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

by

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1 INTRODUCTION

In the early years 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 decline 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; this was a 33 percent decrease during the 17-year period. Needless to say, the total production is a product of the total planted area and the yield per unit of land. How have the movements of these two factors been in the Taiwanese rice production?

To begin with, the total planted area for rice production has shown a strong downward trend; it shrank drastically from 790,248 hectares in 1975 to 391,457 hectares in 1993. This was a 50 percent reduction for the 17-year period. There are two main reasons for such a reduction 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). This was almost a 35 percent increase for the 16-year period, implying a compound annual growth rate of 1.9 percent. It is fairly high on an international standard[1]. The higher yields per hectare have been due largely to improved varieties, more and better use of fertilizers and agri-chemicals, and better cultivation methods based on the rapid mechanization during the study period. In addition to these factors, diversions of marginal paddy fields along with the drastic decrease in the total planted area must have had positive effects on the increase in the yield per hectare.

Due to the sharper declining trend in the planted area than the increasing trend of the yield per hectare, the total production declined accordingly as seen above. A careful scrutiny reveals that the value share of rice production in the total agricultural production decreased steadily from 42.1 percent in

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[1] See Hayami (1995), p.101.

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[3].

The cost function approach is used for the following two reasons. First of all, 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 us to exploit 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 the farmland market does not seem to be competitive so that it is very unlikely that the farm-firm utilizes the optimum level of land for the rice production in Taiwan [4].

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

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

The translog cost function can be used along with the profit-maximizing condition to generate an additional equation representing the optimal choice of the endogenous output (Q) (Fuss and Waverman, 1981, pp. 288-289).

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

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

where P is the price of output[5]. Denoting PQ/C as S_Q, the revenue share equation can be written as

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[3] 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 are to be explained in the next section.

[4] Various regulations have restricted land movements in Taiwanese agriculture.

[5] 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.

$$
\begin{aligned}
S_Q &= \frac{\partial C}{\partial Q}\frac{Q}{C} = \frac{\partial \ln C}{\partial \ln Q} \\
&= \alpha_Q + \sum_{i=1}^{3} \delta_{Qi} \ln P_i + \gamma_{QQ} \ln Q + \delta_{QB} \ln Z_B + \mu_{QT} T \qquad (3)
\end{aligned}
$$

$$i = j = L, I, K.$$

Including the revenue share equation in the estimation of the system of equations will in general lead to more efficient estimation of the coefficients, in particular, of the output-associated variables due to an additional information provided by the revenue share[6].

Any sensible cost function must be homogeneous of degree one in input prices. In the translog cost function (1) this 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 cost function (1) has a general form in the 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 concerning with the production technology will be tested in this study.

First, constant returns to scale (CRTS) 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 $C(Q, P, Z_B, T) = G(Q, Z_B) \cdot H(P, T)$. 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, 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 technological change with respect to output scale is tested by imposing the restrictions, $\delta_{Qi} = 0$ $(i = L, I, K)$.

As shown immediately later when we discuss about the measure of the biases of technological change, the test results of the last two hypotheses are

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

intimately related to the pure bias effect and the scale bias effect as defined by Antle and Capalbo (1988).

The various economic indicators to investigate the technology structure of the Taiwanese rice sector can be obtained by the following equations [7].

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

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

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

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

$$\epsilon_{ii} = S_i \sigma_{ii} \qquad i = L, I, K. \tag{6}$$

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

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),

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

where

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

$$i = L, I, K.$$

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 as proposed by Antle and Capalbo (1988). They proposed a Hicksian

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[7] 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.

(1963) measure of technological change in input space in both single-product and multi-product cases by extending Binswanger's (1974b) definition of the bias measure to nonhomothetic (in the single-product case) and input-output nonseparable (in the multiproduct case) production technologies. According to their definition, the change in optimal cost shares due to technological change can be decomposed into a pure 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 Hicksian bias measure is defined, with land held fixed, as

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

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, it is clear from equation (10) 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 said to be biased toward using (saving) the i-th factor. If $B_i^e = 0$, then technological change is said to be i-th factor neutral. Based on the estimated results of the B_i^e, one can examine 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

$$
B_i^e = \frac{\mu_{it}}{S_i} + \frac{\delta_{Qi}}{S_i}(-\frac{\lambda}{\varepsilon_{CQ}}) \qquad (11)
$$
$$
i = L, I, K.
$$

