

CHAPTER 3

METHODOLOGY

3.1 Conceptual Framework

3.1.1 Pattern of Production Growth

Conventional wisdom maintains that the process of development in agriculture is characterized by an initial phase of increasing input use followed by a phase of increasing factor productivity. This last phase would be characterized by two movements: one of unbalanced increases in factor productivity with one factor in the lead and one of balanced increases during which the contribution to growth of all factor productivities becomes important. This two-stage description is formulated by Hayami and Ruttan (1971) in an authoritative essay that strikes a parallel between agricultural development in Western Europe and Japan and identifies, among the many differences, the described sequence of increases in factor use and factor productivity as the most common element of the two development stories.

The main empirical support of this two-stage hypothesis has been provided by the respective output-land and output-labor ratios. For many countries, these crude ratios seem to move first in response to the scarcity of a specific factor and then together suggesting that the modernization process, once started, spreads to encompass both land saving and labor saving technology.

Hayami and Ruttan's work focused on innovation as a source of factor productivity differences and especially on the role of biological technical progress characterized by substitution of fertilizer for land and of mechanical technical progress characterized by substituting either land or capital (or both) for labor. The analysis of inter-country factor productivity differences as empirical evidence of differential technological progress in turn gave rise to the concept of a meta-production function,

defined at first as the envelope of the individual country production functions. The meta-production function, seen as a technological frontier potentially accessible to all countries, suggests then an alternative way of explaining factor ratio differences across countries as a result of a scatter along an isoquant associated with a given innovation.

In terms of growth theory, the concept of a meta-function leads to a model of development where technological progress facilitates the movement along the innovation isoquant to foster substitution of industrial output for natural ones. In this model, growth is made faster by the partial removal of the constraints imposed by the inelastic supply of land; labor saving and biological and mechanical innovations fulfill the role of easing the transition to new technologies. Apart from these interesting implications for the theory of agricultural development, the concept of the meta-production function provided an imaginative rationale for cross-country production function studies and caused much debate and also led to some further empirical studies.

In a major follow-up, Yamada and Ruttan (1980) extended the earlier analysis of the Hayami-Ruttan study to data centered on 1970 and to four additional countries: Denmark, France, Germany and the United Kingdom. Refining the concept of meta-production function (MPF), the authors distinguished between MPF defined as the envelop of the production points for the most efficient countries, and the innovation possibility curve (IPC) as the envelope of possible neoclassical production functions.

A second stream of studies on cross country comparison of agricultural productivity is based on a more straightforward idea that agricultural growth can be broken down into a yield, an acreage and, in some cases, a cropping intensity component. In Beckman and Paulina's (1979) study, the agricultural growth is conceived as a process where increase in cropping intensity and crop yields takes progressively over as a contributor to growth, while land increases (i.e. increases in the only recognized factor of production), at first of paramount importance in land

abundant countries, is gradually displaced by technical progress as a major component of growth.

Scandizo (1984) showed that, the methodical differences notwithstanding, both the econometric and the growth accounting studies fail to bring out a satisfactory analysis of production in developing countries for two main reasons. On the one hand, imputation of cross-country productivity differences to this or that factor does not explain why and to what extent factor growth and technological progress contributed to output growth. On the other hand, decomposing growth into acreage, yield and cropping intensity does not provide any information on the causes of the increases, nor does it permit to detect changes in the pattern of production, input levels and technology. Regardless of the techniques available, the observed country production points are a scatter of a production isoquant whose size and shape is determined by technical progress as well as by the particular conditions of production of each country. Within this framework, the concept of a meta-production function, along the lines specified by Yamada and Ruttan, provides a useful tool of analysis to identify sources of growth in a non-tautological way.

3.1.2 Technical Efficiency Relative to a Frontier Production Function

Before 1957, an unsolved problem had long been existed, i.e., to empirically estimate a production function which has been defined in the classical manner "..... the function must be so defined that it expresses the *Maximum Product* obtainable from the combination (of factors) at the existing state of technical knowledge" (Carlson, 1939).

More often the empirical estimates of production functions have not utilized the above classical definition. In stead, the usual least square or ordinary least square (OLS) estimate give an "average" or expected value of the functional relationship. Whether one would prefer an "average" versus a "maximum" estimate of the

production function would likely depend upon how the function is to be used. Similarly, whether one would prefer the "efficient" unit isoquant as compared to only "average efficient" isoquant would also seem to depend upon its use.

The frontier production function approach, initiated by Farrell in 1957, has been expanded by various methods of measuring and computing production functions and efficiency (Lovell and Schmidt, 1988). The main approaches include pure programming, modified programming, the deterministic statistical frontier, and the stochastic frontier. Pitt and Lee (1981) indicated that the programming approach and the deterministic frontier approach do not allow for random shocks in the production process; as a result, a few extreme observations can determine the frontier and exaggerate the maximum possible output. However, the stochastic frontier approach can avoid this problem.

