VARIABLE INPUT DEMAND AND RICE SUPPLY IN THE MEKONG DELTA: AN EMPIRICAL ANALYSIS

NGUYỄN HỮU DŨNG, Ph.D*

On the basis of neoclassical economic theory, the general purpose of this study is to undertake an estimation of a system of output supply and factor demand for intensive production system in the Mekong Delta, using a profit function approach. To achieve higher profits from rice production and efficiency of input use, farmers need to operate at the economic optimum rather than the technical optimum. Thus, this paper will explore whether or not farming households are efficient at their current level of inputs' application when input and output prices are taken into account.

1. Introduction

As in other Asian countries with intensive rice farming and high output levels, rice production in Vietnam is characterized by a heavy dependence on agrochemicals. The increased use of these inputs followed a campaign to raise production per hectare and adoption of high-yielding varieties (HYVs). However, efficient input use is crucial for sustainable agriculture. From a microeconomic perspective, agrochemicals should be applied to the level at which the value of the marginal product equals its price, and environmental externalities generated by agrochemicals are taken into account. Against this background, understanding how production inputs are used in relation to yield attainment given the current technology, and whether inputs are applied in an economically efficient way is essential to the rice sector in the coming years.

Rice farms in Vietnam are mainly small-scale units operated by individual households. This implies that farm households take market prices of outputs and inputs as given, and that neoclassical production theory, especially its dual form (that is, the cost/profit function) is a convenient framework for explaining their economic behavior. In addition, farmers are assumed to be concerned with private costs and benefits from their production, and are not expected to take into account longer-term impacts of spillover effects from their farms on human health and the environment. Under these circumstances, it is appropriate to model short-run behavior of farmers in terms of profit maximization, given the technological, economic, and resource constraints.

2. Model specification

In order to derive empirical estimates of agricultural commodity supply and input demand functions, which are crucial for understanding a farmer's response to market price incentives and for development policies, this analysis focuses on the profit function approach for the agricultural production process.

a. The normalized restricted translog profit function and a system of output supply and variable input demand:

For the purpose of empirical implementation, it is necessary to specify an explicit functional form for the profit function. A number of common functional forms have been developed and applied to derive the supply and demand of agricultural commodities in the market, such as: the Cobb-Douglas, generalized Leontief, translog, and general linear functions. Nevertheless, the choice of a functional form should depend on its ultimate use. The translog functional form is employed in this study because it is one of the most commonly used FFFs for the profit function in applied agricultural production analysis. In addition, the translog imposes no restriction on substitution elasticities and fewer prior restrictions on the technology than linear functional forms do (Berndt, 1991: 458; Chambers, 1988: 164).

The normalized restricted translog profit function, for a single output, takes the general forms (See next page):

where: π^* is the restricted profit, defined as total revenue less total costs of variable inputs, normalized by the price of output P_y; P_i^* is the price of variable input X_i normalized by the output price, P_y; Z_k is the k^{th} fixed inputs. $i = h = 1, 2, 3,..., n$ and $k = j = 1, 2, 3,..., m$; ln is the natural logarithm; and, α_0, α_i, γ_{ih}, δ_{ik}, β_k, and ψ_{kj} are parameters to

* University of Economics HCMC

$$(1)\ln \pi^* = \alpha_0 \sum_{i=1}^{n} \alpha_i \ln P_i^* + 1/2 \sum_{i=1}^{n}\sum_{h=1}^{n} \gamma_{ih} \ln P_i^* \ln P_h^* + \sum_{k=1}^{m} \beta_k \ln Z_k + \sum_{i=1}^{n}\sum_{k=1}^{m} \delta_{ik} \ln P_i^* \ln Z_k + 1/2 \sum_{k=1}^{m}\sum_{j=1}^{m} \psi_{kj} \ln Z_k \ln Z_j$$

be estimated. All variable inputs and profit are normalized by the price of output (Yotopoulos and Lau, 1973).

