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Abstract

This study attempts to analyze factors, especially neck blast and technical efficiency, affecting the jasmine and non-jasmine rice production in Thailand. The stochastic production frontier estimation method is thus used. Since the observed data are not sampled randomly from the population, due to the farmer's decision on the selectivity of growing jasmine or non-jasmine rice then the stochastic production frontier method of estimation is modified to include a self-selectivity variable to eliminate biases of the estimated parameters.

Key words: Thailand, neck blast, stochastic production frontier, self-selectivity, jasmine rice, non-jasmine rice.

1. Introduction

Outbreak of neck blast disease on rice in 1992 over 1.25 million rai (.20 million hectare) brought about the damage of over 1 billion baht. Later in 1995, the second wide speed of the disease occurrence called for serious attention to prevent such outbreak. The blast disease (due to *Pyricularic oryzae*) could be normally observed in most rice production areas and in many rice varieties, including glutinous and nonglutinous, in both native and improved varieties.

Since 1998 Thailand has enjoyed fast growing in export value of high quality rice (jasmine). The export value of jasmine rice increased from 1,358 million baht in 1988 to 27,252 million baht in 1997 (Department of Foreign Trade 1998). Production of jasmine rice expanded rapidly in the Northeast as well as the North where over 70 percent of blast disease took place in 1992.

As neck blast disease could cause drastic damage when occurs, scientists pose the question if it is worth conducting biotechnology research on this issue to help alleviate disease effect on yield. Furthermore, economists want to compare the effect of the disease to the effects due to other factors,

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including technical efficiency on the rice production. Since large number of rice varieties are cultivated in the country and jasmine rice became champion product for export as well as for domestic market, the answers to these questions are pertaining to both jasmine and non-jasmine rice.

To investigate technical efficiency, it is needed to first estimate a production frontier. As farmers usually choose one variety to grow for a specific land, the production function of each variety should be estimated by taking into account of variety choice. Modeling without choice variable causes the selectivity problem.

Since each farmer must make his or her decision on the choice of growing jasmine or non-jasmine rice, the observed data are, then, not sampled randomly from the populations of jasmine and non-jasmine rice. There is a variable $Z_i'\gamma$ such that an observation is drawn from the specified model only when $Z_i'\gamma$ crosses some threshold. This implies that the observation is from the subpopulation of the model associated with the selected values of $Z_i'\gamma$. If the observed data are still treated as having been randomly sampled from the population of the model, it potentially biases the result. An auxiliary model generating $Z_i'\gamma$ would lead to the general solution to the selectivity problem. To eliminate the biases of the estimates, information about this auxiliary model must be incorporated in the estimation of the model (Greene, 1995, p637; Maddala, 1983, p222). This method is relevant to the switching regression model with endogenous switching to be discussed below.

The main objective of this study is to estimate stochastic frontiers with self-selectivity in order to investigate factors affecting outputs of jasmine and non-jasmine rice. These factors include production inputs, physical and environmental factors, disease occurrence and technical efficiency. Factors affecting technical inefficiency are investigated as well. To obtain the unbiased estimates of the associated parameters of the model, the following methodology may be used.

2. Methodology

2.1 Switching Regression Model with Endogenous Switching : A Two - Stage Estimation Method

Many models in which the behavior of agents is described by two regression equations have single criterion functions that determine which of these two equations is applicable. A model of two production functions, jasmine and non-jasmine rice, with a criterion function may be written as

Jasmine rice : $y_{1i} = X_{1i}'\beta_1 + u_{1i}$ iff $Z_i'\gamma \geq u_i$ (1)

Non-jasmine rice : $y_{2i} = X_{2i}'\beta_2 + u_{2i}$ iff $Z_i'\gamma < u_i$ (2)

where y_{1i} is jasmine rice output of the ith farm; y_{2i}, non-jasmine rice of the ith farm; X_{1i}, the jasmine rice input vector; X_{2i}, the non-jasmine rice input vector; β_1 and β_2, the parameter vectors; u_{1i} and u_{2i}, error terms. It is assumed that u_i are correlated with u_{1i} and u_{2i} (Maddala, 1983, p223). This model is similar to the Goldfeld and Quandt's switching regression model. Since u_i are correlated with u_{1i} and u_{2i}, Maddala and Nelson (1975) call this model as "a switching regression model with endogenous switching".

Define a dummy variable

$$I_i = 1 \qquad \text{if} \qquad Z_i'\gamma \geq u_i$$
$$I_i = 0 \qquad \text{otherwise}$$

where Z_i is a vector of exogenous variable explaining the decision to grow jasmine or non-jasmine rice and γ, the vector of relevant parameters. In the case that sample separation is observable, I_i can be obtained. The probit maximum likelihood can then be used to estimate γ. Since γ can be estimated only up to a scale factor, it is then assumed that u_{1i}, u_{2i} and u_i have a trivariate normal distribution with mean vector zero and covariance matrix

$$\Sigma = \begin{bmatrix} \sigma_1^2 & \sigma_{12} & \sigma_{1u} \\ \sigma_{12} & \sigma_2^2 & \sigma_{2u} \\ \sigma_{1u} & \sigma_{2u} & 1 \end{bmatrix}$$

The likelihood function for this model is

$$L(\beta_1, \beta_2, \sigma_1^2, \sigma_2^2, \sigma_{1u}, \sigma_{2u}) = \Pi \left[\int_{-\infty}^{Z_i'\gamma} g(y_{1i} - \beta_1' X_{1i}, u_i)\, du_i\right]^{I_i} \left[\int_{Z_i'\gamma}^{\infty} f(y_{2i} - \beta_2' X_{2i}, u_i)\, du_i\right]^{1-I_i} \qquad (3)$$

where g and f are the bivariate normal density function of (u_{1i}, u_i) and (u_{2i}, u_i) respectively (Maddala, 1983, pp223-4) Maximization of likelihood function (3) can be obtained but is cumbersome. Lee (1976), then, proposed a two-stage method which was simple for estimation as follows:

Since production decision depends on criterion function, the expected values of the error terms in (1) and (2) can be expressed as

$$E(u_{1i} | u_i \leq Z_i'\gamma) = E(\sigma_{1u} u_i | u_i \leq Z_i'\gamma) = -\sigma_{1u} \frac{\phi(Z_i'\gamma)}{\Phi(Z_i'\gamma)} \qquad (4)$$

and

$$E(u_{2i} | u_i \geq Z_i'\gamma) = E(\sigma_{2u} u_i | u_i \geq Z_i'\gamma)$$

$$= \sigma_{2u} \frac{\phi(Z_i'\gamma)}{1-\Phi(Z_i'\gamma)} \tag{5}$$

Equations (4) and (5) are no longer equal to zero. Least squares method applied to (1) and (2) then yields biased estimates. Lee (1976) suggested a two-stage method in estimating (1) and (2) by computing W_{1i} and W_{2i} and adding W_{1i} to (1) and W_{2i} to (2) in order to eliminate the bias. Hence

$$y_i = X_{1i}'\beta_1 - \sigma_{1u}W_{1i} + \varepsilon_{1i} \qquad \text{for} \qquad I_i = 1 \tag{6}$$

$$y_i = X_{2i}'\beta_2 + \sigma_{2u}W_{2i} + \varepsilon_{2i} \qquad \text{for} \qquad I_i = 0 \tag{7}$$

where $W_{1i} = \frac{\phi(Z_i'\gamma)}{\Phi(Z_i'\gamma)}$

$W_{2i} = \frac{\phi(Z_i'\gamma)}{1-\Phi(Z_i'\gamma)}$

$\varepsilon_{1i}, \varepsilon_{2i}$ = new residuals with zero conditional means

However, the method proposed by Lee (1976) has the heteroscedasticity problem of which ε_{1i} and ε_{2i} are heteroscedastic. In estimating (6) and (7), weighted least squares (WLS) has to be used instead of ordinary least squares. The variance of ε_{1i} and ε_{2i} can be computed as

$$\text{var}(\varepsilon_{1i} | I_i = 1) = \sigma_1^2 - \sigma_{1u}W_{1i}(Z_i'\gamma + W_{1i}) \tag{8}$$

$$\text{var}(\varepsilon_{2i} | I_i = 0) = \sigma_2^2 + \sigma_{2u}W_{2i}(Z_i'\gamma + W_{2i}) \tag{9}$$

and

$$E(\varepsilon_{1i} | I_i = 1) = 0 \tag{10}$$

$$E(\varepsilon_{2i} | I_i = 0) = 0 \tag{11}$$

The estimates of σ_1^2 and σ_2^2 are obtained from

$$\hat{\sigma}_1^2 = \frac{1}{N_1}\sum_{i=1}^{N_1}[\hat{u}_{1i}^2 + \hat{\sigma}_{1u}^2(Z_i'\hat{\gamma})\hat{W}_{1i}] \tag{12}$$

$$\hat{\sigma}_2^2 = \frac{1}{N_2}\sum_{i=1}^{N_2}[\hat{u}_{2i}^2 + \hat{\sigma}_{2u}^2(Z_i'\hat{\gamma})\hat{W}_{2i}] \tag{13}$$

where N_1 = number of observations for which $I_i = 1$

N_2 = number of observations for which $I_i = 0$

$$\hat{u}_{1i} = y_i - X'_{1i}\hat{\beta}_1 \qquad \text{for} \qquad I_i = 1$$
$$\hat{u}_{2i} = y_i - X'_{2i}\hat{\beta}_2 \qquad \text{for} \qquad I_i = 0$$

(Maddala, 1983, pp 224-6)

However, there is no guarantee that $\hat{\sigma}_1^2$ and $\hat{\sigma}_2^2$ will always be positive. Lee and Trost (1978) suggested two methods in estimating $\hat{\sigma}_1^2$ and $\hat{\sigma}_2^2$. One of which guarantees that the estimates of $\hat{\sigma}_1^2$ and $\hat{\sigma}_2^2$ will always be positive. Freemen et. al. (1998) used this two-stage method for switching regression models to their study.

2.2 Switching Regression and Frontier Estimation

Since the objective of this study is to estimate the jasmine and non-jasmine rice production frontiers, not ordinary frontiers independent from criterion functions, equation (6) and (7) must, then, be modified to be the stochastic frontier functions. Because the error terms of (6) and (7) are heteroscedastic, the WLS method must therefore be used (Maddala, 1983, pp224-6 , Freeman et. al. 1998). The transformed equations (using WLS) from (6) and (7), respectively, are

Jasmine rice production function : $y_{1i}^* = X_{1i}^{*\prime}\beta_1 - \sigma_{1u}W_{1i}^* + \varepsilon_{1i}^*$ (14)

Non-jasmine rice production function : $y_{2i}^* = X_{2i}^{*\prime}\beta_2 + \sigma_{2u}W_{2i}^* + \varepsilon_{2i}^*$ (15)

$$\varepsilon_{1i}^* \sim N(0,\sigma_{\varepsilon_1^*}^2),\ \ \varepsilon_{2i}^* \sim N(0,\sigma_{\varepsilon_2^*}^2)$$

To estimate the production frontiers to measure the technical efficiency, equations (14) and (15) may be expressed as

Jasmine rice production frontier : $y_{1i}^* = X_{1i}^{*\prime}\beta_1 - \sigma_{1u}W_{1i}^* + V_{1i} - \theta_{1i}$ (16)

Non-jasmine rice production frontier : $y_{2i}^* = X_{2i}^{*\prime}\beta_2 + \sigma_{2u}W_{2i}^* + V_{2i} - \theta_{2i}$ (17)

where $V_{1i} \sim N(0,\sigma_{v_1}^2)$, $V_{2i} \sim N(0,\sigma_{v_2}^2)$; θ is truncated normal

$$f(\theta) = \frac{2}{\sigma_\theta (2\pi)^{1/2}} \exp\left(\frac{-\theta^2}{2\sigma_\theta^2}\right) \qquad (\theta \geq 0) \qquad (18)$$

The term $-\theta$ is the one-sided error. This implies that each observation is on or below the frontier. $-\theta$ is called "technical inefficiency" (Maddala, 1983, p195). The θ_{1i} and θ_{2i} are non-negative random variables and called technical inefficiency effects, which are assumed to be independently distributed such that θ_{1i} and θ_{2i} are defined by the truncation (at zero) of the normal distribution with means μ_{1i} and μ_{2i} and variances $\sigma^2_{\theta_1}$ and $\sigma^2_{\theta_2}$ (Seyoum *et al.*,1998). V is the usual two-sided error that represents the random shifts in the frontier due to favorable and unfavorable factors. It captures measurement error in y as well.