Since neutrality of technological change with respect to output scale implies $\partial \ln S_i/\partial \ln Q = 0$, i.e., $\delta_{Qi} = 0$ for all $i (= L, I, K)$, the scale effect vanishes. Thus, the 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),

$$SPB = -\frac{\partial C}{\partial Z_B} = -\varepsilon_{CB} \frac{\hat{C}}{Z_B} \qquad (12)$$

where $\hat{C}$ is the minimized variable costs; and

$$\varepsilon_{CB} = \frac{\partial \ln C}{\partial \ln Z_B} = \beta_B + \sum_{i=1}^{3} \theta_{iB} \ln P_i + \delta_{QB} \ln Q + \theta_{BB} \ln Z_B + \beta_{BR} \ln R \quad (13)$$

$$i = L, I, K.$$

3 THE DATA AND STATISTICAL METHOD

3.1 THE DATA

The variables required to estimate the variable cost function model are 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), and the quantity of land as a fixed input. A pooled cross-section of time-series data were collected and processed for the Taiwanese rice sector for the period 1976-93 based mainly on the *Survey Report of Rice Production Costs (SRRPC)* published annually by the Food Bureau, Taiwan Provincial Government, ROC. 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 $18(years) \times 5(classes) \times 6(districts) = 540$.

Several points are worth mentioning here about the agricultural districts and the sampling procedure of the SRRPC. First, agricultural "district" is used for an area with climatically similar characteristics and in general covers wider areas than prefectures. Taipei district is composed of Taipei and Yilan prefectures; Hsinchu district is composed of Taoyuan, Hsinchu, and Miaoli prefectures; Taichung district is composed of Taichung, Changhwa, and Nantou prefectures; Tainan district is composed of Yunlin, Chiayi, and Tainan prefectures; Kaohsiung district is composed of Kaohsiung and Pingtung prefectures; and Taitung is composed of Taitung and Hwalien prefectures. These six districts cover more than 95 percent of the total rice production in the Province of Taiwan. The most important districts are Hsinchu, Taichung, and Tainan which shared 80.4 percent of the total rice production in, say, 1993.

Second, the survey is conducted by sampling about 530 rice farms for the six districts in 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. 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 were 125 for less 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 sort 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 it includes summer time with high temperature. The total quantities of production of both the first and second crops have been declining; they were 1.38 and 1.27 million metric tons in 1976 and declined 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 greater 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 percent in 1971 to 58 percent in 1993. The harvested areas have been fairly equal between the first and second crops. Thus, the major difference in the total quantities of production between the first and second crops comes from the difference in the yields per hectare of the two crops. Although the yields of the two crops increased consistently over time, the absolute levels of them have been in favor of 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[8].

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 ($N.T. per kilogram) for the Japonica and Indica rice. The total revenue ($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 was multiplied by the planted area to yield the farm-firm labor cost. As for the price of labor (P_L), the Törnqvist-Theil index was obtained by the Caves-Christensen-and-Diewert (CCD) (1982) method. The CCD method is most relevant when it comes to estimating the Törnqvist-Theil index for a pooled cross-section of time-series data set. In the following paragraphs, all indexes were obtained based on this method. The *SRRPC* reports the wage bills for family labor, hired labor, and contract labor and the hours worked 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 male and female labor hours worked. For these wage bills and weighted average wage rates, the CCD method was applied. Needless to say, in measuring the quantity and price of labor as above, we are assuming 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

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

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 fashion 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. 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, it was found from the computation that these expenditures' shares in the total capital costs are very small. Thus, it is safe to say that there would not be much 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, agri-chemicals, 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 indexes for these items were obtained from the *TFSB*.

As for land (Z_B), because 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 $S_Q = TR/C$.

3.2 STATISTICAL METHOD

For statistical estimation, since the quantity of output(Q) in the right-hand-side of the cost function (1) is in general endogenously determined, a simultaneous estimation procedure should be employed in the estimation of the set of equations consisting of the cost function (1), two of the three cost share equations (2)[9] , and one revenue share equation (3). Note here that the estimating model as a whole is complete in the sense that it has as many (four) equations as endogenous variables (four). The method chosen was thus the full information maximum likelihood (FIML) method. 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.

4 EMPIRICAL RESULTS

For the tests of the three hypotheses, i.e., constant returns to scale (CRTS), Hicks neutrality of technological change, and scale neutrality of technological change, 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 the 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 are 14.6 and 7.8, and 18.4 and 11.3, respectively. Thus, the hypotheses of Hicks neutrality and scale neutrality of technological change were 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. This implies that there exist constant returns to scale in the Taiwanese rice sector. This indicates that when the farm-firm increases the scale of rice production in terms of output, the average production cost per unit of output will increase proportionately.

In addition, the joint null hypothesis of 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 statistical significance of them. A casual examination of the coefficients of these dummies tells us that Hsinchu, Taichung, Tainan, and Kaohsiung districts had lower total cost than

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[9] 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.

