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Joint Determination of Demand for Inputs and Choice of Rice Varieties in Northern Thailand

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ABSTRACT

The paper explores the potential of Khao Dawk Mali expansion in Northern Thailand as well as presents estimation of demand for variable inputs and choice of rice varieties as jointly determined by the profit-maximizing farmers. Results reveal that, Khao Dawk Mali provides economic advantage over glutinous varieties and can be conceived as a better alternative crop particularly in areas with inadequate irrigation and water control facilities. Consideration of the possibility of rice variety switching, that is, allowing the movement along a meta-production function, improved the elasticity estimates. A two-stage switching regression procedure which adjusts for selectivity bias is used to estimate the model. From the viewpoint of both cost-effectiveness and distributional consideration, price policies for raising rice yields and farm income in Chiang Mai province should focus on rice prices and tractor power prices.

1. INTRODUCTION

Fierce competition in the already thin world rice market for low quality rice exports raised concerns on the future of rice production in Thailand for its increasing labor wages and production costs and its exporting competitors' lower cost of production. Past results revealed that Thailand enjoys stable earning and low competition in the high quality rice market. Khao Dawk Mali, a non-

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glutinous fragrant variety, considered as the top quality rice in Thailand can be conceived as an alternative crop to overcome the existing bottlenecks.

Over the past decade (1980-1991), Khao Dawk Mali production grew at a remarkable rate of 16.13 percent per year in twelve major growing areas concentrated in the northeast and northern[2] regions of Thailand, while during the same period, the overall rice production grew only at the rate of 1.78 percent per year (Rahman, 1993). Also the export volume of Khao Dawk Mali increased almost six folds from 148.5 thousand tons in 1988 to 823.1 thousand tons in 1991. In the northern region, Khao Dawk Mali is grown as an alternative to high yielding glutinous rice varieties (mostly RD 6 and few RD 10) mainly used for consumption and also for domestic market. The modern rice varieties are, in general, fertilizer responsive varieties with high yields at higher level of fertilization and irrigation, and are well suited under the bio-physical environment of northern Thailand. The national average yield of glutinous variety (RD 6) is 276 kg per rai[3] and Khao Dawk Mali is 260 kg per rai for the wet season crop year 1990/91 (DAE, 1991). However, its further intensification seems to be in contrast with the current government policy of reducing use of chemical fertilizer as well as scarce water for irrigation. Khao Dawk Mali, on the other hand, is less responsive to fertilizer with similar yield potential at low level of fertilization and is drought resistant. Khao Dawk Mali also fetches relatively higher and stable price as compared to the glutinous varieties. Therefore, decision criterion of farmers to choose between Khao Dawk Mali and the glutinous varieties lies in the priority attached to consumption and market. Moreover, various interlinked

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1. Though northern region is considered as the second major Khao Dawk Mali growing area, the total area under Khao Dawk Mali production is much less than the northeastern region.

2. 6.25 rai = 1 hectare.

considerations mentioned above intensify the importance of choice or switching between varieties along with the input level adjustments in response to input and output price changes in order to maximize profit by farmers as evidenced in terms of increasing acreage and production of Khao Dawk Mali. As such, joint determination of farmers' responses to variable input and output price changes and rice variety choice at the farm-level would assist in exploring the potential of Khao Dawk Mali expansion as well as for predicting the impact of alternative policy instruments to assist the rice production sector.

2. THE STUDY AREA

Chiang Mai Valley which stretches over the large part of the provincial area is endowed with favorable production environment for most of the economic crops and is a major supplier of various agricultural produce of the country. The main notable crops are, rice, soybean, onion, garlic, chilly, various vegetables, tobacco and seasonal fruits. Rice based cropping system is the mainstay of the farmers. Moreover, the growth of Khao Dawk Mali production in Chiang Mai province has been remarkable which steadily expanded from 36.4 thousand rai in 1980/81 to 98.8 thousand rai in 1987/88 but then recorded a decline in the subsequent years lowering to 85.7 thousand rai in 1990/91. On the contrary, the yield level boosted up from a mere 380 kg per rai in 1980/81 to 655 kg per rai in 1990/91 (Rahman, 1993). Therefore, for the present study, Chiang Mai province was chosen to represent the resource rich northern region and to investigate the fluctuation in terms of planted area and production.

2.1 Sampling Procedure and Data Collection

Plot-level crop production data for the wet season, crop year 1992, were collected from six districts (*ampho*) of Chiang Mai Province. Multi-stage sampling was used for selection of farm-plots implying that; firstly a purposive selection of districts where Khao Dawk Mali and other glutinous varieties are predominantly cultivated in the northern region of Thailand was made. Also, land type, production environment and income distribution of farmers was considered as much as possible.

Based on various literatures on rice studies, particularly on a recent survey conducted by the Department of Agricultural Extension (DAE), six districts, namely, Phrao, Doi Saket, San Sai, Mae Rim, San Kam Phaeng, and San Pa Tong were chosen in the first stage.

The next stage was a random sampling of fifteen sub-districts (*tambon*) from the above districts. Then a cluster of twenty two villages were chosen for primary data collection, emphasizing wide scatter of farm plots.

