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EMPIRICAL INVESTIGATION OF THE RICE PRODUCTION STRUCTURE IN TAIWAN, 1976–93

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I. INTRODUCTION

IN the early period of Taiwan's economic development, in particular during the 1950s and 1960s, rice production increased rapidly, not only meeting the needs of domestic food consumption but also providing a surplus for export. However, since around the mid-1970s, Taiwan's agriculture has witnessed a general decrease in the production of rice which fell from a peak of 2.71 million metric tons (in terms of brown rice) in 1976 to 1.82 million metric tons in 1993, corresponding to a 33 per cent reduction during the seventeen-year period. Needless to say, the total production is a product of the total planted area and the yield per unit of land. How did these two factors change in the course of rice production in Taiwan?

To begin with, the total planted area for rice production has shown a strong downward trend. It decreased drastically from 790,248 hectares in 1975 to 391,457 hectares in 1993, corresponding to a 50 per cent reduction during the eighteen-year period. There are two main reasons for such a decrease in the rice production: (1) a switch in 1977 from a policy of unlimited purchases to one that limited purchases by the government; and (2) the paddy field diversion program launched in 1984.

On the other hand, however, there has been a significant increase in the yield per hectare from 3,450 kilograms in 1976 to 4,655 kilograms in 1993 (in terms of brown rice), corresponding to almost a 35 per cent increase during the seventeen-year period, and implying a compound annual growth rate of 1.8 per cent which is fairly high on an international standard (see Hayami 1995, p. 101). The higher

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yields per hectare have been due largely to the cultivation of improved varieties, increased and better use of fertilizers and agrichemicals, and better cultivation methods based on rapid mechanization during the study period. In addition to these factors, diversion of marginal paddy fields along with the drastic decrease in the total planted area must have exerted beneficial effects on the increase in the yield per hectare.

Due to the sharper decreasing trend in the planted area compared with the increasing trend of yield per hectare, the total production declined accordingly as seen above. A careful examination reveals that the value share of rice production in the total agricultural production decreased steadily from 42.1 per cent in 1961 to 32.6 and 14.8 per cent in 1976 and 1993, respectively. As a result, although rice is still the dominant crop and the rural economic activities are closely linked to rice cultivation and harvesting, its relative importance has declined substantially.

Given the changing status of the rice industry, the major objective of this study is to quantitatively investigate the technology structure of rice production in Taiwan during the 1976–93 period. In order to achieve this objective, a translog variable (or restricted) cost function framework was employed where labor, intermediate inputs, and capital are treated as variable factors of production and land is treated as a fixed input. Based on the parameter estimates of the system of equations which will be presented in detail in the next section, this study will describe the estimates of the demand and substitution elasticities of the variable factor inputs, scale economies, and the rate and biases of technological change. By treating land as a fixed input and assuming that it is utilized at the optimum level, it is possible to estimate the shadow price (or marginal productivity) of land. It may be interesting to compare the estimated shadow price of land with the actual land rent. This may enable us to determine whether the land market is in equilibrium or not in the Taiwanese rice sector.

Similar studies have been undertaken by Guo (1995, 1996) and Guo and Lin (1993) for the Taiwanese rice industry. Drawing heavily on a series of studies conducted by Epstein (1981, 1983), Epstein and Denny (1983), and Epstein and Yachew (1985), he constructed and estimated a dynamic model of a set of factor demand equations using aggregate time-series data compiled for the rice sector for the period 1952–91. Unfortunately, however, it seems that he has not been able to obtain the factor demand elasticities that are economically significant either in the short run or in the long run.[1] Using a less complicated model, this study attempts to obtain more economically meaningful estimates of factor demand elasticities together with the other economic indicators mentioned above. Furthermore, unlike the studies carried out by Guo, in the present study we used a pooled cross-section

[1] For example, Guo (1995) shows that the short-run own price elasticities for labor, capital, and intermediate inputs are all positive, indicating that the curvature conditions are not satisfied.

of time-series of average farm-firm data compiled for five size classes for the 1976–93 period based mainly on the *Survey Report on Rice Production Costs* published annually by the Food Bureau, Taiwan Provincial Government, Republic of China (ROC). We are not aware of any empirical research on a similar problem for the Taiwanese rice sector in which the *Survey Report on Rice Production Costs* was extensively used to derive the needed variables.

This paper is organized as follows. In Section II, the variable cost function framework is outlined. The data and the statistical estimation procedure are described in Section III. In Section IV, the empirical results are presented. In Section V, the paper is summarized and some concluding remarks are presented.

II. METHODOLOGY

In this study, it is assumed that the farm-firm's production technology is represented by the following translog variable cost function:

$$\begin{aligned}\ln C = {} & \alpha_o + \alpha_Q \ln Q + \sum_{i=1}^{3}\alpha_i \ln P_i + \beta_B \ln Z_B + \beta_T T \\ & + \frac{1}{2}\gamma_{QQ}(\ln Q)^2 + \frac{1}{2}\sum_{i=1}^{3}\sum_{j=1}^{3}\gamma_{ij}\ln P_i \ln P_j \\ & + \sum_{i=1}^{3}\theta_{iB}\ln P_i \ln Z_B + \frac{1}{2}\theta_{BB}(\ln Z_B)^2 \\ & + \sum_{i=1}^{3}\delta_{Qi}\ln Q \ln P_i + \delta_{QB}\ln Q \ln Z_B \\ & + \mu_{QT}(\ln Q)T + \sum_{i=1}^{3}\mu_{iT}(\ln P_i)T \\ & + \beta_{BT}(\ln Z_B)T + \frac{1}{2}\beta_{TT}T^2 \\ & + \sum_{k=2}^{6}d_{Rk}D_{Rk} + \sum_{l=2}^{5}d_{Sl}D_{Sl}, \qquad (1)\end{aligned}$$

where $\gamma_{ij} = \gamma_{ji}$ and $i = j = L$ (labor), I (intermediate inputs), K (capital); P_i are the prices of the variable factor inputs X_i ($i = L, I, K$); Q is the quantity of output; Z_B is the quantity of land; T is time as an index of technological change; and C is the variable cost composed of labor costs ($C_L = P_L X_L$), intermediate inputs costs ($C_I = P_I X_I$), and capital costs ($C_K = P_K X_K$).

