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Labor productivity measurement in Japanese agriculture, 1956–90

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Abstract

This paper investigates the factors responsible for a drastic decline in the growth rate of labor productivity of the agricultural sector for the 1956–90 period. 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.

1. Introduction

Japanese agriculture experienced a high rate of growth of labor productivity during the period of the mid-1950s through the late 1960s, namely 6.81% for the 1956–68 period. However, immediately after this period, it faced a significant slowdown in the growth rate of labor productivity: 3.74% for the 1969–90 period.

The objective of this paper is to investigate empirically the factors responsible for the decline in the growth rate of labor productivity of the agricultural sector for the 1956–90 period. To pursue this objective, this paper devises a new procedure which enables one to link the growth rate of labor productivity with that of total factor productivity (TFP).

The conventional growth accounting method has been applied to a decompositional analysis of the growth rate of labor productivity (Berndt and Watkins, 1981; Denny and Fuss, 1983; Morrison,

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1993). According to this method, the growth rate of labor productivity is decomposed into the rates of growth of factor intensities and TFP. [1] However, to derive this decompositional relationship, one has to introduce the following strict assumptions on the production technology: (1) constant returns to scale; (2) Hicks-neutral technological change (see Hicks, 1963) ; and (3) the producer equilibrium. If any of these assumptions are not satisfied in reality, the conventional growth accounting procedure may cause bias in the results.

Due, in particular, to the first two assumptions, one cannot analyze, by the conventional method, the economic factors behind changes in the growth rates of factor intensities and TFP. While on the one hand shifts in relative prices and the bias of technological change are major possibilities for changes in the growth rate of factor intensities, on the other hand economies of scale and the rate of technological change are major components for changes in the growth rate of TFP.

As will be explained in detail in Section 2, the new procedure decomposes the growth rate of labor productivity into the total substitution effect which consists of the substitution effects due to factor price changes and biased technological change, and the TFP effect which is composed of the effects due to scale economies and technological changes. For the empirical measurement of these effects, a non-homothetic and Hicks non-neutral translog cost function is specified and estimated for the 1956–90 period.

This paper is organized as follows. Section 2 demonstrates a new procedure which links the rate of growth of labor productivity and that of TFP by decomposing the former into various effects. Section 3 presents empirical results. In Section 4, some concluding remarks are offered. The data necessary for the empirical estimation of the translog cost function are given in the Appendix.

[1] Doi (1985) applied this procedure to Japanese rice production for the 1960–80 period.

2. Analytical framework

To begin with, it is assumed that the agricultural sector has a cost function as a dual of the production function which satisfies the neoclassical regularity conditions:

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

where Q is the quantity of output; P is a factor price vector which corresponds to a factor input vector (X), which is composed of labor (X_L), machinery (X_M), intermediate inputs (X_I), land (X_B) and other inputs (X_O); $C = \Sigma_{i=1}^{5} P_i X_i$ is the minimized total cost; t is time as an index of technological change; and C is homogeneous of degree 1 in factor prices.

Shephard's lemma holds for the cost function (see Shephard, 1970):

$$X_i(Q, P, t) = \frac{\partial C(Q, P, t)}{\partial P_i} \qquad i = \mathrm{L, M, I, B, O} \tag{2}$$

which is the cost-minimizing factor demand function. Multiplying both sides of (2) by P_i/C, the cost share equation of the ith factor input S_i can be obtained as:

$$S_i = \frac{P_i X_i}{C} = \frac{\partial C}{\partial P_i}\frac{P_i}{C} = \frac{\partial \ln C}{\partial \ln P_i} \qquad i = \mathrm{L, M, I, B, O} \tag{3}$$

Now, let us decompose the growth rate of labor productivity into various effects. [2] The growth rate of labor productivity can be expressed as the growth rate of output minus the growth rate of labor input:

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

where $G(\cdot)$ 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. Dif-

[2] This procedure can be applied to the decomposition of the growth rate of any single-factor productivity.

