Land Use and Productivity Growth in Thai Agriculture*

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ABSTRACT

Growth in agricultural production in Thailand can no longer rely mainly on an extension of land area. New technology inputs such as fertilisers, mechanisation, water and chemicals have been adopted. This change has raised questions about the technical change and productivity growth in Thai agricultural production. A translog variable cost function framework is used to estimate a system of the cost function and the associated cost share equations for Thai agriculture. The system is estimated using the iterative seemingly unrelated regression method applied to a panel of 92 observations, comprising annual data from 1972 to 1994 for four regions in Thailand. This results indicate that the availabilities of new land on agricultural production could has the influence on productivity growth in Thailand.

Keywords: land use, technical change, productivity growth, translog cost function

1. Introduction

Thai agriculture has experienced rapid growth over the past three decades. During the periods 1963 to 1975, 1975 to 1985, and 1963 to 1985, the annual growth rates of gross value added averaged approximately 4 per cent (Onchan and Isvilanonda 1991,

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p. 60). Although the agricultural sector recorded a negative growth rate of 2 per cent in 1987, due to the drought crisis, agriculture still grew at a high average rate of nearly 4 per cent per annum during the 1980s (Asian Development Bank 1990) and 3 per cent per annum from 1990 to 1995 (Bank of Thailand 1998).

Thai agriculture has been in a transitional stage. In the past, the relatively high growth rate of agriculture was achieved mainly through the expansion of cultivated areas (by deforestation). Since this pattern of growth could not continue and new technology inputs have been used, economists and policy makers have raised the question of the influence of the availability of new land on technical change and productivity growth. The main purposes of this study are to calculate the rate of technical change, to identify the pattern of technical change, and to investigate productivity growth in Thai agriculture.

To achieve the above objective, a translog variable cost function framework is used to construct a system of the cost function and associated cost share equations The resulting system of equations are estimated using panel data comprising 23 years of annual data (1972 to 1994) on the four regions in Thailand. The rates of technical change, and total factor productivity are calculated from these estimates.

This paper is organised into five sections. Following this introduction, the model specification is described. Next, data and their sources are described. The last two sections cover the empirical findings of this study, and conclusions

2. Model Specification

Following the approach of Kuroda (1997), the translog variable cost function is specified in this study as:

$$\ln C = \alpha_0 + \alpha_Q \ln Q + \sum_{i=1}^{5} \alpha_i \ln P_i + \beta_B \ln Z_B + \frac{1}{2}\gamma_{QQ}(\ln Q)^2 + \frac{1}{2}\sum_{i=1}^{5}\sum_{j=1}^{5}\gamma_{ij} \ln P_i \ln P_j$$
$$+ \sum_{i=1}^{5}\theta_{iB} \ln P_i \ln Z_B + \frac{1}{2}\theta_{BB}(\ln Z_B)^2 + \sum_{i=1}^{5}\delta_{Qi} \ln Q \ln P_i + \delta_{QB} \ln Q \ln Z_B$$

$$+\left(\beta_T+\beta_D D_S\right)T+\left(\mu_{QT}+\mu_{QD}D_S\right)(\ln Q)T+\sum_{i=1}^{5}\left(\mu_{iT}+\mu_{iD}D_S\right)(\ln P_i)T$$

$$+\left(\beta_{BT}+\beta_{BD}D_S\right)(\ln Z_B)T+\frac{1}{2}\left(\beta_{TT}+\beta_{TD}D_S\right)T^2, \qquad (1)$$

where $\gamma_{ij}=\gamma_{ji}$ and $i=j=F$ (fertiliser), H (hired labour), K (capital), O (operator labour), and U (unpaid family labour); P_i, are the prices of variable inputs X_i $(i=F,H,K,O,U)$; Z_B is the quantity of land; T is a time trend introduced to proxy disembodied technical change; D_S is a dummy variable interpreted for shifts in technical change parameters (1972-77=1; otherwise = 0);[1] C is the variable cost composed of fertiliser costs $(C_F=P_F X_F)$, hired labour costs $(C_H=P_H X_H)$, capital costs $(C_K=P_K X_K)$, operator labour costs $(C_O=P_O X_O)$ and unpaid family labour costs $(C_U=P_U X_U)$; and α_0,α_Q, α_i,β_B, γ_{QQ},γ_{ij}, θ_{iB},θ_{BB}, δ_{Qi}, δ_{QB}, β_T, β_D, μ_{iT}, μ_{iD}, $\mu_{QT},\mu_{QD},\beta_{BT},\beta_{BD},\beta_{TT}$, and β_{TD} are parameters to be estimated. All variables are implicit functions of time. To avoid complexity of notation, time subscripts, t, are ignored.

