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The Production Structure and the Demand for Labor in Postwar Japanese Agriculture, 1952-82

by

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1. Introduction

The rapid growth of the Japanese economy during the postwar years has accompanied a sizable transfer of labor from agriculture to the non-agricultural sectors. The total number of agricultural gainful workers declined from 15.6 million in 1952 to 5.7 million in 1982. The average rate of decrease was 3.3 percent per year. In terms of labor hours per unit of land, this rate was 4.0 percent for the average farm for the same period.

What were then the factors which can explain this drastic decline in agricultural labor? At least three factors can be considered: (1) the demand for labor in nonagricultural sectors; (2) the supply of labor of agricultural households to both agriculture and nonagricultural sectors; and (3) the demand for labor in agricultural production.

This study will focus on the analysis of the last factor. That is, the production structure of agriculture is to be analyzed by shedding a special light on the demand for labor. For this objective, a translog cost function model will be estimated for the period 1952-82 by making use of farm level data. Similar methods which employ the translog cost function have been used for the analysis of U. S. and Japanese agriculture (Binswanger, Ray, Kako, and Le Thanh Nghiep). However, these studies assumed a priori that the economic agent minimizes costs and the production process is characterized by either homotheticity or Hicks neutral technical change or by both. If, however, the maintained hypothesis of cost-minimizing behavior is rejected through a statistical test, the translog cost function model may not be valid. In addition, if the production process cannot be represented either homotheticity or neutrality, the estimates based on the models with such assumptions will then be biased. This study will thus explicitly test in the process of estimation the hypothesis of cost minimization together with the hypotheses on the functional form such as homotheticity, constant returns to scale, Cobb-Douglas (C-D) production function, and Hicks neutral technical change.

Based on the estimates of the final specification of the translog cost function with the imposition of parameter restrictions if necessary, the Allen partial elasticities of substitution between pairs of factor inputs, own- and cross-price elasticities of demand for factor inputs, and biased impacts of technical change and nonhomotheticity will be estimated. In addition, the changes in relative factor uses for the period 1952-82 will be decomposed into the scale effect, the total substitution effects, and the biased technical change effect. The empirical findings of this study are expected to be useful for policy makers who seek for policies for labor adjustment in agriculture.

2. Methodology

The present study assumes that the farms' production technology may be represented by the translog cost function of the following form:[1/]

$$(1) \qquad \ln C^* = \alpha + \alpha_Q \ln Q + \sum_{i=1}^{5} \alpha_i \ln P_i + \epsilon_t \ln t + \frac{1}{2} \gamma_{QQ} (\ln Q)^2 + \frac{1}{2} \sum_{i=1}^{5} \sum_{j=1}^{5} \gamma_{ij} \ln P_i \ln P_j$$

$$+ \sum_{i=1}^{5} \delta_{Qi} \ln Q \ln P_i + \rho_{tQ} \ln t \ln Q$$

$$+ \sum_{i=1}^{5} \mu_{ti} \ln t \ln P_i + \frac{1}{2} \epsilon_{tt} (\ln t)^2$$

$$i,j = L, M, I, T, O.$$

Where Q is output; P_L, P_M, P_I, P_T, and P_O refer to the prices of labor (X_L), machinery (X_M), intermediate inputs (X_I), land (X_T), and other inputs (X_O), respectively; t is an annual index of time; and C* is the minimized total cost. It is assumed that the translog cost function (1) is twice differentiable, so that the Hessian of this function with respect to the input prices is symmetric. This implies the symmetry restrictions,[2/] $\gamma_{ij} = \gamma_{ji}$ for $i \neq j$ (i,j = L, M, I, T, O).

The cost share functions can be derived through the Shephard duality theorem as:

(2) $$S_i = \frac{\partial C^*}{\partial P_i} \frac{P_i}{C^*} = \frac{\partial \ln C^*}{\partial \ln P_i}$$

$$= \alpha_i + \sum_{j=1}^{5} \gamma_{ij} \ln P_j + \delta_{Qi} \ln Q + \mu_{ti} \ln t$$

$$i, j = L, M, I, T, O.$$

Any sensible cost function must be homogeneous of degree one in input prices. This requires in the translog cost function (1) that $\sum_{i=1}^{5} \alpha_i = 1$, $\sum_{j=1}^{5} \gamma_{ij} = 0$, $\sum_{i=1}^{5} \delta_{Qi} = 0$, and $\sum_{i=1}^{5} \mu_{ti} = 0$ (i, j = L, M, I, T, O). Essentially, the same set of restrictions on parameters follows from the adding-up requirement of the cost shares.

Note that the translog cost function (1) is of a most general form in the sense that no restrictions such as homotheticity and Hicks neutrality are a priori imposed. If the production process is not characterized by these properties, the estimated coefficients of the translog cost function will be biased. Thus, these restrictions concerning the production technology together with the cost-minimizing behavior will first be statistically tested in the process of estimation.