ferentiating totally the labor demand function given in Eq. (2) with respect to time, dividing both sides by X_L and rearranging yields the following equation:

$$\frac{d \ln X_L}{dt} = \frac{\partial \ln X_L}{\partial \ln Q} G(Q) + \sum_{i=1}^{5} \frac{\partial \ln X_L}{\partial \ln P_i} G(P_i) + \frac{\partial \ln X_L}{\partial t} \quad i = L, M, I, B, O$$
$$= \frac{\partial \ln X_L}{\partial \ln Q} G(Q) + \sum_{i=1}^{5} e_{Li} G(P_i) + \frac{\partial \ln X_L}{\partial t} \quad (5)$$

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 ($i = L, M, I, B, O$). Eq. (5) shows that the growth rate of labor input can be decomposed into output effect (the first term), price effect (the second term), and technological change effect (the third term).

The output 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 (3) linked by the first equality sign and rearranging yields:

$$\ln X_L = \ln C + \ln S_L - \ln P_L \quad (6)$$

Using this, the following relations are obtained:

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

$$\frac{\partial \ln X_L}{\partial t} = \frac{\partial \ln C}{\partial t} + \frac{\partial \ln S_L}{\partial t} = \lambda + \frac{1}{S_L} \frac{\partial S_L}{\partial t} \quad (8)$$

where ε_{CQ} is the cost elasticity, and λ indicates the rate of shift of the cost function due to technological change. [3] The second term of (7) indicates the non-homotheticity effect on the demand for labor due to changes in output, while the second term of (8) indicates the effect due to the bias of technological change. Substituting (5), (7) and (8) into (4) and rearranging yields:

$$G\left(\frac{Q}{X_L}\right) = \left[\left\{-\sum_{i=1}^{5} e_{Li} G(P_i)\right\} - \left\{\frac{1}{S_L} \frac{\partial S_L}{\partial \ln Q} G(Q) + \frac{1}{S_L} \frac{\partial S_L}{\partial t}\right\}\right] + \left[(1 - \varepsilon_{CQ}) G(Q) + (-\lambda)\right] \quad (9)$$

The first component of the first term on the right-hand side of (9) indicates the substitution effect on labor demand due to changes in the factor prices. The second component of the first term is the sum of the non-homotheticity effect and biased technological change effect. Following Antle and Capalbo (1988), the sum of these two effects is defined as the (extended) Hicksian biased technological change effect (Blackorby et al., 1977). All the three components of the first term are factors which lead to factor substitutions. Therefore, the sum of these effects is called the total substitution effect in this study.

Next, $(1 - \varepsilon_{CQ})$ of the first component in the second term is the well-known measure of scale economies (Christensen and Greene, 1976). The second component of this term indicates the dual rate of technological change, i.e. the rate of cost diminution. Denny, Fuss and Waverman (1981) showed that when the assumption of constant returns to scale is eliminated, the growth rate of total factor productivity (TFP) is decomposed into the effect due to scale economies, $(1 - \varepsilon_{CQ})$, and the effect due to technological change, $(-\lambda)$. Therefore, the second term of Eq. (9) is exactly equivalent to the growth rate of TFP.

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 (Morrison, 1993, p. 35).

It can be said that this study has modified this procedure by establishing a linkage between labor productivity and TFP in the following sense. Unlike the conventional growth accounting method, if both constant returns to scale and

[3] It is assumed that the price of labor is fixed and therefore not a function of the quantity of output and technological change.

Hicks neutrality are not assumed a priori, changes in the growth rates of factor intensities can be decomposed into price effect, non-homotheticity effect, and biased technological change effect, while changes in the growth rate of TFP can be decomposed into the effects due to scale economies and technological change as shown in Eq. (9). If parameters such as price elasticities of labor demand, cost elasticity, and the rate and bias of technological change are estimated, all of these effects can be quantitatively measured. The empirical estimation of those effects expressed in (9) will not only be very interesting from the academic viewpoint, but also very important from the viewpoint of offering information for policy-makings.