A well behaving variable cost function must be homogeneous of degree one in input prices. Thus, in the translog cost function (1), this condition requires that $\sum_{i=1}^{5}\alpha_i=1$, $\sum_{i=1}^{5}\gamma_{ij}=0$, $\sum_{i=1}^{5}\delta_{Qi}=0$, $\sum_{i=1}^{5}\theta_{iB}=0$, $\sum_{i=1}^{5}\mu_{iT}=0$ and $\sum_{i=1}^{5}\mu_{iD}=0$, for $i=j=F,H,K,O,U$.

Note that labour is divided into three groups: hired labour, operator labour and unpaid family labour at the aggregate level. A study of U.S. agriculture by Tyrchniewicz and Schuh (1969, p. 779) found that the magnitudes of the own-price elasticities of demands for hired labour, operator labour and unpaid family labour were quite

[1] Patamasiriwat and Suewattana (1990, pp. 50-1) suggested that the patterns of growth of Thai agriculture can be divided into two periods. As mentioned earlier, before 1978, the relatively high growth rate of agriculture was achieved mainly through the expansion of cultivated areas by clearing the forests. Since 1978, this pattern of growth could no longer continue because Thailand had reached its land frontier. Therefore, new technology inputs such as fertiliser, modern varieties of crops and water have been widely used in this latter period. The dummy variable, D_S, is included to permit the rate of technical change to vary between these two time periods.

different in both the short run and long run when estimated from a dynamic simultaneous model involving equations for the above three labour groupings. In addition, a study of Thai agriculture by Krasachat (1997), using a dynamic dual model, also indicated that operator labour and unpaid family labour are different inputs. Thus, this study uses the cost function to estimate the effects of operator and unpaid family labour inputs separately.

Observe that, in this study, land is assumed as a quasi-fixed input due to the fact that, similar to Taiwanese agriculture studied by Kuroda (1997), the farmland market does not seem to be competitive because various regulations have been imposed on land movements in Thai agriculture. Thus, it is unlikely that the firm utilises the optimum level of land for agricultural production in Thailand. [2]

Applying Shephard's lemma to equation (1) yields a system of cost share (S_i) equations:

$$S_i = \alpha_i + \sum_{j=1}^{5} \gamma_{ij} \ln P_j + \theta_{iB} \ln Z_B + \delta_{Qi} \ln Q + \left(\mu_{iT} + \mu_{iD} D_S\right) T \qquad (2)$$

$$i = j = F, H, K, O, U.$$

Three hypotheses involving the production technology will be tested in this study. First, constant returns to scale (CRTS) can be tested in the translog variable cost function framework. Kuroda (1997) indicated that the cost function can be written as $C(Q, P, Z_B, T) = G(Q, Z_B) \cdot H(P, T)$ if the primal production function exhibits constant returns to scale. Thus, in the translog cost function (1), this condition requires that $\alpha_Q + \beta_B = 1,\ \delta_{Qi} + \theta_{iB} = \delta_{QB} + \theta_{BB} = \gamma_{QQ} + \delta_{QB} = \mu_{QT} + \beta_{BT} = \mu_{QD} + \beta_{BD} = 0$, for $i = F, H, K, O, U$. Second, Hicks-neutral technical change in variable factor inputs is tested by imposing the conditions: $\mu_{iT} = 0$ and $\mu_{iD} = 0$, for $i = F, H, K, O, U$. Third, neutrality of technical change with respect to output scale is tested by imposing the conditions: $\delta_{Qi} = 0$, for $i = F, H, K, O, U$.

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[2] A formal test for classifying a factor as a quasi-fixed input can be used by applying the approach of Conrad and Unger (1987) but, due to lack of consistent data, this is not applied in this study.

In this study, a few economic indicators to investigate the technology structure of Thai agriculture can be obtained by applying the following equations.

First, following Binswanger (1974), the Allen partial elasticity of substitution (AES) can be calculated as:

$$\sigma_{ij} = \frac{\gamma_{ij} + S_i S_j}{S_i S_j}, \qquad i, j = F, H, K, O, U, \ \ i \neq j, \tag{3}$$

$$\sigma_{ii} = \frac{\gamma_{ii} + S_i^2 - S_i}{S_i^2}, \qquad i = F, H, K, O, U. \tag{4}$$

Second, the own and cross price elasticities are obtained, with land held fixed, by:

$$\varepsilon_{ii} = S_i \sigma_{ii}, \qquad i = F, H, K, O, U, \tag{5}$$

$$\varepsilon_{ij} = S_j \sigma_{ij}, \qquad i, j = F, H, K, O, U, \ \ i \neq j. \tag{6}$$

Third, following Christensen and Greene (1976), scale economies (SCE) for the translog cost function can be defined as:

$$SCE = 1 - \frac{\partial \ln C}{\partial \ln Q} = 1 - \varepsilon_{CQ} \tag{7}$$

where the cost-output elasticity $\left(\varepsilon_{CQ}\right)$ is obtained by,

$$\varepsilon_{CQ} = \alpha_Q + \gamma_{QQ} \ln Q + \sum_{i=1}^{5} \delta_{Qi} \ln P_i + \delta_{QB} \ln Z_B + \left(\mu_{QT} + \mu_{QD} D_S\right) T,$$

$$i = F, H, K, O, U. \tag{8}$$

A positive value of SCE indicates scale economies and a negative one implies scale diseconomies.

