Optimality of Input Used, Input Demand and Supply Response of Rice Production: Experience in MADA Malaysia

Lira Mailena[1], Mad Nasir Shamsudin[1*], Zainalabidin Mohamed[1], Alias Radam[2]
1. Department of Agribusiness and Information System, Faculty of Agriculture, Universiti Putra Malaysia, 43400 UPM Serdang, Malaysia
2. Department of Management and Marketing, Faculty of Economics and Management, Universiti Putra Malaysia, 43400 UPM Serdang, Malaysia
*E-mail: mns@upm.edu.my

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Abstract
This study attempts to measure the optimum use of production inputs and analyze the behavior of input demand and output supply of rice production in MADA, Malaysia. Restricted normalized transcendental logarithm profit function is utilized as it is able to depict the behaviour of input demand and output supply simultaneously. The findings indicate that farmers in MADA were not utilizing the production inputs optimally. Fertilizer prices and area planted had a significant effect on the profit, and farmers are responsive to the changes of input prices in term of input demand behavior. Thus extension with regards to the optimal input used should be emphasized in order to improve the economic efficiency and the profitability of the rice production.
Keywords: Optimum input used, Input demand, Output supply, Rice

1. Introduction

Rice is a staple food for Malaysian with a total consumption of 2.1 million tons in 2010. Production was at 1.5 million tons, with a self-sufficiency level of about 68.23 percent in the same period. Various government interventions which include fertilizer subsidy, price support, and import quota are imposed to improve the yield, productivity, farm income, and the achievement of self-sufficiency level. The achievement towards self-sufficiency, however, is hampered by low productivity at 3.9 ton/ha, compared with Indonesia and Vietnam at 4.9 ton/ha and 5.5 ton/ha respectively (FAO, 2011). Factors that contribute towards the low productivity include small farm size, non-optimal input used, and noncompliance with good farm practices. This study therefore aims to measure the efficiency of input use and analyze the behavior of input demand and output supply of paddy production. The study was conducted at Muda Agricultural Development Authority (MADA) which is the largest granary areas in Malaysia with 96 million hectares of paddy field. Research sample of 150 farmers were drawn using simple random sampling.

2. Methodology

2.1 Duality Approach

The duality approach was widely applied as this approach is able to provide a comprehensive relationship among inputs and output (Beccera, 1992; Siregar, 2007). Duality approach stated that production and profit function can describe the behavior of input demand and output supply equally well if both functions fulfil regular properties. A profit function can be treated as if they come from a production technology function when satisfies the properties of monotonicity and convexity (Mc Fadden, 1978).

Duality approach was prefered to be utilized since it can overcome the problem of solving first order condition by directly specifying suitable maximum profit function rather than production function. Unlike the production function, the profit function involves only input/output prices and quantity of quasi fixed inputs which are not endogenous. By the duality approach, the assumption of profit maximization and competitive market are assured because the derived input demand and output supply equation are obtained from the profit function (Alam, 1991).

Following Lau (1972), the normalized profit function was derived by considering the production function with the neoclassical properties that describes the transformation of variable and fixed inputs into outputs. A profit function was defined as current revenues less current total variable costs and can be written as:

$$\pi' = pF(X_1, \ldots, X_m\ ; Z_1, \ldots, Z_n) - \sum_{i=1}^{m} ci' X_i \qquad (2)$$

where π' is profit, p is the unit price of output and ci' is the unit price of the i $_{th}$ variable input and Z_t is fixed input.

The marginal productivity condition for profit maximization is:

$$p\frac{\partial F(X;Z)}{\partial X_i} = ci' \qquad i = 1, \ldots..m \qquad (3)$$

By defining ci = ci'/p as the normalized price of the i th input, equation (2) could be written as

$$\frac{\partial F}{\partial X_i} = ci \qquad i = 1, \ldots \ldots .m \qquad (4)$$

When P = π'/p as the "Unit Output Price Profit (UOP Profit), similarly with equation (3) which we can rewritten equation (2) as follows:

$$P = \frac{\pi'}{p} = F((X_1, \ldots.,X_m\,;\,Z_1, \ldots, Z_n) - \sum_{i=1}^{m} ciXi \qquad (5)$$

The optimal quantities of variable inputs denoted as Xi* as a function of the normalized prices of the variable input and quantities of the fixed input can be obtained by solving the equation (5) and get the optimal variable input as follows:

$$Xi* = fi\,(c, Z) \qquad i = 1 \ldots \ldots .m \qquad (6)$$

where c and Z are vectors of input price and quantities of fixed input.