In order to obtain the necessary parameters for the decomposition analysis based on Eq. (9), a translog form is specified for the cost function (1):

$$\begin{aligned}\ln C = {} & \alpha_0 + \alpha_Q \ln Q + \sum_{i=1}^{5} \alpha_i \ln P_i + \beta_t t \\ & + \tfrac{1}{2}\gamma_{QQ}(\ln Q)^2 + \tfrac{1}{2}\sum_{i=1}^{5}\sum_{j=1}^{5} \gamma_{ij} \ln P_i \ln P_j \\ & + \sum_{i=1}^{5} \delta_{Qi} \ln Q \ln P_i + \mu_{Qt} \ln Qt \\ & + \sum_{i=1}^{5} \mu_{it} \ln P_i t + \tfrac{1}{2}\beta_{tt} t^2 \end{aligned} \tag{10}$$

where $\gamma_{ij} = \gamma_{ji}$ (symmetry) and $\Sigma_{i=1}^{5}\alpha_i = 1$, $\Sigma_{i=1}^{5}\gamma_{ij} = \Sigma_{i=1}^{5}\delta Q_i = \Sigma_{i=1}^{5}\mu_{it} = 0$ for all $i = j =$ L, M, I, B, O (linear homogeneity in factor prices).

The cost-share (S_i) and revenue share (R) functions are derived through the Shephard's lemma and expressed for the translog cost function of this study as:

$$S_i = \frac{\partial \ln C}{\partial \ln P_i} = \alpha_i + \sum_{j=1}^{5} \gamma_{ij} \ln P_j + \delta_{Qi} \ln Q + \mu_{it} t$$

$$i = j = \mathrm{L, M, I, B, O} \tag{11}$$

$$R = \frac{\partial \ln C}{\partial \ln Q} = \alpha_Q + \sum_{i=1}^{5} \delta_{Qi} \ln P_i + \gamma_{QQ} \ln Q + \mu_{Qt} t \tag{12}$$

The translog cost function (10) has a general form since homotheticity and Hicks neutrality restrictions are not imposed a priori. Instead, these restrictions will be statistically tested in the process of estimation of this function.

If the primal production function is homothetic, then the dual cost function can be written as $C = F(Q, t) \cdot H(P, t)$. This implies the following set of restrictions on the translog cost function (10): $\delta_{Qi} = 0$ ($i =$ L, M, I, B, O), implying that changes in output level do not have any effect on the cost shares.

Next, constant returns to scale can also be easily tested in the cost function framework. 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: $\alpha_Q = 1$, $\gamma_{QQ} = \delta_{Qi} = \mu_{Qt} = 0$ ($i =$ L, M, I, B, O).

Furthermore, 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: $\mu_{Qt} = \mu_{it} = 0$ ($i =$ L, M, I, B, O). [4]

Now, the necessary parameters for the decomposition Eq. (9) can be computed based on the translog cost function (10) as follows.

First, the price elasticities of demand for labor can be computed through (Berndt and Christensen, 1973):

$$e_{\mathrm{LL}} = S_{\mathrm{L}}\sigma_{\mathrm{LL}} \tag{13}$$

$$i = \mathrm{M, I, B, O}$$

$$e_{\mathrm{L}i} = S_i \sigma_{\mathrm{L}i} \tag{14}$$

where σ_{LL} and $\sigma_{\mathrm{L}i}$ are the Allen partial elasticities of substitution and can be obtained by:

$$\sigma_{\mathrm{LL}} = \left(\gamma_{\mathrm{LL}} + S_{\mathrm{L}}^2 - S_{\mathrm{L}}\right)/S_{\mathrm{L}}^2 \tag{15}$$

$$i = \mathrm{M, I, B, O}$$

$$\sigma_{\mathrm{L}i} = \left(\gamma_{\mathrm{L}i} + S_{\mathrm{L}} S_i\right)/S_{\mathrm{L}} S_i \tag{16}$$

[4] To be more specific, this is a test for an extended Hicks-neutral technological change (Blackorby et al., 1977).