Here, in order to take into account heterogeneous intercepts with respect to six different districts and five size classes, regional dummies D_{Rk} ($k = 2, 3, 4, 5, 6$) and size dummies D_{Sl} ($l = 2, 3, 4, 5$) were introduced.[2]

[2] The six regions are Taipei, Hsinchu, Taichung, Tainan, Kaohsiung, and Taitung and the five size classes are 1 (less than 0.5 hectares), 2 (0.5–0.75), 3 (0.75–1.0), 4 (1.0–1.5), and 5 (1.5 and over). The details will be explained in the next section.

The cost function approach is used for the following two reasons. First, the cost function approach yields direct estimates of the Allen partial elasticities of factor demand and substitution. Another reason is that the cost function approach allows to exploit the duality theory without imposing any restrictions on the returns to scale as well as the substitution elasticities in the underlying technology. Furthermore, the treatment of land as a fixed input is due to the fact that since the farmland market does not seem to be competitive it is most unlikely that the farm-firm utilizes the optimum level of land for rice production in Taiwan.[3]

Now, the cost share (S_i) is derived through the Shephard's (1970) lemma as

$$\begin{aligned} S_i &= \frac{\partial C}{\partial P_i}\frac{P_i}{C} = \frac{\partial \ln C}{\partial \ln P_i} \\ &= \alpha_i + \sum_{j=1}^{3}\gamma_{ij}\ln P_j + \delta_{Qi}\ln Q + \theta_{iB}\ln Z_B + \mu_{iT}T. \end{aligned} \tag{2}$$

The translog cost function can be used along with the profit-maximizing condition to derive an additional equation representing the optimal choice of the endogenous output (Q) (Fuss and Waverman 1981, pp. 288–89).

Taking the derivative of the cost function (1) with respect to the endogenous output Q, we obtain

$$\frac{\partial \ln C}{\partial \ln Q} = \frac{\partial C}{\partial Q}\frac{Q}{C} = \frac{PQ}{C},$$

where P is the price of output.[4] Denoting PQ/C as S_Q, the revenue share equation can be written as

$$\begin{aligned} S_Q &= \frac{\partial C}{\partial Q}\frac{Q}{C} = \frac{\partial \ln C}{\partial \ln Q} \\ &= \alpha_Q + \sum_{i=1}^{3}\delta_{Qi}\ln P_i + \gamma_{QQ}\ln Q + \delta_{QB}\ln Z_B + \mu_{QT}T, \quad i = j = L,\ I,\ K. \end{aligned} \tag{3}$$

Including the revenue share equation in the estimation of the system of equations will in general lead to a more efficient estimation of the coefficients, in particular, of the output-associated variables due to the additional information povided by the revenue share.[5]

Any sensible cost function must be homogeneous with degree one in input prices. In the translog cost function (1) this condition requires that $\sum_{i=1}^{3}\alpha_i = 1$, $\sum_{i=1}^{3}\gamma_{ij} = 0$, $\sum_{i=1}^{3}\delta_{Qi} = 0$, $\sum_{i=1}^{3}\theta_{iB} = 0$, and $\sum_{i=1}^{3}\mu_{iT} = 0$ ($i = j = L,\ I,\ K$). The translog

3 Various regulations have restricted land movements in Taiwanese agriculture.

4 In this case, the rice farmer is assumed to equate the marginal revenue to the government-supported rice price, since the output price P includes the government subsidy payments.

5 For a detailed discussion on the inclusion of the revenue share equation in the system of regression equations, see Ray (1982) and Capalbo (1988).

cost function (1) has a general form in a sense that the restrictions of homotheticity and Hicks neutrality with respect to technological change are not imposed a priori. Instead, these restrictions can be statistically tested in the process of estimation of this function. The following three hypotheses concerned with production technology will be tested in this study.

First, constant returns to scale can be tested in the variable cost function framework. If the primal production function exhibits constant returns to scale, then the cost function can be written as $C(Q, P, Z_B, T) = G(Q, Z_B) \cdot H(P, T)$ where $G(Q, Z_B)$ on the right-hand side is a linearly homogeneous function with respect to Q and Z_B. This implies the following set of parameter restrictions on the translog cost function (1); $\alpha_Q + \beta_B = 1$, $\delta_{Qi} + \theta_{iB} = \delta_{QB} + \theta_{BB} = \gamma_{QQ} + \delta_{QB} = \mu_{QT} + \beta_{BT} = 0$ ($i = L, I, K$).

Second, pure Hicks-neutral technological change in the variable factor inputs is tested by imposing the restrictions, $\mu_{iT} = 0$ ($i = L, I, K$).

Third, neutrality of the variable factor shares with respect to output scale is tested by imposing the restrictions, $\delta_{Qi} = 0$ ($i = L, I, K$).

As shown immediately later when we analyze the measure of the biases of technological change, the test results of the last two hypotheses are closely related to the pure bias effect and the scale bias effect as defined by Antle and Capalbo (1988).

The various economic indicators used to investigate the technology structure of the Taiwanese rice sector can be obtained by the following equations.[6]

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

$$\sigma_{ij} = \frac{\gamma_{ij} + S_i S_j}{S_i S_j}, \quad i, j = L, I, K, \ i \neq j, \tag{4}$$

$$\sigma_{ii} = \frac{\gamma_{ii} + S_i^2 - S_i}{S_i^2}, \quad i = L, I, K. \tag{5}$$

Second, the own and cross price elasticities are obtained by:

$$\varepsilon_{ii} = S_i \sigma_{ii}, \quad i = L, I, K, \tag{6}$$

$$\varepsilon_{ij} = S_j \sigma_{ij}, \quad i, j = L, I, K, \ i \neq j. \tag{7}$$

Note that the demand and substitution elasticities are estimated with land held fixed.