Observe that there are parameters which appear in more than one of the five cost share functions and that all of the parameters of the five cost share functions appear in the translog cost function. The equality of these parameters is a necessary condition for the system of equations to be consistent with cost minimizing behavior of the farm. The equality of the parameters can be explicitly tested. If this test is rejected, equation (1) is not valid and hence the imposition of the equality restrictions may cause biases in the estimated parameters of the system of equations. To avoid this, one has to specify a different cost function such as a variable cost function as proposed by Brown and Christensen.

Several hypotheses concerning the structure of technology are also tested. The first hypothesis to be tested is separability of the cost function in output and input prices. Such functional separability indicates homotheticity of the technology. If the cost function is multiplicatively separable, it can be written as $C^* = F(Q) \cdot H(P,t)$. This implies the following set of restrictions on the translog cost function (1); $\delta_{Qi} = 0$ (i = L, M, I, T, O) and $\rho_{tQ} = 0$. This empirically implies that changes in output level or scale do not affect the cost shares. Second, if the primal production function exhibits constant returns to scale, then the cost function can be written as $C^*(Q, P, t) = Q \cdot H(P,t)$. This implies the following set of parameter restrictions on the translog cost function; $\alpha_Q = 1$, $\delta_{Qi} = 0$ ($i = L, M, I, T, O$), and $\rho_{Qt} = 0$. Third, the primal production function is Cobb-Douglas if its dual cost function has the form $C^* = A(t)Q^{a_Q}\prod_i P_i^{a_i}$. In terms of the translog cost function, this implies that $\gamma_{QQ} = 0$, $\gamma_{ij} = 0$ for all i and j, $\delta_{Qi} = 0$ for all i, $\rho_{tQ} = 0$, $\mu_{ti} = 0$ for all i, and $\epsilon_{tt} = 0$ ($i, j = L, M, I, T, O$). Finally, if the production function is characterized by Hicks neutral technical change, the corresponding dual cost function can be written as $C^*(Q, P, t) = A(t)\cdot f(Q, P)$. This implies the following set of parameter restrictions on the translog cost function: $\rho_{tQ} = 0$ and $\mu_{ti} = 0$ for all i (=L, M, I, T, O).

The test of these four hypotheses concerning the production technology will be carried out conditionally on the validity of the equality test, since the equality hypothesis is the maintained hypothesis of the cost function approach used in the present study.

The Allen partial elasticities of substitution (AES) among and price elasticities of demand for factor inputs in the translog cost function framework can be given as (Binswanger 1974a)

$$(3) \qquad \sigma_{ii} = \frac{\gamma_{ii} + S_i - S_i^2}{S_i^2}, \quad i = L, M, I, T, O,$$

$$(4) \qquad \sigma_{ij} = \frac{\gamma_{ij} + S_i S_j}{S_i S_j}, \quad i \neq i, \; i, j = L, M, I, T, O,$$

$$(5) \qquad \eta_{ij} = S_j \sigma_{ij}, \quad i, j = L, M, I, T, O.$$

where S_i's are the cost shares. These AES and hence the price elasticities are not constrained to be constant but may vary with the values of the cost shares.

If the test of hypothesis of Hicks neutral technical change could not be rejected, then the technical change is neutral. If it is rejected, then there exist biased impacts of technical change on the use of factor inputs. It is of great interest to evaluate such impacts numerically. In this study, Hicks' definition of bias in technical change is used in a modified version which leads to a definition of bias in terms of cost shares (Binswanger, 1974b): i.e., $B_i = (\partial S_i/\partial t)(1/S_i)$, where S_i refers to the i-th factor cost share, and $\partial S_i/\partial t$ designates the share change while keeping factor proportions constant. In terms of parameters of the translog cost function of this study, B_i is given by

$$(6) \qquad B_i = \frac{\mu_{ti}}{S_i}\frac{1}{t} .$$

Technical change is defined as i-th factor-saving, neutral, or using according as $B_i < 0$, $B_i = 0$, or $B_i > 0$.

If the test of homotheticity is rejected, then there exist biased effects of scale change on the use of factor inputs. The bias due to a scale change or nonhomotheticity of the production function is conceptually analogous to the bias due to technical change. That is, nonhomotheticity implies that as the scale of operations of the firm increases, given all other technical properties of the production process, unit requirements of one factor input will decline (or increase) compared to those of another factor input (Nadiri).