By substituting (6) into (2) we get the optimal profit function denote as π*' as following

$$\pi^{*\prime} = p(F(X_1^* \;, \ldots \ldots X_m^*\;; Z_1\,, \ldots \; Z_n) - \sum_{i=1}^{m} ci\, X_i^*) \qquad (7)$$

Equation (6) expresses that the profit function gives the maximized value of the profit for each set of values (p, c', Z) that is price of output, price of input and quantity of fixed input. Therefore, unit output price profit function can be rewritten as

$$\pi^* = \frac{\pi^{*\prime}}{p} = G^*\,(c_1, \ldots..,c_m\,; Z_1, \ldots..,Z_n\,) \qquad (8)$$

Then, refer to Sheppard Lemma, the input demand and output supply function denoted as Xi* and V* respectively were the first derivative of equation (7) and can be written as

$$X^* = -\frac{\partial \pi^*\,(c,Z)}{\delta c_i} \qquad i = 1, \ldots\ldots.m \qquad (9)$$

$$V = \partial\,\pi * (c, Z) - \sum_{i=1}^{m} \frac{\vartheta\pi^*(c,Z)}{\vartheta c_i}\, ci \qquad (10)$$

2.2 Normalized Restricted Profit Function

The transcendental logaritm (translog) profit function has been used by some studies as a flexible functional form to estimate the input demand as this function can eliminate problems related to the restrictive as required by Cobb Douglas profit function (Diewert, 1971). According to Christensen, Jorgensen and Lau (1972), the normalized restricted translog profit function for a single output was given by:

$$\ln\pi = \alpha_o + \sum_{i=1}^{n}\alpha_i \ln P_i^* + \sum_{i=1}^{p}\theta_l \ln Z + 0.5\sum_{i=1}^{n}\sum_{j=1}^{n}\gamma_{ij}\ln P_l^*\,\ln P_j^* + 0.5\sum_{i=1}^{n}\sum_{j=1}^{n}\theta_{kl}\ln Z_k\,\ln Z_l + \sum_{i=1}^{n}\sum_{j=n+1}^{p}\beta_{ij}\ln \mathrm{P_i}\ln Z \qquad (11)$$

The partial derivates of restricted profit function with respect to logs of input price yield the negative input demand of input as follows:

$$S_i = -\frac{P_i^*\,X_i}{\pi^*} = \frac{\vartheta \ln\pi^*}{\vartheta \ln P_i^*} = \alpha_i + \sum_{l=1}^{n}\gamma_{il}\,\ln P_l^* + \sum_{k=1}^{m}\delta \ln Z_k \qquad (12)$$

where:

Px = input price for i=1......n

Z= quantity of quasi fixed input for j=1....p

Now, suppose that parameter estimates of equation (10) and (11) have been obtained, the elasticity of variable input demand and output supply with respect to all exogenous variable evaluated at averages of the Si and at a given level of variable input prices for the case of fixed input are linear transformation of the parameter estimates of the profit function (Sidhu, 1981).

Own-price elasticity for variable input demand function are expressed as follow:

$$\eta_{ii} = \frac{\vartheta \ln X_i}{\vartheta \ln P_i} = \frac{\delta \ln \pi}{\vartheta \ln P_i} - 1 + \frac{\vartheta \ln}{\vartheta \ln P_i}\left(-\frac{\vartheta \ln\pi}{\vartheta \ln P_i}\right) \qquad (13)$$

$$\eta_{ii} = -S_i^* - 1 - \frac{\gamma_{ii}}{S_i^*}$$

Likewise, the cross-price elasticity of demand (η_{ih}) for input i ≠ h with respect to the price of i^th^ input can be obtained as follows:

$$\eta_{il} = \frac{\vartheta \ln X_i}{\vartheta \ln P_l} = \frac{\delta \ln\pi}{\vartheta \ln P_l} + \frac{\vartheta \ln}{\vartheta \ln P_l}\left(-\frac{\vartheta \ln \pi}{\vartheta \ln P_i}\right)$$

$$\eta_{il} = -S_l^* - \frac{\gamma_{il}}{S_i^*} \;;\ \text{where } i \neq 1 \qquad (14)$$

