CHAPTER II

METHODOLOGY

2.1 The Meta-Production Function

Hayami and Ruttan (1985) asserted that, a requisite for agricultural productivity growth is the capacity of the agricultural sector to adapt to a new set of factor and product prices. And this adaptation involves not only the movement along a fixed production surface but also the build up of a new production surface that is optimal for the new set of prices. For instance, the use of fertilizer, "even if fertilizer prices decline relative to the prices of land and farm products, increases in the use of fertilizer may be limited unless new crop varieties are developed which are more responsive to high levels of biological and chemical inputs than are traditional varieties" (Hayami and Ruttan, 1985).

Stated in simpler terms, it implies that, "changes in the relative price of fertilizer will induce cultivators to switch to seed varieties of differing fertilizer 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 system and cultivation techniques" (Pitt, 1983). The concept can be best illustrated as follows.

Figure 6 illustrates a conceptual meta-fertilizer response surface U, representing the locus of technically efficient fertilizer-output combinations for a particular agro-climatic environment and fixed level of other factors such as irrigation. It should be noted that, different types of meta-fertilizer response function is associated with each different combination of agro-climatic environment and factor inputs. The fertilizer response surface for the traditional varieties and the modern varieties can be drawn as U_0 and U_1 (Fig. 6a). The meta-fertilizer response surface U, which is the envelope of many such response surfaces encompasses the individual seed variety fertilizer response functions U_0 and U_1, each characterized by a different degree of fertilizer-responsiveness. UAP and UMP, a_0 and m_0, a_1 and m_1, in Fig. 6b, are the average and marginal product curves corresponding, respectively, to U, U_0 and U_1.

U_0 represents the optimal (profit maximizing) variety for the fertilizer/rice price ratio, P_0; and U_1 represents an optimum for P_1. With the fertilizer/rice price ratio of P_0, the profit-maximizing farmer would be at A (or D) on the meta-response function using variety 1. Now, when the fertilizer/rice price ratio declines from P_0 to P_1, and if the individual farmer is not allowed for switching (that is, not permitting movement along the meta-response surface) will result in an increase in the use of fertilizer at C (or F), which is a point inside the meta-production surface. When allowed for seed variety switching, this problem is eliminated, since the new fertilizer-output combination will be at B (or E) with variety type 2 - on the meta-response surface.