A scale change is defined as a change in output caused by a proportional change in all input prices. Therefore, the effects of output change on factor cost shares can be used to measure the nonhomotheticity of the production technology. Antle proposed a measure of nonhomotheticity in a multi-input translog profit function framework. His measure can be translated into a measure of nonhomotheticity in the framework of the multi-factor translog cost function as, $N_i = \partial \ln S_i / \partial \ln Q$. In terms of parameters of the translog cost function in this study, this can be rewritten as,

(7) $$N_i = \frac{\delta_{Qi}}{S_i} .$$

We propose in this paper to define, in a manner analogous to the case of the bias of technical change, as <u>nonhomothetically</u> i-th factor-saving, neutral, or using according as $N_i < 0$, $N_i = 0$, or $N_i > 0$.

These measures of biases, B_i and N_i, will indicate the directions and magnitudes of the effects of non-neutral technical change and nonhomotheticity, respectively, on relative uses of factors of production. However, both measures may not be appopriate to investigate the question of what factor has contributed by how much to actual changes in relative factor uses. In order to measure the degree of such a contribution, it may be useful to apply a decomposition analysis which can be developed as follows.

To begin, write the cost-minimizing input demand as,

(8) $$X_i^* = X_i^* (Q, P_L, P_M, P_I, P_T, P_O, t).$$

By differentiating (8) totally with respect to time, dividing both sides by X_i^*, and expressing the growth rate by $G(\cdot)$, we obtain,

$$G(X_i^*) = \frac{\partial \ln X_i^*}{\partial \ln Q} G(Q) + \sum_{k=1}^{5} \frac{\partial \ln X_i^*}{\partial \ln P_k} G(P_k) + \frac{\partial \ln X_i^*}{\partial t}$$

$$i, k = L, M, I, T, O.$$

A change in relative factor use is given by the change in the factor proportion as $G(X_i^*/X_j^*) = G(X_i^*) - G(X_j^*)$, which, by making use of parameters of the translog cost funtion of this study, reduces to:

$$(9) \qquad G(X_i^*) - G(X_j^*) = \left[\frac{\delta_{Q_i}}{S_i} G(Q) - \frac{\delta_{Q_j}}{S_j} (G(Q)\right] + \left[\sum_{k=1}^{5} S_k \sigma_{ik} G(P_k) - \sum_{k=1}^{5} S_k \sigma_{jk} G(P_k)\right] + \frac{1}{t}\left[\frac{\mu_{ti}}{S_i} - \frac{\mu_{tj}}{S_j}\right]$$

$i \neq j, \quad i, j, k = L, M, I, T, O.$

The first term measures the effect of a scale change on the relative factor use (the scale effect hereafter). Note that if the technology is homothetic, this term vanishes since $\delta_{Qi} = 0$ for all i (=L, M, I, T, O). The second term measures the effect of factor substitutions due to factor price changes (the total substitution effect hereafter). The last term measures the effect of technical change. Note however that if the technical change were Hicks neutral, then its effects on the proportional changes in requirements for the two factor inputs would have to be identical. Therefore, the last term catches the effect of non-neutral technical change (the biased technical change effect hereafter).[3]

3. Statistical Method

For statistical specification we assume an additive error with zero expectations and finite variance for each of the six equations of the model given in equations (1) and (2). The covariance of the errors of any two equations is permitted to be nonzero for the same farm. However, the covariances of the errors of any two equations corresponding to different farms are assumed to be identically zero. Given this specification of errors, Zellner's method provides an asymptotically efficient estimators. Moreover, the efficiency of estimation can be increased by imposing known restrictions on the coefficients in the equations.

We impose a priori only the linear homogeneity restrictions on the translog cost function (1) and the adding-up (which is equivalent to the linear homogeneity) restrictions on the cost share equations. This allows us to exclude arbitrarily any one equation from the five cost share equations. The cost share equation of other inputs was then omitted. The estimates of the coefficients of this equation can easily be obtained by making use of the parameter relationships of the adding-up restrictions after the system is estimated.

The set of final estimating equations are as follows.

$$(10) \quad \ln C^*/P_0 = \alpha + \alpha_Q \ln Q + \sum_{i=1}^{4} \alpha_i \ln P_i/P_0 + \epsilon_t \ln t$$

$$+ \frac{1}{2} \gamma_{QQ} (\ln Q)^2 + \frac{1}{2} \sum_{i=1}^{4} \sum_{j=1}^{4} \gamma_{ij} \ln P_i/P_0 \ln P_j/P_0$$

$$+ \sum_{i=1}^{4} \delta_{Qi} \ln Q \ln P_i/P_0 + \rho_{tQ} \ln Q \ln t$$

$$+ \sum_{i=1}^{4} \mu_{ti} \ln t \ln P_i/P_0 + \frac{1}{2} \epsilon_{tt} (\ln t)^2,$$

$$(11) \qquad S_i = \alpha_i + \delta_{Qi} \ln Q + \sum_{j=1}^{4} \gamma_{ij} \ln P_j/P_0 + \mu_{ti} \ln t \ ,$$

$$i, j = L, M, I, T \ .$$

These five equations may be estimated jointly by Zellner's efficient method. However, since the estimates by Zellner's method are sensitive to which share equation is excluded, the procedure needs to be iterated. Thus, the Iterative Seemingly Unrelated Regression (ISUR) method was employed.[4/] In the process of estimation, the statistical hypotheses described in section two will be tested and, based on the results of the tests, constraints will be imposed on the coefficients in the equations if necessary.[5/]