2.3 Model Estimation

Applying duality approach and by assuming that rice farming maximize short run profit and operate within competitive factor and product market, the construction of translog profit function required the minimum requisite set of variable input and one fixed factor of production. Therefore, a normalized translog profit function is:

$$\ln\pi^{*}= \alpha_0 +\beta s\ln PS+\beta c\ln PC+\beta f\ln PF+\beta w\ln PW+\beta_L\ln PL+\beta_A\ln A+ ½\, \sigma_{ss}\ln PS^2 + ½\, \sigma_{cc}\ln PC^2 + 1/2\, \sigma_{ff} \ln PF^2+ ½\, \sigma_{ww}\ln PW^2 + ½\sigma_{LL} \ln PL^2+ ½\, \sigma_{AA}{*}\ln A^2 + \theta_{BSC} \ln PS \ln PC+ \theta_{BSF} \ln PS \ln PF + \theta_{BSW} \ln PS \ln PW + \theta_{BSL} \ln PS \ln PL + \theta_{BSA} \ln PS \ln A+ \theta_{BCF} \ln PC \ln PF+\theta_{BCW} \ln PC \ln PW+ \theta_{BCL} \ln PC \ln PL + \theta_{BCA} \ln PC \ln A+ \theta_{BFW} \ln PF \ln PW+ \theta_{BFL} \ln PF \ln PL+ \theta_{BFA} \ln PF \ln A + \theta_{BWL} \ln PW \ln PL+ \theta_{BWA} \ln PW \ln A+ \theta_{BLA} \ln PL \ln A+\varepsilon_i \quad (15)$$

where π^* is the restricted normalized profit from rice production per farm as total revenue less total cost of seed, fertilizer, pesticide, weedicide and labour normalized by price of paddy. PS, PC, PF,PW,PL are the price of seed per kg, price of pesticide per litre, price of fertilizer per kg, price of herbicide per litre and wage rate of labour per hour respectively normalized by the price of paddy. The definition of A is the area in hectare as a fix input in paddy farming. The parameter α, β, σ are to be estimated and subscript S, C, F, W, L and A stand for variable input in paddy farming i.e. seed, pesticide, fertilizer, herbicide, labour and area.

The partial derivates of (15) with respect to logs of input price is the negative input share equation for seed, fertilizer, pesticide, herbicide and labour as follows:

$$-\frac{PS^*XS}{\pi^*} = \beta s + \sigma_{SS} \ln PS + \theta_{BSF} \ln PF + \theta_{BSC} \ln PC + \theta_{BSW} \ln PW + \theta_{BSL} \ln PL + \theta_{BSA} \ln A \quad (16)$$

$$-\frac{PF^*XF}{\pi^*} = \beta_F + \sigma_{FF} \ln PF + \theta_{BFS} \ln PS + \theta_{BFC} \ln PC + \theta_{BFW} \ln PW + \theta_{BFL} \ln PL + \theta_{BFA} \ln A \quad (17)$$

$$-\frac{PC^*XC}{\pi^*} = \beta_C + \sigma_{CC} \ln PC + \theta_{BCS} \ln PS + \theta_{BCF} \ln PF + \theta_{BCW} \ln PW + \theta_{BCL} \ln PL + \theta_{BCA} \ln A \quad (18)$$

$$-\frac{PW^*XW}{\pi^*} = \beta_W + \sigma_{WW} \ln PW + \theta_{BWS} \ln PS + \theta_{BWF} \ln PF + \theta_{BWC} \ln PC + \theta_{BWL} \ln PL + \theta_{BWA} \ln A \quad (19)$$

$$-\frac{PL^*XL}{\pi^*} = \beta_L + \sigma_{LL} \ln PL + \theta_{BLS} \ln PS + \theta_{BLF} \ln PF + \theta_{BLC} \ln PC + \theta_{BLW} \ln PW + \theta_{BLA} \ln A \quad (20)$$

Under the assumption of profit-maximization and price taking behaviour, the parameter in Equation (15) must be equal to the corresponding parameter in equation (16), (17), (18),(19) and (20) and must fulfil the symmetry restriction. This concept will provide the principle for testing the hypothesis of profit maximization. The hypothesis of constant to scale in production also can be tested which implied that the transcedental logarithm function satisfy the linear homogeneity and symmetry restriction. Further, the transcedental logaritm function form enables the analyst to test for C-D hypothesis. If the profit function is C-D in nature, the coefficient of the second order terms in profit equation (15) will be zero. Thus, F-test statistic with asymptotic property was conducted to obtain the validity of the imposed restriction (Theil, 1971).

$$F\ value = \frac{(ESS_R - ESS_{UR})/Q}{ESS_{UR}/(N-K)} \quad (21)$$

where :

ESS_R = residual sum of square for restricted model
ESS_{UR} = residual sum of square for unrestricted model
Q = number of restriction imposed
N = number of observation
K = total number of parameter in estimated system of equation

Profit function and share of input are estimated simultaneously in the system so that the share variables sum to unity. This condition leads to their disturbance sum to zero. Hence, one of share equation must be dropped from the system in order to avoid the singularity of the covariance matric of error term.