Fourth, as mentioned earlier, T is a time trend introduced to proxy disembodied technical change. The rate of technical change (υ_t) can be expressed as:

$$\upsilon_t = -\frac{\partial \ln C}{\partial T} = -\Big\{\left(\beta_T + \beta_D D_S\right) + \sum_{i=1}^{5}\left(\mu_{iT} + \mu_{iD} D_S\right)\ln P_i + \left(\mu_{QT} + \mu_{QD} D_S\right)\ln Q$$

$$\left(\beta_{BT} + \beta_{BD} D_S\right)\ln Z_B + \left(\beta_{TT} + \beta_{TD} D_S\right)T\Big\},\ \ i = F, H, K, O, U. \qquad (9)$$

Note that, in this study, technical progress is defined as cost diminution over time. Similar to many studies (e.g., Daly and Rao 1985; Bhattacharyya, Bhattacharyya and Mitra 1997), in order to get a positive estimate of technical change in a case of decreasing cost, a negative sign is applied to the above partial derivative.

Fifth, technical change specified in the translog cost function (1) is allowed to be a non-neutral change in inputs. This study measured the biases of technical change using the approach of Antel and Capalbo (1988) and subsequently applied by Kuroda (1997). Using the cost function (1), the biases of technical change can be calculated, with land held fixed, by:

$$B_i = \frac{\left(\mu_{iT} + \mu_{iD} D_S\right)}{S_i} + \frac{\delta_{Qi}}{S_i}\lambda,\ \ i = F, H, K, O, U \qquad (10)$$

where

$$\lambda = -\frac{\partial \ln C / \partial T}{\partial \ln C / \partial \ln Q} = -\frac{\partial \ln C / \partial T}{\varepsilon_{CQ}}. \qquad (11)$$

Note that the first term of equation (10) is the pure bias effect (a shift in the expansion path) while the second term is the scale effect (a movement along the non-linear expansion path). If there is neutrality of technical change with respect to output scale (that is, $\delta_{Qi}=0$, for all $i=F,H,K,O,U$), the scale effect disappears. Thus, the measurement of biases in technical change contains only the effect of a shift in the expansion path. Technical change is Hicks-saving or -using in input i if B_i is negative and positive, respectively.

Finally, following the approach of Gollop and Roberts (1983) and subsequently applied by Daly and Rao (1985), estimated total factor productivity growth, $\dot{TFP}$, can be decomposed into three parts: scale economies, capacity utilisation, and technical change and can be expressed as:

$$\dot{TFP}=\left(1-\varepsilon_{CQ}\right)\dot{Q}-\varepsilon_{CZ_B}\dot{Z}_B+\upsilon_t\,, \tag{12}$$

where $\left(1-\varepsilon_{CQ}\right)\dot{Q}$ represents the scale effect and relies on the degree of scale economies (ε_{CQ}) and output growth ($\dot{Q}$); $\varepsilon_{CZ_B}\dot{Z}_B$ is the direct effect on productivity growth of changes in capacity utilisation which cause a vertical shift in the average cost curve; υ_t is the contribution of residually determined technical change to productivity growth.

Tests of Technical Change

The translog cost function (1) was specified with a dummy variable, D_S, included as an argument to reflect the influence of the availability of new land in Thai agriculture on the rate of disembodied technical change. The tests of hypotheses related to technical change can be divided into two stages. First, the hypothesis that the availability of new land does not affect the rate of technical change may be considered by testing the hypothesis that $\beta_D=0$, $\mu_{QD}=0$, $\beta_{BD}=0$, $\beta_{TD}=0$ and $\mu_{iD}=0$, for $i=F,H,K,O,U$. Second, the hypothesis of no technical change in Thai agricultural production may be considered by testing the hypothesis that $\beta_T=0$, $\mu_{QT}=0$, $\beta_{BT}=0$, $\beta_{TT}=0$, $\mu_{iT}=0$, $\beta_D=0$, $\mu_{QD}=0$, $\beta_{BD}=0$, $\beta_{TD}=0$ and $\mu_{iD}=0$, for $i=F,H,K,O,U$. The first group of conditions ($\beta_T=0$, $\mu_{QT}=0$, $\beta_{BT}=0$, $\beta_{TT}=0$,

$\mu_{iT} = 0$) suggests that there is no technical change in Thai agriculture. The latter group of conditions implies that if there is no technical change in Thai agriculture, a shift in the rate of technical change in Thai agriculture does not exist.