Taipei district, while Taitung district showed higher total cost than Taipei district[10]. On the other hand, the joint null hypothesis of 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) were re-estimated 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 1. The computed 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 are fairly large, indicating that the estimated coefficients are statistically significant except for a few coefficients. Thus, it can be said that the goodness of fit is considerably good. This set of estimates is referred to as the final specification of the model and will be used for further analyses [11]

4.1 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 mean with land held constant and are reported in Tables 2 and 3, 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, are less than unity in absolute values (0.287, 0.344, and 0.546, respectively), indicating inelastic demand for these

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[10] These tendencies and the magnitudes of the coefficients are almost the same before and after the re-estimation of the system with the imposition of CRTS restrictions and no size dummies discussed next

[11] Monotonicity and concavity were also checked and satisfied not only at the approximation point but also at all the sample observations. Furthermore, due to the parameter restrictions for constant returns to scale, i.e., $\alpha_Q + \beta_B = 1$, $\delta_{Qi} + \theta_{iB} = \delta_{QB} + \theta_{BB} = \gamma_{QQ} + \delta_{QB} = \mu_{Qt} + \beta_{Bt} = 0 \, (i = L, I, K)$, SCE estimated using equations (8), (9), and (10) was unity for all the sample observations.

factor inputs by farm-firms. However, the demand elasticity for capital is the largest in absolute values among the three elasticities. Considering the fact that the most important element of capital input is machinery service employment, 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 AESs between labor and intermediate inputs, labor and capital, and intermediate inputs and capital are 0.37, 0.83, and 0.50, respectively. This indicates that labor and intermediate inputs and intermediate inputs and capital are not good substitutes, but labor and capital are fairly good substitutes.

4.2 RATES AND BIASES OF TECHNOLOGICAL CHANGE

The rates and biases of technological change were estimated using equations (9) 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 exist only slight differences in the magnitudes 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 classified into four trends: (1) it increased sharply from around 2.5 to 3.3 percent for the 1976-80 period; (2) it then slowed down from 3.3 to 2.8 percent for the 1980-1986 period; (3) it increased sharply again from 2.8 to 4.0 percent for the 1986-89 period; and (4) it appears to have started declining again for the 1989-93 period; from 4.0 percent in 1989 to 3.3 percent in 1993, although the rates were still greater than 3 percent. These rates of technological change may be said to be considerably 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 the impetus to the impressive performance. Furthermore, abandonment and diffusions 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 helped raise the yield per hectare of the paddy field utilized for rice production and hence gave positive 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 indicates that the technological diffusion has been neutral irrespective of size classes in Taiwanese rice production. This finding is consistent with the fact that in any villages almost all rice producing farmers utilize almost the same production technology.

Next, Figures 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 movements and magnitudes of the biases over time are very much similar among different size classes. Several important findings emerge from this figure.

First, technological change was biased toward saving labor 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 percent 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 using intermediate inputs. The extent of the intermediate-inputs-using bias was around 5.0 to 7.5 percent which was considerably high. This finding is consistent with the rapid increase in the utilization of chemical-fertilizers and agri-chemicals for rice production. It is interesting to note that the general movements of the intermediate-inputs-using bias is very similar to that of the rate of technological change shown in Figure 1. This may indicate that so-called bio-chemical (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 using capital, and the bias was as rapid as around 5 percent in 1976 but consistently slowed down to 3.0 percent in 1993. This finding of capital-using bias is consistent with the rapid mechanization of rice production during the late 1970s and the pace-down or stabilization after that.

At this point, let us compare these biases with the relative movements of factor prices in order to test whether or not the Taiwanese rice production is consistent with the Hicks induced innovation hypothesis. As described in section three, the factor price indexes were obtained for each size class in each district by the CCD method. Setting the 1976 values of size class 1 of Taipei district to ones, the price indexes were rearranged. A rough investigation of these index numbers tells us that the basic movements of the price indexes are almost the same among different size classes in each district, although there seem to be slight differences among different districts. Thus, as a representative, the price indexes of size class 1 of the Taipei district are given in Figure 3. From the figure, one can easily understand that the prices of intermediate inputs and capital relative to that of labor decreased over time. This indicates that labor is relatively scarce compared to intermediate inputs and capital. As found 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 said to be consistent with the Hicks induced innovation hypothesis[12].

