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An Empirical Analysis of Labor Productivity Growth for the Taiwanese Rice Sector

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Abstract

This paper investigates the factors responsible for a high growth rate of labor productivity of the agricultural sector for the period 1976-93 for Taiwan. This investigation is carried out by a newly devised procedure which decomposes the growth rate of labor productivity into (1) the total substitution effect which consists of the effects due to factor price changes and biased technological change and (2) the TFP effect composed of the effects due to scale economies and technological progress. Based on empirical estimation of the translog cost function, it was found that the total substitution effect contributed to the growth of labor productivity much more than the TFP effect did for the period under question.

Keywords: labor productivity, translog cost function, total substitution effect, TFP effect, Taiwanese rice sector

1. Introduction

In Taiwan the agriculture sector was the backbone of the economy, the main foreign exchange earner and contributed greatly to economic development. Since 1960s, it has rapidly lost ground, slowly declined and increasingly depends for its survival on government protection. Like Japan and South Korea, Taiwan is a rich market that has attracted the attention of world agribusiness. Agriculture's contribution to the net domestic product (NDP) decreased from 30percent in 1960-64 to 6percent in 1985-89 and over this period, agricultural production, consumption, trade, farm operations and income have also changed dramatically (Huang, 1993). Rice is the staple food and still the dominant crop in Taiwan. During 1950s and 1960s, rice production increased rapidly, not only meeting the needs of domestic food consumption but also providing a surplus for export (Kuroda, 1997a). But its relative importance has diminished substantially. The share of rice in total crop decreased from 40.2percent in 1960-64 to about 17.3percent in 1985-89.While the increased production costs led to the uncompetitiveness of Taiwan's rice in the world market, fast economic growth ended the role of rice as a 'wage good' in the domestic market (Huang, 1993).

The high quality of human capital was an important factor for the high rates of economic growth in Taiwan. Human capital includes formal education as well as the ideas, knowledge, experiences, and even attitudes and work ethics acquired through employment and other social and economic interactions, which improved the quality of labor and made them most valuable resources for the country. Emphasis on rural education improved farm management and receptivity to technology and also the capacity for learning by doing in agriculture. Education also increased labor mobility, the labor force participation rate of women and the propensity to develop positive mental constructs toward market and agriculture institution.

The labor productivity growth rate has played an important role in Taiwanese agricultural sector. It grew by 3.0percent, 4.9percent, and 3.3percent annually in 1952-60, 1960-70, and 1970-82 respectively (Mao, 1986). For the economy as a whole, labor productivity grew at annual rates of 8.43percent from 1951 to 1965 and 6.2percent from 1966 to 1980 (Liu, 1985). But the expansion of manufacturing and service sectors caused out-migration of young farmers and thus changed employment structure in the agriculture sector. Agricultural labor force in total employment steadily decreased from 50.9percent in 1960-64 to only 15.3percent in 1985-89 (Huang, 1993).

Taiwan's farming is characterized by small-scale family operations with an average farm size of about 1 hectare. In addition, the distribution of the land is increasingly concentrated in small-size farms. Farm household under1 hectare increased from 66.5percent in 1960 to 75.2 percent in 1990, while farms above 3 hectares decreased from 3.3percent to 2.5percent (Huang, 1993). The total planted area for rice production has shown a strong downward trend from 790,248 hectares in 1975 to 391,457 hectares in 1993 (Kuroda, 1997a).

Since 1965, rice acreage has decreased consistently but productivity per hectare has increased. In 1989, paddy field accounted for 40% of total crop acreage (Huang, 1992). This increased productivity was primarily caused by technological innovation such as improvement in rice varieties, chemical inputs and improved irrigation practices. The establishment of strong agricultural research, extension, and other support institutions along with a steady commitment to rural infrastructure construction provided the essential foundation for high productivity growth in agriculture and the commercialization of the rural economy. Continuous contact with research and extension organizations overtime and successful precedents increased farmers trust and willingness to adopt new technologies. Extension efforts were complemented by special economic incentives to encourage adoption of new techniques and crop varieties. Positive attitudes toward technology adoption were also fostered by the commercialization of agriculture.