Tests of Competitive Behaviour

A well-behaved cost function satisfies homogeneity in prices, monotonicity and concavity (Varian 1984, p. 44) The translog cost function (1) satisfies homogeneity in prices, as mentioned above. The conditions of monotonicity and concavity, however, are not automatically satisfied. Therefore, both monotonicity and concavity are checked in this study.[3] Violation of certain regularity conditions can provide evidence of non-competitive behaviour. Several studies (e.g., Daly and Rao 1985, Bigsby 1994) suggested that the monotonicity property of the cost function is satisfied if the fitted cost shares for each observation are positive.

In addition, the concavity of the estimated cost function is satisfied if the principal minors of the hessian matrix of second order partial derivatives are negative definite (Varian 1984). However, Nautiyal and Singh (1986) and Bigsby (1994) indicated that an equivalent test of concavity is that the symmetric matrix of Allen Partial Elasticities of Substitution (AES) is negative semi-definite, which at a minimum requires that all own AES of the matrix are negative. Since, in this analysis, symmetry is a property of the cost functional form, a study of the signs of the own AES is used to check for violations of concavity. These checks for monotonicity and concavity are conducted at all data points.

3. Data

The empirical application in this study considers aggregate data from each of the four regions of Thailand for the period 1972-94. Inputs are classified into five groups: fertiliser, hired labour, capital, operator labour and unpaid family labour. The data for quantities of labour are based on annual surveys conducted by the National Statistical

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[3] Since statistical testing of monotonicity and concavity of standard duality involves inequality constraints on parameters, it is generally difficult to conduct formal hypothesis tests (Lau 1978).

Office (1997). The data for quantities and prices of fertiliser are derived from several occasional publications of the Ministry of Agriculture and Cooperatives.[4] The figures for quantities of capital are collected from the *Agricultural Statistics of Thailand Crop Year* published annually by the Ministry of Agriculture and Cooperatives (1996). The imported capital prices are obtained from the *Annual Statement of Foreign Trade Statistics* (Ministry of Finance 1995).

Output is aggregated into a single index of agricultural output to conserve degrees of freedom and to avoid any further complexity in econometric modelling. The output index includes the ten major crops.[5] The data for quantities and prices of crops are also taken from the *Agricultural Statistics of Thailand Crop Year*. Note that the actual prices of ten major crops are used. Due to lack of regional price data, the average Whole Kingdom farm price of each crop is used.

As mentioned above, pooled data are used for this study. Thus, multilateral comparisons among the four regions are an important issue in this study. However, because of the disadvantage of the Tornqvist index in multilateral comparisons resulting from its failure in the transitivity property, the Caves, Christensen and Diewert (1982) multilateral index is used to construct any price indexes which involve more than one commodity.[6] Following a number of studies (e.g., McKay, Lawrence and Vlastuin 1980, Wall and Fisher 1987), implicit quantity indexes are obtained by dividing the current value of each input and output by their corresponding CCD price index.

The measurement of hired and operator labour wages are similar to Krasachat (1997). In this study, a proxy for unpaid family labour wage is constructed by combining the above hired and operator labour wage series using the CCD multilateral index, as described in Krasachat (1997).

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[4] Some regional observations were missing in some years. These were estimated by extrapolation from national quantities. For further discussion see Krasachat (1997).

[5] The ten major crops are rice, kenaf, cotton, cassava, groundnuts, soybeans, mungbeans, sugar cane, corn and sorghum. Livestock is a sector which has been very important for Thai agriculture for a long time. Unfortunately, there are no livestock product data available. Thus, the livestock products are not included in this study.

[6] See more discussion on index number methods in Krasachat (1997).

Agricultural land use data are available in the *Agricultural Statistics of Thailand Crop Year*. Eight years of regional land use data are missing. Thus, missing data on land use are extrapolated from the Whole Kingdom data.

4. Empirical Results

Christensen and Greene (1976, p. 662) indicated that the optimal procedure of the translog cost model is to jointly estimate the cost function and cost share equations as a multivariate regression system. In this study, the system of equations (1) and (2) provide a system of a cost function and five cost share equations which is linear in parameters.[7] Because of contemporaneous correlation between the error terms of the two equations being considered, seemingly unrelated regression estimation (Zellner 1962) is used to estimate the unknown parameters of this model.