Third, the rate of technological change (λ), defined as the rate at which output could grow over time with all factor inputs held fixed, can be obtained by (Caves, Christensen, and Swanson, 1981),

[6] Scale economies were not estimated because the test of the hypothesis of constant returns to scale was not rejected. That is, constant returns to scale existed in the Taiwanese rice sector for the study period 1976–93.

$$\lambda = -\frac{\partial \ln C/\partial T}{\partial \ln C/\partial \ln Q} = -\frac{\partial \ln C/\partial T}{\varepsilon_{CQ}}, \tag{8}$$

where

$$-\frac{\partial \ln C}{\partial T} = -(\beta_T + \sum_{i=1}^{3}\mu_{iT} \ln P_i + \mu_{QT} \ln Q + \beta_{BT} \ln Z_B + \beta_{TT}T), \quad i = L, I, K. \tag{9}$$

Fourth, the biases of technological change, if any, can be captured by the non-neutral changes in factor shares. This study applies the bias measure proposed by Antle and Capalbo (1988). They developed an overall Hicksian bias measure (1963) of technological change in input space in both single-product and multiproduct cases by extending Binswanger's definition (1974b) of the bias measure to non-homothetic (in the single-product case) and input-output nonseparable (in the multiproduct case) production technologies. According to their definition, the overall Hicksian bias measure, i.e., the change in optimal cost shares due to technological change, can be decomposed into a pure Hicksian bias effect (interpreted as a shift in the expansion path) and a scale effect (a movement along the nonlinear expansion path). In the single-product case as in the present study where the technology index is assumed to be represented by time variable, the overall Hicksian bias measure is defined, with land held fixed, as

$$\begin{aligned} B_i^e &= \partial \ln S_i(Q,\ P,\ Z_B,\ T)/\partial T \big|_{dC=0} \\ &= B_i + \left(\frac{\partial \ln S_i}{\partial \ln Q}\right)\left(\frac{\partial \ln C}{\partial \ln Q}\right)^{-1}\left(-\frac{\partial \ln C}{\partial T}\right), \end{aligned} \tag{10}$$

where $B_i \equiv \partial \ln S_i(Q,\ P,\ Z_B,\ T)/\partial T$ ($i = L, I, K$) which is the pure bias effect. The second term of equation (10) is the scale effect. Thus, equation (10) indicates that the overall Hicksian bias measure is composed of the pure bias effect and the scale effect. If $B_i^e > 0$ (< 0), then technological change is considered to be biased toward using (saving) the *i*-th factor. If $B_i^e = 0$, then technological change is considered to be *i*-th factor neutral. Based on the estimated results of the B_i^e, one can determine whether or not the direction of the measured factor biases is consistent with the Hicksian induced innovation hypothesis.

Using the parameters of the translog cost function as equation (1), equation (10) can be expressed as

$$B_i^e = \frac{\mu_{it}}{S_i} + \frac{\delta_{Qi}}{S_i}\lambda, \quad i = L, I, K. \tag{11}$$

Since neutrality of technological change with respect to output scale implies that $\partial \ln S_i/\partial \ln Q = 0$, i.e., $\delta_{Qi} = 0$ for all i ($= L, I, K$), the scale effect disappears. Thus, the overall Hicksian bias measure contains only the effect of a shift in the expansion path.

Finally, assuming that the land utilization is at the optimum level, the shadow price (or marginal productivity) of land (SPB) can be obtained from equation (12) as (Halvorsen and Smith 1984),

$$SPB = -\frac{\partial C}{\partial Z_B} = -\varepsilon_{CB}\frac{\hat{C}}{Z_B}, \tag{12}$$

where $\hat{C}$ corresponds to the minimized variable costs, and

$$\begin{aligned}\varepsilon_{CB} &= \frac{\partial \ln C}{\partial \ln Z_B} \\ &= \beta_B + \sum_{i=1}^{3}\theta_{iB}\ln P_i + \delta_{QB}\ln Q + \theta_{BB}\ln Z_B + \beta_{BT}T, \quad i = L, I, K.\end{aligned} \tag{13}$$

III. THE DATA AND STATISTICAL METHOD

A. *The Data*

The variables required to estimate the variable cost function model consist of the variable cost, the total revenue and the quantity and price of total output, and the prices and cost shares of the three variable factors of production (labor, intermediate inputs, and capital), as well as the quantity of land as a fixed input. A pooled cross-section of time-series data was collected and processed for the Taiwanese rice sector for the period 1976–93 based mainly on the *Survey Report of Rice Production Costs* (*SRRPC*). The necessary data were collected for average farm-firm in each of the five size classes from six districts classified in the *SRRPC*. The five size classes are (1) less than 0.5, (2) 0.5–0.75, (3) 0.75–1.0, (4) 1.0–1.5, and (5) 1.5 hectares and over. The six districts are Taipei, Hsinchu, Taichung, Tainan, Kaohsiung, and Taitung. Thus, the sample size is 18 (years) × 5 (classes) × 6 (districts) = 540.

Several aspects are worth mentioning here about the agricultural districts and the sampling procedure used in the *SRRPC*. First, the term agricultural "district" is used for an area with similar climatic conditions and in general it covers wider areas than counties. Taipei district is composed of Taipei and Ilan Counties; Hsinchu district is composed of Taoyuan, Hsinchu, and Miaoli Counties; Taichung district is composed of Taichung, Changhua, and Nantou Counties; Tainan district is composed of Yunlin, Chiayi, and Tainan Counties; Kaohsiung district is composed of Kaohsiung and Pingtung Counties; and Taitung is composed of Taitung and Hualien Counties. These six districts account for more than 95 per cent of the total rice production in the Province of Taiwan. The major districts are Hsinchu, Taichung, and Tainan which accounted for 80.4 per cent of the total rice production in, say, 1993.

Second, the survey was conducted by sampling about 530 rice farms for the six districts each year. In 1993, for example, 528 rice farms were sampled; 52, 112, 115, 118, 75, and 56 farms were assigned to Taipei, Hsinchu, Taichung, Tainan, Kaohsiung, and Taitung, respectively. It seems that these sample numbers reflect the shares of production of these six districts in the total rice production. Furthermore, the distribution of the samples, 528, among the six size classes was 125 for Class 1, 158 for Class 2, 71 for Class 3, 109 for Class 4, and 65 for Class 5, indicating a fairly even sampling. These tendencies in the sampling procedure were consistent over time, although the latter type of distribution is not given for each district.

One can compile each pooled data set separately for the first and second crops. The first crop is produced during March through June and the second crop during July through October. The second crop needs a shorter time because rice grows in summer time when the temperature is high. The total quantities of production of both the first and second crops have been decreasing; they were 1.38 and 1.27 million metric tons in 1976 and decreased to 1.05 and 0.77 million metric tons in 1993 in terms of brown rice. The quantity of production of the second crop used to be slightly larger than that of the first crop until around the late 1960s. Since then, however, the share of the first crop in the total rice production became greater than that of the second crop; it increased from 54 per cent in 1971 to 58 per cent in 1993. The harvested areas have been fairly similar between the first and second crops. Thus, the major difference in the total quantities of production between the first and second crops is due to the difference in the yields per hectare of the two crops. Although the yields of the two crops have increased consistently over time, the absolute levels have been higher for the first crop; the yields of the first and second crops increased from 3,863 and 3,017 kilograms in 1976 to 4,947 and 4,310 kilograms in 1993, respectively. This study utilized the data set for the first crop.[7]

Since the data are expressed in per-hectare terms, it is necessary to multiply the needed variables by the planted area of the average farm-firm in each size class in each district in order to express them in per-farm-firm terms.

