Coimbatore district of the 1977 *kharif* season. The analysis suggests that both groups of producers exhibited similar levels of technical efficiency. Furthermore, the growers of the LBV appear to be allocatively efficient given the variable factors of production included in the analysis. It was estimated that the producers of the EMV were not allocatively efficient with respect to pest management, largely because the variety was not as resistant as the LBV to the BPH found in the area. The producers of the EMV, however, were judged to be allocatively efficient with respect to the other variable inputs: labour, fertilizer and animal power.

The output responses to changing rice price were positive, significant, and greater than one—implying that farmers in the Coimbatore irrigated area at least are responsive to changes in rice prices. Similarly, output response was judged to be sensitive to changes in normalized input prices, with fertilizer and labour having high price elasticities, and pesticides and bullock power comparatively low price elasticities. Fertilizer, labour and land had high production elasticities, and pesticides, bullock power, and capital low elasticities. In each case, the EMV had higher response and production elasticities than the LBV.

The results have several implications. First, it appears that the selection of varieties specifically adapted to a location can contribute to farmers achieving higher levels of effectiveness in the use of particular inputs (in this case insecticides) (13). Second, farmers' supply responses for rice were sensitive to changes in the prices of rice, fertilizer, and (to a lesser extent) labour wages. As aptly pointed by Farmer, paddy farmers in this State are particularly price responsive "and generally more so than outside observers sometimes recognize" (6, p. 310). Third, the analysis provides positive evidence on the farmer's degree of responsiveness to price movements for rice production and input use, information needed in the formulation of effective price policies for this crop.

REFERENCES

1. D. J. Aigner, C. A. K. Lovell and P. Schmidt, "Formulation and Estimation of Stochastic Frontier Production Function Models," *Journal of Econometrics*, Vol. 6, No. 1, January 1977.
2. J. R. Anderson and N. S. Jodha, "On Cobb-Douglas and Related Myths", *Economic and Political Weekly*, Vol. VIII, No. 26, June 30, 1973.
3. G. E. Battese and G. S. Corra, "Estimation of a Production Frontier Model: with Application to the Pastoral Zone of Eastern Australia", *Australian Journal of Agricultural Economics*, Vol. 21, No. 3, December 1977.
4. R. P. Byron, "The Restricted Aitken Estimation of Sets of Demand Relations," *Econometrica*, Vol. 38, No. 6, December 1970.
5. J. L. Dillon and J. R. Anderson, "Allocative Efficiency, Traditional Agriculture and Risk", *American Journal of Agricultural Economics*, Vol. 53, No. 1, February 1971.
6. B. H. Farmer, "The 'Green Revolution' in South Asian Rice-fields: Environment and Production", *The Journal of Development Studies*, Vol. 15, No. 4, July 1979.
7. M. J. Farrell, "The Measurement of Productive Efficiency," *Journal of the Royal Statistical Society*, Series A General, Vol. 120, No. 3, 1957.
8. M. Fuss and D. L. McFadden: Production Economics: A Dual Approach to Theory and Application, North-Holland Publishing Company, Amsterdam, 1978.
9. G. K. Helleiner, "Smallholder Decision Making: Tropical African Experience", in L. G. Reynolds (Ed.): Agriculture in Development Theory, Yale University Press, New Haven, 1975.
10. IRRI: Brown Planthopper: Threat to Rice Production in Asia, Los Banos, Philippines, 1979.
11. P. N. Junankar, "Tests of the Profit Maximization Hypothesis: A Study of Indian Agriculture", *The Journal of Development Studies*, Vol. 16, No. 2, 1980.
12. K. P. Kalirajan: An Analysis of the Performance of the High-Yielding Varieties Programme for Paddy in Coimbatore District, Tamil Nadu, India, Unpublished Ph. D. Dissertation, Australian National University, Canberra, 1979.
13. K. P. Kalirajan and R. T. Shand, "Location Specific Research in the Development of the New Agricultural Technology in India", paper presented at the 23rd Annual Meeting of the Australian Agricultural Economics Society, Canberra, February 1979.
14. L. J. Lau and P. A. Yotopoulos, "Profit, Supply and Factor Demand Functions", *American Journal of Agricultural Economics*, Vol. 54, No. 1, February 1972.
15. M. Lipton, "The Theory of the Optimizing Peasant", *The Journal of Development Studies*, Vol. 4, No. 3, 1968.
16. Programme Evaluation Organisation—Australian National University: The High Yielding Varieties Programme in India 1970-1975, Government of the India, New Delhi, 1977.
17. E. C. Price and R. Barker, "Time Distribution of Crop Labor", *The Philipppine Economic Journal*, Vol. 17, Nos. 1 & 2, 1978.
18. R. K. Sampath, "Nature and Measurement of Economic Efficiency in Indian Agriculture", *Indian Journal of Agricultural Economics*, Vol. XXXIV, No. 2, April-June 1979.
19. T. W. Schultz: Transforming Traditional Agriculture, Yale University Press, New Haven, 1964.
20. F. W. Sheppard: Cost and Production Functions, Princeton University Press, Princeton, 1953.
21. S. S. Sidhu, "Relative Efficiency in Wheat Production in the Indian Punjab", *The American Economic Review*, Vol. LXIV, No. 4, September 1974.
22. S. S. Sidhu and C. A. Baanante, "Farm-level Fertilizer Demand for Mexican Wheat Varieties in the Indian Punjab", *American Journal of Agricultural Economics*, Vol. 61, No. 3, August 1979.
23. P. A. Yotopoulos, "Rationality, Efficiency and Organizational Behaviour through the Production Function, Darkly", *Food Research Institute Studies*, Vol. XIII, No. 3, 1974.
24. P. A. Yotopoulos, L. J. Lau and W. L. Lim, "Microeconomic Output Supply and Factor Demand Functions in the Agriculture of the Province of Taiwan", *American Journal of Agricultural Economics*, Vol. 58, No. 2, May 1976.
25. P. A. Yotopoulos and J. B. Nugent: Economics of Development: Empirical Investigations, Harper and Row, New York, 1976.
26. A. Zellner, "An Efficient Method for Estimating Seemingly Unrelated Regressions and Tests for Aggregation Bias", *Journal of American Statistical Association*, Vol. 57, No. 2, June 1962.