CHAPTER 4

ESTIMATION OF PRODUCTION FUNCTION AND EFFICIENCY

4.1 Specification of Variables

From the discussion of the alternative methods of frontier production estimation in Chapter 3, the transcendental logarithm form, the Cobb-Douglas and the restricted translog forms are used either to test the "goodness of fit" of the model or as the real used empirical model to fit the northern agricultural production situation. Namely, equations (6), and (8) are employed for the above purposes. For this empirical work, the specific variables and notation are defined as follows:

(1) *Y*: output value in monetary form at provincial level, in thousand Baht;

(2) *LAND*: land input, harvested area measured in thousand rais;

(3) *LABR*: labor input, in thousand persons;

(4) *TRAC*: tractors used in agricultural production, measured in thousand units;

(5) *IRRIG*: accumulated irrigation area as input, measured in thousand rais;

(6) *T*: time trend, used to capture technological change. t=1 for 1975, t=2 for 1976, ..., and t=17 for 1991.

(7) *LANDT*: the cross term of land input with time trend t;

(8) *LABRT*: the cross term of labor input with time trend t;

(9) *TRACT*: the cross term of tractor input with time trend t;

(10) *IRRIGT*: the cross term of irrigation input with time trend t;

(11) T^2: the quadratic term of time trend t.

4.2 Preliminary Consideration

In order to apply the model of growth analysis described in Chapter 3, it is necessary to develop estimates of the production function in northern Thailand. As explained in the theoretical discussion, a neoclassical production function will be an adequate representation.

Since the objective is to impute changes in output to input and productivity changes, we require an econometric approach capable of discriminating between the two and capable, in particular, of recognizing changes occurring as a result of movements along the production functional form changes caused by shifts of the meta-function.

4.2.1 The Empirical Model

First, a statistical test has been carried out to test whether the functional form of the production function is non-homothetic (Translog) or homothetic (Cobb-Douglas). For the non-homothetic production function to be Cobb-Douglas, it is necessary that all the interaction terms of inputs have zero coefficient. The conventional F-test was done to test the null hypothesis that all interaction term coefficients are zero. The F-test statistic for H_o: $a_{ij} = 0$ is

$$F = \frac{(\mathbf{e}_*'\mathbf{e}_* - \mathbf{e}'\mathbf{e})\ q}{\mathbf{e}'\mathbf{e}\ (n-k)} \sim F(q, n-k) \qquad (9)$$

Where $\mathbf{e}_*'\mathbf{e}_*$ denotes the restricted residual sum of squares derived from the restricted regression (all coefficients of the interaction terms' are zero), and $\mathbf{e}'\mathbf{e}$ denotes the unrestricted residual sum of squares from the usual OLS regression. n is observations, k is the number of variables, and q is the number of restrictions ($q \leq k$).

After running the restricted and unrestricted regression, substitute the $\mathbf{e}_*'\mathbf{e}_*$ and $\mathbf{e}'\mathbf{e}$ value in formula (9),

$$F = \frac{(11.722 - 7.529)\ 11}{7.529\ (272 - 17)} = 12.91$$

and $F_{0.99}(11,200) = 2.34$, obviously the computed F value is greater than the tabulated F value for (11, 255) degrees of freedom at the 1 percent level of significance. This implies that the null hypothesis cannot be accepted. Thus, the non-homothetic functional form fits the data better than the homothetic form for this particular type of specification.

Although the Trans-log form is superior than the Cobb-Douglas form, on the contrary, the unrestricted Trans-log function failed to yield reasonable coefficients due to serious multicollinearity problem resulted by so many variables. Dawson *et al.* (1991) described their functional form choosing process as "A transcendental logarithmic function was estimated at first, but serious multicollinearity problems among the cross-product terms led us to prefer a Cobb-Douglas specification".

To balance the merits and defects of the Cobb-Douglas and Translog production function forms, the restricted Trans-log production function form (6) is preferred, and was used in the estimation.