Due to out-migration of farmers, mechanization became the only way to overcome the labor constraint. The 1970s were widely agreed on as a turning point that marked the beginning of a new phase in Taiwan's agricultural development – one without an abundance of labor (Huang, 1993). Since, the out-migrants were relatively young, farm labor was aging. Farmers older than 60 years were 3percent of the agriculturally employed in 1965-69, but 12percent in 1985-89 (Huang, 1993).

There are several studies on the Taiwanese rice sector. For example: Effects of government programs on rice acreage decisions under rational expectation (Huang, 1992); Structural change in agricultural economy (Huang, 1993); Rural development and dynamic externalities in structural transformation (Park and Johnston, 1995); An empirical investigation of the rice production structure (Kuroda, 1997a), Effects of R & E activities on rice production (Kuroda, 1997b) and so on. But none has done decomposition analysis of labor productivity growth rate of the rice sector. To fill this gap, this study investigates empirically the factors responsible for the high growth rate of labor productivity of the rice sector for the 1976-93 period. The objective of this study is to investigate which factors are responsible for this increased growth rate, which is directly related to the decomposition analysis of labor productivity growth rate. However, this study is limited to the labor productivity growth rate of the rice sector.

For decomposition analysis of labor productivity growth rate, the conventional growth accounting method has been applied by different researchers (Solow, 1957; Berndt and Watkins, 1981; Denny and Fuss, 1983; Doi, 1985; Morrison, 1993). According to this method, the growth rate of labor productivity is decomposed into the growth rate of factor intensities and TFP. To derive this decomposition, one has to introduce three strict assumptions on the production technology as: (1) constant returns to scale; (2) Hicks-neutral technological change (Hicks, 1963); and (3) the producer equilibrium. If any of these assumptions is not satisfied in reality, the conventional growth accounting procedure may cause bias in the results. In particular, for the first two assumptions, one cannot analyze the economic factors behind changes in the growth rates of factor intensities and TFP by the conventional method. Because, a) shifts in relative prices and bias of technological change are major possibilities for changes in the growth rate of factor intensities, and b) economies of scale and the rate of technological change are major components for changes in the growth rate of TFP.

To pursue the objective, this study uses the device developed by Kuroda (1995) which enables one to link the growth rate of labor productivity with that of total factor productivity (TFP). Kuroda (1995) applied this procedure in his study of labor productivity measurement in Japanese agriculture, 1956-90. The present study is going to decompose the growth rate of labor productivity into factor price effect, fixed input effect, scale effect and technological change effect. For the empirical measurement of these effects, a non-homothetitic and Hicks non-neutral translog variable cost function is specified and estimated for the 1976-93 period. The present study makes a detailed comparison of labor productivity decomposition among six districts and five farm size classes of Taiwan.

2. Method

In this study it is assumed that the rice sector has a variable cost function as a dual of the production function which satisfies the neoclassical regularity conditions,

$$C = G(Q, P, Z_B, T) \tag{1}$$

Where Q is the quantity of output; P is a factor price vector corresponds to a factor input vector X which is composed of labor X_L, intermediate input X_I, and capital X_K; Z_B is land considered as a fixed input; T is time as an index of technological change; $C = \sum_{i=1}^{3} P_i X_i \, (i = L, I, K)$ is the minimized variable cost; and C is homogeneous of degree one in factor prices.

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. In addition, various regulations have restricted land movement in Taiwanese agriculture (Kuroda, 1997).

Through Shepard lemma (Shepard, 1970), the cost minimizing factor demand equation for the variable cost function can be derived as follows:

$$X_i(Q, P, Z_B, T) = \frac{\partial C(Q, P, Z_B, T)}{\partial P_i}, \quad i = L, I, K \tag{2}$$

Multiplying both sides of (2) by P_i / C, the cost share equation of the ith factor input S_i can be obtained as:

$$S_i = \frac{P_i X_i}{C} = \frac{\partial C}{\partial P_i} \frac{P_i}{C} = \frac{\partial \ln C}{\partial \ln P_i}, \qquad i = L, I, K \tag{3}$$

The decomposition procedure for the growth rate of labor productivity into various effects, which is going to be used in this study, can be applied to the decomposition of the growth rate of any single-factor productivity.

The growth rate of labor productivity can be expressed as the growth rate of output minus the growth rate of labor input:

$$\frac{d \ln(Q / X_L)}{dT} = \frac{d \ln Q}{dT} - \frac{d \ln X_L}{dT} = G(Q) - G(X_L) \tag{4}$$

Where G (.) designates the growth rate of a specific variable, and subscript L denotes labor input.

