Bangladesh J. Agric. Econs. XVII, I and 2 (1994) : 17-29

PROFIT EFFICIENCY AMONG RICE PRODUCERS IN NORTHEAST AND NORTHERN THAILAND

Sanzidur Rahman

ABSTRACT

Farm-specific profit inefficiency among Khao Dawk Mali and glutinous rice producers was estimated from a stochastic profit frontier. The mean level of farm inefficiency, given farm-specific prices and level of fixed factors, was estimated at 32% (with range 33%-92%) for Khao Dawk Mali and 20% (with range 50%-93%) for glutinous rice, respectively. The average loss of profit per ha is estimated at Baht 3,858 for Khao Dawk Mali and Baht 2,702 for glutinous rice, respectively. A 25% reduction in the estimated profit loss among Khao Dawk Mali rice producers would generate about Baht 293 million additional profit each season.

I. INTRODUCTION

Rice is the most important food crop in terms of planted area, value of production as well as source of foreign exchange earnings in Thailand. Over the last two decades the Thai agriculture grew at the remarkable rate of 4.5 percent per year (Puapanichya and Panayotou, 1985). However, most of this growth was accomplished through expansion of planted area with little contribution from increase in productivity. The productivity records show that for the period 1907-1990, the rice yield level fluctuated within 1.32 to 2.02 mt per ha and is among lowest in the world (Barker et al., 1985 and BAAC, 1992).

Thailand is self-sufficient in food and a major rice exporter in the world. But fierce competition in world rice market for low quality rice raised concerns on the future of rice production in Thailand for its increasing wages and production cost and its exporting competitor's lower cost of producton. Thailand has a comparative advantage in the world market for Khao Dawk Mali rice (a non-glutinous fragrant variety) with only USA and Pakistan as the competitor (Rahman, 1993). However, in recent years, competition is increasing in this thin world market for high quality rice as well.

Khao Dawk Mali is grown mainly in the wet season and constituted 18.4 percent of all rice areas for the year 1990/9 1. During the past decade (1980 to 1990), Khao Dawk Mali

The author is a Senior Staff Economist, Research and Evaluation Division, BRAC, Dhaka, Bangladesh. The data for the study has been generated during the author's graduate studies at Multiple Cropping Centre (MCC), Chiang Mai University, Thailand, under the project titled "Study of Expansion Potential of High Quality Rice Variety for the Replacement of Low Quality Modern Varieties in Thailand". The present study is an extension of the author's Masters dissertation. The author gratefully acknowledges the contribution of Dr. Songsak Sriboonchitta and Dr. Aree Wiboonpongse of Chiang Mai University at various stages of research.

production grew at a remarkable rate of 16.13 percent per year in twelve major growing areas concentrated in the Northeast and Northern regions of Thailand, while during the same period, overall rice production grew at the rate of only 1.8 percent per year (BAAC, 1992). However, research efforts had not been able to raise the yield of Khao Dawk Mali without sacrificing the quality. Therefore, in the short run, the productivity of Khao Dawk Mali must be increased using the given technology to remain competitive in the world rice market.

This paper examines the level of profit efficiency of Khao Dawk Mali rice vis-a-vis glutinous rice production, assuming that prices, fixed factors and environmental conditions among farms may vary. Glutinous rice (low quality modern variety, particularly RD6 variety) is the major crop grown in the wet season to fulfill domestic demand and also for export. As the production cost is rising, Thailand is losing its market share in the low quality rice market to new entrants, such as Vietnam, Laos, etc. Moreover, with the increase in the per capita income levels, Thai people are shifting towards consumption of high quality rice. Therefore, inproving efficiency in producing low-quality modern rice is also a major concern for Thailand.

II. MEASURING EFFICIENCY AND THE MODEL

Efficiency measurement has long been a subject of study for economists. From an applied perspective, efficiency measurement is important as this is the first step in identifying process for resource savings and increasing productivity, and hence is of great interest for the policy planners. For an individual producer, efficiency in farming would increase income and, therefore, one is more likely to stand better chance of survival in this competitive world.