4.2.2 Test for The Government's Role

This study covered three governmental economic planning periods as mentioned in Chapter 2. In the Fifth plan, government started to emphasize the efficiency of production factor uses. Here a hypothesis has been tested that the Fifth and Sixth Plans have no discernible impact on the rate of any neutral technological progress in the agricultural sector of northern Thailand.

One dummy variable D was added into equation (6) and obtained the following equation:

$$\ln(Y) = a_o + a_t t + D + \sum_i a_i \ln(x_i) + \sum_i a_{it} \ln(x_i) \cdot t + a_{tt} t^2 \qquad (10)$$

Where D is 1 in 1982-1991, 0 elsewhere, representing the fifth and Sixth government planning period;

After running OLS and Frontier regressions, the coefficients of D in equation (10) were obtained (see A1 and A2). Because the t-values of the estimates are so small, none of the estimated coefficients is significantly different from zero at any significant level. Accordingly, the dummy variable were omitted from the equation in the estimations.

4.3 Estimation Result

The results of production function estimation for the different specifications are shown in Table 4.1. The ordinary least squares (OLS) technique is used for the average production function estimation and the maximum likelihood (ML) technique for the frontier production function. For comparison purpose, the Cobb-Douglas form (8) is used for regressions 1 (R1 in Table 4.1). Time trend (T) measures neutral technological change over time. Except for time trend, the coefficients of regression 1 are very significant (at 1 percent level). The sum of production elasticity of land and labor is .719, which implies that traditional inputs still dominate the agricultural production in northern Thailand. Tractors and irrigation also played important roles in agricultural production.

Table 4.1 Estimates of Production Functions

Regression No.	R1 (Average)	R2 (Average)	R3 (Frontier)
Constant	9.95*	10.93*	11.29*
	(49.85)	(31.57)	(37.39)
LABOR	.432*	.563*	.542*
	(16.61)	(10.26)	(9.73)
LAND	.287*	.068***	.059
	(9.99)	(1.27)	(1.20)
TRACTORS	.081*	.095*	.106*
	(3.42)	(2.11)	(2.70)
IRRIGATION	.038*	.015	.016
	(2.93)	(.82)	(.69)
T	.003	-.238*	-.263*
	(.81)	(3.45)	(3.46)
LABORT		-.0128*	-.0107**
		(2.54)	(1.69)
LANDT		.0259*	.0258*
		(4.72)	(3.92)
TRACTORST		-.0045	-.0051
		(1.04)	(.93)
IRRIGATIONT		.0047*	.0045***
		(1.98)	(1.34)
T^2		.00123***	.00142***
		(1.45)	(1.37)
$\lambda = \sigma_u / \sigma_v$			1.382*
			(3.087)
σ	.210*	.195*	.250*
	(23.3)	(23.3)	(10.73)
Log-likelihood			65.736
Observations	272	272	272
R^2	.875	.894	
$\bar{R}^2$	.872	.890	

Note: Numbers in parentheses are *t*-test values. *,** and *** indicate significant at 5%, 10% and 20% level respectively.

Source: Estimated.

Functional form (6) is used for regressions 2 (R2 in Table 4.1) and 3 (R3 in Table 4.1) using the same input variables as regression 1. In addition, the cross-term of each input and time trend captures the relative changes of each input in total input over time. Most of the estimates of coefficients are significant (except *IRRIGATIONT* in regression 2, all the other single asterisks indicated coefficients are significant at 1 percent level).

Regression 2 showed that labor and machinery played a decreasing role in production, whereas production elasticity of land and irrigation increased over time. The significant positive T^2 coefficient suggests that total factor productivity in agricultural production of northern Thailand has increased through neutral technological change over time .

The estimates in R3 have a little change compared with R2. The constant term is higher than in regression 2. The significant level changed with respect to *LAND*, *LABORT*, and *IRRIGATIONT*. Again, the frontier estimation is superior to the average estimation because "the frontier production function methodology assigns behavioral significance to the magnitudes of the error components" (Kalirajan *et al.* 1989).