If θ and V are distributed independently, and from Weinstein's result (1964), We obtain

$$g(\varepsilon_1^*) = \frac{2}{\sigma}\phi\left(\frac{\varepsilon_1^*}{\sigma_{\varepsilon_1^*}}\right)\left[1-\Phi\left(\frac{\varepsilon_1^*\lambda_1}{\sigma_{\varepsilon_1^*}}\right)\right] \quad (19)$$

$$g(\varepsilon_2^*) = \frac{2}{\sigma}\phi\left(\frac{\varepsilon_2^*}{\sigma_{\varepsilon_2^*}}\right)\left[1-\Phi\left(\frac{\varepsilon_2^*\lambda_2}{\sigma_{\varepsilon_2^*}}\right)\right] \quad (20)$$

where

$$\sigma^{*\,2}_{\varepsilon_1} = \sigma^2_{\theta_1} + \sigma^2_{v_1}, \qquad \lambda_1 = \sigma_{\theta_1} / \sigma_{v_1}$$

$$\sigma^{*\,2}_{\varepsilon_2} = \sigma^2_{\theta_2} + \sigma^2_{v_2}. \qquad \lambda_2 = \sigma_{\theta_2} / \sigma_{v_2}$$

$\phi(\cdot)$ and $\Phi(\cdot)$ = density function and distribution function of standard normal distribution respectively.

The estimation method for production frontiers was suggested by Aigner *et al.* (1977). To measure average inefficiency, Aigner *et al.* (1977) suggested to use $\lambda = \sigma_\theta / \sigma_v$ and $E(-\theta) = (2^{1/2} / \pi^{1/2})$. In case of the Cobb-Douglas, the production frontier may be expressed as

$$y = AK^{\alpha}L^{\beta}e^{-\theta}e^{v} \quad (21)$$

In this case the technical efficiency is

$$e^{-\theta} = y/(AK^{\alpha}L^{\beta}e^{v}) \quad (22)$$

where $-\theta$ is half normal. The mean of technical efficiency is, then, obtained as

$$E(e^{-\theta}) = 2\exp\left(\frac{\sigma^2_\theta}{2}\right)[1-\phi(\sigma_\theta)] \qquad \text{(Maddala, 1983, p195)} \quad (23)$$

Jondrow *et al.* (1982) showed the method of estimation of individual farm inefficiency by showing that the expected value of θ for each observation could be obtained from conditional distribution of θ, given ε and with the normal distribution for v and half normal for θ. The expected value of inefficiency for each farm, given ε, can be obtained as

$$E(\theta \mid \varepsilon) = \frac{\sigma_\theta \sigma_v}{\sigma} \left[\frac{\phi(\varepsilon\lambda/\sigma)}{1-\Phi(\varepsilon\lambda/\sigma)} - \frac{\varepsilon\lambda}{\sigma} \right] \quad (24)$$

(Bravo – Ureta and Rieger, 1991; Wang *et al*.,1996)

However, since θ_{1i}'s and θ_{2i}'s are non-negative random variables which are assumed to be independently distributed such that θ_{1i} and θ_{2i} are defined by the truncation (at zero) of normal distributions with mean μ_{1i} and μ_{2i} and variances, $\sigma^2_{\theta_1}$ and $\sigma^2_{\theta_2}$ respectively, Seyoum *et al*. (1998) defined each μ_i as a function of some explanatory variables

$$\mu_{1i} = \omega_{11} + \omega_{12}F_{2i} + \ldots + \omega_m F_{mi} \quad (25)$$

$$\mu_{2i} = \omega_{21} + \omega_{22}F_{2i} + \ldots + \omega_m F_{mi} \quad (26)$$

where $F_2, \ldots, F_n$ are explanatory variables.

The maximum-likelihood estimates for all parameters of the stochastic frontier and inefficiency model, defined by equations (16) and (25); (17) and (26) are simultaneously obtained by using the program, FRONTIER Version 4.1 which estimates the variance parameters in terms of parameterization

$$\sigma^2_{\varepsilon_1} = \sigma^2_{v_1} + \sigma^2_{\theta_1} \quad (27)$$

$$\sigma^2_{\varepsilon_2} = \sigma^2_{v_2} + \sigma^2_{\theta_2} \quad (28)$$

and

$$L_1 = \sigma^2_{\theta_1} / \sigma^2_{\varepsilon_1} \quad (29)$$

$$L_2 = \sigma^2_{\theta_2} / \sigma^2_{\varepsilon_2} \quad (30)$$

(Seyoum *et al*., 1998)

Because we have heteroscedasticity in jasmine and non-jasmine rice production functions mentioned above, the transformed jasmine and non-jasmine rice production equations (14) and (15), then, are used. Therefore there are no constant terms in equations (14) and (15). However, since Frontier Version 4.1 cannot accept the model with no constant term, we then compute the technical efficiencies and regress them on explanatory variables for both jasmine and non-jasmine rice as specified later in equations (33) and (34).

To estimate the criterion function by using the probit model, the following variables are included.

I_i and Z_i		in this study are defined as follows :
I_i	=	1 if jasmine rice, i.e., $\gamma' Z_i \geq u_i$
	=	0 otherwise
Z_i'	=	[DPL, DNE, ATC, P^{JM}, $(P^{JM})^2$, P^{OT}, $(P^{OT})^2$, RATIOW]
D_1	=	1 if the observation is from Phitsanulok province
	=	0 otherwise
D_2	=	1 if the observation is from Tung Gula Ronghai (the northeastern area)
	=	0 otherwise
ATC	=	The farmer's attitude towards rice farming for commercialization (scores)
P^{JM}	=	Jasmine rice price, the i th farmer faced in 1998 (baht/kg)
$(P^{JM})^2$	=	The squares of P^{JM}
P^{OT}	=	Non-jasmine rice price, the i th farmer faced in 1998 (baht/kg)
$(P^{OT})^2$	=	The squares of P^{OT}
Ratiow	=	The ratio of irrigated area to the total area of rice production
γ	=	The vector of parameters

The functional form of the production frontiers for jasmine and non-jasmine rice for this study with selectivity variables are specified respectively as

$$Y = AX_1^{\beta_1} X_2^{\beta_2} X_3^{\beta_3} e^{\sum_{i=1}^{7} \gamma_i D_i} e^{-\sigma_{1u} \left(\frac{\phi(\hat{\alpha}_i Z_i)}{\Phi(\hat{\alpha}_i Z_i)} \right)} e^{v_1 - \theta_1} \quad ; \ i = 1,\ldots 8 \qquad (31)$$

and

$$Y = AX_1^{\beta_1} X_2^{\beta_2} X_3^{\beta_3} e^{\sum_{i=1}^{7} \gamma_i D_i} e^{\sigma_{2u} \left(\frac{\phi(\hat{\alpha}_i Z_i)}{1-\Phi(\hat{\alpha}_i Z_i)} \right)} e^{v_2 - \theta_2} \quad ; \ i = 1,\ldots 8 \qquad (32)$$

where

Y	=	Rice output (kg per *rai* ; 6.25 *rai* = 1 hectare)
X_1	=	Seed (kg per *rai*)
X_2	=	Chemical fertilizer (kg per *rai*)
X_3	=	Labor (man-hours per *rai*)
D_1	=	1 if it is Phitsanulok province
	=	0 otherwise
D_2	=	1 if it is Tung Gula Ronghai (the northeastern area)