The quantity of total output (Q) was obtained by multiplying the amount of production (kilograms) per hectare by the planted area. The price of output (P) was obtained as a weighted average of the government purchasing prices (N.T. dollar per kilogram) for the Japonica and Indica rice. The total revenue ($TR = PQ$) was estimated as a product of the total output and the price. The price data were taken from the *Taiwan Food Statistics Book* (*TFSB*) published annually by the Food Bureau, Taiwan Provincial Government, ROC.

The cost of labor input ($C_L = P_L X_L$) was defined as the sum of the wage bills for family and hired labor and the wage bill for contract work. This sum was multiplied

[7] Indeed, the same estimations were made using the data set for the second crop. The results were very similar in all parameters and economic indicators for the two crops. Thus, it may be safe to use the analysis based on the data set only for the first crop.

by the planted area to yield the farm-firm labor cost. As for the price of labor (P_L), the Törnqvist-Theil index was calculated by the Caves-Christensen-Diewert (CCD) (1982) method. The CCD method is most relevant for the estimation of the Törnqvist-Theil index for a pooled cross-section of time-series data set. In the following paragraphs, all indices were obtained based on this method. The *SRRPC* reports the wage bills for family labor, hired labor, and contract labor and the working hours and the average wage rate for each category separately for male and female. In each category, a weighted average wage rate of male and female labor is estimated in the *SRRPC* by dividing the sum of the wage bills for male and female labor by the sum of the working hours for male and female labor. For these wage bills and weighted average wage rates, the CCD method was applied. Needless to say, in determining the quantity and price of labor as above, we are assuming that there is a perfect substitutability both between male and female labor, and between family, hired, and contract labor.

Unfortunately, however, the wage bills and weighted average wage rates are reported only for the average farm-firm in each district. Therefore, the same price of labor has to be used for the five different size classes in each district.

The cost of capital ($C_K = P_K X_K$) was defined as the sum of the wage bills for animal service and machinery service and expenditures on farm buildings, equipment, and tools. The sum of these expenditures was multiplied by the planted area in order to obtain the cost of capital input for the farm-firm. The price index (P_K) of capital input was obtained by the CCD method in a very similar manner as in the case of labor input. In this estimation, the price index for farm machinery was used for the complex of farm buildings, equipment, and tools taken from the *TFSB*. In this case also, the wage bills and the wage rates for animal and machinery services are reported only for the average farm-firm in each district. Fortunately, however, the expenditures on farm buildings, equipment, and tools are reported for the average farm-firms of the five size classes in all districts. However, the computation showed that these expenditures' shares in the total capital costs were very small. Thus, it is unlikely that there would be appreciable differences in P_K among different size classes in each district.

The cost of intermediate inputs ($C_I = P_I X_I$) was defined as the sum of expenditures on seeds, materials, agrichemicals, and fertilizers. This sum was multiplied by the planted area, yielding the cost of intermediate inputs of the farm-firm. The price index (P_I) was obtained by the CCD method. In this estimation, the price indices for these items were obtained from the *TFSB*.

As for land (Z_B), since it is treated as a fixed input, the planted area was used. It is reported for each size class in each district in the *SRRPC*.

The variable cost (C) can now be estimated as $C = P_L X_L + P_I X_I + P_K X_K$. The cost share of each variable factor input and the revenue share can be obtained as $S_i = C_i/C$, $i = L, I, K$, and $S_Q = TR/C$.

B. *Statistical Method*

For statistical estimation, since the quantity of output (Q) on the right-hand side of the cost function (equation 1) is in general endogenously determined, a simultaneous procedure should be employed for the estimation of the set of equations consisting of the cost function (equation 1), two of the three cost share equations (equation 2),[8] and one revenue share equation (equation 3). Note here that the estimation model as a whole is complete in a sense that it has as many (four) equations as endogenous variables (four). Therefore, the full information maximum likelihood (FIML) method was selected. In this process, the restrictions due to symmetry and linear homogeneity in prices were imposed. The coefficients of the omitted (i.e., the capital) cost share equation were obtained using the linear homogeneity restrictions after the system was estimated.

IV. EMPIRICAL RESULTS

For testing the three hypotheses, i.e., constant returns to scale (CRTS), Hicks neutrality of technological change, and scale neutrality of the variable factor shares, a Wald chi-square test was applied. The computed chi-square statistics for these three hypotheses were 9.5, 495.0, and 883.3 with degrees of freedom, 7, 3, and 3, respectively. The critical values at the 0.05 and 0.01 significance levels for the degrees of freedom 7 and 3 were 14.6 and 7.8, and 18.4 and 11.3, respectively. Thus, the hypotheses of Hicks neutrality and scale neutrality could be strongly rejected both at the 0.05 and at the 0.01 significance level. However, the hypothesis of CRTS could not be rejected both at the 0.05 and at the 0.01 significance level, implying that there are constant returns to scale in the Taiwanese rice sector. These findings indicate that when the farm-firm increases the scale of rice production in terms of output, the average production cost per unit of output will remain at the same minimum level.

In addition, the joint null hypothesis according to which there are no regional differences in the intercept (H_0: $d_{Rk} = 0$ for all $k = 2, 3, 4, 5, 6$) was tested and strongly rejected. Furthermore, the coefficients of all the regional dummy variables had fairly large asymptotically computed t-values, indicating that they were statistically significant. A casual examination of the coefficients of these dummies suggests that the Hsinchu, Taichung, Tainan, and Kaohsiung districts had a lower total cost than the Taipei district, while the Taitung district showed a higher total cost

[8] Due to the linear-homogeneity-in-prices property of the cost function, one factor share equation can be omitted from the simultaneous equation system for the statistical estimation. In this study, the capital share equation was omitted.