A total of 269 sample farmers - 136 Khao Dawk Mali producers and 133 glutinous rice producers, were selected as respondents from the aforementioned 22 villages scattered over six-districts.

2.2 The Production Environment

The production environment of the study area scattered over a 100 km radius comprises of a mix of irrigated agriculture as well as rainfed agriculture with a rice based double cropping system. Khao Dawk Mali is produced largely in Doi Saket, San Sai and Phrao, while glutinous varieties are dominant in San Pa Tong, San Kam Phaeng and Mae Rim. Phrao district is basically considered as out of the lowland agro-ecosystem of the Chiang Mai valley characterized with relatively poor infrastructure network, irrigation system and partially elevated land types. The other five districts have a complex mix of intensive agriculture based systems to semi-industrialized and urban economic systems.

3. METHODOLOGY

Hayami and Ruttan (1985) postulated that changes in the relative price of fertilizer will induce cultivators to switch to seed varieties of differing intensiveness so as to maximize profits with respect to a meta-production function. The meta-production function is the envelope containing the production surfaces of all potential seed varieties, irrigation systems and cultivation techniques (for details see Pitt, 1983; and Hayami and Ruttan, 1985). As Pitt (1983) notes that, ignoring the possibility of seed variety switching leads to underestimates of input demand elasticities, and also the estimation with samples reflecting a single rice variety involves serious selection bias. Therefore, a Two-Stage Switching Regression procedure which adjusts for selectivity bias is used to estimate the normalized restricted translog profit function model.

3.1 Specification of the Model

Farmers are assumed to choose between high quality rice, Khao Dawk Mali and other glutinous rice varieties so as to maximize profits. With every combination of fixed factors and variable factor prices, there is an associated variable profit for the two seed varieties. Farmers will choose to plant Khao Dawk Mali seeds if the variable profit obtained by doing so exceeds that obtained by planting other glutinous rice varieties grouped as one.

The general model consists of two regimes described by the simultaneous equations,

$$I' = (\pi_{qi} - \pi_{gi})\lambda - \varepsilon_i$$

$$\pi_{qi} = P_i\beta_q + Z_i\gamma_q + \varepsilon_{qi} \quad (1)$$
$$\pi_{gi} = P_i\beta_g + Z_i\gamma_g + \varepsilon_{gi} \quad (2)$$

where P_i is a vector of variable factors and output prices; Z_i is a vector of fixed factors; π_{qi} and π_{gi} represent variable profits under the Khao Dawk Mali and glutinous variety regime, respectively; i =

1, 2,..., N; β_q, β_g, γ_q, γ_g, and λ are vector of parameters; and

$$\varepsilon_{qi} \_ N(0,\sigma_q^2),\ \varepsilon_{gi} \_ N(0,\sigma_g^2),\ \varepsilon_i \_ N(0,\sigma_\varepsilon^2)$$

Equations (1) and (2) are variable profit functions. Equation (3) is the selection criterion function, and I' is an unobservable variable. A dummy variable, I_i is observed. It takes the value of 1 if a plot is planted with Khao Dawk Mali, 0 otherwise: i.e.,

$$\begin{aligned} I_i &= 1,\ if\ \ I_{i'} \geq 0 \\ &= 0,\ otherwise \end{aligned} \quad (4)$$

Since Khao Dawk Mali and glutinous varieties are mutually exclusive, planting of both varieties cannot be observed simultaneously on any one plot. Thus, observed variable profit π_i takes the values

$$\begin{aligned} \pi_i &= \pi_{qi},\quad iff\ \ I_i = 1 \\ \pi_i &= \pi_{gi},\quad iff\ \ I_i = 0 \end{aligned} \quad (5)$$

The population regression function for equation (1) may be written as

$$E(\pi_{qi} | P_i, Z_i) = P_i \beta_{qi} + Z_i \gamma_{qi},\qquad i = 1,....N \quad (6)$$

This function could be estimated without bias from a random sample of the population of paddy cultivators. The regression function for the incomplete sample (Khao Dawk Mali cultivators only) may be written as

$$\begin{aligned} &E(\pi_{qi} | P_i, Z_i,\ sample\ \ selection\ \ rule) \\ &\quad = P_i \beta_{qi} + Z_i \gamma_{qi} + E(\varepsilon_{qi} | sample\ \ selection\ \ rule),\quad i = 1,...,N_1 \end{aligned} \quad (7)$$

where without loss of generality the first N_1 observations are assumed to contain data on π_q. If the conditional expectation of ε_{qi} is zero, a regression on the incomplete sample will provide unbiased estimates of β_{qi} and γ_{qi}. Regression estimates of (1) fitted on a selected sample directly, omit the final term, i.e., the conditional mean of ε_{qi}, are shown on the right hand side of equation (7). Thus the bias, that arises from using least squares to fit models for limited dependent variables or models with truncation arises solely because the conditional mean of ε_{qi} is not included as a regressor. Therefore, the bias that arises from selection may be interpreted as arising from an ordinary specification error with the conditional mean deleted as an explanatory variable (Heckman, 1976).