Current interest inefficiency measurements follows from the pioneering work of M. J. Farrell some forty years ago. Farrell (1957) distinguishes between technical and allocative efficiency. Technical efficiency refers to the ability to produce a given level of output with the minimum quantity of inputs under a given technology. Allocative efficiency refers to the choice of the optimal input combinations given relative input prices. The economic efficiency or total efficiency is the product of technical and allocative efficiency. Farrell's model known as the deterministic nonparametric frontier, attributes any deviation from the frontier as inefficiency and assumes no functional form on the data. The major deficiency in Farrell's and all other deterministic models is their sensitivity to extreme observations (Bravo-Ureta and Rieger, 1991). However, the problem of extreme observations has been ameliorated by recent developments in efficiency measurements using the stochastic frontier model developed by Aigner, Lovell and Schmidt (1977). The stochastic frontier model assumes an error term with two additive components - a symmetric component accounting for pure random factors and a one -sided component which capture the effects of inefficiency relative to the stochastic frontier. An extension by Jondrow et al (1982) demonstrated the derivation of individual firm efficiency measures from stochastic frontiers.

In practice, efficiency is usually estimated by separately estimating technical and allocative efficiency from a production frontier using farm level data. Ali and Flinn (1989) argued that, a production function approach may not be appropriate in estimating economic efficiency of individual farms because they may face different prices and factor endowments. As a result, they have different best-practice production functions and thus different optimal operating points. Lau and Yotopoulus (1972) developed and popularized the use of profit function in estimating efficiency by incorporating farm-specific prices and level of fixed factors. However, their model allows to test only average measure of efficiency. Ali and Flinn (1989) showed a measure of farm-specific efficiency by using frontier profit function which is adapted in this study.

Specification of the Model

Profit efficiency is defined as the ability of a farm to achieve highest possible profit, given the prices and levels of fixed factors of that firm. Profit inefficiency in this context is defined as loss of profit from not operating on the profit frontier given price and fixed factor levels (Ali and Flinn, 1989).

The stochastic profit function is defined as,

$$S = f(P, Z, D; \beta) \exp \epsilon, \quad \epsilon = v - u \qquad (1)$$

where S is normalized profit of each farm defined as gross revenue less variable cost, normalized by farm-specific rice price.

P is the vector of the price of variable input faced by each farm normalized by the rice price,

Z is the vector of level of fixed factors on each farm;

D is the vector of the dummy variables for location of each farm,

β is the vector of the parameters to be estimated,

ϵ is an error term where v is a two-sided error term representing the random effects, and $u \geq 0$ is a one-sided error term representing profit inefficiency.

Following Maddala (1977 and 1983), it is assumed that v_j is normally distributed, with $N(0,\sigma^2_v)$ and u_j is half-normally distributed,

$$f(u) = \frac{2}{\sqrt{2\pi}\sigma_u} \exp\left(-\frac{u^2}{2\sigma^2_u}\right) u \geq 0 \qquad (2)$$

which has the population mean and variance, (assuming u and v are independent),

$$E(u) = \sigma_u \sqrt{(2/\pi)}, \; V(u) = \sigma^2_u \frac{(\pi - 2)}{\pi} \qquad (3)$$

when a frontier function of the form of equation (1) is estimated, one can readily obtain residuals of $\epsilon_j = S_j - f(P_j, Z_j, D_j; \beta)$, which can be regarded as estimates of the error term ϵ_j. Jondrow et al. (1982) demonstrated that the expected value of farm-specific inefficiency u_j may be calculated through the following equation

$$E(u_j \mid \in_j) = \sigma^{2*} \frac{f(.)}{1 - F(.)} - \frac{(\in_j, \lambda)}{\sigma} \quad (4)$$

where $\sigma^{2*} = (\sigma^2_u \sigma^2_v) / \sigma^2$

$\lambda = \sigma_u / \sigma_v$

$\sigma^2 = \sigma^2_u + \sigma^2_v$

and f(.) and F(.) represent the standard normal density and cumulative distribution functions, respectively, estimated at $(\in_j\lambda/\sigma)$.

When the nature of the density functions for u and v is specified, the profit frontier with the given error structure defined by equation (1) is estimated using the maximum likelihood techniques (Aigner, Lovell and Schmidt, 1977). The variance estimates used to solve equation (4) are derived from the maximum likelihood estimates (MLE) of equation (1).

The Study Area

The study was conducted in Chiang Mai, Chiang Rai and Surin provinces of Thailand. The first two provinces lie in the northern region partly in the irrigated portion of the Chiang Mai Valley, where Khao Dawk Mali area has been expanding rapidly over the past decade. Also, the yeild levels of Khao Dawk Mali in Chiang Mai province showed a marked increase during the late 1980s. Surin province lies in the northeastern Thailand historically planted with Khao Dawk Mali mainly, but did not experience any change in yield levels over time.