The linkages between demand for variable inputs and their corresponding market prices and fixed inputs are represented by variable input share equations based on Shephard's lemma. Differentiating the translog profit function with respect to gives a system of variable input share equations (Sidhu and Baanante, 1981):

$$(2)\frac{\partial \ln \pi^*}{\partial \ln P_i^*} = -\frac{P_i^* X_i}{\pi^*} = \alpha_i + \sum_{h+1}^{n} \gamma_{ih} \ln P_h^* + \sum_{k=1}^{m} \delta_{ik} \ln Z_k$$

Define $S_i \equiv -\frac{P_i^* X_i}{\pi^*}$ as the relative profit share of the variable input i, and $S_q \equiv -\frac{Q}{\pi^*}$ as the relative profit share of the output. Since the S_i and S_q sum to unity, the output supply equation can be ignored, and the estimation only comprises the translog profit function and the variable input share equations.

From equation (2), the demand for variable input i^{th} will be:

$$(3)X_i = \frac{\pi}{P_i}\left(-\frac{\partial \ln \pi}{\partial \ln P_i}\right), \quad or$$

$$(4)\ln X_i = \ln \pi - \ln P_i + \left(\frac{\partial \ln \pi}{\partial \ln P_i}\right)$$

Following the duality theory, the output supply equation can be written as:

b. Derivation of elasticities:

$$(5)Q = \pi + \sum_{i=1}^{n} P_i X_i \quad ,or$$

$$(6)\ln Q = \ln \pi + \ln\left(1 - \sum_{i=1}^{n} \frac{\partial \ln \pi}{\partial \ln P_i}\right)$$

Price elasticities of demand for inputs and output supply: Price elasticities of demand for inputs, and output supply could be derived from the estimated parameters of the system of equations presented above (Sidhu and Baanante, 1981). The elasticities are evaluated at the simple averages of S_i, denoted as S_i^* and at given levels of variable input prices, and quantity of fixed inputs.

Using equation (4), the own-price elasticity of demand for input X_i can be computed as:

while the cross-price elasticities of demand for

$$(7)\eta_{ii} = -S_i^* - 1 - \frac{\gamma_{ii}}{S_i^*}, i = 1,..., n$$

input i with respect to the price of h^{th} input can be obtained from (4):

$$(8)\eta_{ih} = -S_h^* - \frac{\gamma_{ih}}{S_i^*}, i,h = 1,.., n \ \ but \ \ i \neq h$$

From (4), the elasticity of demand for input i with respect to the price of output can also be derived as:

$$(9)\eta_{iy} = \sum_{i=1}^{n} S_i^* + 1 + \sum_{h=1}^{n} \frac{\gamma_{ih}}{S_i^*}, i,h = 1,..., n$$

With respect to the k^{th} fixed input Z_k the elasticity of demand for input i will be

$$(10)\eta_{ik} = \sum_{i}^{n} \delta_{ik} \ln P_i + \beta_k - \frac{\delta_{ik}}{S_i^*}$$

Using equation (6), the elasticities of output supply with respect to output price (ε_{qq}), the price of the i variable input (ε_{qi}), and fixed inputs (ε_{qk}) are given by:

$$(11)\varepsilon_{qq} = \sum_{i=1}^{n} S_i^* + \sum_{i=1}^{n}\sum_{h=1}^{n} \gamma_{ih} / \left(1 + \sum_{h=1}^{n} S_h^*\right), i,h = 1,..., n$$

$$(12)\varepsilon_{qi} = -S_i^* - \sum_{h=1}^{n} \gamma_{ih} / \left(1 + \sum_{h=1}^{n} S_h^*\right), i,h = 1,..., n$$

$$(13)\varepsilon_{qk} = \sum_{i=1}^{n} \delta_{ik} \ln P_i + \beta_k - \sum_{i=1}^{n} \delta_{ik} / \left(1 + \sum_{i=1}^{n} S_h^*\right)$$

Production elasticities: From parameters estimated from the normalized translog profit function, production elasticities of fertilizers and pesticides can be calculated by using a set of relations between the production and the normalized profit function.