The growth rate of labor input $G(X_L)$ can further be decomposed into several effects. Differentiating totally the labor demand function given in equation (2) with respect to time, dividing both sides by X_L and rearranging yields the following equation:

$$\begin{aligned} G(X_L) &= \frac{d \ln X_L}{dT} \\ &= \sum_{i=1}^{3} \frac{\partial \ln X_L}{\partial \ln P_i} G(P_i) + \frac{\partial \ln X_L}{\partial \ln Q} G(Q) + \frac{\partial \ln X_L}{\partial \ln Z_B} G(Z_B) + \frac{\partial \ln X_L}{\partial T} \\ &= \sum_{i=1}^{3} e_{Li} G(P_i) + \frac{\partial \ln X_L}{\partial \ln Q} G(Q) + \frac{\partial \ln X_L}{\partial \ln Z_B} G(Z_B) + \frac{\partial \ln X_L}{\partial T} \\ & \qquad i = L, I, K. \end{aligned} \tag{5}$$

Where $e_{Li} (= \partial \ln X_L / \partial \ln P_i)$ is the price elasticity of labor demand with respect to the price of the ith input ($i = L, I, K$). Equation (5) shows that the growth rate of labor input can be decomposed into the price effect (the first term), the output effect (the second term), the fixed input effect (the third term) and the technological change effect (the fourth term).

The output effect, the fixed input effect, and the technological change effect may further be decomposed as follows. Taking the natural logarithms of both sides of the labor cost share equation given in equation (3) linked by the first equality sign and rearranging yields:

$$\ln X_L = \ln C + \ln S_L - \ln P_L \tag{6}$$

Using (6), the following relations are obtained.

$$\frac{\partial \ln X_L}{\partial \ln Q} = \frac{\partial \ln C}{\partial \ln Q} + \frac{\partial \ln S_L}{\partial \ln Q} = \varepsilon_{CQ} + \frac{1}{S_L} \frac{\partial S_L}{\partial \ln Q} \tag{7}$$

$$\frac{\partial \ln X_L}{\partial \ln Z_B} = \frac{\partial \ln C}{\partial \ln Z_B} + \frac{\partial \ln S_L}{\partial \ln Z_B} = \varepsilon_{CB} + \frac{1}{S_L}\frac{\partial S_L}{\partial \ln Z_B} = \varepsilon_{CB} + \frac{\theta_{LB}}{S_L} \tag{8}$$

$$\frac{\partial \ln X_L}{\partial T} = \frac{\partial \ln C}{\partial T} + \frac{\partial \ln S_L}{\partial T} = \lambda + \frac{1}{S_L}\frac{\partial S_L}{\partial T} \tag{9}$$

Where ε_{CQ} and ε_{CB} are the cost-output elasticity and the cost-fixed input elasticity, respectively, and λ indicates the rate of shift of the cost function due to technological change. The second term of (7) indicates the bias effect on the demand for labor due to changes in output; the second term of (8) indicates the labor bias due to changes in the fixed input; and the second term of (9) indicates the labor bias of technological change. Substituting (5), (7), (8), and (9) into (4) and rearranging yields

$$G(\frac{Q}{X_L}) = [-\sum_{i=1}^{3} e_{Li} G(P_i)] + [\varepsilon_{CB} G(Z_B)] + [\{-\frac{1}{S_L}\frac{\partial S_L}{\partial \ln Z_B} G(Z_B)\} + \{-\frac{1}{S_L}\frac{\partial S_L}{\partial \ln Q} G(Q)\}$$
$$+\{\frac{1}{S_L}\frac{\partial S_L}{\partial T}\}] + [(1-\varepsilon_{CQ})G(Q) + (-\lambda)] \tag{10}$$

According to Caves *et.al.*, 1981, the productivity growth rate with inputs held constant in the case of a single-output variable cost function is given by,

$$PGQ = -(\frac{\partial C}{\partial T})/(\frac{\partial C}{\partial Q}) = -\lambda / \varepsilon_{CQ} \tag{11}$$