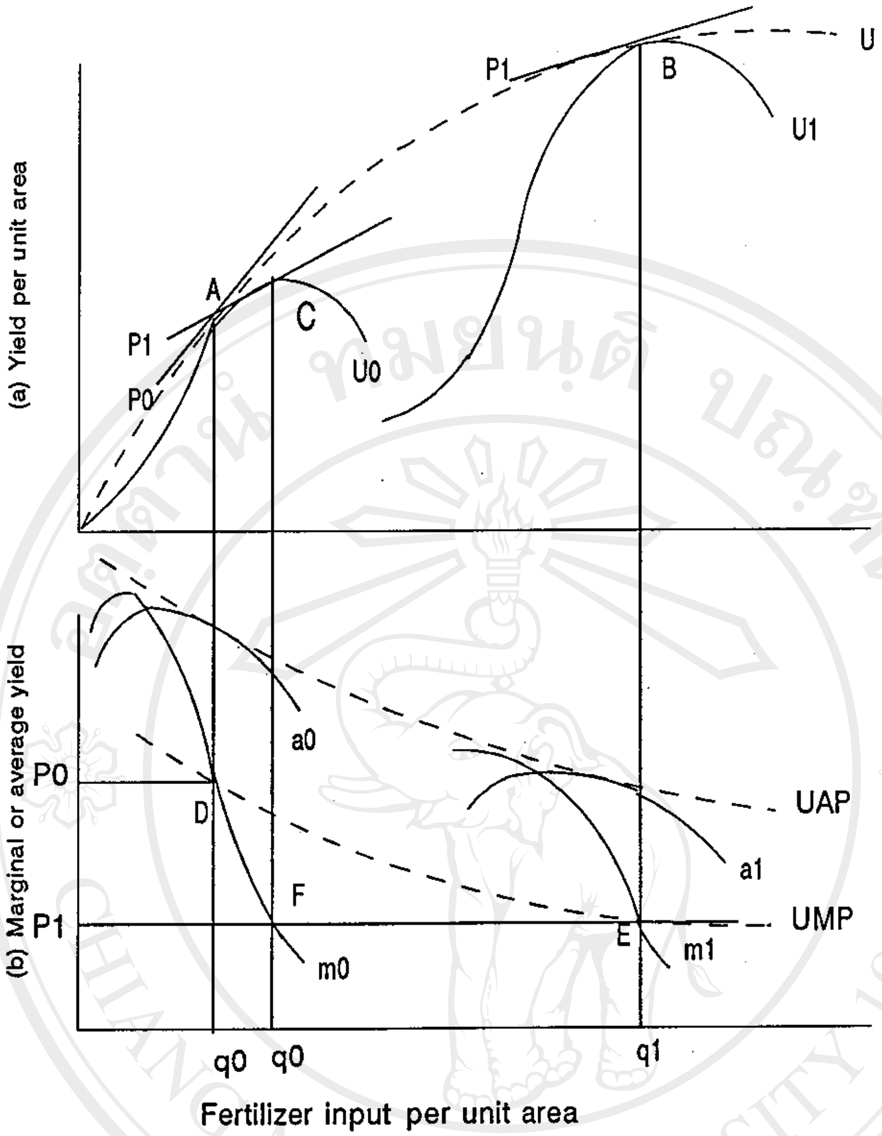

Figure 6. Fertilizer response on a meta-production surface

Source: Adapted from Hayami and Ruttan (1985).

Point C represents an equilibrium for a response surface U_0 if undertaken by farmers, but a disequilibrium in terms of potential alternatives described by the meta-production function U. It is worthy to note that fertilizer response to price is larger for movements along the meta-response surface than along the seed variety specific surface (Hayami and Ruttan, 1985 and Pitt, 1983).

2.2 Scope and Limitation

The present study will focus for the non-glutinous high quality rice, Khao Dawk Mali, which is mainly produced for export and other glutinous rice varieties, such as RD 6, RD 10, Neaw San Pa Tong (NSPT) etc., mainly used for consumption. Confining the scope to only glutinous rice varieties is reasonable as large percentage of farmers grow only glutinous rice in the wet season. On the other hand, apart from Khao Dawk Mali, few other non-glutinous varieties are grown in Chiang Mai valley area in the same season. For example, only 7 percent of total area were under other non-glutinous rice, such as RD 15, RD 21, RD 23 and Basmati in northern Thailand (DAE, 1991). Therefore, the study will concentrate on the issue of cultivators' response to price changes by adjusting their main variable inputs, such as fertilizer, labor, and tractor power, as well as by switching between Khao Dawk Mali and other glutinous rice varieties. The selection of these varieties is justified on the basis of two major policy issues and the subsequent analysis presented above.

2.3 Data Collection

Crop input-output data were collected from a sample of individual farm plots of wet rice from six districts of Northern Thailand. 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, the 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, San Kam Phaeng, San Sai, Doi Saket, San Pa Tong and Mae Rim from Chiang Mai province 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 wider scatter of farm-plots. The major guideline in this sampling process came from the provincial, district and sub-district level agricultural extension officials.

2.4 Data Collected

This study considers only two distinct categories of rice, the high quality traditional variety, Khao Dawk Mali, and the other glutinous varieties grouped as one, as the focal issue. The data gathered include the following attributes:

Input-output data at farm-level - area cultivated, rice varieties planted, input used, yield, volume marketed, etc.

Socio-economic Profile - farm size, tenurial status, factor endowments (land, labor, etc.), age and education of household head, family size, number of dependents, farm income, off-farm income, cropping patterns, etc.

Access to Infrastructure - water control facilities, electricity, transport facilities, marketing channels, credit availability etc.

2.5 Specification of the Model

Farmers are assumed to choose between high quality rice, Khao Dawk Mali and other glutinous rice varieties (GV) 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,

$$\pi_{qi} = P_i \beta_q + Z_i \gamma_q + \epsilon_{qi} \qquad (1)$$

$$\pi_{gi} = P_i \beta_g + Z_i \gamma_g + \epsilon_{gi} \qquad (2)$$

$$I' = (\pi_{qi} - \pi_{gi}) \lambda - \epsilon_i \qquad (3)$$

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

$$\epsilon_q \sim N(0, \sigma_q^2), \ \epsilon_g \sim N(0, \sigma_g^2), \ \epsilon_i \sim N(0, \sigma_\epsilon^2)$$

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.,

$$I_i = 1,\ if\ I'_i \geq 0$$
$$= 0,\ otherwise \qquad (4)$$

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

$$\pi_i = \pi_{qi},\ iff\ I_i = 1$$
$$\pi_i = \pi_{gi},\ iff\ I_i = 0 \qquad (5)$$

Heckman (1976) indicated that, all of the models in the literature developed for limited dependent variables and sample selection bias may be interpreted within a missing data framework. Suppose that we seek to estimate equation (1), but that for some observations from a larger random sample data are missing on π_q. But, there is a sample of N_1 complete observations.