	=	0 otherwise
D_3	=	1 if using other chemical substance
	=	0 otherwise
D_4	=	1 if it is transplanting rice
	=	0 otherwise
D_5	=	1 if it is irrigated area
	=	0 otherwise
D_6	=	1 if it had severe drought
	=	0 otherwise
D_7	=	1 if it had neck blast
	=	0 otherwise
$\frac{\phi(\hat{\alpha}_i Z_i)}{\Phi(\hat{\alpha}_i Z_i)}$	=	Selectivity variable for jasmine rice equation
$\frac{\phi(\hat{\alpha}_i Z_i)}{1-\Phi(\hat{\alpha}_i Z_i)}$	=	Selectivity variable for non-jasmine rice equation

The inefficiency equations for jasmine and non-jasmine rice shown in equations (25) and (26) are modified to be the technical efficiency equations as follows:

For jasmine rice: $TE_{1i} = \delta_{11} + \delta_{12}EDU + \delta_{13}AGEH + \delta_{14}LA + \delta_{15}LAMAN + \delta_{16}LNLAND + \delta_{17}SKILL1 + \delta_{18}RFER + \delta_{19}DSEED + \gamma_{11}D_1 + \gamma_{12}D_2 + u_1$ (33)

For non-jasmine rice: $TE_{2i} = \delta_{21} + \delta_{22}EDU + \delta_{23}AGEH + \delta_{24}LA + \delta_{25}LAMAN + \delta_{26}LNLAND + \delta_{27}SKILL2 + \delta_{28}RFER + \delta_{29}DSEED + \delta_{210}ATC + \gamma_{21}D_1 + \gamma_{22}D_2 + u_2$ (34)

Where $TE = e^{-E(\theta/\varepsilon)}$

and $E(\theta/\varepsilon)$ is estimated using equation (24)

EDU = highest education (years) of the members in the household

AGEH = age of the farmers (years)

LA = labor force (adult persons) in the household

LAMAN = ratio of male labor to total labor in the household

LNLAND	= (natural log of) total cultivated land of the household including rice and non-rice (rais)
RFER	= reasons for choosing type of formula fertilize
1 = as recommended by expert/suitable to soil type	
0 = otherwise	
DSEED	= 1 if seed rate is in the recommended range
	= 0 otherwise
SKILL1	= 1 if farmers' reason for growing jasmine is "being skillful"
SKILL2	= 1 if farmers' reason for growing non-jasmine is "being skillful"
ATC	= Farmers' attitude as defined in the probit model
D1	= 1 if it is Pitsanuloke province
	= 0 otherwise
D2	= 1 if it is Tung Gula Ronghai
	= 0 otherwise
u	= error term

3. Data Collection

The data used in this study were collected by interviewing farmers in three areas, i.e., Chiang Mai Province , Phitsanulok Province and Tung Gula Rong Hai, TGR, the northeastern area and major jasmine rice production area of the country. The sample size was 489 observations comprising 112, 176 and 201 observations from the corresponding areas. The same farmers who grew jasmine and non-jasmine would form two observations in the respective models

Three set of variables were prepared for three models, i.e., probit variety - choice model, production frontier model and technical efficiency model. Some of the variables appear in more than one model. All variables are described as follows.

The farmer's attitude towards rice farming for commercialization (ATC) measured in terms of scores ranging from 5, the lowest degree of commercialization, to 25, the maximum degree. These scores were evaluated from five questions, namely, (1) Does your production aim for sale before consumption? (2) Do you always think of how to maximize profit when you produce? (3) Do you always think of the return on borrowed money and whether it is worth doing? (4) Do you always set a target of yield per unit of land regardless of production cost? (5) Do you use your borrowed money (planned for production) for social function when necessary? Each question is scored 1 to 5 for least agreed to most agreed except for questions (4) and (5) the scores run in the reverse order. The sum of the scores from five questions represents the farmer's attitude variable. This variable is expected to have positive relationship to the jasmine rice choice.

Prices of jasmine rice (P^{JM}) and other rice (P^{OT}) are measured in nominal term (baht/kg) with positive and negative relationship respectively to jasmine rice choice.

The production area dummy variables D_1 and D_2 represent Phitsanulok and TGR where physical and biological environments differ from Chiang Mai. These area dummy variables not only reflect differences in physical environment but also marketing environment in the choice model.

Other environmental variables included are (1) ratio of irrigated to nonirrigated area of rice production on each farm (Ratiow). The higher the ratio, the greater probability of choosing jasmine rice becomes. (2) Dummy variables of being irrigated (D_5) and having severe drought (D_6) are expected to have positive and negative relationship with the production of rice respectively.

Neck blast disease (D_7) is a dummy variable [since degree of severity of blast was not measured for non-jasmine (only for jasmine was available)]. It takes value 1 when the farmer indicated having observed disease in his field.

Input variables includes seed (X_1), chemical fertilizer (X_2), labor (X_3) and other chemical input usually referring to insecticide, fungicide and pesticide (D_3) taking the value of 1 if the farmer used these other chemical input and 0 otherwise. Except for the D_3, all variables were measured per area (*rai*) and expected to have positive relationship to production output. As for other chemicals which farmers usually applied mostly as defensive measure, the positive sign is expected. It is not possible to measure the quantity of chemical used because farmers applied various kinds of chemical that comes in different forms (liquid or powder).

Machine time especially tractor time spent on land preparation was not included in the production model since most farmers paid for hired tractor service at fixed rate per unit of land. The working time per unit of land would be approximately equal to all observations. This is because the contract is based on the same amount of service, i.e., finished ploughing.

Household characteristics are hypothesized to affect technical efficiency are average age and education of the household members (years) labor force. (adult persons), and the ratio of male labor to total labor.

The management skill is un-quantifiable but it is expected to have high impact on efficiency. Therefore, 3 proxy variables are proposed.

1. Reasons for choosing type of chemical fertilizer. Farmers who choose certain formulas basing on the suitability to soil type and/or expert's recommendation are assumed to have better management than those make their choice basing on price, credit and familiarity etc.