However, it is not likely that both

$$E(\varepsilon_{qi} | I_i = 1) = 0, \quad E(\varepsilon_{gi} | I_i = 0) = 0 \quad (8)$$

This would occur only in very special situations (Lee, 1978). In the model, suppose that $\lambda > 0$, then it is likely that an observation of $I_i = 1$ will be associated with a positive value of ε_{qi} or negative value ε_{gi}. That is, random factors associated with high Khao Dawk Mali profit are likely to be associated with observed adoption.

3.2 Estimation Procedure

Estimation of the variable profit functions (7) with selected samples can be accomplished with the Two-stage Switching Regression method described by Pitt (1983), Lee (1978) and Heckman (1976). The objective is to find an expression that adjusts the profit function error terms so that they have zero means. A reduced-form seed selection equation is obtained by substituting the profit functions (1) and (2) into the seed selection equation (3).

$$I_{i'} = \theta_0 + P_i \theta_1 + Z_i \theta_2 - \varepsilon_{i'} \quad (9)$$

By estimating (9) as a typical probit equation, it is possible to compute the probability that any plot has missing data on π_{qi} or π_{gi}. The probit reduced form itself shows how prices and fixed factors affect the probability of adopting Khao Dawk Mali. If the joint density of ε_{qi}, ε_{gi} and ε_i is multivariate normal, then the conditional expectation on the right-hand side of (7) is (Maddala, 1983)

$$E(\varepsilon_{qi} \mid I_i = 1) = \sigma_{1\varepsilon'} \left(\frac{-f(\phi_i)}{F(\phi_i)}\right) \quad (10)$$

where F is the cumulative normal distribution and *f* is its density function, both evaluated at φ_i. $F(\varphi_i)$ is the probability that π_{qi} is observed and $\sigma_{1\varepsilon'} = Cov(\varepsilon_q, \varepsilon')$.

The two-stage procedure uses $-f(\varphi_i)/F(\varphi_i)$ and $f(\varphi_i)/[1 - F(\varphi_i)]$ as regressors in the Khao Dawk Mali and glutinous variety profit function, respectively, to purge them of bias. Estimates of φ_i are just $\theta\_0 + P_i\theta\_1 + Z_i\theta\_2$, obtained from the estimated probit reduced-form equation (9).

We get estimates θ_0, θ_1, and θ_2 using the probit Maximum Likelihood (ML) method. Then, conditional on selection status, the variable profit equation for Khao Dawk Mali is,

$$\pi_{qi} = P_i \beta_q + Z_i \gamma_q + \sigma_{1\varepsilon'} \left(\frac{-f(\phi_i)}{F(\phi_i)}\right) + \xi_{qi} \quad (11)$$

The variable profit equation for glutinous varieties is,

$$\pi_{gi} = P_i \beta_g + Z_i \gamma_g + \sigma_{2\varepsilon'} \left(\frac{f(\phi_i)}{1 - F(\phi_i)}\right) + \xi_{gi} \quad (12)$$

where $\sigma_{2\varepsilon'} = Cov(\varepsilon_g, \varepsilon')$. After obtaining $\varphi\_$ from the probit estimates of θ_0, θ_1 and θ_2 and substituting it for φ_i in equations (11) and (12), these equations can be estimated by Ordinary Least Squares (OLS). The third term in both equations is the seed selection variable (W).

Two common alternative functional forms are translog and Cobb-Douglas. The former one does not maintain additivity or unitary Hicks-Allen elasticities of substitution as the later (Pitt, 1983 and Johnston, 1984). The translog variable profit function for each seed variety can be written as

$$\ln \pi' = \alpha_0 + \alpha_i \sum_i \ln P_{i'} + \frac{1}{2} \sum_i \sum_h \gamma_{ih} \ln P_{i'} \ln P_{h'} + \sum_i \sum_k \delta_{ik} \ln P_{i'} \ln Z_k$$

$$+ \sum_k \beta_k \ln Z_k + \frac{1}{2} \sum_k \sum_j \psi_{kj} \ln Z_k \ln Z_j + \sigma_{tu} W + \xi \quad (13)$$

$$(i = h = 1,2,3,....,n + k = j = 1,2,3,.....,m; t = 1,2)$$

where $\gamma_{ih} = \gamma_{hi}$ for all *h*, *i*, and the function is homogenous of degree one in prices of all variable inputs and output. The definition of the variables and the notation used are as follows: π' is the restricted variable profit normalized by the price of output (π/P_y), (the profit refers to total revenue less total variable input costs); P_i' is the normalized price of variable input X_i (P_i/P_y), Z_k is the quantity of the *k*th fixed factors; *ln* is the natural logarithm; the parameters α_0, α_i, γ_{ij}, β_k, δ_{ik}, ψ_{kj} and σ_{tu} are to be estimated.

From the profit function (13), the following equation can be derived for a variable input (Diewert, 1974 and Sidhu and Baanante, 1981)

$$S_i = -\frac{P_{i'} X_i}{\pi'} = \frac{\partial \ln \pi'}{\partial \ln P_{i'}} = \alpha_i + \sum_h \gamma_{ih} \ln P_{h'} + \sum_k \delta_{ik} \ln Z_k \quad (14)$$

where S_i is the ratio of variable expenditures for the *i*th input to variable profit. Profits and variable input demands are determined simultaneously. Under price-taking behavior of the farms, the normalized input prices and quantities of fixed factors are considered to be the exogenous variables.