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

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

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

$$E(\pi_{qi}|P_i, Z_i, \textit{sample selection rule})$$

$$= P_i\beta_{qi} + Z_i\gamma_{qi} + E(\epsilon_{qi}|\textit{sample selection rule}), \quad i = 1, \ldots, N_1 \quad (7)$$

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}, 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

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

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.

2.6 Estimation

The variable profit functions of (1) and (2) are represented by Transcendental Logarithmic (translog) functions. The translog form is much less restrictive than the Cobb-Douglas form. It does not maintain additivity or unitary Hicks-Allen elasticities of substitution (Pitt, 1983). The translog variable profit function can be written as

$$\ln\pi' = \alpha_0 + \alpha_i\Sigma_i \ln P_i' + \frac{1}{2}\Sigma_i\Sigma_h\gamma_{ih}\ln P_i'\ln P_h' + \Sigma_i\Sigma_k\delta_{ik}\ln P_i'\ln Z_k$$

$$+ \Sigma_k\beta_k\ln Z_k + \frac{1}{2}\Sigma_k\Sigma_j\psi_{kj}\ln Z_k\ln Z_j \qquad (9)$$

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 - total revenue less total variable input costs - normalized by P_y, the price of output; P_i' is the price of variable input X_i, normalized by P_y, the price of output; Z_k is the quantity of the *k*th fixed factors; $i = h = 1, 2, 3, ..., n + k = j = 1, 2, 3, ..., m$; *ln* is the natural logarithm; the parameters α_0, α_i, γ_{ij}, β_k, δ_{ik} and ψ_{kj} are to be estimated.

From the profit function (9), the following equation can be derived for a variable input (Diewert, 1974 and Sidhu and Baanante, 1981)

$$S_i = -\frac{P'_i X_i}{\pi'} = \frac{\partial \ln \pi'}{\partial \ln P'_i} = \alpha_i + \Sigma_h \gamma_{ih} \ln P'_h + \Sigma_k \delta_{ik} \ln Z_k \qquad (10)$$

where S_i is the ratio of variable expenditures for the ith 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.

Estimation of the variable profit functions (7) with selected samples can be accomplished with the Two-stage Switching Regression method described by 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).

$$I'_i = \theta_0 + P_i\theta_1 + Z_i\theta_2 - \epsilon'_i \qquad (11)$$

By estimating (11) 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

$$E(\epsilon_{qi}|I_i=0) = \sigma_{1\epsilon'}\left(\frac{-f(\phi_i)}{F(\phi_i)}\right) \tag{12}$$

where F is the cumulative normal distribution and f is its density function, both evaluated at ϕ_i. $F(\phi_i)$ is the probability that π_{qi} is observed.

The two-stage procedure uses $-f(\phi_i)/F(\phi_i)$ and $f(\phi_i)/[1 - F(\phi_i)]$ as regressors in the Khao Dawk Mali and glutinous variety profit function, respectively, to purge them of bias. Estimates of ϕ_i are just $\hat{\theta}_0 + P_i\hat{\theta}_1 + Z_i\hat{\theta}_2$, obtained from the estimated probit reduced-form equation (11).

We get estimates $\hat{\theta}_0$, $\hat{\theta}_1$, and $\hat{\theta}_2$ using the probit Maximum Likelihood (ML) method. Then, conditional on selection status, the variable profit equation for Khao Dawk Mali is,

$$\pi_{qi} = P_i\beta_q + Z_i\gamma_q + \sigma_{1\epsilon'}\left(\frac{-f(\phi_i)}{F(\phi_i)}\right) + \xi_q \tag{13}$$

where f is the density function and F the distribution function of the standard normal, $\phi_i = \theta_0 + P_i\beta_q + Z_i\gamma_q$, and $\sigma_{1\epsilon'} = Cov(\epsilon_q, \epsilon')$. Similarly, conditional on selection status, the variable profit equation for glutinous varieties is,

$$\pi_{gi} = P_i\beta_g + Z_i\gamma_g + \sigma_{2\epsilon'}\left(\frac{f(\phi_i)}{1-F(\phi_i)}\right) + \xi_g \tag{14}$$

where $\sigma_{2\varepsilon'}$ = Cov(ε_g,ε'). After getting $\phi^{\hat{}}$ from the probit estimates of θ_0, θ_1 and θ_2 and substituting it for ϕ_i in equations (13) and (14), these equations can be estimated by Ordinary Least Squares (OLS). However, a more efficient estimate would be obtained by estimating jointly the profit function and the share equations using Zellner's Seemingly Unrelated Regressions Estimator (SURE) (Heckman, 1976).