TABLE I

FIML ESTIMATES OF THE TRANSLOG VARIABLE COST FUNCTION FOR THE TAIWANESE RICE SECTOR WITH THE IMPOSITION OF THE CRTS RESTRICTIONS, 1976–93 (FIRST CROP)

Parameter	Coefficient	*t*-statistic	Parameter	Coefficient	*t*-statistic
α_0	11.182	357.2	θ_{BB}	0.639	20.4
α_Q	1.598	71.9	δ_{QL}	–0.209	–18.4
α_L	0.559	65.1	δ_{QI}	0.138	20.8
α_I	0.170	24.4	δ_{QK}	0.071	7.5
α_K	0.271	5.1	δ_{QB}	–0.639	–20.4
β_B	–0.598	–280.3	μ_{QT}	0.002	3.1
β_T	–0.038	–5.7	μ_{LT}	–0.016	–18.5
γ_{QQ}	0.639	13.5	μ_{IT}	0.006	8.0
γ_{LL}	0.086	7.6	μ_{KT}	0.010	1.2
γ_{II}	0.082	9.3	β_{BT}	–0.002	–1.0
γ_{KK}	0.050	3.7	β_{TT}	–0.000	–0.0
γ_{LI}	–0.059	–9.0	d_{R2}	–0.202	–9.6
γ_{LK}	–0.026	–3.6	d_{R3}	–0.225	–11.1
γ_{IK}	–0.023	–2.3	d_{R4}	–0.212	–7.2
θ_{LB}	0.209	10.9	d_{R5}	–0.164	–7.3
θ_{IB}	–0.138	–11.0	d_{R6}	0.032	1.7
θ_{KB}	–0.071	–7.5			

Estimation Equations	$\bar{R}^2$
Cost function	0.932
Labor share equation	0.718
Intermediate-inputs share equation	0.614
Revenue share equation	0.645

than the Taipei district.[9] On the other hand, the joint null hypothesis according to which there are no size differences in the intercept (H_0: $d_{Sl} = 0$ for all $l = 2, 3, 4, 5$) was not rejected. Indeed, the asymptotically computed *t*-values of all the size dummy coefficients were less than unity, indicating that they are not statistically significant.

Thus, the system of equations (1), (2), and (3) was reestimated with an additional imposition of the parameter restrictions of CRTS and no size effects on the intercept. The coefficients of the omitted (capital) cost share equation were obtained using the parameter relations of linear homogeneity restrictions. The results are presented in Table I. The computed $\bar{R}^2$'s were 0.932, 0.718, 0.614, and 0.645 for the variable cost function, labor share equation, intermediate-inputs share equation, and revenue share equation. Furthermore, except for only a few coefficients, the (asymptotically) computed *t*-statistics were fairly large, indicating that the esti-

[9] These tendencies and the magnitude of the coefficients were almost the same before and after the reestimation of the system with the imposition of CRTS restrictions and no size dummies.

TABLE II

DEMAND ELASTICITIES IN RELATION TO FACTOR PRICES

	Labor	Intermediate Inputs	Capital
Labor price (P_L)	−0.287 (−18.7)	0.063 (5.1)	0.223 (3.9)
Intermediate inputs price (P_I)	0.209 (5.1)	−0.344 (−8.8)	0.135 (2.0)
Capital price (P_K)	0.461 (12.9)	0.084 (2.3)	−0.546 (−10.0)

Note: All the elasticities were estimated at the geometric means. The figures in parentheses are asymptotic *t*-statistics.

TABLE III

ALLEN PARTIAL ELASTICITIES OF SUBSTITUTION

	Labor	Intermediate Inputs	Capital
Labor	−0.512 (−18.7)	0.374 (5.1)	0.825 (12.9)
Intermediate inputs		−2.028 (−8.8)	0.497 (2.3)
Capital			−2.014 (−3.9)

Note: All the elasticities were estimated at the geometric means. The figures in parentheses are asymptotic *t*-statistics.

mated coefficients were statistically significant except for a few coefficients. Thus, it appears that the goodness of fit is considerably high. This set of estimates is referred to as the final specification of the model and will be used for further analyses.[10]

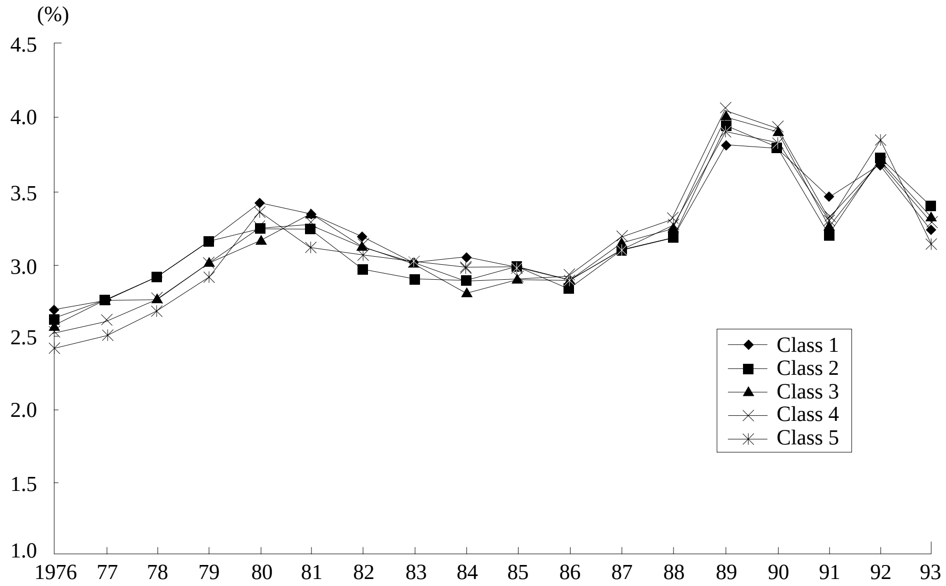
A. *Factor Demand and Substitution Elasticities*

Factor demand elasticities with respect to factor prices as well as the Allen partial elasticities of substitution were computed at the geometric means with land held constant and are reported in Tables II and III, respectively. At least, the following two findings are noteworthy in these tables.

First, the own-price elasticities of demand for all the variable factors, i.e., labor, intermediate inputs, and capital, were less than unity in absolute values (0.287, 0.344, and 0.546, respectively), indicating the existence of an inelastic demand for

[10] Monotonicity and concavity were also checked and satisfied not only at the approximation point but also in all the sample observations.

Fig. 1. Technological Change Rate, 1976–93: Taipei



these factor inputs by farm-firms. However, the demand elasticity for capital was the largest in absolute values among the three elasticities. Considering the fact that machinery service employment is the most important element of capital input, rice producers are relatively more sensitive to changes in the price of machinery service than to the changes in the prices of labor and intermediate inputs.

Second, the Allen partial elasticities of substitutions between labor and intermediate inputs, labor and capital, and intermediate inputs and capital were 0.37, 0.83, and 0.50, respectively. These figures indicate that labor and intermediate inputs and intermediate inputs and capital are not good substitutes, while labor and capital are fairly good substitutes.