A total of 559 farmers were randomly selected as respondents from some 30 villages in 10 districts of these three provinces — Chiang Mai province : 269 sample farmers (136 Khao Dawk Mali producers and 133 glutinous rice producers), Chiang Rai province : 159 sample farmers (84 Khao Dawk Mali producers and 75 glutinous rice producers), and Surin province : 131 Khao Dawk Mali producers. Data on these wet rice crops were collected for the crop year 1992.

III. RESULTS DISCUSSION

In this section the results are presented in terms of pofitability of Khao Dawk Mali and glutinous rice production, estimation of the profit function and extent of farm specific profit loss.

The Production Environment

The general socio-economic information of the sample farms are provided in Table 1. The mean level of land ownership as well as operation size is lowest in Chiang Mai and highest in Surin per farm. This is because, Chiang Mai city is the second largest metropolis in Thailand and the level of industrialization and urbanization are increasing rapidly resulting in higher land prices in the areas closer to the city.

Majority of the sample farmers were owner operators with high incidence of tenancy in the Chiang Mai area. The higher input prices in Chiang Mai indicates that farming is becoming very expensive and as such efficiency improvement becomes more crucial to remain competitive in crop production in this region.

Profitability of Rice Production

Table 2 presents the average cost and profitability of Khao Dawk Mali and glutinous rice production at farm specific prices for the crop year 1992. Profitability is highest in Chiang

Table 1. General socio-economic information of the sample farms in three provices of Thailand.

Attributes	Chiang Mai	Chiang Rai	Surin
Demographic			
Family size (persons)	4.03	4.60	5.02
Land ownership (ha/farm)			
Homestead area	0.14	0.13	0.19
Owned land	1.47	2.13	3.95
Size of rented-in land	0.71	0.13	0.64
Size of rented-out land	0.16	0.04	0.12
Operation size	2.05	2.29	4.32
Khao Dawk Mali	1.44	0.83	4.13
Glutinous rice	1.59	1.69	—
Tenancy (percent)			
Owner operator	51.67	93.70	80.91
Pure tenant/landless	19.44	—	6.11
part tenant	28.89	6.30	12.98
Prices			
Rice price (baht/kg)	3.78	3.94	4.15
Price of seed (baht/kg)	6.79	5.22	4.15
Wage rate (baht/day)	72.27	68.18	53.24
Tractor rate (baht/ha)	1339.88	832.63	568.75
Farming experience (years)			
Overall farming	24.69	28.69	30.89
Growing Khao Dawk Mali	8.68	11.79	15.55
Growing glutinous rice	6.53	24.94	—

Note : 1 US$ = 25 baht (approx.)

Table 2. Average cost and profitability at farm specific prices of rice production, 1992.

Variety/Province	Weight[a]	Yield (ton/ha)	Paddy price (baht/kg)	Gross values (baht/ha)	Variable cost (baht/ha)	Profits[b] (baht/ha)
Chiang Mai						
Khao Dawk Mali	0.607	4.02	4.12	16,578	5,732	10,845
Glutinous rice	0.343	3.75	3.38	12,681	5,736	6,945
Chiang Rai						
Khao DawkMali/RD	0.509	3.25	4.00	12,861	4,652	8,209
Glutinous rice	0.491	3.41	3.89	13,288	4,829	8,459
Surin						
Khao Dawk Mali	1.000	1.64	4.15	6,789	3,903	2,886
Glutinous rice	—	—	—	—	—	—

a The proportion of total rice area : Chiang Mai — 307 ha; Chiang Rai — 266 ha; and Surin —541 ha.

b Profits = Gross value of production minus costs of seed, fertilizer, manure, irrigation, pesticides, hired labor, hired tractor price and imputed value of family and exchange labor and imputed value of tractor price.

Note : 1 US$ = 25 baht (approx.)

Mai largely due to higher yields as Chiang Mai Valley is one of the most productive agricultural area in Thailand. The yield level in the Surin province, a dry region, is about one third as compared to Chiang Mai. The analysis of factor shares in rice production for Khao Dawk Mali rice shows that, average profitability is about 65 percent of the gross value of production for Chiang Mai and Chiang Rai province but is only 43 percent in Surin (Table 3). However, when farm family income is considered, the differences become negligible in all the study areas due to variation in the use of hired labor and purchased inputs. For glutinous rice, profitability is lower in Chiang Mai but similar in Chiang Rai when compared to profits derived from Khao Dawk Mali production.