Then, the cost elasticity (ε_{CQ}) can be rewritten as,

$$\varepsilon_{CQ} = -\lambda / PGQ \tag{12}$$

Thus, equation (10) can be rewritten as,

$$G(\frac{Q}{X_L}) = \left[-\sum_{i=1}^{3} e_{Li} G(P_i)\right] + \left[\varepsilon_{CB} G(Z_B)\right]$$
$$+\left[\left\{-\frac{1}{S_L}\frac{\partial S_L}{\partial \ln Z_B} G(Z_B)\right\} + \left\{-\frac{1}{S_L}\frac{\partial S_L}{\partial \ln Q} G(Q)\right\} + \left\{\frac{1}{S_L}\frac{\partial S_L}{\partial T}\right\}\right] + [(1+\lambda / PGQ)G(Q) + (-\lambda)] \tag{13}$$

The first term on the right hand side of (13) indicates the sum of the substitution effects on labor demand due to changes in the variable input prices and the quantity of the fixed input, land. The second term is the sum of the bias effects due to the fixed input, output scale, and technological change. Following Antle and Capalbo (1988), the sum of these three effects may be defined as the (extended) Hicksian biased technological change effect (Blackorby, et al. 1977). All the components of the first and second terms are factors which lead to factor substitutions. Therefore, the sum of these effects is called the total substitution effect in this study.

Next, [(1+λ /PGQ)G(Q)] in the third term may be defined as the scale-induced technological progress. The second component of the third term ($-\lambda$) indicates the dual rate of technological progress, i.e., the rate of cost diminution. Thus, the sum of these two effects may be defined as the total technological progress effect.

According to the conventional growth accounting procedure with the assumptions of producer equilibrium, constant returns to scale, and Hicks neutral technological change, the growth rate of labor productivity can be decomposed into the growth rates of factor intensities and the growth rate of TFP (Solow, 1957; Morrison, 1993).

Kuroda (1995) showed, in the case of the total cost function, that unlike the conventional growth accounting method, if both constant returns to scale and Hicks neutrality are not assumed a priori, changes in the growth rates of factor intensities can be decomposed into price effects, bias effects due to output scale and technological change, while changes in the growth rate of TFP can be decomposed into the effects due to scale economies and technological progress.

This study has extended Kuroda's procedure to the case of the variable cost function. That is, if the cost function is non-homothetic and Hicks non-neutral in the space of the variable inputs, the rate of growth of labor productivity can be decomposed into the total substitution effects which are composed of price effects, and bias effects due to the fixed inputs, output scale, and technological change, and the total technological progress effects consisting of the rate of the scale-induced technological progress and the rate of cost diminution.

If parameters such as price elasticities of labor demand, cost elasticity, cost-fixed inputs elasticities, and the rate and biases of technological change are estimated, all of these effects can be quantitatively measured. The empirical estimation of these effects expressed in equation (13) will not only be very interesting from the academic viewpoint, but also very important from the viewpoint of offering information for policy-makers.

In order to obtain the necessary parameters for the decomposition analysis based on Eq. (13), a translog form is specified for the variable cost function (1):

$$\begin{aligned}\ln C = {} & \alpha_0 + \alpha_Q \ln Q + \sum_{i=1}^{3} \alpha_i \ln P_i + \beta_B \ln Z_B + \beta_T T \\ & + \frac{1}{2}\gamma_{QQ}(\ln Q)^2 + \frac{1}{2}\sum_{i=1}^{3}\sum_{j=1}^{3}\gamma_{ij} \ln P_i \ln P_j \\ & + \sum_{i=1}^{3}\theta_{iB} \ln P_i \ln Z_B + \frac{1}{2}\theta_{BB}(\ln Z_B)^2 \\ & + \sum_{i=1}^{3}\delta_{Qi} \ln Q \ln P_i + \delta_{QB} \ln Q \ln Z_B \\ & + \mu_{QT}(\ln Q)T + \sum_{i=1}^{3}\mu_{iT}(\ln P_i)T \\ & + \beta_{BT}(\ln Z_B)T + \frac{1}{2}\beta_{TT}T^2 \\ & + \sum_{k=2}^{6} d_{Rk} D_{Rk} + \sum_{l=2}^{5} d_{Sl} D_{Sl} \end{aligned} \tag{14}$$

Where $\gamma_{ij} = \gamma_{ji}$ and $i = j = L, I, K.$

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 (Note 1).