B. *Rates and Biases of Technological Change*

The rates and biases of technological change were estimated using equations (8) and (11), respectively, for each year of the 1976–93 period. Indeed, these estimations were carried out for each of the five size classes in each of the six districts. Since there were only slight differences in the magnitude of the rates and biases among the six districts, the Taipei district was chosen as representative.

To begin with, Figure 1 shows the trend of the rates of technological change over the 1976–93 period for the five size classes in the Taipei district. At least, two important features are noteworthy. First, the rate of technological change can be characterized by four trends: (1) it increased sharply from around 2.5 to 3.3 per cent for the 1976–80 period; (2) it then slowed down from 3.3 to 2.8 per cent for the 1980–1986 period; (3) it increased sharply again from 2.8 to 4.0 per cent for the 1986–89 period; and (4) it appears to have started decreasing again for the 1989–93 period, from 4.0 per cent in 1989 to 3.3 per cent in 1993, although the rates were still higher than 3 per cent. These rates of technological change can be considered to be very high for agricultural production, indicating that the rice sector in Taiwan has shown a good performance in the development and diffusion of new technologies since the mid-1970s. Government policies introduced for farmland consolidation, scale enlargement, and mechanization during this period must have been conducive to the impressive performance. Furthermore, abandonment and diversion of cultivation of marginal paddy fields along with the rapid decrease in the planted area during the study period must have been another factor which contributed to the increase of yield per hectare of the paddy fields utilized for rice production and hence exerted beneficial effects on the rate of technological change.

Another feature is that the technological change rates were very similar and consistent among the five size classes for the whole period. This fact indicates that technological diffusion had been neutral irrespective of size classes in Taiwanese rice production. This finding is consistent with the fact that in all the villages most of the rice-producing farmers utilize almost the same production technology.

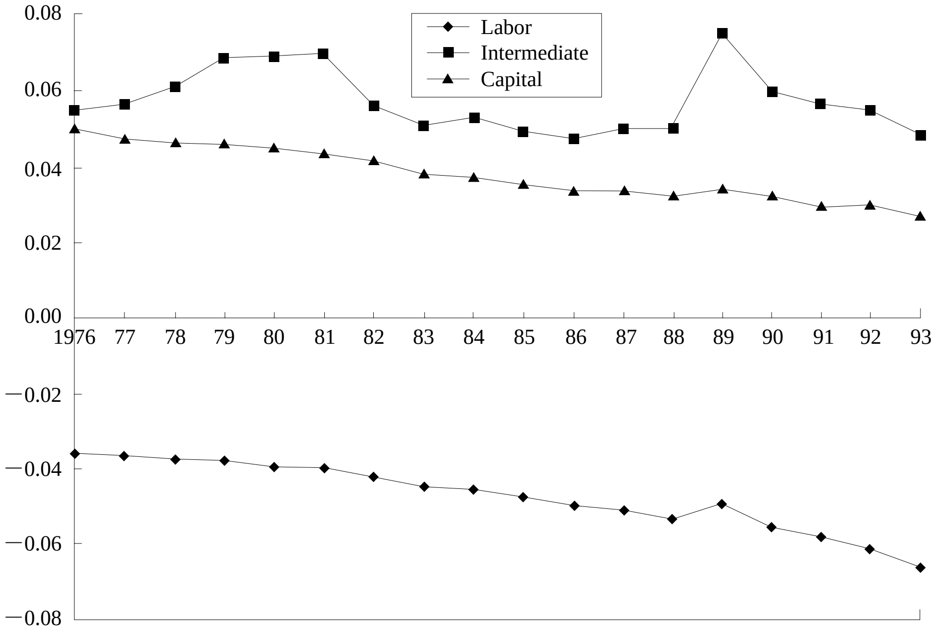
Next, Figure 2 shows the biases of technological change for labor, intermediate inputs, and capital for the 1976–93 period in the Taipei district. The biases only for size class 1 are shown, because as in the case of the technological change rates, the movement and magnitude of the biases over time were very similar among different size classes. Several important findings emerge from this figure.

First, technological change was biased toward labor-saving as shown by the negative rates over the entire study period. Furthermore, the degree of the labor-saving bias increased consistently over time from around 3.5 in 1976 to around 7.0 per cent in 1993 in absolute values. This finding corresponds to the accelerated migration of labor from the agricultural to nonagricultural sectors during this period.

Second, the technological change was biased toward intermediate-inputs-using. The extent of the intermediate-inputs-using bias ranged from 5.0 to 7.5 per cent which was considerably high. This finding is consistent with the rapid increase in the utilization of chemical fertilizers and agrichemicals for rice production. It is interesting to note that the general trend of the intermediate-inputs-using bias is very similar to that of the rate of technological change shown in Figure 1. This fact may indicate that so-called biochemical (BC) type technological change which in general raises yields per hectare must have been a dominant factor to determine the movements of the rate of technological change during the period 1976–93.

Third, technological change was biased toward capital-using, and the bias was as high as around 5 per cent in 1976 but consistently decreased to 3.0 per cent in 1993.

Fig. 2. Biases of Technological Change, 1976–93: Taipei, Class 1

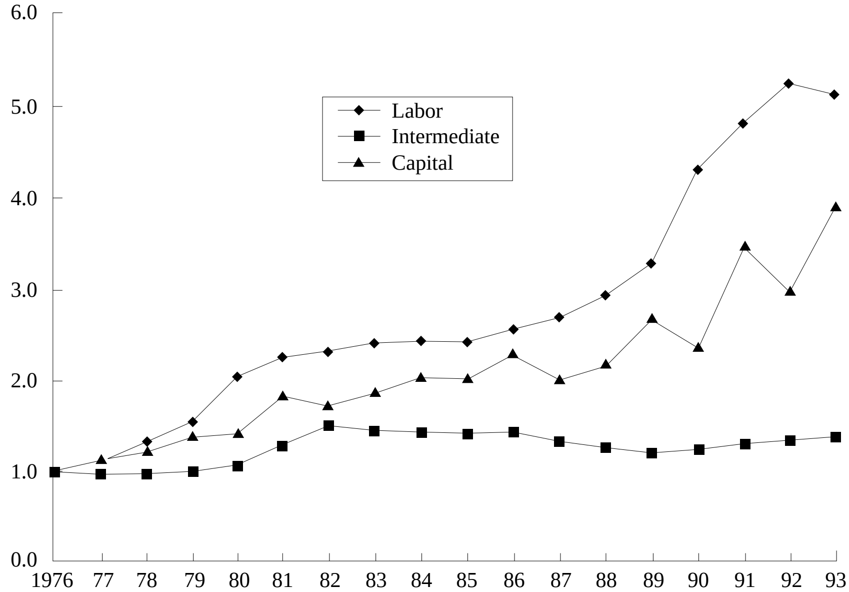


This finding of capital-using bias is consistent with the rapid mechanization of rice production during the late 1970s and the deceleration or stabilization afterward.