The obvious trait of the stochastic frontier model is that the error term is composed of two parts, a symmetric component and a one-side component. The symmetric component in this context refers to the error term with zero mean and normal distribution, which permits random variation of the frontier across firms, and captures the effects of measurement error, other statistical noise, and random shocks beyond the firm's control. The one-side component, with half-normal distribution, captures the effects of inefficiency relative to the stochastic frontier.

Aigner *et al.* (1977), Battese *et al.* (1977), Meeusen (1977) and Kalirajan *et al.* (1982) estimated stochastic production frontiers and estimated population average technical efficiency, but not estimates of the technical efficiency for individual observations in the sample. Jondrow *et al.* (1982), Kalirajan *et al.* (1983, 1989), Dawson *et al.* (1991), Johnson *et al.* (1994) studied individual firm-specific technical efficiencies using cross-section data or panel data. All the estimation methods related to the technical efficiency especially firm or farm specific technical efficiency provide meaningful implication for policy analysis.

3.2 Empirical Framework

3.2.1 Effects of Input Growth, Technological and Efficiency Change

Conventional productivity theory defines that total production growth consists of movements along the production function (an increase of total inputs) and shifts of the production function (technological change), assuming that the firm is perfectly efficient in production. The growth rate of total factor productivity is the growth rate of total output minus the growth rate of total input; hence, technological change is considered the unique source of productivity growth, and the effects of efficiency improvement of productivity growth are ignored. The assumption of perfect efficiency in production is unrealistic. Differences among firms between realized output and potential output are caused by differences in the capacity to use new technology and in the motivations of farmers. If this assumption is relaxed, total production growth can be attributed to efficiency improvement, to increased inputs and technological change. Different policy inferences may be drawn inasmuch as technological change and efficiency improvement represent fundamentally different sources of growth in production. Thus, an alternative approach will be employed to capture all three effects on production growth.

In this study technological change is defined as a shift of the frontier production along the meta-production function. Efficiency improvement is defined as the decrease in the distance between the firm's realized output and its potential output (or frontier). The different sources of production growth are shown in Figure 3.1. At times 1 and 2, the producer faces production frontiers 1 and 2, respectively. If production were perfectly efficient, output would be T_1^* at time 1 and T_2^* at time 2. However, the producer's realized output is Y_1 at time 1 and Y_2 at time 2 owing to production inefficiency. Technological change is measured by the distance between frontier 2 and frontier 1, i.e., $T_2^* - T_1^*$. Inefficiency is measured as the distance between the frontier

and the output realized by the producer, i.e., E_1 at time 1 and E_2 at time 2. Hence the improvement of efficiency over time is the difference between E_1 and E_2 . The contribution of input change is measured as Z . Therefore, the total production growth can be decomposed to Three effects: input growth and technological change and efficiency improvement:

$$Y_2 - Y_1 = Z + (T_2^* - T_1^*) + (E_1 - E_2)..$$

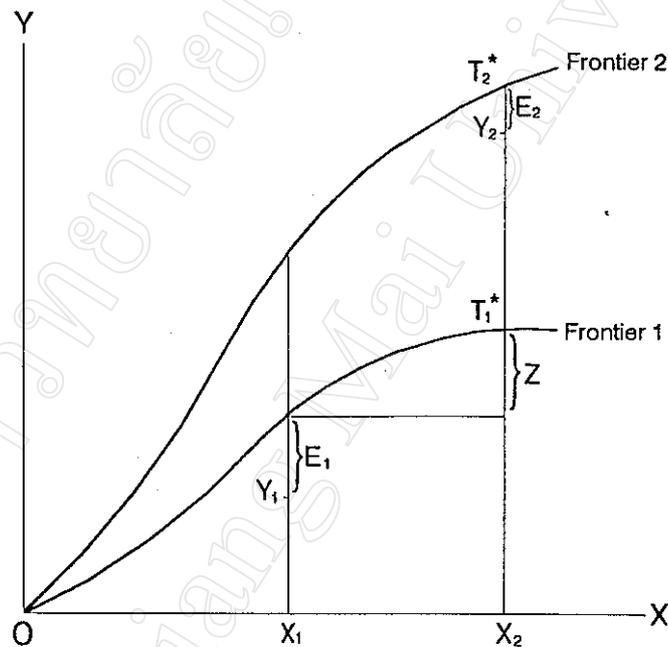


Figure 3.1 Effects on production growth of input increase, technological change, and efficiency improvement

3.2.2 Specification of the Stochastic Frontier Production Function and Functional Forms

As mentioned in 3.1.2, the programming and deterministic approach is quite sensitive to outlier of the sample data. In this study, the stochastic frontier approach is employed to avoid this problem.