$$(14)\frac{\partial \ln q}{\partial \ln x_i} = -\frac{\theta}{1-\theta}$$

$$where\ \theta = \frac{\partial \ln \pi^*}{\partial \ln P_i^*} = \alpha_i + \sum_{h=1}^{n} \gamma_{ih} \ln P_h^* + \sum_{k=1}^{m} \delta_{ik} \ln Z_k$$

c. Empirical estimation of model:

The profit function in translog form expressing the maximizing profit of a farm household as a function of the prices of inputs and outputs and the fixed factors of production is specified in actual variables as in equation (15) below. There are three variable inputs and two fixed inputs specified in the profit function. To understand the relative economic efficiency of IPM farmers and non-IPM farmers, and capture the difference in soil fertility, two dummy variables are added in the model. Their definitions and notations, along with other variables, are as follows:

(15) The normalized restricted translog profit function:

$$\ln \pi^* = \alpha_o + \alpha_W \ln P_W^* + \alpha_F \ln P_F^* + \alpha_P \ln P_P^* + \tfrac{1}{2}\gamma_{WW}(\ln P_W)^2 + \tfrac{1}{2}\gamma_{FF}(\ln P_F)^2 +$$
$$\tfrac{1}{2}\gamma_{PP}(\ln P_P^*)^2 + \gamma_{WF}\ln P_W^* \ln P_F^* + \gamma_{WP}\ln P_W^* \ln P_F^* + \gamma_{FP}\ln P_F^* \ln P_P^* + \beta_L \ln Z_L + \beta_E \ln Z_E$$
$$+ \tfrac{1}{2}\psi_{LL}(\ln Z_L)^2 + \tfrac{1}{2}\psi_{EE}(\ln Z_E)^2 + \psi_{LE}\ln Z_L . \ln Z_E + \delta_{WL}\ln P_W^* \ln Z_L + \delta_{WE}\ln P_W^* \ln Z_E +$$
$$\delta_{FL}\ln P_F^* \ln Z_L + \delta_{FE}\ln P_F^* \ln Z_E + \delta_{PL}\ln P_P^* \ln Z_L + \delta_{PE}\ln P_P^* \ln Z_E + \lambda_1 IPM + \lambda_2 SOIL$$

π^*	Restricted profit from rice production per farm, defined as total revenue less total variable costs of labor, chemical fertilizers and pesticides normalized by output price. This profit is known as the Unit-Output-Price (UOP) profit.
P_W^*	Wage rate per day normalized by output price . The wage rate is derived by dividing the total labor expenditure in rice production by the quantity of labor, including both family and hired labor. It is expected to have negative effects.
P_F^*	Price of NPK fertilizer nutrient per kilogram normalized by output price . It is expected to have negative effects.
P_P^*	Price of pesticides per gram of active ingredient normalized by output price . This variable expected to have negative effects.
Z_L	Land input measured in acres of rice grown. It is expected to have positive effects on profit, inputs demand and output supply.
Z_E	The education level of main family labor (over 15 years of age). Primary school = 1, Secondary school = 2; and High school and Upper = 3. It is expected to have positive effects.
IPM	Dummy variable taking the value of 1 for farms practising IPM, and 0 otherwise. The sign for this variable is expected to be positive for IPM farmers.
SOIL	Dummy variable represented for land classes from 1 to 5, which captures difference in soil fertility. Land class 1 is the most fertile and provides the highest rice yield.