At this stage, let us compare these biases with the relative movements of factor prices in order to determine whether or not the Taiwanese rice production is consistent with the Hicksian induced innovation hypothesis. As described in Section III, the factor price indices were obtained for each size class in each district by the CCD method. Setting the 1976 values of size class 1 of the Taipei district to unity, the price indices were rearranged. A rough investigation of these index numbers indicates that the basic movements of the price indices were almost the same among different size classes in each district, although there seem to be slight differences among the districts. Thus, as a representative, the price indices of size class 1 of the Taipei district are given in Figure 3. The figure reveals that the prices of intermediate inputs and capital relative to that of labor decreased over time. This fact indicates that labor is relatively scarce compared to intermediate inputs and capital. As stated above, the biases were toward saving the relatively more expensive factor input, i.e., labor, and toward using relatively less expensive factor inputs, i.e., intermediate inputs and capital. This finding may thus be consistent with the Hicksian induced innovation hypothesis.[11]

[11] Kuroda (1987, 1988) obtained very similar results for postwar Japanese agriculture.

Fig. 3. Factor Prices, 1976–93: Taipei, Class 1 (1976 = 1.0)



C. *Shadow Price and Actual Rent of Land*

The shadow price of land (*SPB*) was estimated for each size class in each district for the 1976–93 period based on equation (12). In addition, the actual land rent was obtained from the *SRRPC* for each size class in each district for the same period. Although there were slight differences in the estimates of *SPB*s and actual rents among districts, the general movements over time and the differentials among size classes were very similar. The estimated values of the *SPB*s and the actual rents for the Taipei district are presented in Figures 4 and 5, respectively, as representative values. Note here that both the *SPB*s and actual rents are expressed in nominal terms. Furthermore, in order to determine whether or not the land market in the Taiwanese rice production had ever been in the state of equilibrium, the ratio of the *SPB* to the actual rent was calculated for each size class in the Taipei district, and given in Figure 6. At least, two important findings emerge from the figures.

To begin with, although there are some differentials both in the *SPB*s (Figure 4) and in the actual rents (Figure 5) among different size classes, these differentials were not consistent over time. To be more specific, judging from the movements only of the *SPB*s over time, one could not determine precisely which scale farms had been performing better in the utilization of land.[12]

[12] The *SPB*s in 1989 were extremely low due to the extremely low yields in this year in all the districts except for Taitung for unknown reasons. This phenomenon may be ascribed to climatic factors or due to just sampling errors in the *SRRPC*.