4.4 Production Elasticity for Different Factors

Production elasticity is calculated from functional form (6). Production elasticity for input *i* in this production functional form is:

$$\varepsilon_{it} = \partial \ln Y / \partial \ln x_{it} = a_i + a_{it} t \qquad (11)$$

Thus, if $a_{it} > 0$, production elasticity of input *i* is increasing; if $a_{it} < 0$, production elasticity of input *i* is decreasing.

Table 4.2 shows that production elasticity (calculated using regression 3.) of labor and machinery are decreasing by 2% and 5% per year, respectively. The annual rates of increases in production elasticity by 30% for land; and 6% for irrigation, —are greater than the rates of decreases for labor and machinery.

Table 4.2 Production Elasticity for Different Inputs, 1975-1991

Year	Labor	Land	Tractors	Irrigation	Total
1975	.531	.085	.101	.021	.738
1976	.521	.111	.096	.025	.753
1977	.510	.136	.091	.030	.767
1978	.499	.162	.086	.034	.781
1979	.489	.188	.081	.039	.797
1980	.478	.214	.076	.043	.811
1981	.467	.240	.070	.048	.825
1982	.456	.265	.065	.052	.838
1983	.446	.291	.060	.057	.854
1984	.435	.317	.055	.062	.869
1985	.424	.343	.050	.066	.883
1986	.414	.369	.045	.071	.899
1987	.403	.394	.040	.075	.912
1988	.392	.420	.035	.080	.927
1989	.382	.446	.030	.084	.942
1990	.371	.472	.025	.089	.957
1991	.360	.498	.020	.094	.972

Source: Computed.

The results in Table 4.2 can be compared to those of other studies. For example, Taylor *et al.* (1986) conducted a study titled "Agricultural Credit Programs and Production Efficiency: An Analysis of Traditional Farming in Southeastern Minas Gerais, Brazil", an analysis of the effects of an integrated rural development program. They found labor as the most important variable, with elasticity 0.6531; land accounted for a small share with elasticity 0.0894. The elasticity of these two factors are in line with the present results in the early year, 1975.

In Hayami and Ruttan case, three data sets were used, i.e. 1969, 1965 and 1955-60-65 for 43 countries, of which 23 were developed countries. Land was generally non significant or had low elasticity ranging between 0.33 and 0.49. Labor elasticity were, however, partially in line with the present results, as they ranged between 0.33 and 0.47 and so did to some extent tractors (0.04 - 0.19). The low value of land elasticity is in part explained by the correlation between the land and the livestock variables (the correlation coefficient between the two variables was above 0.9). Dung Nguyen used data for the period 1955-60-65-70-75 for the same countries of the Hayami and Ruttan's sample to obtain estimates of elasticity ranging between negative to 0.02 for land, 0.32 to 0.36 for livestock, 0.36 to 0.39 for labor and 0.15 to 0.31 for machinery although the same observation on the correlation between the livestock and land variables applies.

Mittelhammer *et al.* found that the production elasticities of land, ranged from 0.3348 to 0.3535; labor, 0.4808 to 0.5949; and capital 0.1578 to 0.2017 using three different regression approaches (See Table 4.3). The results especially the mean elasticities shown in Table 4.2 are broadly in line but slightly lower than that shown in Table 4.3. It is confirmed that land and labor used to account for large elasticity in Thailand. In 1991 the elasticities of land and labor were still large even though they reduced, indicating that Thailand agriculture used relatively more traditional inputs during 1975 - 1991.

Table 4.3 Production Elasticity for Inputs in Thailand Agriculture (1950-76)

Model No.	Land	Labor	Capital
1	.3384	.5949	.1578
2	.3535	.5775	.1562
3	.3436	.4808	.2017

Note: Model 1 is mixed estimation; model 2 is mixed estimation with exact linear restrictions; model 3 is principal components regression (PCR).
Source: Quoted from Mittelhammer *et al.* (1980).