The parameter estimates of the system of equations (1) and (2) are reported in Table 1. Approximately a half of the estimated parameters are at least twice their corresponding asymptotic standard errors. The estimated R^2 values for the translog cost function and the cost share equation of fertiliser, hired labour, capital and operator labour are, respectively, 0.99, 0.30, 0.62, 0.78 and 0.63.[8] This implies that the equation system explains a large proportion of the variation in the dependent variables.

The time-series, cross-sectional (panel) data comprises 23 years of data on four regions, giving a total of 92 observations. Possible regional differences in climate, natural resources, etc., are accounted for through the inclusion of regional dummy variables in the cost function (1). This permits the intercepts in the cost function to differ in the different regions. In addition, applying a Wald Chi-Square test, the null hypothesis of no regional differences is strongly rejected as a composite hypothesis. The marginal effects are, however, assumed to be the same in the four regions. This

[7] Due to the homogeneity-in-prices property of the cost function, one cost share equation must be omitted from the equation system for the statistical estimation. In this study, the unpaid family labour equation was dropped.

assumption may be incorrect, but its validity cannot be tested with these data because of degrees of freedom limitations.

Tests of Hypotheses

Hypothesis test results regarding structure of production technology are presented in Table 2. Wald Chi-Square tests were used in all cases. Regarding the tests of the three hypotheses: constant returns to scale (CRTS), Hicks neutrality of technical change and the neutrality of technical change with respect to output scale, it was found that all three hypotheses involving the structure of production technology are rejected.

Hypothesis test results regarding technical change are also presented in Table 2. Wald Chi- Square tests were also used in all cases. To begin with we considered a hypothesis regarding differences in rates of technical change between the two sub-periods of 1972-77 and 1978-94. The null hypothesis of no differences in the technical change parameters in Thai agriculture between the two periods is rejected. This indicates that the reduced availability of new land (in the latter sub-period) appears to have affected the rates of technical change in Thai agriculture.

The null hypothesis of no technical change in Thai agriculture is rejected as a composite hypothesis. The estimated results show that technical change in Thai agriculture during the study period exists.

Note that the results of technical change in this study is consistent with other studies of Thai agriculture (e.g., Patamasiriwat and Suewattana 1990, Krasachat 1997).

The model was estimated maintaining homogeneity and symmetry in prices. Monotonicity and concavity in prices were checked following estimation and found not to be satisfied with respect to the prices of fertiliser and capital at some data points. The reasons for these violations could be due to data problems, or may be a consequence of imperfect competition in output and input markets, as a result of intervention by the government in certain markets in Thai agriculture. One possible

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[8] See more details in the previous footnote.

method of addressing this issue is to adapt the shadow price approach of Atkinson and Halvorsen (1984) to the dual framework but this is beyond the scope of this study.

Elasticity Calculations

Applying equations (3)-(6), Tables 3 and 4 present factor demand elasticities with respect to factor prices and the Allen partial elasticities of substitution calculated at the sample means of the data with land held constant, respectively. The analysis indicates two main findings.

First, the own-price elasticities of demand for all the variable factors (i.e., fertiliser, hired labour, capital, operator labour and unpaid family labour) have a negative sign, as one would expect, but they are quite inelastic, indicating inelastic demand for these factor inputs by firms. In addition, the demand elasticity for capital is the smallest in absolute values among the five elasticities. This may be because capital is a fixed rather than a variable factor.

Second, the only AESs between capital and fertiliser, hired labour and unpaid family labour are -0.478, -0.734 and -0.205, respectively. This indicates that capital and hired labour and unpaid family labour are complementarities.

Scale Economies

In order to investigate the influence of the availabilities of new land on Thai agricultural production, the scale economies were calculated using equations (7) at the sample means of the data for two sub-periods of 1972-77 and 1978-94 in Thailand. The empirical results show that the scale economy value was 1.204 per cent during the period of 1972-77, and it decreased to 1.127 per cent during the period of 1978-94. This indicates that Thai agricultural production operated under scale economies for both sub-periods. In other words, there exist cost advantages in increasing production scale in Thai agriculture. However, there exists a decrease in the returns to scale because of the limitation of new land on agricultural production.

Measurements of Rates and Biases of Technical Change

Similar to scale economies, in order to investigate the influence of the availabilities of new land on Thai agricultural production, the rates and biases of technical change were calculated using equations (9) and (10), respectively, at the sample means of the data for two sub-periods of 1972-77 and 1978-94. The empirical results show that the average annual rate of technical progress was -0.005 per cent during the period of 1972-77, and it increased to 0.008 per cent during the period of 1978-94. The results indicate *negative* technical progress during the first sub-period and quite low technical progress during the latter sub-period in Thai agriculture. This may be the result of a number of factors. First, as mentioned above, the relatively high growth rate of Thai agriculture was achieved by the expansion of cultivated areas for much of the sample period providing little pressure for the application of new technology. Second, the government have applied price controls to several agricultural export commodities, especially rice and rubber, and have also implemented import quota and tariff policies in some input markets, such as fertiliser and farm machinery.[9] These government policies may have depressed technical change by altering the price-cost ratio in the agricultural sector, especially in the rice sector (Warr 1993, p. 37). The low rates of technical progress indicated in the model results here are also reflected in reported low levels of adoption of new technologies such as modern high-yielding varieties of rice and fertiliser (Setboonsarng and Evenson 1991, p. 206).