The coefficient estimates of the profit functions obtained from this two-stage procedure are consistent (Pitt, 1983).

3.3 Input Demand Elasticities After Allowing for Seed Switching

After obtaining the parameter estimates of equations (13) and (14), one can get the elasticities of variable input demands and output supply with respect to all exogenous variables evaluated at averages of the S_i and at given levels of variable input prices and fixed factors which are linear transformations of the parameter estimates of the profit function (For details see Sidhu and Baanante 1981).

The price elasticity of demand for inputs allowing for seed switching can be readily calculated from the parameters of the probit seed selection equation and the corresponding sets of input demand equations or share equations.

The expected demand for variable input *i* by a representative cultivator having mean levels of fixed factors and facing mean prices is

$$E(X_i) = E(X_i | I = 1)Prob(I = 1) + E(X_i | I = 0)Prob(I = 0), \quad (15)$$

where $E(X_i | I = 1)$ and $E(X_i | I = 0)$ are the demand for input *i* under a Khao Dawk Mali and a glutinous variety regime, respectively; and Prob (I = 1) and Prob (I = 0) are probabilities of observing a Khao Dawk Mali and a glutinous variety regime, respectively. The log derivative of this expectation with respect to the price of *i*th input is the total price elasticity of demand (η), which can be reduced to (Pitt, 1983)

$$\eta = \frac{\eta_q E(X_i | I = 1)Prob(I = 1)}{E(X_i)} + \frac{\eta_g E(X_i | I = 0)Prob(I = 0)}{E(X_i)} + \frac{\zeta_q [E(X_i | I = 1) - E(X_i | I = 0)]Prob(I = 1)}{E(X_i)} \quad (16)$$

where ζ_q is the elasticity of the probability of choosing Khao Dawk Mali variety with respect to the price of the *i*th input, and for estimating the total own price-elasticity of demand, η_q and η_g are given by

$$\eta_t \;=\; - S_{i'} - 1 - \frac{\gamma_{ii,t}}{S_{i'}} \qquad t = KDML,\ \ Glutinousvariety \quad (17)$$

Similarly, the total cross-price elasticity of demand with respect to input prices and cross-price elasticities with respect to fixed factors can be obtained from the above expression (16) by replacing (17) with appropriate expression as required.

4. DECISION MAKING AND CHOICE OF RICE VARIETIES

4.1 Farmers' Choice Criteria: The First Stage Probit Estimation of the Reduced-Form Seed Selection Equation

The variables included in the profit function and the probit reduced-form seed selection equation are: π' defined as the restricted profit from rice production per farm - total revenue less total costs of labor, seeds, chemical fertilizer, manures, irrigation, pesticides, and tractor power normalized by the price of rice; P_W' is the normalized wage rate of labor per day; P_F' is the normalized price per kg of fertilizer materials; and P_M' is the normalized price of tractor power per rai.

The definitions of the two fixed inputs included in the specification of the profit function, are, Z_L is the land input measured as rai of rice grown per farm; and Z_A is the quantity of farm equipment and machinery used for rice production per farm measured as baht of total stock value.

Six dummy variables were incorporated in the model reflecting the farmers' ranking of factors affecting their decision to choose varieties. D_1 = 1 for profit motive, 0 otherwise; D_2 = 1 for ready marketability, 0 otherwise; D_3 = 1 for drought resistance, 0 otherwise; D_4 = 1 for short maturity, 0 otherwise; D_5 = 1 for consumption motive, 0 otherwise and D_6 = 1 for disease resistance, 0 otherwise.

The first stage maximum likelihood estimates of the probit reduced-form seed selection equation are presented in Table 1. About 89 percent of the observations are accurately predicted and the McFadden's R-squared was 0.644. The profit motive and the ready marketability of Khao Dawk Mali are significantly positively related to the probability of adoption of Khao Dawk Mali while consumption desire is significantly negatively associated. The coefficients of Table 1 cannot directly reveal the sign or magnitude of the change in the probability of planting Khao Dawk Mali in response to changes in the exogenous variables. The information on the magnitude and direction of the factors affecting seed selection decision is provided as elasticities in Table2.

Table 1. Probit reduced-form of seed selection equation

Exogenous Variables	Estimated Coefficients	Standard Error
Intercept	92.4742	41.7700
$\ln P_W'$	-38.9804	17.2900
$\ln P_F'$	4.1108	14.8600
$\ln P_M'$	-13.2307	8.3020
$½(\ln P_W')^2$	8.3392	4.6040
$½(\ln P_F')^2$	-12.3573	6.2150
$½(\ln P_M')^2$	1.3217	1.2760
$\ln P_W'.\ln P_F'$	0.0079	4.3660
$\ln P_W'.\ln P_M'$	2.0955	1.4780
$\ln P_F'.\ln P_M'$	1.1955	1.7980
$\ln Z_L$	-7.6138	4.2750
$\ln Z_A$	0.3930	1.7410
$\ln P_W'.\ln Z_L$	2.0658	0.9225
$\ln P_W'.\ln Z_A$	0.0644	0.3990
$\ln P_F'.\ln Z_L$	-1.7782	1.0970
$\ln P_F'.\ln Z_A$	-0.3593	0.5537
$\ln P_M'.\ln Z_L$	0.0936	0.4833
$\ln P_M'.\ln Z_A$	0.0358	0.1926
$½(\ln Z_L)^2$	0.2769	0.3799
$½(\ln Z_A)^2$	-0.1020	0.0801
$\ln Z_L .\ln Z_A$	0.1268	0.1308
D_1	1.3288	0.3648
D_2	0.7937	0.2832
D_3	0.1852	0.3831
D_4	0.0405	0.5624
D_5	-1.3634	0.3390
D_6	-0.2695	0.3619
Accuracy of Prediction	= 88.57 percent	
McFadden R^2	= 64.46 percent	