α, β, γ, δ, ψ, λ are parameters to be estimated, and the subscripts W, F, P, L, E denoted for inputs in the production: labor, fertilizers, pesticides, land, and education, respectively. From (2), the three variable input share equations (S_i) of labor, fertilizers and pesticides are obtained as follows:

Labor share equation (16)

$$S_W \equiv -\frac{P_W^* X_W}{\pi^*} = \alpha_W + \gamma_{WW}\ln P_W^* + \gamma_{WF}\ln P_F^* + \gamma_{WP}\ln P_P^* + \delta_{WL}\ln Z_L + \delta_{WE}\ln Z_E$$

Fertilizer share equation (17)

$$S_F \equiv -\frac{P_W^* X_W}{\pi^*} = \alpha F + \gamma_{FW}\ln P_W^* + \gamma_{FF}\ln P_F^* + \gamma_{FP}\ln P_P^* + \delta_{FL}\ln Z_L + \delta_{FE}\ln Z_E$$

Pesticide share equation (18)

$$S_P \equiv -\frac{P_P^* X_P}{\pi^*} = \alpha_P + \gamma_{PW}\ln P_W^* + \gamma_{PF}\ln P_F^* + \gamma_{PP}\ln P_P^* + \delta_{PL}\ln Z_L + \delta_{PE}\ln Z_E$$

Where X_W, X_F, X_P are denoted for quantities of variable inputs used in rice production, respectively. The measurement units of these variables are man-days for labor, kilogram of nutrients for fertilizers, and grams of active ingredient for pesticides.

d. Model estimation and statistical inference:

Since the input demand share equations have cross-equation symmetry constraints, and disturbances across input demand share equations may be contemporaneously correlated, the profit and input demand share equations should be estimated jointly (Berndt, 1991: 462; Lau and Yotopoulos, 1972). A maximum likelihood estimator is employed to estimate parameters of a system of the profit and input demand share equations (15), (16), (17), and (18), with cross-equation symmetry constraints imposed. The symmetry constraints among input demand share equations require that $\gamma_{ih} = \gamma_{hi}$, where i, h = 1,..., n, but i≠h. In the absence of symmetry restrictions, there are 41 parameters to be estimated, 23 in the profit function and six in each of three input share equations. When cross-equation symmetry constraints $\gamma_{FW}=\gamma_{FW}$, $\gamma_{WP}=\gamma_{PW}$, $\gamma_{PF}=\gamma_{FP}$ are imposed, the number of parameter drops to 38. For profit maximization, parameters of the input share equations have to be equal to the corresponding parameters of the profit function, maintaining the symmetry constraints (Lau and Yotopoulos, 1972; Sidhu and Baanante, 1981). This results in a total of 18 restrictions to be imposed in the system, and the number of free parameters to be estimated being reduced from 38 to 23.

For statistical inference on the validity of parameters estimated and restrictions imposed in the system of equations, there are three common test statistics that could be used interchangeably: the Wald, Lagrange multiplier (LM) and likelihood ratio (LR) tests procedures. In this study, the Wald and the likelihood ratio (LR) test statistics are used since it is easy to implement from the standard output of the value of the sample maximized log-likelihood functions from the software program (LIMDEP). In addition, the t-statistics for each of the coefficients estimated are actually square roots of the Wald test for testing whether the coefficient equals zero.

3. The data

The target region is the Mekong Delta (MKD), which is the biggest rice-growing region in Vietnam. The principal data source for analysis is the information collected through the survey of farming households in the MKD during the 2000/2001 dry season. Stratified sampling was employed to meet the criteria and reduce bias and sampling variability. Stratified sampling offers increased probability of accuracy and reduces sampling error (Henry, 1998: 117-26). The random sampling of farmers engaging in different levels of intensive rice cultivation is a requirement of the stratified sampling method.

The study sites comprised six villages in four provinces: Tiền Giang (Nhị Mỹ in Cai Lậy District), Đồng Tháp (Tân Phú Trung in Châu Thành District and Tân Bình in Thanh Bình District), An Giang (Vĩnh Mỹ in Châu Đốc District and Long Điền B in Chợ Mới District) and Cần Thơ (Thạnh Hòa in Phụng Hiệp District). A total of 30 randomly selected farming households were interviewed in each of the six villages, making a total sample of 180 in the MKD. The approach used for obtaining data was direct interviews with a questionnaire. The survey was conducted in cooperation with officials of the local Agricultural Extension Services, Plant Protection Sub-departments, People's Committees and the local chapter of the Farmers' Association. A final sample size comprised of 157 households with complete information are used in the analysis.