4.5 Production Efficiency

Using Equation (2) and the results of the frontier production function from regression 3 in Table 4.1, the level and variability of technical efficiency for each region are calculated in Table 4.4. In 1975, technical efficiency was about 80%. Efficiency has been improved in a slow rate or stagnant. Compare 1991 with 1975, the annual growth rate is about 0.1%.

The technical efficiency among the four zones, horizontally, in 1975-76 period the variation among zones are comparatively large. In 1977-1981, the average 78-81 efficiency rank had no change among zones compared with the average 75-76 efficiency rank. The deference narrowed over the Fifth and Sixth National Plan period, and in 1991, the coefficient of variation was only .047. Apparently, the balance achieved with the technical efficiency decrease in Zone A and increase in Zone C (see Figure 4.1).

Vertically, the productive efficiency in Zone A decreased by 0.528% per year even though it's average 87-91 rank was still the first; in Zone C, the only increasing zone among the four, increased by 2.49% per year; in Zone B and Zone D, decreased by .231% and .256% per year, respectively. The situation of changes in the four zones during 82-91 and 75-91 periods are listed in the bottom part of Table 4.4. Details will be discussed in Chapter 5.

Table 4.4 Level and Variability in Technical Efficiency of Four Zones, 1975-1991

Year	Zone A	Zone B	Zone C	Zone D	Regional Average	C.V.
1975	.911	.786	.588	.872	.800	.182
1976	.938	.727	.673	.893	.833	.158
Average 75-76	.926	.757	.629	.882	.817	
Rank	1	3	4	2		
C.V. 75-76	.019	.055	.095	.017		
Rank	3	2	1	4		
1977	.919	.753	.610	.691	.755	.176
1978	.916	.766	.700	.869	.826	.120
1979	.938	.812	.707	.832	.841	.115
1980	.865	.730	.723	.889	.810	.109
1981	.883	.717	.785	.911	.836	.109
Average 77-81	.909	.756	.704	.849	.814	
Rank	1	3	4	2		
C.V. 77-81	.033	.049	.089	.104		
Rank	4	3	2	1		
1982	.874	.636	.828	.845	.800	.136
1983	.891	.597	.699	.905	.786	.194
1984	.914	.682	.791	.921	.847	.137
1985	.877	.721	.789	.907	.834	.103
1986	.907	.692	.782	.881	.827	.121
Average 82-86	.894	.664	.779	.895	.819	
Rank	2	4	3	1		
C.V. 82-86	.020	.074	.061	.033		
Rank	4	1	2	3		
1987	.924	.658	.701	.848	.789	.159
1988	.927	.739	.846	.897	.866	.097
1989	.851	.804	.868	.875	.852	.038
1990	.880	.779	.769	.820	.816	.062
1991	.834	.757	.822	.835	.813	.047

(to be continued)

Table 4.4 (continued)

Year	Zone A	Zone B	Zone C	Zone D	Regional Average	C.V.
Average 87-91	.890	.747	.805	.858	.830	
Rank	1	4	3	2		
C.V. 87-91	.047	.074	.084	.036		
Rank	3	2	1	4		
C.V. 82-91	.034	.091	.071	.040		
Rank	4	1	2	3		
C.V. 75-91	.034	.081	.107	.062		
Rank	4	2	1	3		
Annual Growth Rate (%)	-.528	-.231	2.49	-.265	.102	

Note: C.V. is coefficient of variation.

Source: Calculated.