As error term of the profit function and cost share equations are likely to be correlated contemporaneously due to large number of common explanatory variables. Thus Ordinary Least Square (OLS) is not applicable to estimate the equation in the system. OLS is also not appealing as we need to impose cross equation restriction. This problem can be overcome by using Zellner's estimation procedure for Seemingly Unrelated Regression (SUR) to obtain estimates which are asymptotically equivalent to Maximum Likelihood Estimation (MLE) when iterated to convergence and invariant to which share equation is deleted.

3. Results and Discussion

The structure of production cost and revenue on rice farming is presented in Table 1. The average production obtained by sample farmers was about 2.2 mt/ha and price received by farmer was RM 1.41/kg. With total variable cost was RM 634.35 per hectare, farmers received a gross income of RM2,494.94 per hectare. From the composition of variable cost, cost for fertilizer was dominated the total cost on paddy production at 46.4 percent, followed by the cost of seed and labour which was at 17.4 percent and 15.9 percent respectively.

Table 1. Production cost and revenue of rice production, MADA, Malaysia

Item	**RM**
Revenue	**3,129.29**
Production (2,212 kg) x paddy price (RM 1.41/kg)	
Variable Cost (RM/ha)	
Seed	110.22
	(17.37)
Fertilizer	294.41
	(46.41)
Pesticide	85.94
	(13.55)
Weedicide	43.19
	(6.81)
Labour	100.57
	(15.85)
Total Variable Cost	634.35
Gross Income (RM/ha)	2,494.94

Note: Figures in parenthesis are share of input cost in percentage

The optimum use for each input per hectare at farm level and its optimum score are presented in Table 2. The optimum level for seed, fertilizer, chemical, weedicide and labour are 174 kg, 205 kg, 0.81 liter, 6.79 liter, and 37 manhour respectively. Compared to an actual use of production inputs, the use of seed and labor were still lower than its optimum level. Conversely, the utilization of fertilizer has exceeded its optimum level. Since the use of chemical and pesticide were likely lower than its optimum level, farmers could increased its consumption in order to improve their economic efficiency.

Table 2. Optimum and actual utilization of inputs of rice production, MADA, Malaysia

	seed (kg)	fertilizer (kg)	chemical (ltr)	weedicide (ltr)	Labor (manhour)
Optimum input use	174	205	0.81	6.79	37
Actual input use					
average	66.39	349.59	1.02	1.15	32.86
min	14.06	134.70	0.00	0.00	2.80
max	90.13	658.92	10.74	8.45	98.30

Before proceeding to the estimated parameter of normalized restricted transcedental logaritm profit and input share equation, two hypothesis tests were carried out. They are test for the validity of profit maximization and Cobb Douglas hypothesis. The null hypothesis in the first test indicates that the parameters of the input share equations (16), (17), (18), (19) and (20) are equal to the corresponding same parameter on the profit equation (15). An F-test statistics indicates that the null hypothesis cannot be rejected at the 0.05 level of significance. It means that the profit maximization assumption was valid.

The second test was conducted in order to check the Cobb-Douglas (C-D) hypothesis where the coefficients of second order term should be zero. Based on the F-test, the hypothesis on Cobb Douglas was rejected, suggesting that the translog profit function was more suitable for data.

Theoretically, estimated parameters of translog form of normalized restricted profit function and share input equation were not able to be used because they included large number of parameters. These parameters were mainly used to derive empirical measure of elasticity so that the usual interpretation of translog parameter could be ignored. However, this paper will explain those estimated parameters briefly especially for profit function and is presented on Table 3.