4. The Data

The data required for the estimation of the model are the total cost, the quantity of output, and the prices and cost shares of the five factors of production; labor, machinery, intermediate inputs, land, and other inputs. The major sources of data used to process these variables are the Survey Report on Farm Household Economy (FHE hereafter) and the Survey Report on Prices and Wages in Rural Villages (PWRV hereafter) published annually by the Ministry of Agriculture, Forestry, and Fisheries. The data processing was carried out for the national average farm for the period 1952-82. Thus the number of observations is 31.

Now, the quantity and price indexes of output (Q and P_A) were computed by following Törnqvist approximation method of the Divisia index.[6/] For this computation eleven different categories of farm products were distinguished for crop and livestock products. The base year of these (and the following) indexes is 1952.

The quantity and price indexes of machinery (X_M and P_M), intermediate inputs (X_I and P_I), and other inputs (X_0 and P_0) were also constructed by the Törnqvist method. In these computations, the cost of machinery ($P_M X_M$) was defined as the sum of the costs for machinery, energy, and rentals; the cost of intermediate inputs ($P_I X_I$) as the sum of the expenditures on fertilizer, feed, agri-chemicals, materials, clothes, and others; and the cost of other inputs ($P_0 X_0$) as the sum of the expenditures on animals, plants, and farm buildings and structures. The necessary data were taken from the FHE. In addition, the price data necessary for computing the Törnqvist indexes were obtained from the PWRV.

The quantity of labor (X_L) was defined as the total number of male-equivalent labor hours of operators, family, and hired workers. The number of male-equivalent labor hours by female workers was estimated by multiplying the number of female labor hours by the ratio of female daily wage rate to male wage rate which can be obtained annually from the PWRV. The price of labor (P_L) was obtained by dividing the wage bill for temporary hired labor by the number of male-equivalent labor hours of temporary hired labor. The labor cost ($P_L X_L$) was defined as the sum of the labor cost for operator and family workers imputed by P_L and the wage bill for hired labor.

The quantity of land (X_T) was defined as the total area of arable land. The price of land (P_T) was obtained by dividing the cost for rented land by the rented land area. The land cost ($P_T X_T$) was estimated by multiplying P_T by X_T.

Finally, the total cost (C) was defined as the sum of the expenditures on these five categories of factor inputs, i.e., $C = \sum_{i=1}^{5} P_i X_i$ (i = L, M, I, T, O). The cost share (S_i) was obtained by dividing the expenditure on each category of factor inputs ($P_i X_i$) by the total cost (C).

5. Empirical Results

Tests of Hypotheses and Final Specification

The five statistical hypotheses described in section two were tested.[7/] They are (1) equality, (2) homotheticity, (3) constant returns to scale, (4) Cobb-Douglas production function, and (5) Hicks neutral technical change. We employed test statistics based on F ratios. To control the overall level of significance of the series of tests, the overall level of significance was set at 0.05. This implies that the probability of rejecting a true hypothesis in our series of tests is 0.05. We first assigned a level of significance of 0.01 to the test of the equality restrictions implied by cost minimization. We then assigned a level of significance of 0.04 to the rest four tests of restrictions on the technology structure. These four sets of tests are nested; under the null hypothesis, the sum of levels of significance provides a close approximation to the level of significance for the four sets of tests simultaneously.

Test statistics are presented in Table 1. At a level of significance of 0.01 we cannot reject the equality hypothesis, indicating that the restrictions implied by cost minimization is valid. Proceeding conditionally on the validity of the hypothesis of cost minimization, the four hypotheses

Table 1. Statistical Hypotheses Tested

Hypothesis		Computed F	Critical $F_{0.01}$
1. Equality	(28, 99)	1.21	2.03
Conditional on equality			
2. Homotheticity	(5, 127)	11.4	3.17
3. Constant returns to scale	(7, 127)	29.1	2.79
4. C-D production function	(21, 127)	110.6	2.03
5. Hicks neutral technical change	(5, 127)	10.7	2.96

Note: Figures in parentheses are the degrees of freedom.

concerning the technology structure were tested.

First, we reject the null hypothesis of homotheticity. This implies that changes in output level or scale affect the cost shares. Second, we reject the null hypothesis of constant returns to scale, indicating that there exist economies (or diseconomies) of scale in agricultural production. Third, we reject decisively the null hypothesis that the production technology is represented by Cobb-Douglas function. This means that there are pairs of factor inputs whose AES are not unity. Finally, we reject the null hypothesis of Hicks neutral technical change, implying that there exist biased impacts of technical change on relative uses of factor inputs.