Empirical Model

The Cobb-Douglas profit frontier was specified as

$$\ln S = \ln\alpha + \beta_w \ln P_w' + \beta_F \ln P_F' + \beta_M \ln P_M' + Y_L \ln Z_L' + Y_A \ln Z_A' + \delta_{CH} D_{CH} + \delta_{CR} D_{CR} + v + u, \quad (5)$$

where S is the normalized profit as defined in equation (1); P_w is the normalized price of labor; P_F is normlized price of fertilizer, P_M is normalized price of tractor power, Z_L is the farm size, Z_A is the level of farm assets in value terms utilized for rice production; D_{CR} is the area dummy, D_{CR} = 1 for crops grown in Chiang Rai province and 0 otherwise; D_{CH} is the area dummy, C_{DR} = 1 for crops grown in Chiang Mai province and 0 otherwise, v and u are the error terms defined in equation (1).

The model specified in equation (5) was first estimated by using OLS method and then by MLE method. The estimation is done by LIMDEP software program.

Table 3. Factor shares in rice production

Factors	Khao Dawk Mali		Glutinous variety	
	Baht per ha	% of Gross Value of prod.	Baht Per ha	% of Gross Value of prod.
Chiang Mai				
Material inputs	1,192	7.19	1,319	10.40
Family supplied	130	0.79	226	1.78
Purchased	1,062	6.40	1,093	8.62
Human labor	3,294	19.87	2,897	23.55
Family	419	2.53	507	3.99
Hired	2,875	17.34	2,480	19.56
Tractor power	1,248	7.52	1,430	11.28
Family supplied	341	2.06	311	2.45
Hired	907	5.46	1,119	8.83
Profit[a]	10,845	65.42	6,946	54.77
Gross value of production	16,578	1000.00	12,681	100.00
Farm family income[b]	11,605	70.01	7,763	61.22
Chiang Rai[c]				
Material inputs	1,190	9.25	1,181	8.88
Family supplied	113	0.88	98	0.73
Purchased	1077	8.37	1,083	8.15
Human labor	2,693	20.94	2,749	20.68
Family	863	6.71	628	4.72
Hired	1,830	14.23	2,121	15.96
Tractor power	769	5.98	902	6.78
Family supplied	596	4.63	422	3.17
Hired	173	1.35	480	3.61
Profit[a]	8,209	63.83	8,459	63.65
Gross value of production	12,861	100.00	13,288	100.00
Farm family income[b]	9,777	76.02	9,599	72.24

Table 3. Continued

Factors	Khao Dawk Mali		Glutinous variety	
	Baht per ha	% of Gross Value of prod.	Baht Per ha	% of Gross Value of prod.
Surin				
Material inputs	1,401	20.63	—	—
Family supplied	379	5.58	—	—
Purchased	1,022	15.05	—	—
Human labor	1,934	28.48	—	—
Family	1,288	18.97	—	—
Hired	646	9.51	—	—
Animal/Tractor power	569	8.37	—	—
Family supplied	325	4.80	—	—
Hired	244	3.57	—	—
Profit[a]	2,886	42.51	—	—
Gross value of production	6,789	100.00	—	—
Farm family income[b]	4,879	71.86	—	—

a Profit = Gross value of production minus total cost.
b Farm Family Income = Gross value of production minus purchased input costs.
c Khao Dawk Mali includes RD 15 for Chiang Rai province.
Note : 1 US$ = 25 baht (approx.)

For the profit frontier of Cobb-Douglas type, the profit efficiency of the jth farm is given by exp $(-u_j)$ or profit inefficiency by $[1 - \exp(-u_j)]$. Profit loss due to inefficiency was then calculated as maximum profit at firm-specific prices and fixed factors (i.e., S calculated from the profit frontier) multiplied by farm-specific inefficiency.

Estimation of Profit Function

The OLS and MLE estimates of equation (5) on a per farm basis are presented in Table 4. The estimated regression coefficients are similar between the OLS and MLE models of individual crops. The variance ratio parameter, $\lambda' = (\sigma^2_u/\sigma^2)$, applied by Ali and Flinn (1989), is found to be large and statistically greater than zero (0.89 for Khao Dawk Mali and 0.97 for glutinous rice, respectively), given the (0,1) interval, within which λ' lies. This implies that variation in actual profit between farms arise mainly from differences in farmer practices rather than from random variability.

Table 4. OLS and MLE Estimates of Profit Function for Khao Dawk Mali and Glutinous Rice Production in Three Provinces of Thailand, 1992 Crop.