Second, the non-homotheticity and biased technological change effects with respect to labor are given, respectively, by:

$$\frac{1}{S_L}\frac{\partial S_L}{\partial \ln Q}=\frac{\delta_{QL}}{S_L} \quad (17)$$

$$\frac{1}{S_L}\frac{\partial S_L}{\partial t}=\frac{\mu_{Lt}}{S_L} \quad (18)$$

Finally, the cost elasticity and the dual rate of technological change can be obtained respectively by:

$$\varepsilon_{CQ}=\frac{\partial \ln C}{\partial \ln Q}=\alpha_Q+\sum_{i=1}^{5}\delta_{Qi}\ln P_i+\gamma_{QQ}\ln Q+\mu_{Qt}t \quad (19)$$

$$i=\mathrm{L,M,I,B,O}$$

$$\lambda=\frac{\partial \ln C}{\partial t}=\beta_t+\sum_{i=1}^{5}\ln P_i+\mu_{Qt}\ln Q+\beta_{tt}t \quad (20)$$

Note here that if the production technology is characterized by constant returns to scale and Hicks-neutral technological change, then $\varepsilon_{CQ}=1$, $\delta_{QL}=0$ and $\mu_{Lt}=0$. This implies that the growth rate of labor productivity in Eq. (9) can be decomposed into the substitution effect due only to changes in the factor prices and (neutral) technological change effect. Note further that the technological change effect $(-\lambda)$ can be computed as residual in Eq. (9). If this procedure is employed, however, there is a possibility for this effect to capture measurement errors on parameters such as e_{Li}, ε_{CQ}, δ_{QL}, μ_{Lt} and S_L. In order to avoid such errors, this paper employs a procedure where the technological change effect $(-\lambda)$ is parametrically obtained through Eq. (20).

Since the right-hand-side variable Q in the cost function (10) 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, four of the five cost share equations, and one revenue share equation. The method chosen was iterative three stage least squares (I3SLS). The I3SLS procedure is an extension to simultaneous-equation system of the Zellner (1962) treatment of groups of seemingly unrelated regression equations which contain jointly dependent endogenous variables (Johnston 1972, pp. 395–400). The required instrumental variables consisted of variables exogenous to the cost structure-output and input prices and time. [5] In this process, the restrictions due to symmetry and linear homogeneity in prices were imposed. The coefficients of the omitted cost share equation were obtained using the linear homogeneity restrictions after the system was estimated.

3. Empirical results

For the tests of the three hypotheses, i.e. homotheticity, constant returns to scale and Hicks neutrality, a Wald Chi-square test was applied. The computed Chi-square statistics for these three hypotheses were 52.6, 322.1 and 73.4 with degrees of freedom 5, 8 and 6, respectively. Hence, all the three hypotheses concerning the structure of production technology were strongly rejected at the 0.01 significance level. This implies that the decompositional analyses based on the conventional growth accounting method such as Doi (1985), Hayami (1975) and Yamada (1984) may have biases in the results.

Thus, no further restrictions other than those for the symmetry and homogeneity were imposed in estimating the system of equations. The coefficients of the omitted (in the present case, the other inputs) cost share equation were obtained using the parameter relations of linear homogeneity restrictions. The results are presented in Table 1. This set of estimates is referred to as the final specification of the model and will be used for further analyses. [6]

[5] Furthermore, in a sector-level analysis, the price of land may be considered to be endogenous. However, it is very likely in postwar Japanese agriculture that prices of lands even for farming purposes have in general been strongly affected by land prices for non-agricultural purposes such as constructions of factories, roads, railroads, and residential housings. It is thus assumed in this paper that the price of land is exogenous in the cost function model.

[6] Monotonicity and concavity of the cost function were checked and satisfied for the approximation point.