2. Farmers' reason for growing jasmine (or non-jasmine) rice is "being skillful" in growing the given variety. The skill score of 4 to 5 reflecting high level of skill is coded as 1 and score 1-3 is regarded as low skill.
3. Good management may be reflected by application of appropriate rate of input use. Despite of varying input level is acceptable, out of range of input rate also indicates management skill. Dummy variable for seed rate is used for this purpose. The variable takes value of 1 when seed rate is within the recommended range (eg. 5-10 km/rai for transplanting cultivation method).

Table1 : Descriptive statistics of variables for a probit criterion function

Variable	**N**	**Minimum**	**Maximum**	**Mean**	**SD**
I	489	0.00000	1.00000	0.57669	0.49459
D_1	489	0.00000	1.00000	0.35992	0.48047
D_2	489	0.00000	1.00000	0.41104	0.49253
ATC	489	10.00000	25.00000	16.72597	2.76293
P^{JM}	489	4.20000	11.25000	7.36707	1.30899
$(P^{JM})^2$	489	17.64000	126.56300	55.98360	20.13395
P^{OT}	489	2.94000	10.00000	5.04902	0.91990
$(P^{OT})^2$	489	8.64360	100.00000	27.38511	11.18330
Ratiow	489	0.00000	1.00000	0.27223	0.32746

Source : Calculation from survey

Table2 : Descriptive statistics of variables for jasmine rice production function

Variable	N	Minimum	Maximum	Mean	SD
(Y)	282	11.66672	921.59881	354.70531	185.35869
(X_1)	282	2.00000	70.39977	16.56432	11.77531
(X_2)	282	0.90000	68.25018	13.21683	7.98064
(X_3)	282	1.20000	84.40022	20.91309	15.75100
(D_1)	282	0.00000	1.00000	0.26596	0.44263
(D_2)	282	0.00000	1.00000	0.52837	0.50008
(D_3)	282	0.00000	1.00000	0.76241	0.42636
(D_4)	282	0.00000	1.00000	0.41489	0.49358
(D_5)	282	0.00000	1.00000	0.26241	0.44073
(D_6)	282	0.00000	1.00000	0.18794	0.39136
(D_7)	282	0.00000	1.00000	0.74468	0.43682
Selectivity Variable	282	0.14298	1.13717	0.61098	0.27047

Source : Calculation from survey

Table 3 : Descriptive statistics of variables for non-jasmine rice production

Variable	N	Minimum	Maximum	Mean	SD
(Y)[b]	207	16.00002	1,050.00478	431.00815	188.36119
(X_1)[b]	207	1.95440	58.82342	15.169591	10.16220
(X_2)[b]	207	1.72000	40.00000	12.44645	7.07310
(X_3)[b]	207	1.06667	81.81822	21.78613	16.80959
(D_1)[b]	207	0.00000	1.00000	0.48792	0.50107
(D_2)[b]	207	0.00000	1.00000	0.25121	0.43476
(D_3)[b]	207	0.00000	1.00000	0.83575	0.37140
(D_4)[b]	207	0.00000	1.00000	0.51691	0.50093
(D_5)[b]	207	0.00000	1.00000	0.28502	0.45252
(D_6)[b]	207	0.00000	1.00000	0.10628	0.30894
(D_7)[b]	207	0.00000	1.00000	0.68600	0.46525
$\frac{\phi(\hat{\alpha}_i Z_i)}{1-\Phi(\hat{\alpha}_i Z_i)}$[a]	207	0.43918	1.65978	0.83235	0.25815

Source : [a] Calculation

[b] Survey

Table 4 : Descriptive statistics of variables for efficiency equation for jasmine rice

Variable	N	Mean	SD	Minimum	Maximum
TE	263	0.6093	0.1966	0.0485	0.9352
AGEH	263	48.9366	11.5451	25.5000	88.0000
LA	263	2.5932	1.1875	1.0000	8.0000
LAMAN	263	0.5212	0.1559	0.0000	1.0000
SKILL1	263	0.8859	0.3185	0.0000	1.0000
D2	263	0.5437	0.4990	0.0000	1.0000
D1	263	0.2471	0.4321	0.0000	1.0000
RFER	263	0.1521	0.3598	0.0000	1.0000
EDU	263	6.1559	5.8761	1.0000	23.0000
LNLAND	263	3.1866	0.8597	1.0986	5.6699
DSEED	263	0.4259	0.4954	0.0000	1.0000

Table 5 : Descriptive statistics of variables for efficiency equation for non-jasmine rice

Variable	N	Mean	SD	Minimum	Maximum
TE	184	0.6306	0.1900	0.0769	0.9293
AGEH	184	49.1576	12.1912	25.5000	86.0000
LA	184	2.5815	1.1375	1.0000	8.0000
LAMAN	184	0.5084	0.1562	0.0000	1.0000
SKILL2	184	0.8696	0.3377	0.0000	1.0000
ATC	184	16.6902	2.5940	10.0000	25.0000
RFER	184	0.2554	0.4373	0.0000	1.0000
LNLAND	184	3.4736	0.9209	1.3863	5.6699
EDU	184	5.7391	6.1027	1.0000	23.0000
DSEED	184	0.4891	0.5012	0.0000	1.0000

4. Empirical Results

The accuracy of prediction of the estimated probit criterion function by maximum likelihood method was 65.85%. There were three variables which were significant, i.e. D_2, Ratiow and ATC at 1%, 1%, and 10% levels of significance (Table 6). All price variables were insignificant. The ratio of irrigated area to the total area of rice production, and Tung Gula Ronghai dummy variables were highly significant in a positive relationship to selection of growing jasmine rice. Also, the farmer's attitude towards rice farming for commercialization is significant but at a lower level of 10%.

From this estimated probit criterion function, we estimated the jasmine and non-jasmine rice production frontiers with maximum likelihood estimation. The results for jasmine and non-jasmine rice production frontiers were shown in Tables 7 and 8 respectively. The estimates of the parameters for jasmine rice production frontier have the signs as expected.

All of the estimated coefficients of the variables in the production frontier including $\sigma^2_{\varepsilon_1}$ and X_1 for jasmine rice were significantly different from zero at least (at 10% level of significance) except the estimated coefficients of $(\ln X_1)^*, D^*_1, D^*_3$ and D^*_4, which were seed, Phitsanulok province, other chemical substance, and transplanting rice variables respectively. That $X_1 = \sigma_{\theta_1} / \sigma_{v_1}$ was significant (at 1% level of significance) implied that the jasmine rice production frontier did exist. And that the selectivity variable was significant (at 10% level of significance) confirmed that the jasmine rice production function with self-selectivity used in this study was correct.