[a] D_1 = Profit motive, D_2 = Ready marketability, D_3 = Drought resistance, D_4 = Short maturity, D_5 = Consumption motive, D_6 = Disease resistance.

McFadden $R^2 = 1 - \log L_{max}/\log L_0$

Source: Computed

All the six elasticities (at the sample means) are significantly different from zero suggesting that seed selection is quite responsive to changes in prices (Table 2). This means, an increase in rice price will induce the farmers to choose to plant Khao Dawk Mali. On the other hand, an increase in the prices of inputs, such as labor, fertilizer, and tractor power prices, will have an opposite effect, that is, reduce the probability of planting Khao Dawk Mali. The elasticity of probability with respect to land area is positive, though small, suggesting that larger farms tend to choose Khao Dawk Mali for production.

Table 2. Elasticities of the probability of planting Khao Dawk Mali at sample means

Exogenous Variable	Estimates	t-Ratio
Rice Price[a]	2.7890	4.276***
Price of Labor[b]	-2.1574	-13.499***
Fertilizer Price[b]	-2.0576	-13.077***
Tractor Power Price[b]	-0.9465	-14.715***
Area	0.0662	1.675*
Farm Assets	0.0389	2.803***

*** Significant at 1 percent level
* Significant at 10 percent level
[a] Elasticity of probability computed at a given level of fertilizer, labor and tractor power prices.
[b] Elasticity of probability computed at a given level of output price.
Source: Computed

5. INPUT DEMAND AND OUTPUT SUPPLY ESTIMATIONS

5.1 Maximization of the Profit Function: The Second Stage Estimation

The profit function and the corresponding three share equations are jointly estimated using the Seemingly Unrelated Regression Estimator method for each regime in the second stage after incorporating the selectivity variable obtained from the probit estimation.

Table 3 provides the joint restricted parameter estimates of the normalized restricted translog profit function and labor, fertilizer, and tractor power share equations adjusted for selectivity bias for Khao Dawk Mali and glutinous variety, respectively. Both the Wald Test and

Likelihood Ratio Test satisfy the validity of the estimation of two functions and are highly significant (see at the bottom of Table 3). This implies, among other things, that the sample farms, on an average, maximize profits with respect to normalized prices of the variable inputs, thus supporting empirically the assumption of profit maximization. Evidence of profit maximizing behavior of the Thai farmers were also found by Puapanichya and Panayotou (1985) and Adulavidhaya *et al.* (1979).

At the bottom of the profit function Table 3, the coefficients and standard errors of the selectivity variables appear, $-f(\varphi_i)/F(\varphi_i)$ for Khao Dawk Mali function and $f(\varphi_i)/[1-F(\varphi_i)]$ for the glutinous variety function. The selection variable is significantly different from zero at the 5 percent level of significance in the Khao Dawk Mali function. This is the evidence of pronounced selection bias in estimating equations from a subsample of cultivators (Pitt, 1983). On the other hand, there appears to be no significant selection bias in the estimation of the glutinous variety function. Therefore, two stage estimation of glutinous function will perform equally well as the single stage estimation from a subsample of glutinous variety cultivators since the selectivity variable is not significant[4]. In other words, direct estimation of the profit function of the glutinous variety will not be biased.

3. In general, the selectivity variable may be significant in any or both of the equations (Lee, 1987 and Pitt, 1983).

Table 3. Joint estimation of the normalized profit function and factor share equations for variable inputs in Khao Dawk Mali and Glutinous varieties, adjusted for selectivity bias