4. Estimation results

a. Testing of profit maximization:

The first hypothesis test concerns the empirical validity of symmetry restrictions across input share equations in the model. Given symmetry, the second is for testing the profit maximization assumption. The LR test statistic shows the validity of the symmetry and parametric constraints through imposition of restrictions on the system of equations.

The null hypotheses of symmetry and profit maximization are not rejected in the 2000/01 model. The computed χ^2(18 d.f.) of the LR test for profit maximization is 34.16, and the critical χ^2 at 1% level of significance equals 34.81. Thus, the null hypothesis cannot be rejected at the 1% level of significance. This implies that, among other things, farming households maximize profits by equating the marginal values of variable inputs to normalized prices of variable inputs. That is, fertilizers, pesticides and labor were used at their economically optimal levels in the 2000/01 winter-spring season. The testing result of the model thus empirically supports the assumption of profit maximization.

b. Parameters estimated from the model:

The parameters of the system of equations for the model are given in Table 1. Table 1 shows that 16 out of the total 23 coefficients in the profit equation[1] are statistically significant at 5% level or higher. The large number of significant cross-product terms indicate the high degree of interdependence between inputs and output in production. Negative cross-product coefficients imply a complementarity in variable inputs and a

[1] Parameters of the three share equations are not presented here. Readers can be found by tracking their correspondent parameters in the profit function.

negative impact on profits. The significant coefficients of the two fixed factors, land and education, indicate that the level of education and farm size have positive influence in providing higher profit from rice production. Statistical significance at 1% level of the dummy variable IPM (λ_1) means that farmers who apply the IPM technique do achieve higher profit than the non-IPM farmers. Higher profitability in rice production of IPM farmers is perhaps due to more effective use of inputs in the production process. The SOIL coefficient representing soil fertility in rice production in the study sites is statistically significant at 1% level, implying a lower profit to farming households that cultivate rice on less-fertile soils.

Table 1: Parameter estimates of the system of normalized translog profit and variable input share equations, MKD 2000/01 survey

Variables	Parameters	Estimated	Standard error	t-ratio
Intercept	α_0	5.112	0.274	18.62***
$\ln P_W$	α_W	0.661	0.132	4.98***
$\ln P_F$	α_F	0.166	0.069	2.40**
$\ln P_P$	α_P	0.210	0.038	5.48***
$\ln P_W \ln P_W$	γ_{WW}	-0.319	0.041	-7.64***
$\ln P_F \ln P_F$	γ_{FF}	-0.158	0.029	-5.55***
$\ln P_P \ln P_P$	γ_{PP}	-0.045	0.004	-10.86***
$\ln P_W \ln P_F$	γ_{WF}	-0.049	0.021	-2.23**
$\ln P_W \ln P_P$	γ_{WP}	-0.004	0.010	-0.32^{NS}
$\ln P_F \ln P_P$	γ_{FP}	0.001	0.006	0.16^{NS}
$\ln Z_L$	β_L	0.680	0.077	8.83***
$\ln Z_E$	β_E	0.193	0.095	2.03**
$\ln Z_L \ln Z_L$	ψ_{LL}	-0.085	0.068	-1.25^{NS}
$\ln Z_E \ln Z_E$	ψ_{EE}	0.006	0.140	0.041^{NS}
$\ln Z_L \ln Z_E$	ψ_{LE}	-0.036	0.025	-1.41^{NS}
$\ln P_W \ln Z_L$	δ_{WL}	0.042	0.019	2.25**
$\ln P_W \ln Z_E$	δ_{WE}	-0.012	0.007	-1.71*
$\ln P_F \ln Z_L$	δ_{FL}	0.006	0.010	0.64^{NS}
$\ln P_F \ln Z_E$	δ_{FE}	0.001	0.003	0.33^{NS}
$\ln P_P \ln Z_L$	δ_{PL}	-0.007	0.004	-1.70*
$\ln P_P \ln Z_E$	δ_{PE}	-0.005	0.002	-2.50***
IPM	λ_1	0.033	0.017	1.91**
SOIL	λ_2	-0.053	0.007	-7.25***

Note: ***,**,* : significant at 1%, 5%, and 10% levels, respectively.