4.3 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 exist slight differences in the estimates of SPBs and actual rents among districts, the general movements of them over time and the differentials of them among size classes are very similar. The estimated values of the SPBs and the actual rents for the Taipei

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

district are presented in Figures 4 and 5, respectively as representative. Note here that both the SPBs and actual rents are expressed in nominal terms. Furthermore, in order to examine whether or not the land market in the Taiwanese rice production has 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 exist some differentials both in the SPBs (Figure 4) and in the actual rents (Figure 5) among different size classes, those differentials were not consistent over time. To be more specific, judging from the movements only of the SPBs over time, one could not tell for sure which scale farms have been performing better in the utilization of land [13].

However, it is very clear from Figure 6 that for all the size classes the SPBs were consistently greater than the actual land rents over the 1976-93 period with exception being that of the year 1989. Assuming that the actual land rent is the market rent of land, this finding indicates that the land utilization level for rice production has been lower than an optimum level. This may have been due 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 SPBs and actual rents imply that the rice farmers would be better off if they produce 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 would have impeded the structural change for larger scale farming to take place in the rice production and hence restricted the land movements from smaller to larger scale farms.

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[13] The SPBs in 1989 were extremely low due to the extremely low yields in this year in all the districts except for Taitung. It is not clear at this point of time why the yields were that low in 1989. It may have been due to climatic reasons or due to just sampling errors.

5 SUMMARY AND CONCLUSIONS

This study has investigated quantitatively the production technology of the rice industry in Taiwan for the 1976-93 period using the translog variable cost function framework. Several important findings may be summarized as follows.

1. The demand elasticities for labor, intermediate inputs, and capital are all less than unity in absolute values, indicating the demand for these inputs are not elastic.
2. The substitution elasticities between labor and intermediate inputs, labor and capital, and intermediate inputs and capital are all positive. This indicates that the three variable factor inputs are all mutually substitutes.
3. It was found that constant returns to scale have existed in the rice production in Taiwan given the present production technology. This implies that doubling the output scale will double the total cost, i.e., the average cost will remain at the same level. In other words, the small and large scale farm-firms are equally efficient in terms of average cost.
4. The rate of technological change has been considerably high in rice production. This implies that technological progress has shifted the total cost curve downward fairly rapidly in rice production. This in turn indicates that technological innovations and diffusions in the Taiwanese rice production have been considerably effective. Furthermore, an increased quality of land due to withdrawals of marginal paddy fields from rice production must have given a positive 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 Hicks induced innovation theory.

6. The shadow price of land has been higher than the actual land rent. This implies that the level of land utilization has not been at the optimum level in the Taiwanese rice production. This in turn implies that rice farmers would be better off if they produce the 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 consumption 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 meet this requirement, technological progress will have to be promoted in such a way to break the existing situation of constant returns to scale and bring about increasing returns to scale in rice production; e.g., by a promotion of a larger scale mechanization with more effective consolidation of paddy fields. Towards this end, the government will have to introduce policy measures to promote technological innovations and more smooth land movements for larger scale farming with smaller number of entrepreneurial rice farmers.

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Table 1: 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_o	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			

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

Table 2: Demand Elasticities with Respect to Factor Prices

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

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

Table 3: Allen Partial Elasticities of Substitution

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

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

Figure 1. Technological Change Rate, 1976-93: Taipei (In percent)