Now the cost share (S_i) are derived as

$$\begin{aligned} S_i &= \frac{\partial C}{\partial P_i}\frac{P_i}{C} = \frac{\partial \ln C}{\partial \ln P_i} \\ &= \alpha_i + \sum_{j=1}^{3}\gamma_{ij} \ln P_j + \delta_{Qi} \ln Q + \theta_{iB} \ln Z_B + \mu_{iT} T \end{aligned} \tag{15}$$

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).

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 (Note 2). Denoting PQ/C as S_Q, the revenue share equation can be written as

$$\begin{aligned} S_Q &= \frac{\partial C}{\partial Q}\frac{Q}{C} = \frac{\partial \ln C}{\partial \ln Q} \\ &= \alpha_Q + \sum_{i=1}^{3}\delta_{Qi} \ln P_i + \gamma_{QQ} \ln Q + \delta_{QB} \ln Z_B + \mu_{QT} T \end{aligned} \tag{16}$$

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

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 additional information provided by the revenue share (Note 3).

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 $\sum_{i=1}^{3}\mu_{iT} = 0 \quad (i = j = L, I, K).$ The translog cost function (13) has a general form in the sense that the restrictions of homotheticity and Hicks neutrality in the space of the variable inputs 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 $C(Q, P, Z_B, T) = G(Q, Z_B).H(P, T)$ 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); $\alpha_Q + \beta_B = 1, \delta_{Qi} + \theta_{iB} = \delta_{QB} + \theta_{BB} = \gamma_{QQ} + \delta_{QB} = \mu_{QT} + \beta_{BT} = 0 (i = L, I, K).$

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

As shown immediately later when we discuss the measure of the biases of technological change, the test results of the last two hypotheses are 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 equations as detailed below: (Note 4)

Now, the necessary parameters for the decomposition equation (13) can be computed based on the translog cost function (14) as follows. First, the price elasticities of demand for labor can be computed through (Berndt and Christensen, 1973),

$$e_{LL} = S_L \sigma_{LL} \tag{17}$$

$$e_{Li} = S_i \sigma_{Li} \tag{18}$$

$$i = I, K$$

Where σ_{LL} and σ_{Li} are the Allen partial elasticities of substitution and can be obtained by

$$\sigma_{LL} = (\gamma_{LL} + S_L^2 - S_L) / S_L^2 \tag{19}$$

$$\sigma_{Li} = (\gamma_{Li} + S_L S_i) / S_L S_i \tag{20}$$

$$i = I, K.$$

Next, for the estimation of the fixed factor effect of the total substitution effects, ε_{CB} is given by

$$\varepsilon_{CB} = \frac{\partial \ln C}{\partial \ln Z_B} = \beta_B + \sum_{i=1}^{3}\theta_{iB}\ln P_i + \delta_{QB}\ln Q + \theta_{BB}\ln Z_B + \beta_{BT}T \tag{21}$$

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

Third, the labor bias effects with respect to output scale, fixed input, and technological change are given respectively by

$$\frac{1}{S_L}\frac{\partial S_L}{\partial \ln Q} = \frac{\delta_{QL}}{S_L} \tag{22}$$

$$\frac{1}{S_L}\frac{\partial S_L}{\partial \ln Z_B} = \frac{\theta_{BL}}{S_L} \tag{23}$$

$$\frac{1}{S_L}\frac{\partial S_L}{\partial T}=\frac{\mu_{LT}}{S_L} \tag{24}$$

$$\varepsilon_{CQ}=\frac{\partial \ln C}{\partial \ln Q}=\alpha_Q+\sum_{i=1}^{3}\delta_{Qi}\ln P_i+\gamma_{QQ}\ln Q+\delta_{QB}\ln Z_B+\mu_{QT}T \tag{25}$$

$$\lambda=\frac{\partial \ln C}{\partial T}=\beta_T+\sum_{i=1}^{3}\ln P_i+\mu_{QT}\ln Q+\beta_{BT}\ln Z_B+\beta_{TT}T \tag{26}$$

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

2.1 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 hectare, (2) 0.5-0.75 hectare, (3) 0.75-1.0 hectare, (4) 1.0-1.5 hectare, 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) x 5(classes) x 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 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 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 to58 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 (Note 5).