The measures of biases in technical change are presented in Table 5. They were estimated at the sample means of the periods of 1972-77 and 1978-90, because the findings indicate that the rates of technical change are different between the two periods. The analysis indicates two main findings. First, technical change was biased toward saving hired labour, operator labour and unpaid family labour as indicated by negative rates during the two sub-periods. Second, technical change was biased toward using fertiliser and capital. These findings are consistent with the rapid increases in quantities of capital and chemical fertiliser used in Thai agriculture at the aggregate level over the study period (see more details in Krasachat 1997).

Sources of Productivity Growth

It should be noted that, in this study, the growth rates of total factor productivity comprise three important parts: scale effect, capacity utilisation and technical change, as expressed by equation (12). The empirical results indicate that the scale economies, which contributed 0.039 and 0.013 per cent to the growth rates of during the period of 1972-77 and 1978-94, were offset by decreasing quasi-fixed effects and technical change did not play an important role in determining the growth rates of TFP in the respective periods. The effects of quasi-fixed input (land) and technical change were, respectively, -0.038 and -0.005 per cent during the period of 1972-77 and around -0.025 and 0.008 per cent during 1978-94. As a consequence, the annual growth rate of TFP averaged around -0.004 per cent during the two periods. The *negative* estimated TFP growth may be partly explained by low technical change as a result of adverse government policies, as mentioned earlier, and, in particular, a decrease in the scale effect due to the influence of the availabilities of new land on Thai agricultural production during the period of 1978-94. In addition, it may be because of low output growth due to a decline in soil fertility and loss of topsoil from erosion in Thai agriculture.

5. Conclusions

A translog cost function was specified for Thai agriculture. A system of six equations was derived, comprising one cost function and five cost share equations. The parameters in this system were estimated using seeming unrelated regression estimation.

The own-price elasticities of demand for all the variable factors have a negative sign, as one would expect, but are quite inelastic. Capital and hired labour and unpaid family labour are complementarities.

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[9] See more details in Krasachat (1997).

There exist differences in the rates of technical change between the two sub-periods. Technical change was biased toward saving hired labour, operator labour and unpaid family labour and also biased toward using fertiliser and capital.

The validity of the results, however, are called into question by observed violations of monotonicity and concavity conditions. These suggest that the assumption of competitive product and factor markets may have been false, or alternatively that the data used may not be without problems. However, it should be noted that the econometric estimates in this study appear to be essentially consistent with the present state of Thai agriculture. The concavity violations can be rationalised when the degree of government intervention into these markets is taken into account.

This results indicate that there exist differences in the values of scale economies, the rates of technical change and the sources of productivity growth between the two periods. This implies that the availabilities of new land on agricultural production could have the influence on productivity growth in Thailand.

References

Antel, J.M. and Capalbo, S.M. 1988, ‘An introduction to recent developments in production theory and productivity measurement’, in *Agricultural Productivity Measurement and Explanation*, eds S.M. Capalbo and J.M. Antel, Resources for the Future, Washington, D.C.

Asian Development Bank. 1990, *Asian Development Outlook 1990*, Manila.

Atkinson, S.E. and Halvorsen, R. 1984, ‘Parametric efficiency tests, economies of scale, and input demand in U.S. electric power generation’, *International Economic Review* 25(3), 647-62.

Bank of Thailand, 1998, *Monthly Bulletin, 1997-1998*, Bangkok.

Bhattacharyya, A., Bhattacharyya, A. and Mitra, K. 1997, ‘Decomposition of technological change and factor bias in Indian power sector: an unbalanced panel data approach’, *Journal of Productivity Analysis* 8(1), 35-52.

Bigsby, H.R. 1994, 'Production structure and the Australian sawmilling industry', *Australian Journal of Agricultural Economics* 38(3), 271-88.

Binswanger, H.P. 1974, 'A cost function approach to the measurement of elasticities of factor demand and elasticities of substitution', *American Journal of Agricultural Economics* 56(2), 377-86.

Caves, D.W., Christensen, L.R. and Diewert, W.E. 1982, 'Multilateral comparisons of output, input, and productivity using superlative index numbers', *Economic Journal* 92, 73-86.