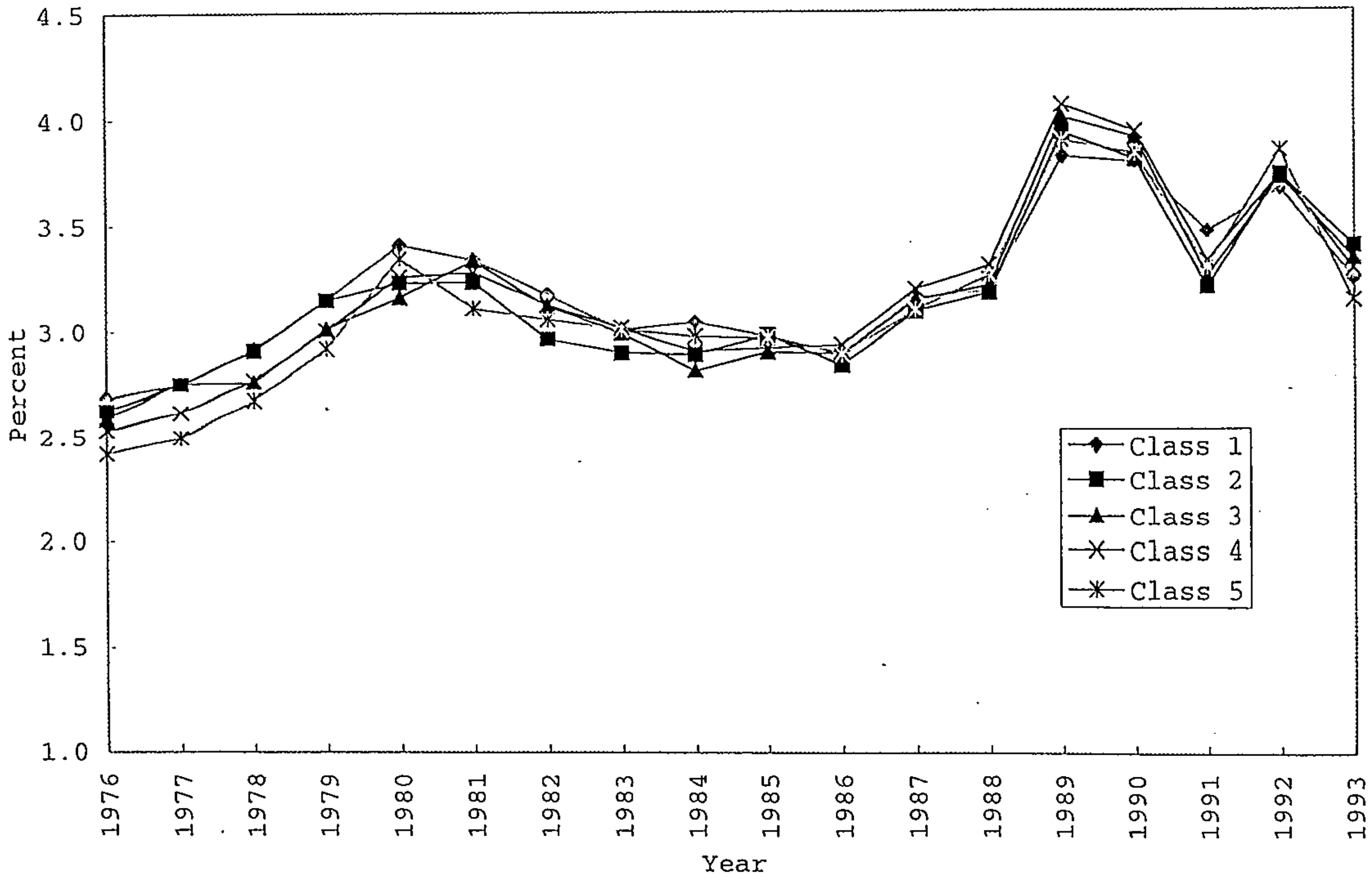

Figure 2. Biases of Technological Change, 1976-93: Taipei, Class 1