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 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, and 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 Tornqvist-Theil index was obtained by the Caves-Christensen-and-Diewert (CCD) method (Caves, et al. 1982). The CCD method is most relevant when it comes to estimating the Tornqvist-

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 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 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 the estimation, the price index for farm machinery was used for the complex of farm building, 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 building, equipment, and tools are reported for the average farm-firm 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 many 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 indices 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 $S_Q = TR/C$.

Note 5.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 stick to the analysis based on the data set only for the first crop.

2.2 Statistical Method

For statistical estimations, since the quantity of output (Q) in the right-hand-side of the cost function (14) 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 (14), two of the three cost share equations (15) (Note 6), and one revenue share equation (16). 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.

3. Results & Discussion

For the tests of 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 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 were strongly rejected both at the 0.05 and at the 0.01 significance levels. However, the hypothesis of CRTS could not be rejected both at the 0.05 and at the 0.01 significance levels, which implies the existence of 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 remain at the same minimum level.

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 Taipei district (Note 7), while Taitung district showed higher total cost than Taipei district. 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 (14), (15) and (16) 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 high. This set of estimates is referred to as the final specification of the model and will be used for further analyses (Note 8).

Factor demand elasticities with respect to factor prices as well as the Allen partial elasticities of substitution and fixed input elasticity, scale and technological change effect were computed by using estimated parameter of Table 1, for the entire 1976-93 period. Several findings are noteworthy here from the computed result:

First, the own-price elasticities of demand for labor are less than unity in absolute value (0.287) indicating that the demand for labor in agriculture is inelastic. This inelastic demand for labour in agriculture may be linked to the out-migration of workers from the agriculture to the manufacturing and services sectors.

Second, the substitution elasticities between labor and intermediate input and between labor and capital are all positive indicate that the variable factor inputs are mutually substitutes and own substitution effect was dominant.

Table 1. FIML estimates of the translog variable cost function for the Taiwanese rice sector with the imposition of the CRTS restrictions, for 1976-1993 (First Crop)

Parameter	Coefficient	t-statistics	Parameter	Coefficient	t-statistics
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			

Estimating Equations	$\overline{R}^2$
Cost Function	0.932
Labor Share Equation	0.718
Intermediate Input Share Equation	0.614
Revenue Share Equation	0.645

Third, the Allen Elasticity of Substitution (AES) between labor and intermediate inputs and labor and capital are 0.37, and 0.83 respectively which indicates that labor and intermediate inputs are not good substitutes, but labor and capital are fairly good substitutes. That is, technical possibilities of substitution exist between labor and capital, which support the findings of Kuroda (1997a).

Table 2 and Table 3 represent the labor productivity growth rate for the Taiwanese rice sector by districts and by farm sizes respectively. It is found that among farm sizes, labor productivity growth rates are more or less similar but it varies district to district. Based on equation 13 the decomposition was executed for the entire 1976-93 period by districts and farm sizes. The results are presented in Tables 4-7. Based on the results, a general evaluation will first be made and then followed by the differences between six districts and five farm size classes. Table 4 shows the fixed input effect, scale effect and technological change effect at the means and it is found that the technological change effect is the highest among these three effects and bias effect is higher than the cost reduction effect.

Table 2. Labor Productivity Growth Rate for Taiwanese rice sector by districts, 1976-93

Districts	Output Growth Rate	Labor Growth Rate	Labor Productivity Growth Rate
Taipei	0.017	-0.078	0.094
Hsinchu	0.014	-0.078	0.092
Taichung	0.010	-0.077	0.087
Tainan	0.007	-0.096	0.103
Kaohsiung	0.006	-0.090	0.096
Taitung	0.015	-0.087	0.102
Taiwan	**0.012**	**-0.084**	**0.096**

Note: All the figures are simple averages of all samples.

Table 3. Labor Productivity Growth Rate for Taiwanese rice sector by farm size, 1976-93

Farm Size (hectares)	Output Growth Rate	Labor Growth Rate	Labor Productivity Growth Rate
> 0.50	0.019	-0.078	0.097
0.50 - 0.75	0.010	-0.086	0.096
0.75 - 1.00	0.010	-0.087	0.097
1.00 - 1.50	0.005	-0.089	0.094
1.50 & above	0.014	-0.081	0.095
Taiwan	**0.012**	**-0.084**	**0.096**

Note: All the figures are simple averages of all samples.