Consider the following production function:

$$Y_{it} = f(x_{it}, b)e^{v_{it}} e^{u_{it}}, \text{ or}$$

$$\ln Y_{it} = \ln f(x_{it}, b) + v_{it} + u_{it} \quad (1)$$

Where i denotes the i th firm or region, and t denotes time t ; Y_{it} is output; x_{it} is $1 \times k$ rows of inputs; $f(x_{it}, b)$ is potential output; v_{it} is a stochastic variable representing uncontrolled random shocks in production; and u_{it} is one-sided distribution, $u \leq 0$, which represents technical inefficiency. In (1), $f(x_{it}, b)e^{v_{it}}$ is the stochastic frontier, given that v_{it} consists of random factors outside the firm's control. The non positive disturbance u indicates that output must lie on or below the frontier $f(x_{it}, b)e^{v_{it}}$ because $e^{u_{it}}$ has a value between zero and one. Assume that for $t \neq t'$, $E(u_{it}u_{it}') = 0$ for all i , and $E(u_{it}u_{it}') = 0$ for all $i \neq j$. In this specification, the firm's inefficiency may change over time by learning from experience. We also assume u is truncated normal with variance σ_u^2 , v is normal with mean zero and variance σ_v^2 , and $E(u_{it}v_{it}') = 0$.

The efficiency for a firm or region i at time t , then, is defined as

$$e^{u_{it}} = \frac{Y_{it}}{f(x_{it}, b)e^{v_{it}}},$$

that is, the ratio of observed output to the maximum achievable stochastic level given that technical efficiency is fully realized (expected output).

Based on the conditional distribution of u_{it} , given the distribution $v_{it} + u_{it}$, the efficiency of a specific firm or region at a given time can be measured as (Kalirajan *et al.*, 1983; Fan, 1991)

$$E \left\{ \exp \left(\frac{u_{it}}{u_{it} + v_{it}} \right) \right\} = \exp \left[-\frac{\sigma_u \sigma_v}{\sigma} \left(\frac{f(\cdot)}{1 - F(\cdot)} - \frac{\varepsilon_{it} \sqrt{\gamma}}{\sigma(1 - \gamma)} \right) \right] \quad (2)$$

Where

- (i) $\varepsilon_{it} = u_{it} + v_{it} = \ln y_{it} - \ln f(x_{it}, b)$,
- (ii) σ is standard error of ε_{it} , and $\sigma^2 = \sigma_u^2 + \sigma_v^2$,
- (iii) $\gamma = \sigma_u^2 / \sigma^2$, where γ lies in the interval (0,1), and
- (iv) $f(\cdot)$ and $F(\cdot)$ are the values of the standard normal density function and standard normal distribution function evaluated at

$$\frac{\varepsilon_{it} \sqrt{\gamma}}{\sigma(1 - \gamma)}$$

The following step of the specification is to choose an appropriate functional form. Consider a production process that uses n inputs to produce one output represented by the production function:

$$Y = f(x_1, \dots, x_n, T) \quad (3)$$

Where Y is output, x_i is i th input and T is used to catch technical progress (time trend). The unrestricted translog function form (4) can be used to represent production function (3).

$$\ln(Y) = a_0 + a_1 t + \sum_i a_i \ln(x_i) + \sum_i \sum_j a_{ij} \ln(x_i) \ln(x_j) + \sum_i a_{it} \ln(x_i) \cdot t + a_{tt} t^2 \quad (4)$$

However, the translog form needs considerable data and has many variables which may lead to multicollinearity problems. Consider a restriction that all inputs are separable from each other, but each input cannot be separated from technical progress:

$$Y = f\{g_1(x_1, T), \dots, g_n(x_n, T)\} \quad (5)$$

The theoretical background of this form comes from the fact that every factor input changes over time while the effects among inputs are indirect through time. Then, the following production function form can be used to represent (5):

$$\ln(Y) = a_0 + a_t t + \sum_i a_i \ln(x_i) + \sum_i a_{it} \ln(x_i) \cdot t + a_{tt} t^2 \quad (6)$$

If all inputs and time are considered separable, the production function can be expressed as

$$Y = f\{g_1(x_1), \dots, g_n(x_n), T\} \quad (7)$$

The Cobb-Douglas production function form (8) can be used to represent (7).

$$\ln(Y) = a_0 + \sum_i a_i \ln(x_i) + a_t t \quad (8)$$

Owing to the serious multicollinearity problem of the translog form, and the restrictive constancy of production elasticity and the unitary substitution between factors in the Cobb-Douglas form, functional form (6) is used for the estimations. The Cobb-Douglas form and average production functions are also estimated for comparison purposes².