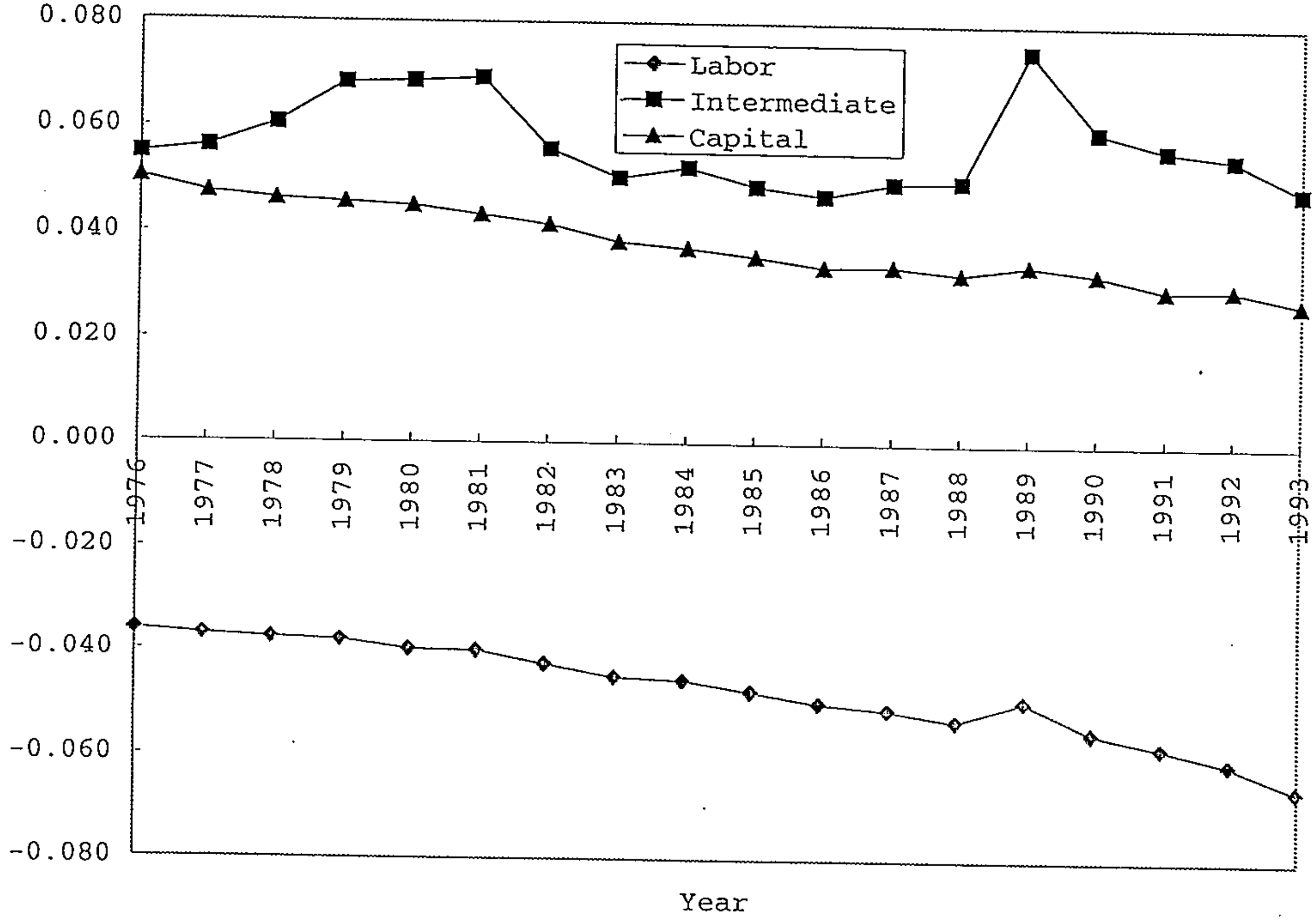

Figure 3. Factor Prices, 1976-93: Taipei, Class 1 (Taipei-Class-1-1976=1.0)