		Khao Dawk Mali		Glutinous variety	
Exogenous Variables	Parameters	Estimated Coefficient	Standard Error	Estimated Coefficient	Standard Error
Profit Function					
Intercept	α_0	4.426390	1.41800	-6.451160	3.76700
ln P_W'	α_W	1.248510	0.43320	4.268910	1.55000
ln P_F'	α_F	0.155517	0.04858	0.964339	0.25340
ln P_M'	α_M	0.537954	0.27050	2.833110	0.54070
½(ln P_W')²	γ_{WW}	-0.505934	0.08738	-0.885752	0.37550
½(ln P_F')²	γ_{FF}	-0.037314	0.01704	-0.167022	0.05582
½(ln P_M')²	γ_{MM}	-0.167047	0.03508	-0.481910	0.05545
ln P_W'.ln P_F'	γ_{WF}	-0.059198	0.01193	-0.241562	0.05893
ln P_W'.ln P_M'	γ_{WM}	-0.036987	0.04430	-0.311021	0.11020
ln P_F'.ln P_M'	γ_{FM}	-0.007711	0.00591	-0.077961	0.02755
ln Z_L	β_L	1.185680	0.31690	1.731000	0.64760
ln Z_A	β_A	-0.183577	0.14070	0.234516	0.25850
ln P_W'.ln Z_L	δ_{WL}	-0.055211	0.04877	-0.372954	0.13300
ln P_W'.ln Z_A	δ_{WA}	0.006163	0.02154	-0.037885	0.04869
ln P_F'.ln Z_L	δ_{FL}	0.001186	0.00544	0.012171	0.02538
ln P_F'.ln Z_A	δ_{FA}	-0.001656	0.00254	0.001791	0.00985
ln P_M'.ln Z_L	δ_{ML}	-0.050464	0.02905	-0.045298	0.05392
ln P_M'.ln Z_A	δ_{MA}	0.014067	0.01277	-0.017442	0.02042
½(ln Z_L)²	ψ_{LL}	0.059403	0.04085	0.052972	0.11250
½(ln Z_A)²	ψ_{AA}	0.015272	0.01205	-0.009744	0.01711
ln Z_L .ln Z_A	ψ_{LA}	-0.006197	0.01750	0.025866	0.02710
Selectivity variable	σ_{1u}, σ_{2u}	0.151716	0.06902	-0.082994	0.11150
D_1	ω_1	0.294021	0.08896	0.026461	0.09123
D_2	ω_2	0.007646	0.04638	-0.023041	0.09586
D_3	ω_3	0.033761	0.05918	0.010550	0.08703
D_4	ω_4	0.005025	0.09492	-0.025109	0.09321
D_5	ω_5	-0.153482	0.08516	0.059358	0.08232
D_6	ω_6	0.095372	0.06342	0.007431	0.08375

Table 3. (continued)

Exogenous Variables	Parameters	Khao Dawk Mali Estimated Coefficient	Khao Dawk Mali Standard Error	Glutinous variety Estimated Coefficient	Glutinous variety Standard Error
Labor Share Equation					
Intercept	α_W	1.248510	0.43320	4.268910	1.55000
ln P_W'	γ_{WW}	-0.505934	0.08738	-0.885752	0.37550
ln P_F'	γ_{WF}	-0.059198	0.01193	-0.241562	0.05893
ln P_M'	γ_{WM}	-0.036987	0.04430	-0.311021	0.11020
ln Z_L	δ_{WL}	-0.055211	0.04877	-0.372954	0.13300
ln Z_A	δ_{WA}	0.006163	0.02154	-0.037885	0.04869
Fertilizer Share Equation					
Intercept	α_F	0.155517	0.04858	0.964339	0.25340
ln P_W'	γ_{FW}	-0.059198	0.01193	-0.241562	0.05893
ln P_F'	γ_{FF}	-0.037314	0.01704	-0.167022	0.05582
ln P_M'	γ_{FM}	-0.007711	0.00591	-0.077961	0.02755
ln Z_L	δ_{FL}	0.001186	0.00544	0.012171	0.02538
ln Z_A	δ_{FA}	-0.001656	0.00254	0.001791	0.00985
Tractor Power Share Equation					
Intercept	α_M	0.537954	0.27050	2.833110	0.54070
ln P_W'	γ_{MW}	-0.036987	0.04430	-0.311021	0.11020
ln P_F'	γ_{MF}	-0.007711	0.00591	-0.077961	0.02755
ln P_M'	γ_{MM}	-0.167047	0.03508	-0.481910	0.05545
ln Z_L	δ_{ML}	-0.050464	0.02905	-0.045298	0.05392
ln Z_A	δ_{MA}	0.014067	0.01277	-0.017442	0.02042

Test of Hypotheses:	**Khao Dawk Mali**	**Glutinous Variety**
Wald Test: χ^2 (18 degrees of freedom)	= 36.36***	68.07***
Likelihood Ratio Test: χ^2 (18 degrees of freedom)	= 33.87**	53.83***

*** Significant at 1 percent level

** Significant at 5 percent level

[a] D_1 = Profit motive, D_2 = Ready marketability, D_3 = Drought resistance, D_4 = Short maturity, D_5 = Consumption motive, D_6 = Disease resistance.

Selectivity Variable: Khao Dawk Mali $= -f(\varphi_i)/F(\varphi_i)$

Glutinous variety $= f(\varphi_i)/[1-F(\varphi_i)]$

Source: Computed

The coefficients are generally larger in magnitude for glutinous function since the profitability in glutinous variety production is significantly lower as compared to Khao Dawk Mali, as such, variations in input prices and exogenous factors would lead to larger decreases in profitability in absolute terms. The reverse is true for the smaller coefficients in Khao Dawk Mali function.

5.2 Input Demand and Output Supply Elasticities

The estimates presented in Table 3 form the basis for deriving elasticity estimates for rice supply and input demand for the variable inputs of labor, fertilizer, and tractor power. These elasticities are evaluated at simple averages of the S_i, variable input prices and fixed inputs. This provides the basis of using equation (16), which uses elasticity estimates from each regime plus the elasticities of the probabilities presented in Table 1. The elasticity estimates of individual varieties, and total elasticity of demand after allowing for seed switching adjustments (or permitting movements along the meta-response surfaces) are presented in Table 4.