Source: Estimated from system of translog profit and variable input demand functions (equations 15, 16, 17 and 18).

The parameters estimated from the system of equations, however, are interesting not in themselves since there are complex interactions between variables and the effects of each variable input price on profit are not clear-cut. Final conclusions can be drawn from the elasticities to be discussed in the next section

c. Estimated elasticities of output supply and variable input demands:

Elasticities of output supply and variable input demand with respect to (w.r.t.) market prices and fixed inputs are presented in Table 2. The standard errors are presented in brackets under the elasticity estimates. The effects of changes in prices and levels of fixed factors on output supply and input demand are theoretically correct, and most elasticities are found to be statistically significant at the critical 1% level.

- Output supply elasticities:

The elasticities of output supply w.r.t. rice price, prices of variable inputs, and levels of fixed inputs, derived from (11), (12) and (13), have expected positive signs. The elasticity of output supply w.r.t. its own price (ε_{qq}) is 0.23, and significantly different from zero. The inelasticity of own-output supply reveals that with current rice varieties, farmers are not able to increase significant output supply as there is a rise in the market price of rice. This implies a limitation in current rice production technology.

Rice output supply is slightly influenced negatively when there is an increase in prices of variable inputs. The elasticities of output supply w.r.t. prices of fertilizers and pesticides and wage rates are inelastic and significantly different from zero, at 0.09, 0.06 and 0.04, respectively. Increase in the wage rate and prices of fertilizers and pesticides leads to a reduction in the quantities of inputs used, and thus output supplied. Both education and farm size (size of the area in which rice is grown) have positively influenced output supply. The largest positive effect on production is the change in farm size. Output supply is approximately doubled when there is a 100 per cent increase in farm size.

Table 2: Price elasticities of output supply and variable input demand for rice production

Supply / Demand	Rice price	Wage	Fertilizer Price	Pesticide Price	Land	Education
Output	0.227	-0.086	-0.059	-0.039	1.021	0.146
	(0.035)	(0.030)	(0.019)	(0.008)	(0.063)	(0.091)
t-ratio	6.39**	-2.79***	-3.05***	-4.67***	16.25***	1.60*
Labour	0.462	-0.361	-0.041	-0.059	0.928	0.170
	(0.148)	(0.126)	(0.066)	(0.032)	(0.084)	(0.094)
t-ratio	3.11***	-2.84***	-0.62NS	-1.86*	11.05***	1.82*
Fertilizer	0.497	-0.071	-0.355	-0.070	1.022	0.131
	(0.162)	(0.115)	(0.150)	(0.031)	(0.082)	(0.093)
t-ratio	3.05***	-0.62	-2.36**	-2.26**	12.46***	1.40NS
Pesticide	0.897	-0.281	-0.191	-0.425	.952	0.202
	(0.192)	(0.150)	(0.084)	(0.059)	(0.098)	(0.095)
t-ratio	4.67***	-1.86*	-2.26**	-7.16***	9.63***	2.13**

Note: ***,**,* : significant at 1%, 5%, and 10% levels, respectively.

Source: Estimated from parameters of translog profit function, and sample means of rice price, wage, prices of fertilizers and pesticides.

- Demand and cross-demand elasticities for variable inputs:

Profit maximization requires that all of the own-price elasticities of demand for variable inputs are negative. As shown in Table 2, the demand for labor, fertilizers and pesticides w.r.t. their own-prices has the correct signs. All these elasticities are less than one in absolute value, implying inelastic response of input factor utilization. The own-price elasticity of demand for pesticides (η_{PP} = -0.43) is higher than those for labor and fertilizers (η_{FF} = -0.36, and η_{WW} = -0.36, respectively), implying that, for an equivalent rise in prices, farmers' response to a change in pesticide price is relatively higher than the change in wage rate and fertilizer price.