Table 1
Parameter estimates of the translog cost function for Japanese agricultural sector, 1956–90

α_O	12.0457	γ_{BB}	0.0406	δ_{QL}	−0.0710
	(0.0069)		(0.0241)		(0.0326)
α_Q	0.8478	γ_{OO}	0.0930	δ_{QM}	0.0227
	(0.0110)		(0.0080)		(0.0157)
α_L	0.2980	γ_{LM}	−0.0064	δ_{QI}	0.1902
	(0.0042)		(0.0052)		(0.0406)
α_M	0.0885	γ_{LI}	0.0422	δ_{QB}	−0.1212
	(0.0011)		(0.0132)		(0.0378)
α_I	0.3099	γ_{LB}	−0.0877	δ_{QO}	−0.0207
	(0.0029)		(0.0121)		(0.0151)
α_B	0.1818	γ_{LO}	−0.0704	μ_{Qt}	0.0041
	(0.0035)		(0.0050)		(0.0021)
α_O	0.1219	γ_{MI}	−0.0063	μ_{Lt}	−0.0046
	(0.0011)		(0.0097)		(0.0008)
β_t	−0.0084	γ_{MB}	−0.0282	μ_{Mt}	0.0019
	(0.0012)		(0.0074)		(0.0004)
γ_{QQ}	0.7227	γ_{MO}	−0.0011	μ_{It}	0.0004
	(0.1064)		(0.0049)		(0.0009)
γ_{LL}	0.1223	γ_{IB}	−0.0143	μ_{Bt}	0.0023
	(0.0126)		(0.0213)		(0.0010)
γ_{MM}	−0.0143	γ_{IO}	−0.0546	μ_{Ot}	0.0001
	(0.0055)		(0.0112)		(0.0004)
γ_{II}	0.0331	γ_{BO}	0.0331	β_{tt}	0.0005
	(0.0294)		(0.0084)		(0.0001)

Note: Figures in parentheses are asymptotic standard errors. R^2 was 0.9757.

Using parameter estimates of the translog cost function in Table 1, the factor demand and substitution elasticities, the rate and bias of technological change, and the cost elasticity were computed for the individual sample for the entire 1956–90 period as well as for the approximation point (1985). To save space, only those for the approximation point are presented in Table 2. As may be inferred from the values of the computed asymptotic values, the variations of these indicators over the entire period were fairly small. Several findings are noteworthy here from this table:

First, the own-price elasticity of demand for labor was found to be −0.291, indicating that the demand for labor in agriculture is inelastic. Technical possibilities of substitution exist between labor and machinery, and labor and intermediate inputs. In particular, intermediate inputs are rather good substitutes for labor. Furthermore, land and other inputs were found to be complement of labor. Generally speaking, these results support the findings of Kako (1978), Chino (1984) and Kuroda (1987) to name only a few.

Second, the negative rate of cost diminution is 0.0079, indicating that the annual rate of technological progress was 0.79% for the approximation point.

Third, both non-homotheticity bias and technological change bias were found to be negative. This indicates that technological change was biased towards saving labor.

Finally, because the cost elasticity ε_{CQ} is 0.848, $(1-\varepsilon_{CQ})$ is equal to 0.152, indicating that there existed increasing returns to scale.

It must be noted here that when an aggregate data set is used to estimate the cost function as in this study, the magnitude of the cost elasticity (which measures the cost reduction effect with respect to an increase in the output level) may not directly be regarded as indicating the existence of scale economies. This is because it is very likely that even if the output scales of the individual firms have remained the same, an increase in the number of firms has caused an increase in the level of the aggregate output. However, this paper argues as follows. Even if such a phenomenon has occurred, if one still obtains a less-than-unity cost elasticity based on the aggregate data set which reflects the increase in the aggregate output level due to the increase in the number of firms, he may assert that there exist scale economies in that industry, because such a finding may indicate that there exist firms in that industry which enjoy scale economies by increasing the output levels.