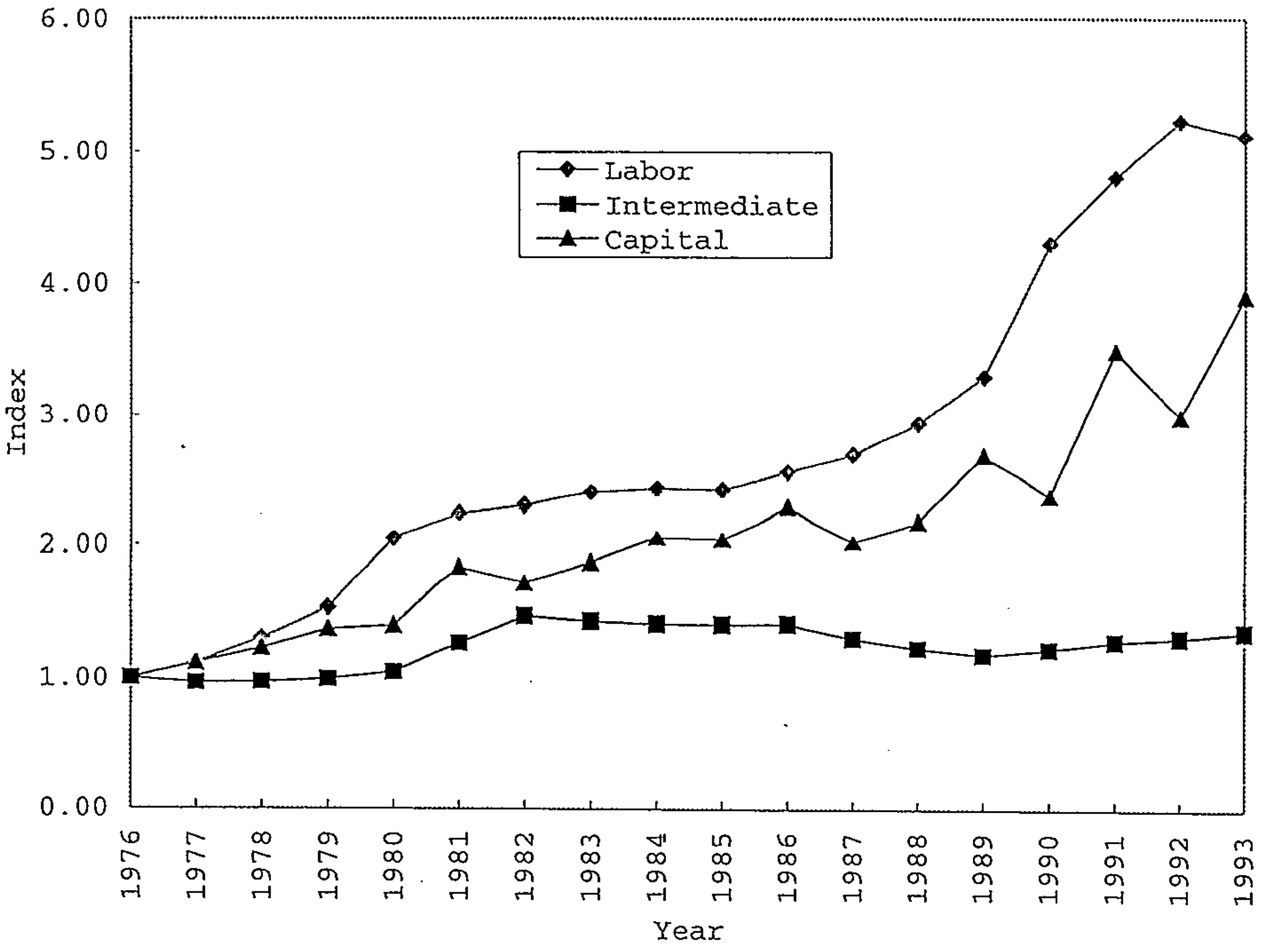

Figure 4. Shadow Price of Land, 1976-93: Taipei ($N.T. per Hectare)

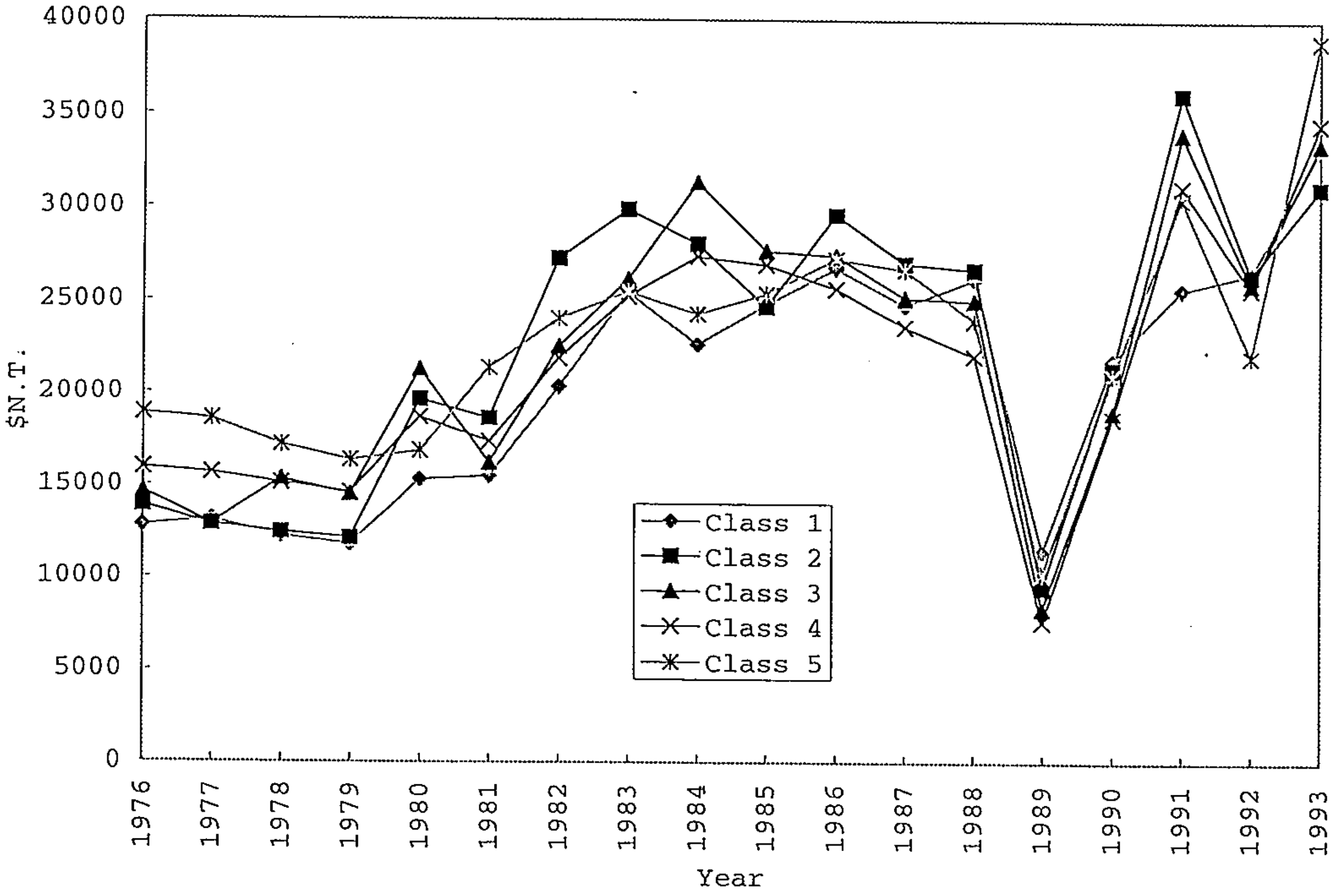

Figure 5. Actual Land Rent, 1976-93: Taipei ($N.T. per Hectare)