Fig. 4. Shadow Price of Land, 1976–93: Taipei

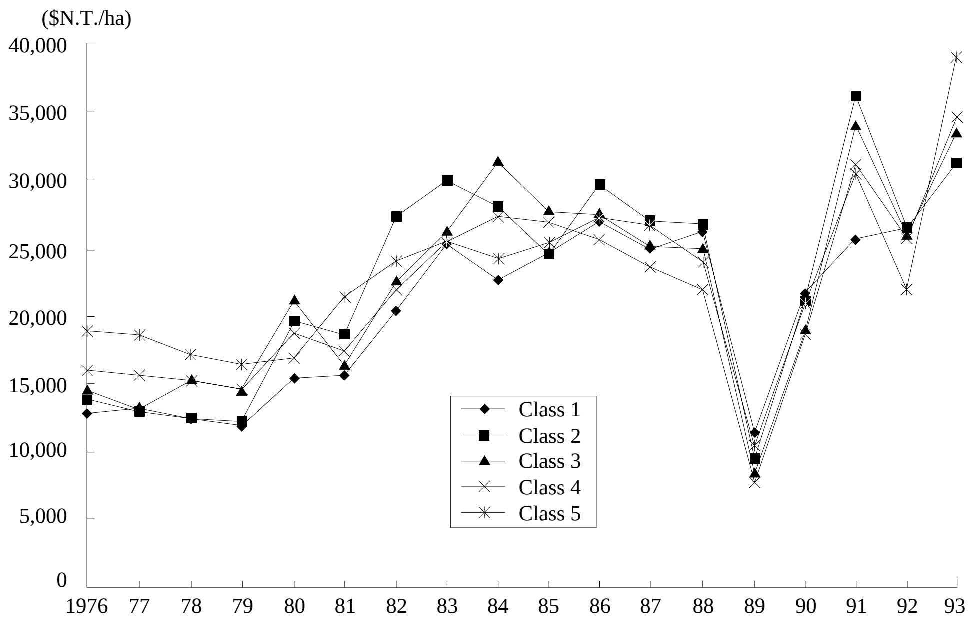


Fig. 5. Actual Land Rent, 1976–93: Taipei

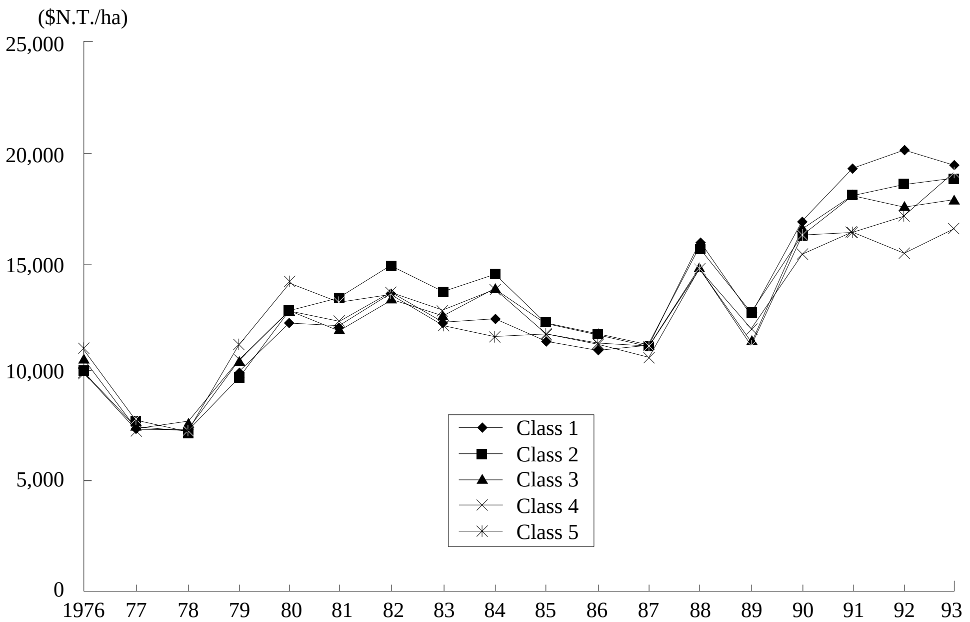
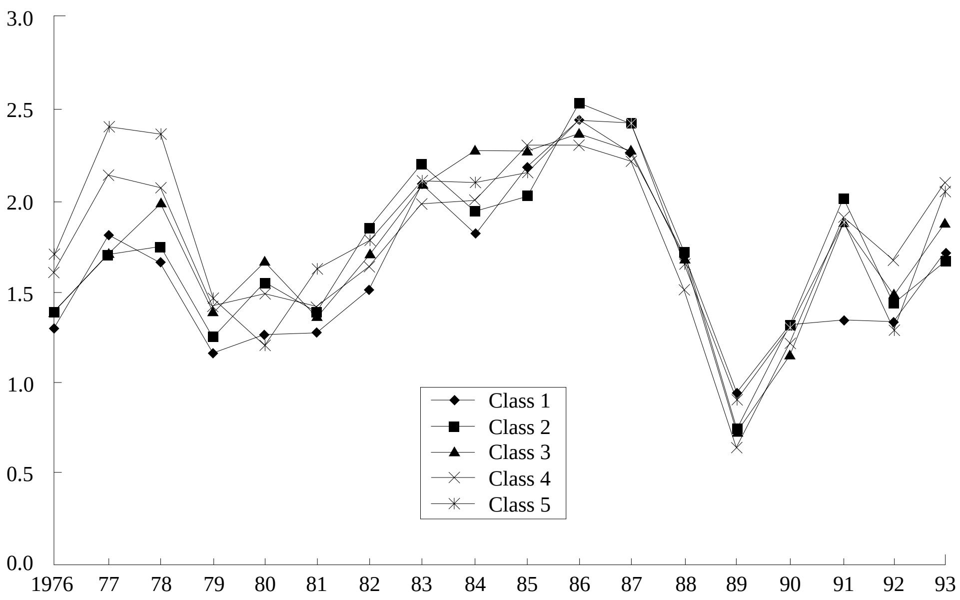


Fig. 6. Ratio of the Shadow Price to the Actual Rent of Land, 1976–93: Taipei



However, Figure 6 shows clearly that for all the size classes the *SPB*s were consistently higher than the actual land rents over the 1976–93 period except for the year 1989. Assuming that the actual land rent corresponds to the market rent of land, this finding indicates that the land utilization level for rice production had been lower than the optimum level. This finding may be attributed to the government rice production policies such as the Six-Year Rice Production and Paddy Field Diversion Programs introduced in 1984 and 1990 which aimed at restricting the planted areas for rice production.

On the other hand, the discrepancies between the *SPB*s and actual rents imply that the rice farmers would have been better off if they had produced rice by themselves rather than renting out their lands. This is true not only for small-scale rice farmers but also for large-scale rice farmers. Together with the existence of constant returns to scale, this fact may have prevented the structural change for larger-scale farming from taking place in rice production and hence restricted the land movements from smaller to larger-scale farms.

V. SUMMARY AND CONCLUSIONS

In this study the production technology of the rice industry in Taiwan for the 1976–

93 period was investigated quantitatively using the translog variable cost function framework. Several important findings can be summarized as follows.

1. The demand elasticities for labor, intermediate inputs, and capital were all less than unity in absolute values, indicating that the demand for these inputs is not elastic.
2. The substitution elasticities between labor and intermediate inputs, labor and capital, and intermediate inputs and capital were all positive, indicating that the three variable factor inputs can be mutually substituted.
3. It was found that there were constant returns to scale in the rice production in Taiwan under the present production technology. This fact implies that doubling the output scale would double the total cost, i.e., the average cost would remain at the same level. In other words, the small and large-scale farm-firms were equally efficient in terms of average cost.
4. The rate of technological change has been considerably high in rice production, implying that technological progress shifted the total cost curve downward fairly rapidly in rice production. This in turn indicates that technological innovation and diffusion in the Taiwanese rice production have been considerably effective. Furthermore, the increase in the quality of land due to the removal of marginal paddy fields from rice production must have exerted a beneficial effect on the increase in the yield per hectare and hence the rate of technological change.
5. Technological change has been biased toward saving labor, and using intermediate inputs and capital. These biases have been consistent with changes in the relative prices of these factor inputs, i.e., saving a relatively more expensive factor input (labor) and using relatively less expensive factor inputs (intermediate inputs and capital). In this sense, the pattern of technological change in the Taiwanese rice production has been consistent with the Hicksian induced innovation theory.
6. The shadow price of land has been higher than the actual land rent, suggesting that the level of land utilization had not been optimum in the Taiwanese rice production. This in turn implies that rice farmers would have been better off if they had produced rice themselves rather than renting out their lands.

As a concluding remark, it may be worthwhile considering the implications of these findings for future rice production in Taiwan.

According to Y. H. Lee (1996):

> Rice production policy will focus less on self-production and self-sufficiency and give greater emphasis on more balanced and diversified sources of supply. The guaranteed price system will remain in effect until 1997, when a thorough reappraisal of rice policy will be undertaken. After accession to the WTO, there will be a 20% cut in the total Aggregate Measurement of Support (AMS), with priority given to reducing price support for upland field grains. Further liberalization of the economy, changes in food con-

sumption patterns, and higher levels of rice imports are all expected to reduce the amount of land required for rice production in the future.

Given such a condition for the future, the rice industry in Taiwan will have to be more efficient in terms of production cost. To satisfy this requirement, technological progress will have to be promoted in such a way as to break the existing situation of constant returns to scale and bring about increasing returns to scale in rice production; e.g., by the promotion of a larger-scale mechanization with more effective consolidation of paddy fields. To achieve this objective, the government will have to introduce policy measures to promote technological innovations and more flexible land movements for larger-scale farming with smaller number of entrepreneurial rice farmers.

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