Table 6 : Estimates of parameters of a probit criterion function by maximum likelihood method

Variable	Coefficient	Standard – error	t - Statistic	Prob
Constant	-1.61513	1.69673	-0.952	0.3411
D_1	-0.04842	0.16622	-0.291	0.7708
D_2	0.84065	0.17921	4.691****	0.0000
ATC	0.03862	0.02323	1.662**	0.0964
P^{JM}	0.29800	0.43228	0.689	0.4906
$(P^{JM})^2$	-0.02494	0.02794	-0.893	0.3720
P^{OT}	-0.11191	0.16077	-0.696	0.4864
$(P^{OT})^2$	0.01600	0.01327	1.206	0.2277
Ratiow	0.71067	0.20129	3.531****	0.0004
Accuracy of Prediction = 65.85 percent McFedden R^2 = 0.093741				

Source : Calculation

Note : McFedden R^2 = $1 - \frac{\text{Log} - \text{likelihood}}{\text{Restricted} - L}$

: **** Significant at 1 percent level

: *** Significant at 5 percent level

: ** Significant at 10 percent level

Table 7 : Estimates of parameters of jasmine rice production frontier

Variable	Coefficient	T – ratio
Production Function		
Constant (A^*)	5.99861	19.284****
$(\ln X_1)^*$	0.05933	1.160
$(\ln X_2)^*$	0.18902	3.970****
$(\ln X_3)^*$	0.11929	3.164****
D_1^*	0.02883	0.470
D_2^*	-0.12051	-0.777
D_3^*	-0.54057	-3.250****
D_4^*	-0.00658	-0.058
D_5^*	0.33818	3.023****
D_6^*	-0.43274	-6.259****
D_7^*	-0.20306	-3.271****
Selectivity Variable*	-0.38486	-1.948**
Variance Parameters		
$\sigma^2_{\varepsilon_1}$	0.76968	22.428****
λ_1	3.76162	4.915****

Source : Calculation with Limdep Version 7.0

Note : Selectivity Variable* = $\frac{\phi(\hat{\alpha}_i Z_i)}{\Phi(\hat{\alpha}_i Z_i)}$

: $\lambda_1 = \frac{\sigma_{\theta_1}}{\sigma_{v_1}}$

: $\sigma_{\varepsilon_1} = \sqrt{\sigma^2_{\theta_1} + \sigma^2_{v_1}}$

: **** Significant at 1 percent level

: *** Significant at 5 percent level

: ** Significant at 10 percent level

: All variables were weighted by $\text{var}(\varepsilon_{1i} | I = 1)$

Table 8 : Estimates of parameters of non-jasmine rice production frontier

Variable	Coefficient	t – ratio
Production Function		
Constant (A^*)	5.31212	10.900****
$\ln X_1^*$	0.03011	0.328
$\ln X_2^*$	0.17821	3.213****
$\ln X_3^*$	0.02447	0.377
D_1^*	0.20496	2.131***
D_2^*	0.18363	0.843
D_3^*	-0.21863	-1.079
D_4^*	0.23801	1.987***
D_5^*	0.43708	2.465***
D_6^*	-0.30281	-3.003****
D_7^*	-0.04000	-0.536
Selectivity Variable*	0.22087	1.080
Variance Parameters		
$\sigma^2_{\varepsilon_2}$	0.74023	16.294****
λ_2	3.89922	2.853****

Source : Calculation with Limdep Version 7.0

Notes : Selectivity Variable = $\dfrac{\phi(\hat{\alpha}_i Z_i)}{1-\Phi(\hat{\alpha}_i Z_i)}$

: $\lambda_2 = \dfrac{\sigma_{\theta_2}}{\sigma_{v_2}}$

: $\sigma_{\varepsilon_2} = \sqrt{\sigma^2_{\theta_2} + \sigma^2_{v_2}}$

: **** Significant at 1 percent level

: *** Significant at 5 percent level

: ** Significant at 10 percent level

: All variables were weighted by $\text{var}(\varepsilon_{2i} | I = 0)$

Likewise, all of the estimates in the production frontier as well as $\sigma^2_{\varepsilon_2}$ and $\lambda_2 = \sigma_{\theta_2} / \sigma_{v_2}$, except the estimates of $(\ln X_1)^*, (\ln X_3)^*, D_1^*, D_2^*, D_7^*$ and selectivity variable, for non-jasmine rice were significantly different from zero at least at 5% level of significance. Because of the significance of λ_2 , it was explicit that the production frontier for non-jasmine rice was present.

The production elasticities with respect to chemical fertilizer and labor for jasmine and non-jasmine rice were 0.18902, 0.11929, 0.17821 and 0.02447 respectively. However, the production elasticity with respect to labor in the non-jasmine rice production frontier was not significant. Neck blast disease, on average, reduced the output of jasmine rice in the 1999/2000 production year significantly while the blast did not reduce the non-jasmine rice production significantly in the same year. Drought had, on average, a greater negative effect on the production of both jasmine and non-jasmine rice than the neck blast.

The average technical efficiency for jasmine and non-jasmine rice were 60.72% and 62.81% respectively (Tables 9 and 10). In three areas, Chiang Mai, Phitsanulok and Tung Gula Ronghai, the technical efficiencies in Chiang Mai and Phitsanulok were almost the same at 64.285% and 64.68% respectively for jasmine rice. The efficiencies of these two areas were higher than Tung Gula Ronghai by approximately 13% (Table 9).

For non-jasmine rice, the technical efficiency in Chiang Mai was the highest at 66.92% which was followed by Phitsanulok at 63.13%. Tung Gula Ronghai showed, again, the lowest efficiency at 57.95% (Table 10). The distributions of technical efficiencies of jasmine and non-jasmine rice were presented in Figure 1.

The results of the analysis of factors affecting technical efficiency for jasmine and non-jasmine rice are presented in Tables 11 and 12 respectively. The Ordinary Least Squares regression reveals that the model has low degree of explanation but its F statistic is significant at probability equal 0.02. The factors that had negative relationship with the level of technical efficiency were the farmers' age and total cultivated land. This indicates that when households cultivated on bigger farms for rice and other crops, efficiency of rice production declined. Besides, younger farmers were more efficient than the older operators. The ratio of male labor to total labor force of the household and two management proxi variables were positively related to the technical efficiency. The highest education level of household members and the appropriate seed rate and regional dummy variables had no significant impact on efficiency. Some of the hypothesized variables were dropped from this model since they caused multicollinearity problem.

As for non-jasmine rice, the model couldnot explain the technical efficiency satisfactory (F statistic is insignificant). This is not totally unexpected since non-jasmine rice included several rice varieties which might cause difficulty in scrutinizing/disaggregating technical efficiency in relation to each explanatory variable. Two variables that had significant relationship to the efficiency were attitudes toward commercialization (ATC) and reasons for fertilizer choice. Both variables reflect management ability. Farm size (cultivated land or LNLAND) had no relationship to efficiency level. Male labor ratio was not significant in this model. However, its relationship to the efficiency was positive and consistent to the finding of jasmine rice model.