Based on the results of the tests of hypotheses, the system of the translog cost function and the four cost share equations were jointly estimated by imposing the restrictions which are tested but not rejected. In the present case, only the equality restrictions were imposed. The implied estimates of the parameters of the system of equations can immediately be obtained by making use of the parameter relationships of the linear homogeneity restrictions. The estimates of the translog cost function is presented in Table 2.[8/] This set of estimates is referred to as our final specification and will be used for further analyses.[9/]

Allen Partial Elasticities of Substitution and Price Elasticities of Demand

In order to measure factor substitution possibilities we computed the AES (σ_{ij}) and price elasticities of demand (η_{ij}) as formulated in (3), (4), and (5). The results are presented in Table 3. Several important findings emerge from this table.

Table 2. Estimates of the Translog Cost Function for 1952-82

Parameter	Coefficient	t-value	Parameter	Coefficient	t-value
α	5.121	14.86	γ_{MI}	-0.0397	-4.200
α_Q	-1.377	-1.385	γ_{MT}	0.006	0.465
α_L	0.6986	33.17	γ_{MO}	-0.003	
α_M	0.0256	1.566	γ_{IT}	-0.0348	-2.861
α_I	0.1331	7.166	γ_{IO}	0.0320	
α_T	0.0498	1.987	γ_{TO}	-0.0151	
α_O	0.0929		δ_{QL}	-0.1276	-3.506
ϵ_t	0.5903	1.447	δ_{QM}	-0.0050	-0.201
γ_{QQ}	-2.552	-1.979	δ_{QI}	0.0871	2.876
γ_{LL}	-0.0657	-2.548	δ_{QT}	0.0191	0.511
γ_{MM}	0.0673	6.218	δ_{QO}	0.0405	
γ_{II}	0.0425	3.128	ρ_{tQ}	-0.4149	-1.756
γ_{TT}	-0.0000	-0.001	μ_{tL}	-0.0460	-3.319
γ_{OO}	-0.0553		μ_{tM}	0.0277	2.686
γ_{LM}	-0.0251	-2.111	μ_{tI}	0.0330	2.782
γ_{LI}	0.0136	0.866	μ_{tT}	-0.0128	-0.805
γ_{LT}	0.0499	3.132	μ_{tO}	-0.0147	
γ_{LO}	0.0409		ϵ_{tt}	1.130	2.051

Note: The coefficients without the t-values were computed by making use of the linear homogeneity restrictions.
In this computation, however, the statistically insignificant coefficients at the 20 percent level were assumed to be zero.

Table 3. Own-Price Elasticities and Allen Partial Elasticities of Substitution (Averages for 1952-82)

	Labor	Machinery	Intermediate inputs	Land	Other Inputs
Own-price elasticities	-0.61 (0.09)	-0.25 (0.16)	-0.59 (0.00)	-0.88 (0.04)	-1.96

Allen partial elasticities of substitution

	Machinery	Intermediate inputs	Land	Other Inputs
Labor	0.55 (0.07)	1.0 (0)	1.91 (0.24)	2.48
Machinery		-0.96 (0.73)	1.0 (0)	0.58
Intermediate inputs			-0.82 (0.90)	3.99
Land				-1.64

Note: Standard errors in parentheses are computed as follows:

$$SE(\eta_{ii}) = \frac{SE(\gamma_{ii})}{S_i} \; ; \; SE(\sigma_{ij}) = \frac{SE(\gamma_{ij})}{S_i S_j}$$

For the estimates concerning with other inputs, standard errors cannot be computed, since the $\hat{\gamma}_{iO}$ (i = L, M, T, I, O) were obtained as implied estimates through the linear homogeneity constraints.

First, the own-price elasticities of demand for all the factor inputs except for other inputs were found to be less than one in absolute values, indicating inelastic demand for factor inputs by farms. This result is consistent with that found by Kako. Second, intermediate inputs, land, and other inputs were found to be good substitutes for labor. However, the AES between labor and machinery is less than one, indicating that the price-induced substitutability between these two factor inputs has been low. Our estimate, 0.55, is fairly smaller than Kako's 0.93. This difference may have come not only from his assumption of homotheticity in the model, but also from the different data sets used in the two studies. Third, intermediate inputs which are composed mainly of fertilizers, agri-chemicals, and feed were found to be a complement of both machinery and land.

In sum, the substitutability of labor with machinery, intermediate inputs, land, and other inputs and the complementarity of intermediate inputs with machinery and land may indicate that simultaneous promotion of mechanical and bio-chemical technologies in postwar Japanese agriculture has played an important role in reducing labor input in production.