Table 3. Estimated restricted translog profit function of rice production, MADA, Malaysia

	Intercept	Price of Seed	Price of Fertilizer	Price of Pesticide	Price of Weedicide	Price of Labor	Area
Share of seed	-0.0504	-0.1689***	0.0652*	0.0166	0.0017	-0.0281*	0.1256
to Profit	(-0.500)	(-5.1200)	(1.8500)	(0.7400)	(0.1800)	(-1.7200)	(0.9500)
Share of fertilizer	0.3794***	0.0652*	-0.2873***	0.0075	-0.0116	-0.0203	0.1355
to profit	(-2.24)	(1.8500)	(-4.7400)	(0.1900)	(-0.9200)	(-0.9700)	(1.3500)
Share of weedicide	-0.0008	0.0017	-0.0116	0.0019	-0.0062	-0.0090	-0.0658*
to profit	(0.0001)	(0.1800)	(-0.9200)	(0.2500)	(-0.8200)	(-1.0700)	(-1.7500)
Share of labour	0.076172	-0.0281*	-0.0203	-0.0194	-0.0091	-0.0280	-0.1007
to profit	(1.9000)	(-1.7200)	(-0.9700)	(-1.4500)	(-1.0700)	(-1.4700)	(-1.4900)
Profit function	6.5850***	-0.0504	-0.3794***	0.2500	-0.00008	0.0762	0.7010**
	(8.870)	(-0.500)	(-2.2400)	(0.9000)	(0.0001)	(1.1000)	(1.9000)

Note : Figures in parenthesis are t-stat
***significant at 1 percent level
**significant at 5 percent level
*significant at 10 percent level

Since profit maximization was hold in this estimation, factors affecting the profit is are the point of discussion. Based on Table 3, there are two production inputs which were significantly influence the profit function. They were price of fertilizer and planted area for paddy. Negative sign of fertilizer price confirmed that a cheaper price of fertilizer increased the profit. Further, the large farm size could increase profit due to the positive sign of area for rice production.

Elasticities of input demand and output supply on paddy production are presented in Table 4. Those essentially indicate on how the farmer respon of those to the changes in input prices. Own-price elasticities of demand for production inputs had negative signs as expected and were statistically significant, except for a pesticide demand. The estimated elasticity for seed demand with respect to its price was -0.527.

The estimated elasticity for fertilizer demand respect to its price was about -0.079 and was the lowest one comparing to other inputs. It indicated an increase of 1 percent in fertilizer price decreased 0.079 percent of the demand for fertilizer. Then, the estimated elasticities for weedicide and labor demand were -0.774 and -0.721 respectively. These indicated that an increase of 1 percent in weedicide price and wage, the demand for weedicide and labor decreased by 0.774 percent and 0.721 percent respectively.

The expected sign of the supply elasticity with respect to the price of variable inputs were negative as well. This implies that the increased price of inputs will lead to the decreasing of inputs use, and thus would reduce paddy yield and production. Out of five input prices, fertilizer price appeared to be an important factor influencing the output supply as this price is statistically significant at the 5 percent level. The negative sign of this price implied the increasing of fertilizer price would decrease the output since farmers decrease the use of fertilizer in rice farming.

Table 4. Input demand and output supply elasticity of rice production, MADA, Malaysia

Output/Input	Price of Seed	Price of Fertilizer	Price of Pesticide	Price of Weedicide	Price of Labour
Seed Demand	**-0.527****	-0.850*	-0.213*	-0.042***	0.193
	(1.631)	(-0.629)	(-0.160)	(-0.017)	(0.271)
Fertilizer Demand	-0.399	**-0.079***	-0.087***	0.028	0.014
	(-0.295)	(1.300)	(-0.034)	(0.052)	(0.092)
Pesticide Demand	-0.416	-0.362***	**-0.151**	-0.062**	0.287
	(-0.312)	(-0.141)	(0.902)	(-0.038)	(0.365)
Weedicide Demand	-0.174***	0.245	-0.133**	**-0.774*****	0.287
	(-0.071)	(0.467)	(-0.080)	(0.251)	(0.365)
Labour Demand	0.255	0.038	0.194	0.091	**-0.721*****
	(0.358)	(0.259)	(0.247)	(0.116)	(0.358)
Paddy Supply	-0.193	-0.276**	-0.065	0.006	0.050
	(0.487)	(1.717)	(-4.716)	(0.003)	(-0.972)

Note : *** = significant at 1 percent level
** = significant at 5 percent level
* = significant at 10 percent level

4. Conclusion

In general, the inputs were used not at their optimum level. The estimated restricted normalized transcendental logarithm profit function was particularly attractive for input demand and output supply as it was able to depict their behaviour simultaneously. With regard to the profit, fertilizer prices and area planted had significant effect on the profit. Thus extension with regards to the optimal input used should be emphasized in order to improve the economic efficiency and the profitability of rice production.

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