Christensen, L.R. and Greene, W.H. 1976, 'Economies of scale in U.S. electric power generation', *Journal of Political Economy* 84(4), 655-76.

Conrad, K. and Unger, R. (1987), 'Ex post tests for short- and long-run optimisation', *Journal of Econometrics* 36, 339-58.

Daly, M.J. and Rao, P.S. 1985, 'Productivity, scale economies, and technical change in Ontario Hydro', *Southern Economic Journal* 52(1), 167-180.

Gollop, F.M. and Roberts, M.J. 1983, 'Environmental regulations and productivity growth: the case of fossil-fueled electric power generation', *Journal of Political Economy*, 91(4), 654-74.

Krasachat, W. 1997, *The Dynamic Adjustment of Structure and Demand for Labour in Thai Agriculture*, Ph.D. thesis, University of New England, Armidale.

Kuroda, Y. 1997, *An Empirical Investigation of the Rice Production Structure in Taiwan, 1976-93*, Discussion Paper No. 730, Institute of Policy and Planning Sciences, University of Tsukuba, Tsukuba.

Lau, L.J. 1978, 'Testing and imposing monotonicity, convexity and quasi-convexity constraints', in P*roduction Economics: A Dual Approach to Theory and Applications*, eds M. Fuss and D. McFadden, vol. 1, North-Holland, Amsterdam, pp. 409-54.

McKay, L., Lawrence, D. and Vlastuin, C. 1980, 'Input demand and substitution in the Australian sheep industry', *Review of Marketing and Agricultural Economics* 48(2), 57-69.

Ministry of Agriculture and Cooperatives. 1995, *Agricultural Statistics of Thailand Crop Year 1971/72-1995/96*, Centre for Agricultural Statistics, Bangkok.

Ministry of Finance. 1995, *Annual Statement of Foreign Trade Statistics*, Department of Customs, Bangkok.

National Statistical Office. 1997, *Report on Labour Force Survey (Round 3), Whole Kingdom, 1971-94*, Bangkok.

Nautiyal, J.C. and Singh, B.K. 1986, 'Long-term productivity and factor demand in the Canadian pulp and paper industry', *Canadian Journal of Agricultural Economics* 34 (1), 21-44.

Onchan, T. and Isvilanonda, S. 1991, *Technology and Productivity: A Comparative Study of Thailand and Japan, A Research Report*, Centre for Applied Economic Research, Kasetsart University, Bangkok.

Patamasiriwat, D. and Suewattana, S. 1990, 'Sources of growth of agricultural production 1961-85: analysis based on Thailand Development Research Institute model', *Thammasart Economic Journal* 8(1), 43-69 (in Thai).

Setboonsarng, S. and Evenson, R.E. 1991, 'Technology, infrastructure, output supply, and factor demand in Thai agriculture', in *Research and Productivity in Asian Agriculture*, eds R.E. Evenson and C.E. Pray, Cornell University Press, Ithaca, pp. 206-16.

Tyrchniewicz, E.W. and Schuh, G.E. 1969, 'Econometric analysis of the agricultural labour market', *American Journal of Agricultural Economics* 51(4), 770-87.

Wall, C.A. and Fisher, B.S. 1987, *Modelling a Multiple Output Production System: Supply Response in the Australian Sheep Industry*, Research Report No. 11, Department of Agricultural Economics, University of Sydney, Sydney.

Warr, P.G. 1993, 'The Thai economy', in *The Thai Economy in Transition*, ed. P.G. Warr, Cambridge University Press, New York.

Zellner, A. 1962, 'An efficient method of estimating seemingly unrelated regressions and tests for aggregation bias', *Journal of the American Statistical Association* 57(298), 348-68.

Table 1: Seemingly Unrelated Regression Parameter Estimates of the Translog Variable Cost Function for Thai Agriculture