Biased Impacts of Technical Change and Nonhomotheticity

Estimates of biases caused by technical change (B_i) and by nonhomotheticity (N_i) as measured respectively by equations (6) and (7) are presented in Table 4. According to this table, technical change was found to be labor- and other-inputs-saving, machinery-and intermediate-inputs-using, and land-neutral. The directions of the bias of technical change towards saving labor and using machinery and intermediate inputs appear to be associated

Table 4. Technical Change Biases (B_i) and Nonhomotheticity (N_i)
(Averages for 1952-82)

	Labor	Machinery	Intermediate inputs	Land	Other Inputs
B_i	-0.0103	0.0463	0.0237	0	-0.0307
N_i	-0.249	0	0.447	0	0.743

Note: Equations (6) and (7) were respectively used for the computations of B_i and N_i.

respectively with the rising trend of the price of labor and the declines in the prices of machinery and intermediate inputs relative to the output price. In this sense, the bias of technical change with respect to these factor inputs may be said to be consistent with the Hicksian induced innovation hypothesis. On the other hand, scale change was found to be nonhomothetically labor-saving, intermediate- and other-inputs using, and machinery- and land-neutral.

We may say from these findings that biases caused by technical change and nonhomotheticity had significant impacts on the drastic decline in labor input in postwar Japanese agriculture.

Decomposition Analysis of Changes in Relative Factor Uses

The decomposition was carried out for all the factor combination ratios by making use of equation (9). However, since our interest in this study is centered around labor demand in agriculture, the estimates for only four factor combination ratios related to labor are presented in Table 5. They are labor/machinery (L/M), labor/intermediate inputs (L/I), labor/land (L/T), and labor/other inputs (L/O).

As clearly seen in column 2 in Table 5, labor input declined drastically relative to all the other four factor inputs; the annual rates of decrease over the 1952-82 period were 12.0, 12.5, 4.0, and 5.5 percent relative to machinery, intermediate inputs, land, and other inputs, respectively. The factors responsible for these drastic decline in labor input relative to the other factor inputs are now investigated by relying on Table 5.

First, the decline in labor relative to machinery is attributed largely

Table 5. Decomposition Analysis of Annual Changes in Factor Proportions with Respect to Labor, 1952-82

(unit: %)

	Change in factor proportion	Scale effect	Total substitution effect	Biased technical change effect
Labor/Machinery	-11.95 (100.0)	-0.87 (7.3)	-5.42 (45.4)	-5.66 (47.4)
Labor/Intermediate inputs	-12.48 (100.0)	-2.43 (19.5)	-7.82 (62.6)	-2.23 (17.9)
Labor/Land	-3.97 (100.0)	-0.87 (21.9)	-3.44 (86.6)	0.34 (-8.5)
Labor/Other inputs	-5.49 (100.0)	-3.47 (63.1)	-2.28 (41.5)	0.26 (-4.7)

Note: Equation (9) was used to compute the three effects. The effects of biased technical change were obtained as residuals: That is, (change in factor proportion) - (scale effect ÷ total substitution effect).

to the total substitution effect and the biased technical change effect; 45 and 47 percent are explained by these two effects, respectively, for the period 1952-82. The contribution of the scale effect was only 7 percent. Our result does not support Kako's where the biased technical change explained as much as 70 percent of the decline in labor relative to machinery and the rest 30 percent was due to the total substitution effect for the period 1953-70. This larger estimate of the biased technical change effect by Kako might have come from his assumption of homotheticity so that he failed to distinguish the scale effect.

Second, the decline in labor relative to intermediate inputs is explained largely by the total substitution effect; the contribution of this effect was about 63 percent on the average for the 1952-82 period. The contributions of the biased technical change effect and the scale effect were on the average 18 and 20 percent, respectively.

Third, the most important factor responsible for the decline in labor relative to land was found to be the total substitution effect. In addition, the scale effect was also fairly important as indicated by a 22 percent contribution.

Finally, the decrease in labor relative to other inputs is explained mainly by the scale effect and the total substitution effect. In particular, the significant contribution of the scale effect is noteworthy; it was as large as 63 percent on the average during the whole period 1952-82. On the other hand, the biased technical change effect was negligible.

6. Concluding Remarks

The major findings in this paper can be summarized as follows. Although farmers have behaved so as to minimize costs, the production process of postwar Japanese agriculture has been characterized neither by Hicks neutrality nor homotheticity. Biases caused by technical change and nonhomotheticity were found to have resulted in significant impacts on reducing labor relative to the other factor inputs during the postwar years. These findings imply that estimation of models with the assumption of Hicks neutrality and/or homotheticity will cause significant biases in the estimates.

On the other hand, the price-induced substitutions along an isoquant hyperplane were also found to have had significant impacts on the drastic decline in labor relative to all the other inputs. We may thus conclude that the development of the biases of labor-saving and machinery- and intermediate-inputs-using technical change, together with the price-induced substitutions between labor and all the other factor inputs, has allowed a substantial amount of labor to migrate to the non-agricultural sectors during the postwar years in Japan.