In reality, the total number of farms decreased, while the level of total output increased during the 1956–90 period in postwar Japanese agriculture. In the process of decrease in the total number of farms, the numbers of larger scale farms increased, which may indicate the existence of scale economies in the agricultural industry. Furthermore, empirical results based on per-farm databases have shown that there have existed scale economies in postwar Japanese agriculture with similar magnitudes as the one obtained in this paper (Kako, 1979; Chino, 1984; Kuroda, 1989). Thus, the cost elasticity obtained in this

Table 2
Selected parameter estimates at the approximation point

Demand and Allen substitution elasticities					Cost elasticity	Rate of cost diminution	Non-homotheticity bias	Technological change bias
e_{LL}	e_{LM}	e_{LI}	e_{LB}	e_{LO}				
σ_{LL}	σ_{LM}	σ_{LI}	σ_{LB}	σ_{LO}	ϵ_{CQ}	λ	δ_{QL}/S_L	μ_{Lt}/S_L
−0.291	0.067	0.451	−0.112	−0.114	0.848	−0.0079	−0.238	−0.0156
−0.978	0.756	1.457	−0.619	−0.937	(77.4)	(−7.1)	(−2.2)	(−5.8)
(−6.9)	(3.9)	(10.2)	(−2.8)	(−7.0)				

Figures in parentheses are asymptotic *t*-values. The *t*-values for the demand and substitution elasticities are theoretically equal (Binswanger, 1974).

paper may be used as a measure of scale economies.

It may be worth explaining at this juncture about the divisions into several sub-periods of the 1956–90 period. To begin with, the entire period was divided into two sub-periods, 1956–68 and 1969–90. The year 1969 was chosen as a benchmark year for this subdivision because this was the year where an acreage restriction program was introduced for the first time in the postwar years into the Japanese rice, a crop that is widely considered as the most important product of the Japanese agriculture. Note that the 1956–68 period corresponds to the period of rapid growth of the Japanese economy as a whole which ended in 1972. In this period, the average annual compound rate of growth was 9.3%.

During the 1969–90 period, while the government consistently strengthened the acreage restriction programs, it launched an important program of reorganizing paddy utilization for rice production in 1978. The program has been aimed at encouraging movements of paddy fields in order for large scale farms to exploit scale economies. Thus, choosing 1978 as another benchmark year, the 1969–90 period was further divided into two sub-periods, 1969–77 and 1978–90. Although for the first several years of the 1969–77 period, the growth rate of the Japanese economy as a whole was still high, it became

Table 3
Decomposition of the growth rate of labor productivity, 1956–90 (unit: %)

Period	Growth rate of labor productivity	Total substitution effect					TFP effect			Nonparametrically estimated TFP growth rate	Residual
		Price effect	Hicks-biased technical change effect: Non-homotheticity effect	Biased technical change effect	Sub-total	Total	Scale economies effect	Technical change effect	Total		
1956–68	6.81	2.93	0.75	1.41	2.16	5.09	0.61	1.43	2.04	2.58	−0.32
	(100.0)	(43.0)	(11.0)	(20.7)	(31.7)	(74.7)	(9.0)	(21.0)	(30.0)		(−4.7)
1969–90	3.74	1.19	0.07	1.48	1.55	2.74	0.05	1.01	1.06	1.17	−0.06
	(100.0)	(31.8)	(1.9)	(39.6)	(41.4)	(73.3)	(1.3)	(27.0)	(28.3)		(−1.6)
1969–77	5.16	1.45	0.18	1.37	1.55	3.00	0.13	1.25	1.38	1.06	0.78
	(100.0)	(28.1)	(3.5)	(26.6)	(30.0)	(58.1)	(2.5)	(24.2)	(26.7)		(15.1)
1978–90	2.46	1.16	−0.04	1.55	1.51	2.67	−0.03	0.86	0.83	1.26	−1.04
	(100.0)	(47.2)	(−1.6)	(63.0)	(61.4)	(108.5)	(−1.2)	(35.0)	(33.7)		(−42.3)
1956–90	4.90	1.89	0.26	1.45	1.71	3.60	0.19	1.17	1.36	1.41	−0.06
	(100.0)	(38.6)	(5.3)	(29.6)	(34.9)	(73.5)	(3.9)	(23.9)	(27.8)		(−1.2)

Table 4
Components of the price effect, 1956–90 (unit: ‰)