Parameter	Coefficient	Parameter	Coefficient	Parameter	Coefficient
α_0	8.276	γ_{HU}	-0.009	μ_{QD}	-0.011
	(5.628)		(0.020)		(0.010)
α_Q	0.014	γ_{KO}	-0.011	μ_{FT}	0.005
	(0.665)		(0.014)		(0.001)
α_F	0.362	γ_{KU}	-0.042	μ_{FD}	0.003
	(0.134)		(0.018)		(0.004)
α_H	0.519	γ_{OU}	0.002	μ_{HT}	0.00003
	(0.094)		(0.026)		(0.0009)
α_K	0.310	γ_{UU}	0.046	μ_{HD}	-0.004
	(0.098)		(0.033)		(0.002)
α_o	0.171	θ_{FB}	-0.097	μ_{KT}	0.012
	(0.121)		(0.021)		(0.001)
γ_U	-0.362	θ_{HB}	-0.143	μ_{KD}	0.005
	(0.155)		(0.013)		(0.004)
β_B	-2.091	θ_{KB}	-0.178	μ_{OT}	-0.007
	(2.699)		(0.021)		(0.001)
γ_{QQ}	0.334	θ_{OB}	0.120	μ_{OD}	0.003
	(0.104)		(0.018)		(0.003)
γ_{FF}	0.039	θ_{UB}	0.298	μ_{UT}	-0.010
	(0.032)		(0.021)		(0.001)
γ_{HH}	0.072	θ_{BB}	1.180	μ_{UD}	-0.007
	(0.020)		(0.692)		(0.004)
γ_{KK}	0.090	δ_{QF}	0.033	β_{BT}	-0.021
	(0.016)		(0.010)		(0.010)
γ_{OO}	0.056	δ_{QH}	0.056	β_{BD}	0.004
	(0.029)		(0.006)		(0.018)
γ_{UU}	0.046	δ_{QK}	0.073	β_{TT}	-0.0006
	(0.033)		(0.010)		(0.0006)
γ_{FH}	-0.010	δ_{QO}	-0.079	β_{TD}	0.039
	(0.018)		(0.009)		(0.008)
γ_{FK}	-0.014	δ_{QU}	-0.082	D_2	0.046
	(0.016)		(0.010)		(0.143)
γ_{FO}	-0.017	δ_{QB}	-0.317	D_3	0.109
	(0.024)		(0.203)		(0.022)
γ_{FU}	0.003	β_T	0.092	D_4	-0.115
	(0.027		(0.045)		(0.209)
γ_{HK}	-0.023	β_D	-0.113		
	(0.010)		(0.055)		
γ_{HO}	-0.030	μ_{QT}	0.002		
	(0.019)		(0.003)		

Note: Standard errors of estimates are in parenthesis.

Table 2: Hypothesis Tests

Hypotheses	Test Values	Critical Values (5 %)	Results
1. Constant returns to scale (CRTS)	430.20	$\chi^2(10) = 18.31$	Rejected
2. Hicks neutrality of technical change in the variable factor inputs	159.35	$\chi^2(10) = 18.31$	Rejected
3. Neutrality of technical change with respect to output scale	165.67	$\chi^2(5) = 11.07$	Rejected
4. No differences in technical change parameters	53.93	$\chi^2(8) = 15.51$	Rejected
5. No technical change	625.14	$\chi^2(17) = 27.59$	Rejected

Table 3: Demand Elasticities with Respect to Factor Prices

	Fertiliser	Hired Labour	Capital	Operator labour	Unpaid Family Labour
Fertiliser	-0.503	0.029	-0.049	0.152	0.369
	(0.338)	(0.183)	(0.167)	(0.249)	(0.284)
Hired Labour	0.021	-0.316	-0.075	0.097	0.272
	(0.134)	(0.152)	(0.078)	(0.143)	(0.152)
Capital	-0.046	-0.096	-0.013	0.224	-0.070
	(0.157)	(0.100)	(0.158)	(0.139)	(0.172)
Operator Labour	0.044	0.039	0.069	-0.500	0.347
	(0.073)	(0.057)	(0.043)	(0.089)	(0.078)
Unpaid Family	0.104	0.104	-0.021	0.335	-0.523
Labour	(0.080)	(0.058)	(0.052)	(0.076)	(0.097)

Note: (1) Standard errors are in parentheses.
(2) Elasticities are calculated at mean of data set.

Table 4: Allen Partial Elasticities of Substitution

	Fertiliser	Hired Labour	Capital	Operator labour	Unpaid Family Labour
Fertiliser	-5.235	0.219	-0.478	0.463	1.083
	(3.525)	(1.399)	(1.633)	(0.756)	(0.833)
Hired Labour		-2.410	-0.734	0.295	0.796
		(1.160)	(0.767)	(0.436)	(0.446)
Capital			-0.129	0.681	-0.205
			(1.545)	(0.423)	(0.506)
Operator Labour				-1.521	1.017
				(0.270)	(0.230)
Unpaid Family					-1.534
Labour					(0.285)

Note: (1) Standard errors are in parentheses.
(2) Elasticities are calculated at mean of data set.

Table 5: Measurements of Biases in Technical Change in Thai Agriculture

Periods	Fertiliser	Hired Labour	Capital	Operator Labour	Unpaid Family Labour
1971-77	0.112	-0.022	1.969	-0.014	-0.047
	(0.043)	(0.037)	(0.687)	(0.017)	(0.010)
1978-94	0.027	-0.026	0.052	-0.005	-0.015
	(0.019)	(0.029)	(0.035)	(0.018)	(0.014)

Note: Standard errors are in parentheses.