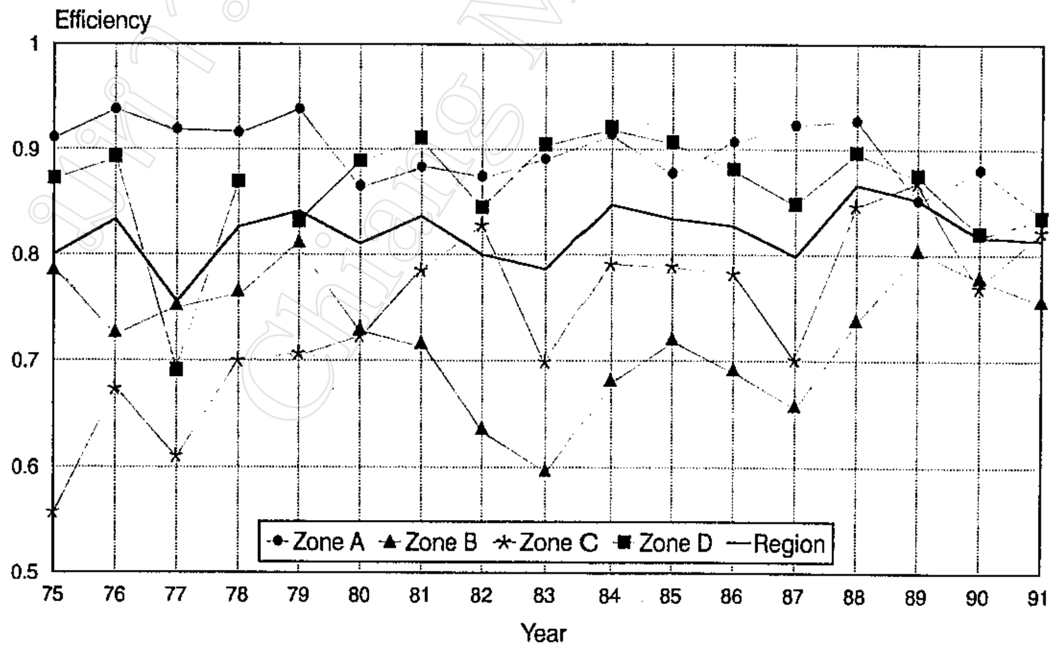

Figure 4.1 Technical efficiency in Northern Thailand, 1975-1991

Source: Drawn from the data of Table 4.4.

4.6 Statistical Characteristics and Limitation of the Study

As for most empirical research in social sciences, measurement problems and data availability have imposed a serious limitation on this study. Because of the large sample of provinces used, unavoidable measurement and aggregation errors suggest some caution in interpreting the results obtained.

The land measurement adopted, based on data on harvested land, does not take into account differences in soil fertility, topography and climate. The labor measure used, on the other hand, relies on the population in labor force. These data reflect more the availability (i.e. the supply) of labor than its demand as a productive factor. They do not, therefore, capture variations in employment due to changes in cropping patterns or technological progress except to the extent to which these changes are reflected in the participation rates. More subtle changes due to improvement in the human capital are similarly excluded.

Among the data directly used in the estimation of the frontier production function, the total number of tractors were particularly unsatisfactory for three reasons. First, the total number of tractors as the measure used, is at best , only a gross measure of the stock of machinery available at a given point in time. For reasons similar to the ones mentioned for the labor measure, it is neither sensitive to changes in the rate of employment of tractors available, nor to differences in the employment of different types of tractors. Second, the same measure is subject to large aggregation errors since it gives the same weight to all pieces of machinery regardless of their power, the implements attached and the related functions. Third, it is unsatisfactory even as a measure of available stock, as it does not take into account the vintage of the machinery, degree of depreciation and working order vis-a-vis spare parts.

Similarly, statistics on irrigated land were quoted from the Royal Irrigation Department, which mainly measured the capacity of the Royal Projects which can served areas mainly in the wet season.

For various reasons such as multicollinearity, autocorrelation and other unmanageable error patterns, aggregate data are often characterized by unreliability of a more subtle nature, causing particular difficulties to statistical inference and estimation. Nevertheless, this study showed a picture of production growth in the whole agricultural sector. Without the study on aggregate production, it is hardly to fully understand the production and its growth process, and in turn it is difficult to select suitable measures for increasing production in the agricultural sector of the northern Thailand (also see the Usefulness of the Study in Chapter 1).