² The traditional estimation of a production function assumes that every firm is technically efficient, resulting in the average production function, $Y_{it} = f(x_{it}, b)e^{\varepsilon_{it}}$, where ε_{it} has normal distribution and $\varepsilon_{it} \sim N(0, \sigma^2)$.

3.3 Scope and Data

This study considers the whole agricultural sector of northern Thailand. Pooling data from 17 provinces from 1975 to 1991, covering 272 observations³, are used in the estimation.

The data are aggregated data. The sub-aggregates are (a) crop production, (b) livestock, (c) forestry, (d) fishery, (e) agricultural services, and (f) simple agricultural processing products.

The sub-aggregates from (a) to (d) are explained as follows:

(a) The sub-sector of crop production includes the following items--

Rice: major and second rice (non-glutinous and glutinous)

Principal upland crops (or field crops): maize, peanut, mungbean, soy bean, sorghum, sesame, kenaf, cotton, upland price, castor bean, sugar cane, cassava, pineapple, sweet potato, water melon, potato, jute, tobacco.

Principal vegetable crops: chili, bird pepper, garlic, shallot, tomato, cabbage, cucumber (large and small varieties), yard long bean, Chinese cabbage, leaf mustard Chinese, pakchloi Chinese cabbage, Chinese kale, water convolvulus, pumpkin, white gourd, taro, and miscellaneous crops.

Fruit crops: banana, mango, coconut, kapok, longan, tamarind, jack fruit, langsat, sapodilla, sugar apple, lime, durian, lichee, tangerine, guava, Pamela, cashew nut, orange, santol, and miscellaneous crops.

(b) The livestock sector includes the following production items: cattle, buffaloes, swine, chicken, ducks, hens' egg, ducks' egg, other poultry, etc..

³ Payao was not separated from Chiang Rai in 1975, joining the two provinces' data in one from 1977-1991, got the observations 272 (16 provinces×17 years).

(c) Fishery activities in Thailand are principally divided into 2 categories: inland fisheries and marine fishery. In northern region, there is no marine fishery. The inland fisheries compose of two main activities, i.e., harvesting from wild and aquaculture. Wild freshwater fishes were totally harvested from public water bodies, and cultured species were obtained from ponds, paddies, ditches, and cages.

(d) Forestry, includes teak, yang, all other timbers and forest products.

Most of the data used in this study are from Vichya Nagarugsa's data disk (Krung Thai Bank, 1995) or from Thailand statistical year book. These are:

(1) Agricultural output, measured in thousand Baht, is defined as gross value of agricultural products, serves as the aggregate total output using 1988 constant prices. All definitions follow *National Income of Thailand*. The time series of provincial monetary value of total production (measured in 1988 constant prices) before 1980 are reported in *Gross Provincial Product*, various issues published by NESDB. The data after 1981 is collected from the Northern Center, NESDB.

(2) Agricultural land, measured in rais, is defined as the harvested areas under paddy, field crops, fruit tree and tree crops, vegetable and flowers explained in above (a). The data before 1985 and during 1990-1991, are collected from *Provincial Statistical Report*, National Statistical Office, Office of the Prime Minister as well as Provincial Statistical Office. The data between 1985 and 1989 are collected from *Statistical Report of Region: Northern Region*, National Statistical Office, 1990 and 1992 editions. For the fruit tree item, some year's data are not reported, the planted area as reported by *Thailand Agricultural Statistical Yearbook* are used. Since this study includes livestock production, the grass land is included in the land input, which was converted to harvested area equivalent quantity which was weighted by .0124, that means one unit of grass land is equivalent to .0124 unit of harvested area (Fan). In the study, forest land are not included.

(3) Agricultural labor, measured in persons at year end (stock term). The definition follows the Office of Agricultural Economics as the female and male population, aged 15 to 64.

(4) Tractors, measured in unit, as provided by *Agricultural Statistical Year Book*, is treated as the total number of tractors under usable condition owned by farmers. For some years only regional data reported, the provincial data is quoted from the census data (1983, 1988) and, in the inter census periods, is typically an extrapolation as cited from Vichya.

(5) Irrigation, is defined as accumulated irrigation area, measured in rais.

In addition to these data, a number of other variables were tried in the model test run, but failed to yield statistically significant coefficients. These are:

Water pump, as provided by *Agricultural Statistical Year Book* in units.

Livestock, again as provided by *Agricultural Statistical Year Book*, is the total number of cattle and buffaloes measured in heads.

Education level, provided by Vichya, is defined as the years of education farmers attended.