In the translog function, the impact across variable input demand functions for labor, fertilizer, and animal power of a given change in any of the exogenous variables is not symmetric. It varies across demand equations, which is consistent with *a priori* theoretical expectations (Sidhu and Baanante, 1981).

All the own-price elasticities are less than one (except labor price for glutinous variety) indicating an inelastic response of factor utilization. The finding are consistent with the estimates for Chiang Mai valley by Sriboonchitta (1983).

Allowance for seed switching raises the total elasticites substantially (ranging from 16 percent to 58 percent) indicating the supply of rice and demand for inputs become more elastic. The total elasticity of output supply rises from 0.28 to 0.45 (or increases by 58 percent). The total input demand for fertilizer, labor and tractor increase by 16, 49 and 42 percent, respectively (Table 4).

Table 4. Derived elasticity estimates for rice supply and demand for variable inputs of rice

Elasticity of	Rice price	Fert. price	Labor price	Tractor price	Farm assets	Land
Khao Dawk Mali rice						
Output supply	0.1919	-0.0117	-0.0756	-0.0485	0.0400	0.7699
Fert. demand	0.1441	-0.5190	-0.0436	-0.0613	0.0793	0.6902
Labor demand	0.2917	-0.0682	-0.2704	-0.0896	0.0407	0.8347
Tractor Demand	0.4657	-0.0238	-0.2229	-0.2189	0.0247	0.9964
Glutinous rice						
Output supply	0.7898	-0.0511	-0.7099	-0.2089	0.0107	0.3179
Fert. demand	0.6879	-0.4492	-0.0905	-0.1481	0.0063	0.1231
Labor demand	1.7329	-0.0164	-1.4644	-0.2478	0.0396	0.4895
Tractor demand	1.2068	-0.0635	-0.5877	-0.5551	0.0425	0.2685
Total elasticity of supply and demand (with seed switching adjustments)						
Output supply	0.4458	-0.0176	-0.1693	-0.0728	0.0369	0.7197
Fert. demand	0.2268	-0.6014	-0.0513	-0.0738	0.0699	0.6185
Labor demand	0.5282	-0.0566	-0.6963	-0.1133	0.0389	0.7423
Tractor demand	0.5654	-0.0292	-0.2723	-0.3731	0.0265	0.8349

Source: Computed

All the three variable inputs are complements, rather than substitutes, as indicated by the negative cross-price elasticities between inputs. Complementarity in inputs for Thai agriculture, including rice, were also validated by Puapanichya and Panayotou (1985) and Adulavidhaya *et al.* (1979) and Sriboonchitta (1983). The fixed inputs appear to be important in influencing rice supply. Their influence, however, is not uniform on labor, fertilizer and tractor power demand functions. The exogenous increases in land quantity and expansion in farm capital, will raise rice supply and demand for all variable inputs of production. The elasticities of output supply with respect to the value of fixed farm assets and land size were 0.04 and 0.72, respectively. This indicates that one percent increase in the value of fixed farm assets would increase output supply by 0.04 percent, while a one percent increase in land size would increase output supply by 0.72 percent.

5.3 Policy Analysis

The ultimate purpose of this study is to identify cost-effective policy instruments for raising crop yields and income of the farm families which is also a central objective of the Thai agricultural policy. Fifteen policy alternatives are considered: four single instrument policies (fertilizer price, labor price, tractor power price and rice price); six two-instrument combinations; four three-instruments combinations; and, one four-instrument combination. For analysis, we consider the effect of a 10 percent reduction in input prices (i.e., fertilizer, labor and machinery subsidies) and a 10 percent increase in rice prices (output subsidy) both individually and in combination.

The procedure used to calculate the cost-effectiveness of the policy alternatives were adopted from Puapanichya and Panayotou (1985) : First, based on the elasticity estimates the percentage changes in input use and crop production as a result of these subsidies were calculated (Table 5). Second, using these percentages and the estimated input and production data of the sample (Table 6), the absolute changes in input use and crop production were calculated on a *per rai basis* (as a representative for Chiang Mai province as a whole) which were then converted to costs and value, respectively, using the corresponding post-subsidy prices.

The difference between the change in value and the change in costs is the benefit to the farmers from the subsidy-induced increase of production. To arrive at the total net benefit to the farmers from the subsidy, we have to add the savings in input cost and increase in output value from the pre-subsidy level of production. Next step is to calculate the cost of subsidy to the government which equals the unit output subsidy multiplied by the post subsidy output plus the unit subsidy multiplied by the post subsidy input use. Finally, the difference between the total benefit to the farmers and the cost to the government gives the net social benefit of the subsidy. The various policy alternatives are ranked according to the ratio of their net social benefit to their cost on a per rai basis.