Variable	Khao Dawk Mali		Glutinous Rice	
	OLS	MLE	OLS	MLE
Intercept	6.010	6.361	8.665	8.092
	(.354)[a]	(.337)[a]	(.971)[a]	(.764)[a]
$\ln P_w$	-0.186	-0.161	-0.286	-0.272
	(.172)	(.131)	(.252)	(.229)
$\ln P_F$	-0.224	-0.139	-0.494	-0.161
	(.183)	(.127)	(.285)[c]	(.191)
$\ln P_M$	-0.227	-0.129	-0.441	-0.169
	(.067)[a]	(.074)[c]	(.111)[a]	(.095)[c]
$\ln Z_L$	0.962	0.926	0.883	0.835
	(.045)	(.046)[a]	(.074)[a]	(.065)[a]
$\ln Z_A$	-0.008	-0.007	-0.002	-0.016
	(.018)	(.017)	(.029)	(.025)
D_{CH}	1.584	1.332	—	—
	(.158)[a]	(.172)[a]	—	—
D_{CR}	1.176	1.101	0.001	0.039
	(.154)[a]	(.165)[a]	(.029)	(.115)
R^2	0.613		0.607	
Log-likelihood function	-281.5	-256.6	-197.2	-174.3
σ	0.546	0.984	0.635	1.0003
		(.030)[a]		(.050)[a]
σ_u^2		0.712		0.987
σ_v^2		0.086		0.025
Population mean of profit inefficiency (%)		33.0		21.2
Variance		25.8		35.9

a Significant at 1 percent level

b Significant at 5 percent level

c Significant at 10 percent level

Farm-Specific Profit Efficiency

The estimated population mean and variance of loss in profit is calculated by using equation (2). The mean level of inefficiency were 33%, and 21% for Khao Dawk Mali and glutinous rice, respectively. The mean profit inefficiency calculated from the sample data, using equation(4) was, 32% and 20% for Khao Dawk Mali and glutinous rice, respectively (Table 5). Fifteen percent of the Khao Dawk Mali rice producers are operating below 60 percent level of efficiency as compared to only five percent for glutinous rice producers indicating that profitability from Khao Dawk Mali farming could be improved largely with better use of existing technology.

Table 5. Frequency Distribution of Farm Specific Profit Efficiency among Rice Farmers.

Efficiency Level (%)	Profit Efficiency	
	Khao Dawk Mali	Glutinous rice
> 95	0 (0.0)	0 (0.0)
> 90 ≤ 95	2 (0.6)	11 (5.3)
> 85 ≤ 90	4 (1.1)	44 (21.2)
> 80 ≤ 85	10 (2.8)	65 (31.3)
> 75 ≤ 80	38 (10.8)	52 (25.0)
> 70 ≤ 75	88 (25.1)	18 (8.7)
> 65 ≤ 70	93 (26.5)	11 (5.3)
> 60 ≤ 65	65 (18.5)	2 (1.0)
> 60	51 (14.5)	5 (2.4)
Mean	67.8	80.4
Minimum	32.5	49.8
Maximum	92.4	93.4

Note : The top figure is the number of farms and the figure in parentheses is the percent of farms.

The frequency distribution of loss in profit is shown in Table 6. Thirty three percent of the Khao Dawk Mali rice producers are losing more than Baht 5000 per ha from their maximum profit level under given technology and level of fixed factors as compared to only two percent for glutinous rice producers.

The regional distribution of mean level of profit loss indicates large variation across regions as well as crop varieties (Table 7). The mean level of profit loss is much higher, (Baht 3,858 per ha) in Khao Dawk Mali production as compared to the glutinous reice (Baht 2,702 per ha), respectively. The largest farm specific loss in profit for Khao Dawk Mali is Baht 9,006 per ha and for glutinous rice is Baht 5,543 per ha. Across regions, rice producers in Chaing Mai incur highest loss per ha for Khao Dwk Mali (Baht 5,419). At the per farm level,

Table 6. Frequency Distribution of Profit Loss in Rice Production

Range of Loss in Profit (Baht/ha)	Khao Dawk Mali	Glutinous rice
0 - 500	1	0
	(0.3)	(0)
500.1 - 1000	7	3
	(2.0)	(1.4)
1000.1 - 1500	35	18
	(10.0)	(8.7)
1500.1 - 2000	53	36
	(15.1)	(17.3)
2000.1 - 2500	27	44
	(7.7)	(21.2)
2500.1 - 3000	22	32
	(6.3)	(15.4)
3000.1 - 3500	12	24
	(3.4)	(11.5)
3500.1 - 4000	25	33
	(7.1)	(15.9)
4000.1 - 4500	24	7
	(6.8)	(3.4)
4500.1 - 5000	28	6
	(8.0)	(2.9)
5000.1 - and above	117	5
	(33.3)	(2.4)

Note : The top figure is the number of farms and the figure in parentheses is the percent of sample farmers.

mean profit loss in producing Khao Dawk Mali across regions is similar (Baht 7,307 pr farm). These reults indicate that, clear opportunities exist to increase profit levels of Khao Dawk Mali as well as glutinous rice in these provinces by better use of the given technology and levels of fixed factors.