From Table 5, it can be observed that for the entire 1976-93 period, total substitution effect is higher than that of total technological progress effect and contributed about 66.5percent to the growth rates of labor productivity. Hicksian biased technological change effect due to fixed input, output scale and technological change contributes 43.7per cent. Substitution effect due to price effect and changes in quantity of fixed input contributes 22.8 percent and total technological progress effect contributes 32.6 percent to the growth rates of labor productivity. Therefore, Hicksian biased technological change effect contributed the highest among the three effects. Among all effects, the sum of cost reduction effect and biased technological change effect contributes about 81 per cent to the growth rate.

Table 4. Fixed input effect, Scale effect and Technological change effect at the means.

Fixed Input Effect			Scale Effect			Technological Change Effect		
Quantity of of Fixed Input	Bias Effect of Fixed Input	Total	Scale Induced Technological Progress	Bias Effect due to Output Scale	Total	Rate of Cost Diminution	Bias Effect	Total
-0.001	-0.001	-0.002	-0.007	0.004	-0.003	0.024	0.028	0.052

Table 5. Decomposition of Labor Productivity Growth Rate, 1976-93 (unit:%)

Growth Rate of Labor Productivity	Total Substitution Effect								Total Technological Progress Effect			Residual
	Substitution Effect			Hicksian Biased Technological Change Effect				Total Effect	Scale Induced Technological Progress	Rate of Cost Diminution	Total	
	Price Effect	Changes in Quantity of Fixed Input	Total	Fixed Input	Output Scale	Technological Change	Total					
9.58	2.05	0.13	2.18	-0.38	0.59	3.98	4.19	6.37	-0.67	3.79	3.12	0.09
(100)	21.4	1.4	22.8	-4.0	6.5	41.5	43.7	66.5	-7.0	39.6	32.6	0.9

Note: The figures are simple average of all samples.

Contribution of different effects to the labor productivity growth rate by districts and farm sizes are presented in Table 6 and Table 7 respectively. These contributions differ among districts but are found to be fairly close for different farm sizes which might be due to the fact that different farms and all the rice producing farmers are using the same production technology. It is found that for every district and farm size, biased technological change effect has the highest contribution whereas total technological progress effect has moderate and substitution effect and the other effects have very low contribution to the growth rate of labor productivity. The growth rate of labor productivity for the whole period found by computation is 9.58. The constant return to scale (CRTS) characteristics in the rice sector may be linked to the small farm size especially since labour productivity does not vary with farm size. The largest contribution of the substitution effect (namely the Hicksian biased technological change effect) to labour productivity growth is linked to the fact that input growth is no longer independent of technical when technical change is Hicks biased.

Table 6. Decomposition of Labor Productivity Growth Rate by Districts (unit: %)

Districts	Growth Rate of Labor Productivity	Total Substitution Effect								Total Technological Progress Effect			Residual
		Substitution Effect			Hicksian Biased Technological Change Effect				Total Effect	Scale Induced Technological Progress	Rate of Cost Diminution		Total
		Price Effect	Changes in Quantity of Fixed Input	Total	Fixed Input	Output Scale	Technological Change	Total					
Taipei	9.44	1.08	0.27	1.35	-0.83	0.74	3.37	3.28	4.63	-0.7	4.49	3.79	1.02
	100	11.4	2.9	14.3	-8.8	7.8	35.7	36.4	49.0	-7.4	47.6	40.1	10.8
Hsinchu	9.2	1.32	-0.18	1.14	0.52	0.68	3.62	4.82	5.96	-0.73	3.91	3.18	0.04
	100	14.3	-2.0	12.4	5.7	7.4	39.3	53.6	64.8	-7.9	42.5	34.6	0.4
Taichung	8.74	2.57	0.29	2.86	-0.82	0.55	4.13	3.86	6.72	-0.68	3.74	3.06	-1.03
	100	29.4	3.3	32.7	-9.4	6.3	47.3	42.9	76.9	-7.8	42.8	35.0	-11.8
Tainan	10.25	3.26	-0.06	3.2	0.17	0.4	4.32	4.89	8.09	-0.51	3.60	3.09	-0.93
	100	31.8	-0.6	31.2	1.7	3.9	42.1	54.3	78.9	-5.0	35.1	30.1	-9.1
Kaohsiung	9.62	2.63	0.23	2.86	-0.63	0.4	4.52	4.29	7.15	-0.5	3.35	2.85	-0.36
	100	27.3	2.4	29.7	-6.5	4.2	47.0	47.7	74.3	-5.2	34.8	29.6	-3.7
Taitung	10.19	1.44	0.24	1.68	-0.68	0.78	3.88	3.98	5.66	-0.89	3.66	2.77	1.76
	100	14.1	2.4	16.5	-6.7	7.7	38.1	44.2	55.5	-8.7	35.9	27.2	17.3

Note: The figures are simple average of all samples.