Table 5. Effects of selected policies on wet season rice production in Chiang Mai province

Policy	Farmers' response (% effect on input and output)			
	Use of Fertilizer	Use of Labor	Use of Tractor	Rice Output
1. 10 % ↓ in fert. price	6.014	0.566	0.292	0.176
2. 10 % ↓ in wage rate	0.513	6.963	2.723	1.693
3. 10 % ↓ in trac. price	0.738	1.133	3.731	0.728
4. 10 % ↑ in rice price	2.268	5.282	5.654	4.458
5. (1) + (2)	6.527	7.529	3.015	1.869
6. (1) + (3)	6.752	1.699	4.023	0.904
7. (1) + (4)	8.282	5.848	5.946	4.634
8. (2) + (3)	1.251	8.096	6.454	2.421
9. (2) + (4)	2.781	12.245	8.377	6.151
10. (3) + (4)	3.006	6.415	9.385	5.186
11. (1) + (2) + (3)	7.265	8.662	6.746	2.597
12. (1) + (2) + (4)	8.795	12.811	8.669	6.327
13. (1) + (3) + (4)	9.020	6.981	9.677	5.362
14. (2) + (3) + (4)	3.519	13.378	12.108	6.789
15. (1) + (2) + (3) + (4)	9.533	13.944	12.400	7.055

Source: Computed

Table 6. Base-line data used for calculating costs and benefits of alternative inputs and output price policies

Fertilizer quantity (kg/rai)	16.79
Fertilizer price (baht/kg)	5.47
Labor amount (man-day/rai)	6.18
Wage rate (baht/man-day)	72.27
Tractor quantity (unit/rai)	1.00
Tractor rate (baht/rai)	214.38
Rice production (kg/rai)	627.00
Rice price (baht/kg)	3.78

Note: Estimated at the sample means for wet season rice production (all varieties).
Source: Computed

Table 7 summarizes the results of these calculations. For rice production in Chiang Mai province, the most cost-effective policy appears to be an increase in output price. A 248 baht subsidy per rai will give a net benefit of 315 baht per rai to the farmers and 68 baht per rai to the country with a rate of return of 27 percent. Input price subsidies, particularly fertilizer (which has been a common approach in the past plans), cannot be justified because of its negative net impact on the economy as well as resultant negligible benefit to farmer. The reason could be attributed to persistent low fertilizer application rate (particularly in wet season rice) with consequent little response in yield resulting in an inelastic demand. Subsidizing labor price, on the other hand, might not be desirable since it will reduce the relative share of labor in the production economy thereby affecting distributive justice.

Table 7. Cost-effectiveness of alternative policies for rice production

Policy Alternatives	Net benefit to farmers (baht/rai)	Government subsidy (baht/rai)	Net impact of policy (baht/rai)	Cost effect-iveness %
1. 10% ↓ in fert. price	5.23	9.73	-4.51	-46.30
2. 10% ↓ in labor price	50.50	44.94	+5.56	+12.36
3. 10% ↓ in trac. price	25.75	21.50	+4.25	+19.77
4. 10% ↑ in rice price	315.42	247.57	+67.85	+27.41
5. (1) + (2)	55.73	54.68	+1.05	1.92
6. (1) + (3)	30.98	31.24	-0.26	-0.82
7. (1) + (4)	320.65	257.73	+62.92	+24.41
8. (2) + (3)	76.25	66.44	+9.81	+14.76
9. (2) + (4)	365.92	296.53	+69.39	+23.40
10. (3) + (4)	341.17	270.80	+70.37	+25.99
11. (1) + (2) + (3)	81.48	76.18	5.30	+6.96
12. (1) + (2) + (4)	371.15	306.68	+64.47	+21.02
13. (1) + (3) + (4)	346.40	280.95	+65.45	+23.30
14. (2) + (3) + (4)	391.67	319.75	+71.92	+22.49
15. (1) + (2) + (3) + (4)	396.90	329.91	+66.99	+20.31

Source: Computed

For the combination policies, most cost-effective appears to be a combination of rice price and tractor power price subsidy. A total subsidy of 271 baht per rai would yield a net benefit of 341 baht per rai to farmer and 70 baht per rai to the country with a 26 percent rate of return. As providing a complete set of policies is beyond the scope of this study, it seems that price policies for raising rice yields and farm incomes in Chiang Mai province should focus on rice prices and tractor power prices.

6. CONCLUSION

The current results revealed that Khao Dawk Mali production demonstrated clear advantage over glutinous varieties when economics of production is considered. The bio-physical environment in the study areas appeared to be suitable for growing either varieties, thereby, offering more flexibility in switching varieties for farmers. Therefore, in areas with inadequate irrigation and water control, expansion of Khao Dawk Mali can be considered because of its tolerance to drought conditions and relative economic advantage.

Based on the implications drawn from the economic analysis and farmers' preferences (in the probit model) and subject to the given condition of higher and more price certainty and favorable move towards increased consumption demand for high quality rice, it can be concluded that, Khao Dawk Mali offers a better alternative cash crop for the rice farmers in Chiang Mai province. However, a number of caveats are in order. Firstly, the disease susceptibility of Khao Dawk Mali should be given due consideration. Secondly, major concern lies in the acceptance of the quality standards of Khao Dawk Mali by the exporters. Finally, in order to balance between the consumption and higher income priorities, farmers could partly allocate their land to glutinous rice for consumption and partly to Khao Dawk Mali for the market. From the viewpoint of both the cost-effectiveness and distributional considerations for the target beneficiaries, the rice farmers, it can be concluded that, price policies for raising rice yields and farm income in Chiang Mai province should focus on rice prices and tractor power prices.

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