Table 7. Average Loss in Profit in Rice Production in Thailand, 1992

Province	Khao Dawk Mali	Glutinous rice
	Baht Per Farm	
Chaig Mai	7665	2023
	(5418)	(1400)
Chiang Rai	7175	4531
	(4564)	(2412)
Surin	7012	—
	(3768)	—
All Area	7307	2927
	(5204)	(2702)
	Baht Per Hectare	
Chaig Mai	5419	2591
	(1321)	(1056)
Chiang Rai	4564	2899
	(1529)	(914)
Surin	1785	—
	(535)	—
All Area	3858	2702
	(2002)	(1016)

Note : Figures in parentheses indicate standard deviation.

CONCLUSION

Thailand can perform much better by ensuring better use of existing technology to improve the profitability of rice production and be competitive in the world rice market. The efficiency gap in glutinous rice production is much less as about 60 percent of the sample farms are already operating at over 80 percent economic efficiency level as compared to only less than five percent of Khao Dawk Mali rice producers operating at this level of economic efficiency. If only 25 percent of the estimated loss in profit were eliminated on the 0.30 million ha of

Khao Dawk Mali rice grown in these three provinces, the farmer's return would increase by Baht 293 million each season. Thus, the benefits of promoting increased efficiency in Khao Dawk Mali production appears to be vital for retaining Thailand's share in the international high quality rice market.

From a methodological point of view, estimation of farm-specific inefficiency through profit frontier approach is a theoretical improvement over the production frontier approach as it takes into account farm specific prices and levels of fixed factors. However, the analysis would be further improved if additional farm-specific environmental factors, e.g., soil quality parameters, could be entered as arguments in the model.

REFERENCES

Aigner, D. J., C. A. Knox Lovell, and P. Schmidt (1977). "Formulation and Estimation of Stochastic Frontier Function Models", *J. Econometrics*, **6** : 21-37.

Ali, M. and J. C. Flinn (1989). "Profit Efficiency Among Basmati Rice Producers in Pakistan Punjab", *Amer. J. Agr. Econ.* **71** : 303-310.

Bank of Agriculture and Agricultural Cooperatives (1992). *Statistical Data*, (Unpublished). Thailand.

Barker, R., R. W. Herdt, and B. Rose (1985). *The Rice Economy of Asia.* Baltimore : John Hopkins University Press.

Bravo-Ureta, B. E., and L. Rieger (1991). "Dairy Farm Efficiency Measurment Using Stochastic Frontiers and Neoclassical Duality", *Amer. J. Agr. Econ.* **73** : 421-427.

Farrell, M. J. (1957). "The Measurement of Productive Efficiency", *J. Royal Statist. Sco.* Series A (general) **21** : 253-281.

Jondrow, J., C. A. Knox Lovell, I. S. Materov, and P. Schimdt (1982). "On the Estimation of Technical Inefficiency in the Stochastic Frontier Production Function Model", *J. Econometrics*, **19** : 233-238.

Lau, L. J. and P. A. Yotopoulus (1972). "Profit, Supply, and Factor Demand Functions", *Amer. J. Agr. Econ.*, **54** : 11-18.

Maddala, G. S (1977). *Econometrics.* McGraw-Hill Book Company.

Maddala, G. S (1983). *Limited Dependent and Qualitative Variables in Econometrics.* Cambridge University Press.

Puapanichya, K., and T. Panayotou (1985). "Output Supply and Input Demand in Rice and Upland Crop Production : The Quest for Higher Yields in Thailand". In T. Panayotou (ed.), *Food Policy Analysis in Thailand.* Bangkok : Agricultural Development Council.

Rahman, Sanzidur (1993). Joint Determination of Demand for Inputs and Choice of Rice Varieties : A Meta-Production Function Approach. Unpublished M. S. Thesis. Thailand : Chiang Mai University.