Meanwhile, the biases of technical change were found to be consistent with the induced-innovation hypothesis. This may imply that both agricultural research agencies and farmers have been responsive to changes in the relative prices of factor inputs over time (Hayami and Ruttan, Binswanger and Ruttan). We may thus say that technical change characterized especially by a rapid mechanization during the postwar years has been developed in the direction of facilitating the substitution of relatively abundant factors such as machinery and intermediate inputs for the scarce factor, i.e., labor, in accordance with market price signals. The results of this study may thus suggest that agricultural development policies be formed so as to take advantages of the price-responsiveness of both farmers and agricultural research agencies.

An important limitation of this study is the implicit assumption of the constancy of the γ_{ij} coefficients over the sample period. This limitation may be overcome by introducing the translog cost function with time-varying parameters as developed by Stevenson and Greene. Furthermore, since livestock production has grown so rapidly that the share of it in the total agricultural production has become almost as equal to that of rice production in the recent years, a multi-output model may give us better estimates with less aggregation bias. In both cases, however, a substantial number of observations is required.

Footnotes

1/ We have chosen to use the cost function for three reasons. First, the government has regulated output prices through price programs at certain levels during the period under question. This may have disturbed the principle of marginal cost pricing on the part of farmers, which in turn implies that an approarch such as a profit function may not be appropriate. Moreover, the government introduced in the late 1970s an allotment program particularly for rice production which has been the most important product in Japanese agriculture in order to balance the supply with the demand. The level of output could then be treated as exogenous. Second, the cost-function approach yields direct estimates of the various Allen partial elasticities of substitution. Third, the cost-function approach allows us to exploit duality theory without imposing any restrictions on the returns to scale in the underlying technology.

2/ Christensen, Jorgenson, and Lau (1973, p.35) give a clear distinction between the "symmetry" restrictions and the "equality" restrictions. The former is related to the symmetric Hessian of a twice-differentiable function, while the latter refers to the equality of parameters appearing in more than two equations in the system of, say, the translog cost function and the cost share functions.

3/ The first term can be dirived as follows. Since $S_i = P_i X_i^* / C^*$, $\ell n\ X_i^* = \ell n\ C^* + \ell n\ S_i - \ell n\ P_i$. Then, $\frac{\partial\ \ell n\ X_i^*}{\partial\ \ell n\ Q} = \frac{\partial\ \ell n\ C^*}{\partial\ \ell n\ Q} + \frac{\partial\ \ell n\ S_i}{\partial\ \ell n\ Q}$.

Thus, $\frac{\partial \ln X_i^*}{\partial \ln Q} - \frac{\partial \ln X_j^*}{\partial \ln Q} = \frac{\partial \ln S_i}{\partial \ln Q} - \frac{\partial \ln S_j}{\partial \ln Q}$.

In terms of parameters of the translog cost function of this study, this term is given by $\delta_{Qi}/S_i - \delta_{Qj}/S_j$. This term in effect measures the bias caused by nonhomotheticity.

The second and last terms can be interpreted diagramatically by relying on Figure 1 where I_t, E_t, and P_t are the isoquant, the equilibrium point, and the relative factor price respectively, and the slope of OR_t gives the factor proportion of X_i and X_j in the base period. Suppose now technical change took place and the isoquant shifted from I_t to I_{t+1} and that there was a change in the relative factor price from P_t to P_{t+1}. By drawing a tangent which is parallel to P_{t+1} to isoquant I_t, the shift from E_t to E_{t+1} can be decomposed into the substitution effect $E_t E_{t+1}^*$ which is attributable exclusively to the change in the relative factor price and technical change effect $E_{t+1}^* E_{t+1}$ under a proportional change in the relative factor price. The former effect corresponds to the second term in equation (9).

The latter effect needs a further explanation. Since

$\frac{\partial \ln X_i^*}{\partial t} = \frac{\partial \ln C^*}{\partial t} + \frac{\partial \ln S_i}{\partial t} - \frac{\partial \ln P_i}{\partial t}$, $\frac{\partial \ln X_i^*}{\partial t} - \frac{\partial \ln X_j^*}{\partial t} =$

$\left(\frac{\partial \ln S_i}{\partial t} - \frac{\partial \ln S_j}{\partial t}\right) - \left(\frac{\partial \ln P_i}{\partial t} - \frac{\partial \ln P_j}{\partial t}\right)$. However, since we are evaluating the effect of technical change with a proportional change in the relative factor price as seen in the figure, the last term of this equation vanishes, and the first term reduces to $\frac{1}{t}\left[\frac{\mu_{ti}}{S_i} - \frac{\mu_{tj}}{S_j}\right]$ in terms of the translog cost function of this study. This term actually measures the biased effect of technical change.

4/ Refer to Oberhofer and Kmenta for details.