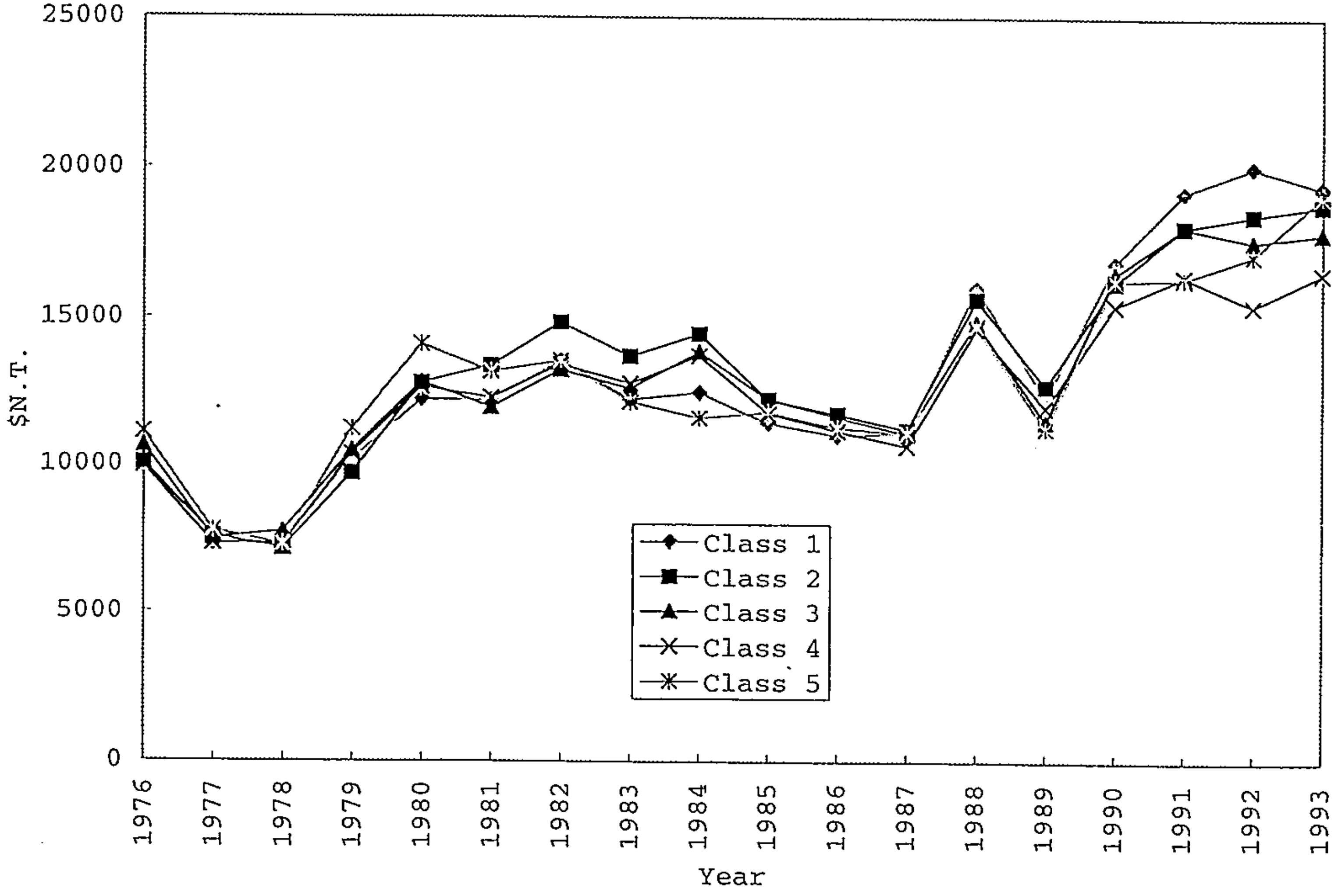

Figure 6. Ratio of the Shadow Price to the Actual Rent of Land, 1976-93: Taipei