All cross-price elasticities of demand for inputs η_{ih} are generally small, less than one in absolute value, and negative in signs. The low cross-price elasticities of demand reflect limited price responsiveness across the inputs. The effect of wage rate change on fertilizer demand is smaller than on the demand for pesticides. All negative signs of cross-price elasticities of demand reveal that labor, fertilizers and pesticides are gross complements in rice production. The complementary relationships between labor and fertilizers, labor and pesticides, and fertilizers and pesticides are reasonable.

Variable input demand elasticities w.r.t. fixed factors of production, namely land and education, indicate the response to exogenous changes in these factors, holding the prices of output and variable inputs constant. The demand for labor, fertilizers and pesticides is most heavily influenced by expansion of farm size. The input demand elasticities w.r.t. farm size are approximately uniform and statistically different from zero. The influence of more education of main household laborers on the demand for variable inputs is also quite important. It increases the demand for all, labor, fertilizers and pesticides.

A rise in the price of rice will have an expansive effect on the demand for variable inputs used in rice production. Elasticities of demand for labor, fertilizers and pesticides w.r.t. rice price are all positive in sign, consistent with the expectation. The pesticide demand elasticity w.r.t. rice price (η_{PY} = 0.89) is almost twice in absolute value as much as those of labor (η_{WY} = 0.46) and fertilizers (η_{FY} = 0.49), indicating that when there is a rise in rice price, farmers will use more pesticides than fertilizers and labor.

d. Production elasticities of fertilizers and pesticides:

Production elasticities of fertilizers and pesticides calculated from equation (14) are 0.15 and

0.09, and statistically significant at 1% and 5% levels, respectively. The positive sign of these elasticities indicates that fertilizers and pesticides contributed positively to rice yields in the 2000/01 winter-spring season. However, an increase in one of these inputs while keeping the others constant does not result in a high increase in rice production. The low response of rice yields to changes in the application of fertilizers and pesticides suggests that increasing agrochemical inputs to HYV used by farmers is not a wise investment. Since rice yields may reach the ceiling, new rice varieties providing higher yields would be worth investigating and recommending to farmers.

5. Concluding remarks

There are a number of significant issues that can be drawn from the study. ***First,*** the study examined simultaneously the demand and supply sides of rice production by farming households via the profit function approach, which is common in contemporary studies of production economics. The use of the translog profit function allowed a considerably disaggregated analysis of farm production.

Second, rice-growing farmers have responded rationally to market signals. From a microeconomic perspective, production inputs should be applied to the level at which the value of the marginal product equals its price. The study found that rice farmers responded rationally to market signals in the transition from a centrally-planned to a market-oriented economy. The assumption of profit maximization is accepted for the 2000/01 winter-spring season, supporting this argument.

Third, increase in the prices of inputs relative to the rice price was among the factors influencing the reduction and downward adjustment in fertilizer, pesticide doses, and labor applied per hectare per crop. All estimated elasticities have the correct signs and are inelastic (negative for input demand and positive for rice supply). The study also found that the impact of a given change in any of the exogenous variables across variable input demands for labor, fertilizers and pesticides is not symmetric, and that labor, fertilizers and pesticides are gross complements in rice production, thus quite consistent with a priori theoretical expectations.

Fourth, profitability was also influenced by factors other than market prices of inputs and outputs. Farmers who apply the IPM technique do achieve higher profit than non-IPM farmers, and that farming households that cultivate rice in less-fertile soils obtain a lower profit. Profit increases positively with expansion of fixed factors of production, rice land size and education of main household laborers.

A final issue arising from the findings in this study is how to improve rice-farming household income during the transition to a market-oriented economy. Possible farmer's responses to market price changes also raise a number of issues for investigation. Do rice farmers continue to exhibit profit maximization behavior in a competitive market? What policy measures should be introduced to help farmers obtain a higher market price for rice while reducing the effects on consumers? All these issues, for sustainable development of the rice sector, need to be carefully investigated, as the livelihood of many rice-farming households in the MKD is at stake■

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