The coefficient estimates of the profit functions obtained from this two-stage procedure are consistent (Lee, 1978). The correct asymptotic covariance matrix is very complicated. The formula used in calculating the asymptotic variance is discussed in Lee *et al.* (1980).

The vectors of explanatory variables used are the variable input prices, fertilizer, labor and tractor power, and the levels of fixed factors, land area and farm capital assets.

2.7 Input Demand Elasticities

After getting the parameter estimates of equations (9) and (10), 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. However, in order to allow for the seed switching options a further treatment would be necessary on these estimates discussed later in this chapter.

From (10) the demand equation for the *i*th variable input can be written as (Sidhu and Baanante, 1981)

$$X_i = \frac{\pi}{P_i}\left(-\frac{\partial \ln\pi}{\partial \ln P_i}\right) \tag{15}$$

$$\ln X_i = \ln\pi - \ln P_i + \ln\left(-\frac{\partial \ln\pi}{\partial \ln P_i}\right) \tag{16}$$

The own-price elasticity of demand (η_{ii}) for X_i then becomes

$$\eta_{ii} = -S_i' - 1 - \frac{\gamma_{ii}}{S_i'} \tag{17}$$

where S_i' is the simple average of S_i.

Similarly, from (16) the cross-price elasticity of demand (η_{ih}) for input *i* with respect to the price of the *h*th input can be obtained

$$\eta_{ih} = -S_h' - \frac{\gamma_{ih}}{S_i'} \tag{18}$$

where $i \neq h$.

The elasticity of demand for input i (η_{iy}) with respect to output price, P_y, can also be obtained from (16),

$$\eta_{iy} = \Sigma_i S_i' + 1 + \Sigma_h \frac{\gamma_{ih}}{S_i'} \qquad (19)$$

where $i = 1, \ldots n$, $h = 1, \ldots, n$.

Finally the elasticity of demand (η_{ik}) for input i with respect to kth fixed factor Z_k is obtained from (16)

$$\eta_{ik} = \Sigma_i \delta_{ik} \ln P_i + \beta_k - \frac{\delta_{ik}}{S_i'} \qquad (20)$$

2.8 Output Supply Elasticities

Output supply elasticities with respect to output prices and variable inputs of production and quantities of fixed factors evaluated at averages of the S_i and at given levels of exogenous variables, can also be expressed as linear functions of parameters of the restricted profit function. From the duality theory (Lau and Yotopoulus, 1972) the equation for output supply V can be written as (Sidhu and Baanante, 1981)

$$V = \pi + \Sigma_i P_i X_i \qquad (21)$$

The various supply elasticity estimates can be derived from this equation. Rewriting (21) with the help of (15) as follows

$$\ln V = \ln\pi + \ln(1 - \Sigma_i \frac{\partial \ln\pi}{\partial \ln P_i}) \tag{22}$$

Then the elasticity of supply (ε_{vi}) with respect to the price of the ith variable input is given by

$$\varepsilon_{vi} = -S_i' - \frac{\Sigma_h \gamma_{hi}}{1 + \Sigma_h S_h'} \tag{23}$$

where $i = h = 1,\ldots,n$.

The own-price elasticity of supply (ε_{vv}) is given by

$$\varepsilon_{vv} = \Sigma_i S_i' + \frac{\Sigma_i \Sigma_h \gamma_{ih}}{1 + \Sigma_h S_h'} \tag{24}$$

Finally, the elasticity of output supply (ε_{vk}) with respect to the fixed inputs Z_k is given by

$$\varepsilon_{vk} = \Sigma_i \delta_{ik} \ln P_i + \beta_k - \frac{\Sigma_i \delta_{ik}}{1 + \Sigma_h S_h'} \tag{25}$$

2.9 Input Demand Elasticities After Allowing for Seed Switching

The price elasticity of demand for inputs allowing for seed switching can be readily calculated from the parameters of the probit see selection equation and the corresponding three 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

$$E(X_i) = E(X_i|I=1)\,Prob(I=1) + E(X_i|I=0)\,Prob(I=0), \tag{26}$$

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

$$\eta = \frac{\eta_q E(X_i|I=1)\,Prob(I=1)}{E(X_i)} + \frac{\eta_g E(X_i|I=0)\,Prob(I=0)}{E(X_i)}$$

$$+ \frac{\zeta_q [E(X_i|I=1) - E(X_i|I=0)]\,Prob(I=1)}{E(X_i)} \tag{27}$$

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

$$\eta_p = -S_i' - 1 - \frac{\gamma_{iip}}{S_i'} \quad \text{p = KDML, Glutinous variety} \qquad (28)$$

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 (27) by replacing (28) with (16), (17) and (18) as required.