Efficiency of both jasmine and non-jasmine production should be explored further to achieve high degrees of explanation (R^2).

Table 9 : Technical efficiency for jasmine rice

Technical efficiency	Chiang Mai (% of farmers)	Phitsanulok (% of farmers)	Tung Gula Raonghai (% of farmers)	Total (% of farmers)
Very low (0.0000 – 0.2000)	0.0	0.0	5.4	2.8
Low (0.2001 – 0.4000)	6.9	9.3	22.1	15.6
Moderate (0.4001 – 0.6000)	27.6	24.0	23.5	24.5
High (0.6001 – 0.8000)	48.3	54.7	28.9	39.7
Very high (0.8001 – 1.0000)	17.2	12.0	20.1	17.4
Total	100.0	100.0	100.0	100.0
Average technical efficiency	**0.6428**	**0.6468**	**0.5139**	**0.6072**

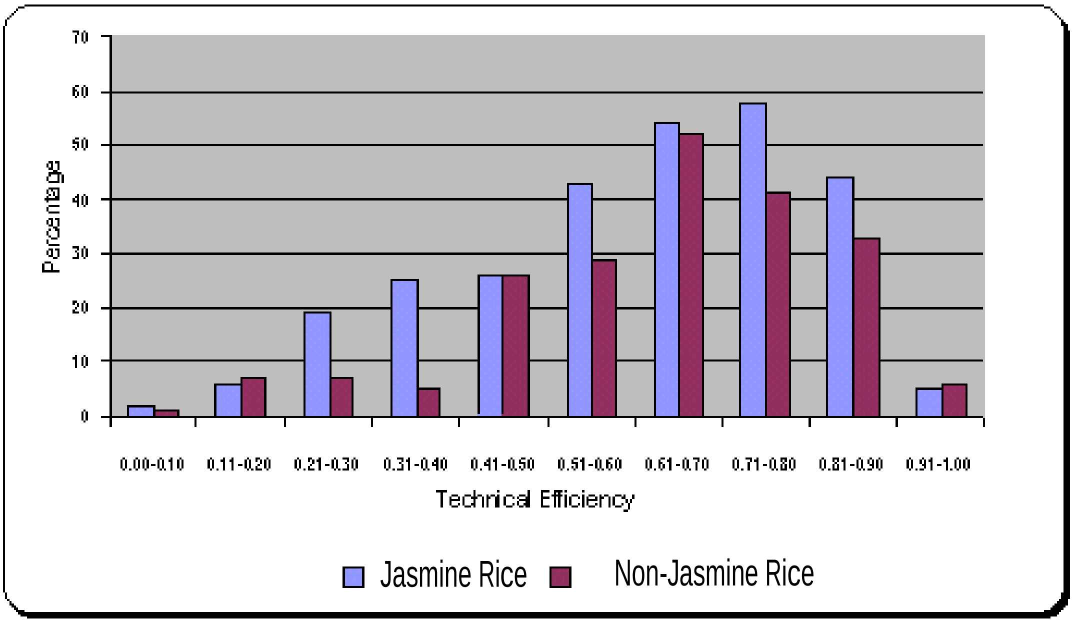
Source : Calculation

Table 10 : Technical efficiency for non-jasmine rice

Technical efficiency	Chiang Mai (% of farmers)	Phitsanulok (% of farmers)	Tung Gula Raonghai (% of farmers)	Totall (% of farmers)
Very low (0.0000 – 0.2000)	0.0	1.0	13.5	3.9
Low (0.2001 – 0.4000)	0.0	6.9	9.6	5.8
Moderate (0.4001 – 0.6000)	27.8	30.7	17.3	26.6
High (0.6001 – 0.8000)	55.6	44.6	34.6	44.9
Very high (0.8001 – 1.0000)	16.7	16.8	25.0	18.8
Total	100.0	100.0	100.0	100.0
Average technical efficiency	**0.6692**	**0.6313**	**0.5795**	**0.6281**

Source : Calculation

Figure 1 Distributions of technical efficiencies of jasmine rice and non-jasmine rice



Source : Tables 9 and 10

Table 11: Estimated coefficients of efficiency equation for jasmine rice

Variable	Coefficient	t - ratio
Constant	0.64107	7.423***
AGEH	-0.00169	-1.782*
LAMAN	0.15677	2.221**
SKILL	0.05830	1.669*
RFER	0.05710	2.224**
LNLAND	-.03045	-2.264**
EDU	0.00151	0.764
DSEED	-0.00779	-0.318

$R^2 = 0.60931$ $adjR^2 = 0.03515$ F-test = 2.36   Prob value = 0.02346

Source: Calculation from Limdep Version 7.0

Note : *** Significant at 1 percent level

** Significant at 5 percent level

* Significant at 10 percent level

: No significant heteroscedasticity

Table 12 : Estimated coefficients of efficiency equation for non-jasmine rice

Variable	Coefficient	t - ratio
Constant	0.04430	3.106***
AGEH	-0.00010	-0.092
LAMAN	0.09378	1.046
AT	0.00877	1.839*
LNLAND	-0.00749	-0.498
DSEED	0.01882	0.646
RFER	0.05990	2.070**
$R^2 = 0.05266$	$adjR^2 = 0.02055$ F-test = 1.64	Prob value = 0.13867

Source: Calculation from Limdep Version 7.0

Note : *** Significant at 1 percent level

** Significant at 5 percent level

* Significant at 10 percent level

: No significant heteroscedasticity occurred and it was corrected

5. Policy Implication

The percents of the output reduction due to the drought were 35.13 and 26.13 while due to the neckblast were substantially lower at 18.38 and insignificantly different from zero for jasmine and non-jasmine rice respectively, in the 1999/2000 production year. This implies that the effect of severe drought was more severe than that of the neckblast. Irrigation policy for jasmine rice production area should receive more attention relative to the neckblast. It also implies that jasmine rice variety that could tolerate drought should be developed. The average technical efficiency for jasmine rice was just 60.72%. There was a substantial gap to enhance yield per *rai* through the improvement of technical efficiency. Unfortunately the efficiency model for jasmine rice could not perform at the satisfactory degree.

However, it is obvious that farmers' management skill and attitudes need to be improved. Agricultural trainings should be provided to all farmers but the older farmers need intesive attention. The large farmers also require higher management skill in order to allocate their resource efficiently.