5/ Note however that the tests of the equality hypothesis and the hypotheses on the technology structure can now be expressed in simpler forms because of the a priori imposition of the linear homogeneity restrictions.

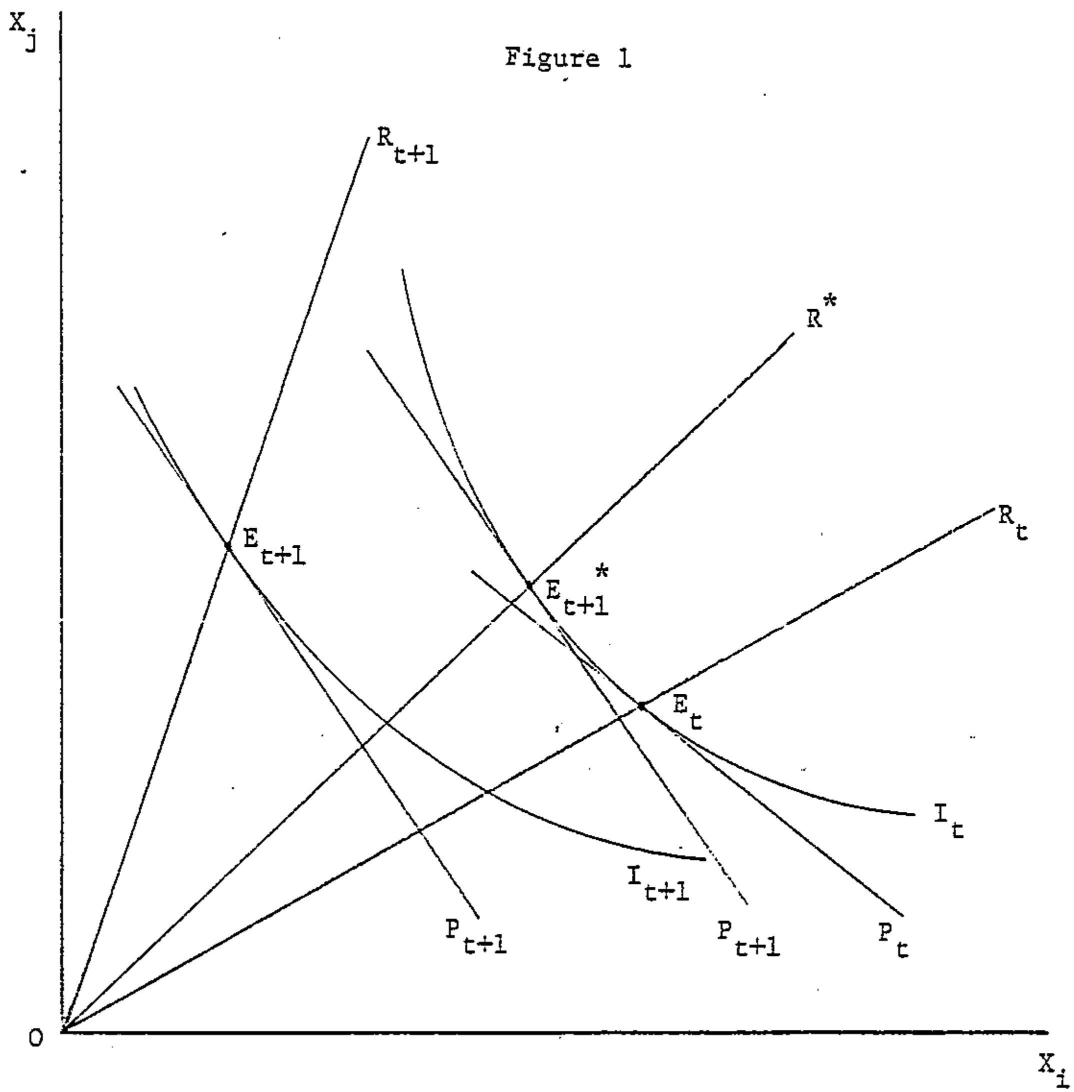
6/ Refer to Binswanger (1974a, p.385) for the details of computation.

7/ The translog cost function (10) and the four cost share equations (11) were estimated first by ordinary least squares method in order to see the goodness of fit. The R^2's were 0.999, 0.984, 0.924, 0.820, and 0.888 respectively for the translog cost function, the labor cost share, the machinery cost share, the intermediate inputs cost share, and the land cost share equations, indicating a fairly good fit of the model.

8/ The estimates of the cost share equations were omitted, since they are all included in the estimates of the translog cost function.

9/ The fitted cost function was checked for monotonicity and concavity at each observation. The result was that all the five cost shares estimated were positive and the Hessian was negative semi-definite at each observation, implying that the translog cost function represented by the estimated parameters in Table 2 is well-behaved within the region of sample observation.

Figure 1



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