Table 7. Decomposition of Labor Productivity Growth Rate by Farm Sizes (unit: %)

Farm Sizes	Growth Rate of Labor Produc-tivity	Total Substitution Effect								Total Technological Progress Effect			Residual
		Substitution Effect			Hicksian Biased Technological Change Effect				Total Effect	Scale Induced Technological Progress	Rate of Cost Diminution	Total	
		Price Effect	Changes in Quantity of Fixed Input	Total	Fixed Input	Output Scale	Technological Change	Total					
> 0.50	9.69	2.04	0.54	2.58	-1.52	0.97	3.97	3.42	6.00	-1.12	3.79	2.67	1.02
	100	21.1	5.6	26.6	-15.7	10.0	41.0	35.3	61.9	-11.6	39.1	27.6	10.5
0.50 - 0.75	9.61	2.07	-0.001	2.069	-0.005	0.50	3.98	4.48	6.54	-0.55	3.79	3.24	-0.17
	100	21.5	0.0	21.5	-0.1	5.2	41.4	46.6	68.1	-5.7	39.4	33.7	-1.8
0.75 - 1.00	9.67	2.05	-0.01	2.04	0.03	0.52	3.98	4.53	6.57	-0.59	3.79	3.2	-0.09
	100	21.2	-0.1	21.1	0.3	5.4	41.2	46.8	67.9	-6.1	39.2	33.1	-0.9
1.00 - 1.50	9.44	2.04	-0.20	1.84	0.57	0.24	3.96	4.77	6.61	-0.26	3.79	3.53	-0.7
	100	21.6	-2.1	19.5	6.0	2.5	41.9	50.5	70.0	-2.8	40.1	37.4	-7.4
1.50 & above	9.47	2.05	0.33	2.38	-0.96	0.72	3.98	3.74	6.12	-0.83	3.79	2.96	0.38
	100	21.6	3.5	25.1	-10.1	7.6	42.0	39.5	64.6	-8.8	40.0	31.3	4.0

Note: The figures are simple average of all samples.

The above findings reflect that technological change effect is the dominant factor influencing labor productivity growth rate, which implies that technological innovation and diffusions have been considerably effective. Price effect shows that farmers are sensitive to changes in the factor prices. Negative scale effect is caused by negative growth rates of labor input, and biased technological change towards saving labor and capital and the use of intermediate input. Negative fixed input effect may be caused by a decrease in planted area of rice for the diversified crop program, changes in food consumption pattern and for some other use of land (Huang, 1992).

This study has shown that using a variable cost function framework, the growth rate of labor productivity can be decomposed into (1) the total substitution effect, which consists of the effects due to factor price changes and biased technological change and (2) TFP effect, composed of the effects due to scale economies and technological progress. Based on the empirical estimations, the findings of the study may be summarized as follows:

First, it was found that the total substitution effect contributed to the growth of labor productivity much more than the TFP effect did.

Second, negative growth rate of labor input and biased technological change towards labor saving caused negative scale effect.

Third, decreased rice planted area and changed in consumption pattern caused negative fixed input effect.

Fourth, total technological change effect i.e. sum of biased effect and cost reduction effect has contributed about 81per cent, the highest value for all districts and farm sizes.

This study may conclude that the Taiwanese rice sector's major source of labor productivity growth for the 1976-93 period was attributed to the total substitution effect and all these factors which are intimately associated have also been responsible for the increase in the growth rate of labor productivity.

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Notes

Note 1. 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.

Note 2. 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.

Note 3. For a detailed discussion on the inclusion of the revenue share equation in the system of regression equations, see Ray (1982) and Capalbo (1988).

Note 4. 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.

Note 5. 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 stick to the analysis based on the data set only for the first crop.

Note 6. 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.

Note 7. 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.

Note 8. Monotonicity and concavity were also checked and satisfied not only at the approximation point but also at all the samples observations.