6. Conclusion

Since the observed data used in this study are not sampled randomly from the population, due to the farmer's decision on the selectivity of growing rice or non-jasmine rice, then the stochastic production frontier method of estimation to investigate the technical efficiency has to be modified to include a self-selectivity variable to eliminate biases of the estimated parameters. To improve jasmine rice yield per *rai,* irrigation policy for jasmine rice production area, jasmine rice drought and neckblast resistance variety development and technical efficiency improvement are strongly recommended. The maximum gains are 39.28, 35.13 and 18.38 percents for the each improvement of technical efficiency, drought and neckblast respectively. Since the determinants explaining the inefficiency equation for jasmine rice investigated in this study are dubious, further research on this issue is needed.

7. References

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

Bravo – Ureta, B. and L. Rieger. (1991). "Dairy Farm Efficiency Measurement Using Stochastic Frontiers and Neoclassical Duality." *Amer. Journal of Agricultural Economics.* 73 : 421-427.

Freeman, H.A., S.K.Ehui and M.A.Jabbar. (1998). Credit constraints and Smallholder dairy production in the East African Highlands : Application of a Switching Regression Model." *Journal of Agricultural Economics* . 19 : 33-44

Goldfeld, S.M., and R.E. Quandt. (1973). "The Estimation of Structural shifts by Switching Regression." *Annuals of Economic and Social Measurement*. 2: 475-85.

Greene, W.H. (1995). *LIMDEP, version 7.0 User's Manual, Book II, Part VI-X.*

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

Lee, L.F. (1976). "Estimation of Limited Dependent Variable Models by Two Stage Methods." Ph.D. dissertation. University of Rochester.

Lee, L.F., and R.D. Trost. (1978). "Estimation of Some Limited Dependent variable Models with Applications to Housing Demand." *Journal of Econometrics*. 8 : 357–382.

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

Maddala, G.S., and F. Nelson. (1975). "Switching Regression Model with Exogenous and Endogenous Switching" *Proceedings of American Statistical Association* (Business and Economics Section). 423-426.

Seyoum, E.T., G.E.Battese and E.M.Fleming. (1996). "Technical Efficiency and Productivity of Maize Producers in Eastern Ethiopia : A Study of Farmers within and outside the Sasakawa-Global

2000 Project" CEPA Working Papers No. 6/96. Department of Econometrics, University of New England, Australia.

Seyoum, E.T., G.E.Battese and E.M.Fleming. (1998). "Technical Efficiency and Productivity of Maize Producers in Eastern Ethiopia : A Study of Farmers within and outside the Sasakawa-Global 2000 Project." *Agr. Econ*. 19 : 341-348.

Wang, J., E. Wailes, and G. Cramer.(1996). "A Shadow–Price Frontier Measurement of Profit Efficiency in Chinese Agriculture." *Amer. Journal of Agricultural Economics*. 78 : 146-156.

Weinstein, M.A.(1964). "The Sum of Values From a Normal and Truncated Normal Distribution." *Technometrics.* 6 : 104-105.

Appendix

Table 1

```
| Ordinary    least squares regression  Weighting variable = none
| Dep. var. = TE       Mean=   .6092780719    , S.D.=   .1965653186
| Model size: Observations =     263, Parameters =   8, Deg.Fr.= 255
| Residuals:  Sum of squares= 9.506318518    , Std.Dev.=   .19308
| Fit:        R-squared=  .060931, Adjusted R-squared =    .03515
| Model test: F[  7,    255] =    2.36,    Prob value =    .02346
| Diagnostic: Log-L =     63.4251, Restricted(b=0) Log-L = 55.1581
|             LogAmemiyaPrCrt.=   -3.259, Akaike Info. Crt.= -.421
| Autocorrel: Durbin-Watson Statistic =   1.73466,   Rho =    .13267
| Results Corrected for heteroskedasticity
| Breusch - Pagan chi-squared =     9.7934, with   7 degrees of
freedom |
+-----------------------------------------------------------------------
+
+---------+------------+----------------+--------+---------+----------
+
|Variable | Coefficient| Standard Error |t-ratio |P[|T|>t] | Mean of
X|
+---------+------------+----------------+--------+---------+----------
+
 Constant  .6410566801      .86355910E-01    7.423   .0000
 AGEH     -.1692252916E-02  .94950657E-03   -1.782   .0759  48.936616
 LAMAN     .1567733585      .70588815E-01    2.221   .0272  .52121673
 SKILL     .5830238529E-01  .34924142E-01    1.669   .0963  .88593156
 RFER      .5710088267E-01  .25675202E-01    2.224   .0270  .15209125
 LNLAND   -.3044589666E-01  .13445098E-01   -2.264   .0244  3.1865847
 EDU       .1514175691E-02  .19810168E-02     .764   .4454  6.1558935
 DSEED    -.7790242691E-02  .24523942E-01    -.318   .7510  .42585551
```

Table 2

```
| Ordinary    least squares regression    Weighting variable = none     |
| Dep. var. = TE       Mean=   .6306171397    , S.D.=   .1900244187     |
| Model size: Observations =     184, Parameters =   7, Deg.Fr.=    177 |
| Residuals:  Sum of squares= 6.260020549    , Std.Dev.=         .18806 |
| Fit:        R-squared=  .052660, Adjusted R-squared =         .02055 |
| Model test: F[  6,    177] =    1.64,    Prob value =         .13867 |
| Diagnostic: Log-L =     49.9445, Restricted(b=0) Log-L =     44.9676 |
|             LogAmemiyaPrCrt.=   -3.305, Akaike Info. Crt.=      -.467 |
| Autocorrel: Durbin-Watson Statistic =   1.79449,   Rho =       .10276 |
| Results Corrected for heteroskedasticity                             |
| Breusch - Pagan chi-squared =     5.5692, with   6 degrees of freedom |
+-----------------------------------------------------------------------+
+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |t-ratio |P[|T|>t] | Mean of X|
+---------+--------------+----------------+--------+---------+--------
--+
 Constant  .4430176316      .14264738        3.106   .0022
 AGEH     -.1013305378E-03  .11035262E-02    -.092   .9269  49.157609
 LAMAN     .9378158408E-01  .89684620E-01    1.046   .2971  .50836957
 ATC       .8771515561E-02  .47694622E-02    1.839   .0676  16.690217
 LNLAND   -.7485149291E-02  .15032509E-01    -.498   .6192  3.4736185
 DSEED     .1882472081E-01  .29133098E-01     .646   .5190  .48913043
 RFER      .5989505054E-01  .28933641E-01    2.070   .0399  .25543478
```