Period	Labor $-e_{LL}G(P_L)$	Machinery $-e_{LM}G(P_M)$	Intermediate inputs $-e_{LI}G(P_I)$	Land $-e_{LB}G(P_B)$	Other inputs $-e_{LO}G(P_O)$	Total
1956–68	3.51	0.00	−0.71	0.06	0.07	2.93
1969–90	2.08	−0.10	−1.78	0.62	0.37	1.19
1969–77	4.48	−0.23	−4.49	0.90	0.79	1.45
1978–90	0.90	0.04	−0.12	0.30	0.04	1.16
1956–90	2.94	−0.06	−1.79	0.47	0.33	1.89

much moderate after 1973 when the 'oil crisis' occurred. This moderate economic growth continued also for the 1978–90 period: the average annual compound growth rate for the 1973–90 period was 4.1%.

Now, the means of these parameters for each sub- and entire periods together with the growth rates of the quantity of output $G(Q)$ and the factor prices $G(P_i)$ were used for the decomposition analysis based on Eq. (9). [7] The decomposition was executed for the four sub-periods and for the entire 1956–90 period.

The results are presented in Table 3. Based on the results, a general evaluation will first be made and then followed by the differences between the sub-periods.

To begin with, for the entire 1956–90 period as well as for the two sub-periods, 1956–68 and 1969–90, it was observed that the total substitution effect contributed more than 70% to the growth rates of labor productivity. In particular, the price effect and the biased (in the present case, labor-saving) technological change effect were dominant.

As can be seen from the parameter estimates of μ_{it} in Table 1, technological change was found to be labor-saving, machinery- and land-using, and intermediate- and other-inputs-neutral. This finding supports in general the similar findings by Kako (1979), Kawagoe et al. (1986) and Kuroda (1989). The bias of technological change towards saving labor and using machinery is associated, respectively, with the rising trend of the price of labor and the declines in the prices of machinery inputs relative to the output price. In this sense, the bias of technological change with respect to these factor inputs is consistent with the Hicksian induced innovation hypothesis. This implies that the substitution effect due to biased technological change may be regarded, in a broader sense, as part of the substitution effect due to factor price changes. Thus, it may be said that the major part of the total substitution effect was composed of the substitution effects due to factor price changes. That these substitution effects due to price changes were dominant in explaining changes in the growth rates of labor productivity indicates that farmers have been very sensitive to changes in the factor prices.

What about the TFP effect? As shown in the decomposition Eq. (9), the TFP effect consists of the effects due to economies of scale and technological change. According to Table 3, the TFP effect contributed almost 30% to the growth rates of the labor productivity, for the sub- as well as for the whole periods. More specifically, the effect due to technological change was found to be much more dominant than the effect due to scale economies. This result is consistent with that by Kuroda (1989) who decomposed the TFP growth rates for different size classes of farms for the 1958–85 period.

The growth rates of non-parametrically obtained TFP are also presented in Table 3. It may be safe to say that they are fairly close to the parametrically estimated growth rates of TFP. The discrepancies between the two estimates may

[7] As inferred from the t-value for each parameter at the approximation point given in Table 2, the mean values of each parameter for the sub-periods were very close to the value at the approximation point except for the rate of cost diminution.

be largely due to measurement errors of the parameters of the system of cost function and the cost and revenue share equations.

Next, let us examine the differences in the substitution effects between the sub-periods. Firstly, the total substitution effect drastically declined from 5.09% for the 1956–68 period to 2.74% for the 1969–90 period, although their degrees of contribution to the growth rates of labor productivity were fairly close: 74.7% and 73.3%, respectively. The major factor for this decline was found to be the drastic decrease of the price effect, namely from 2.93% for 1956–68 to 1.19% for 1969–90.

To further interpret this finding, let us look into the components of the price effect, $-e_{Li}G(P_i)$, in Table 4 for the two sub-periods 1969–77 and 1978–90 instead of 1969–90. Although the magnitude of the price effects for these two sub-periods were found to be fairly close: 1.45% and 1.16%, respectively, the components behind these figures were substantially different.

After the 'oil crisis' occurred in 1973, all the factor prices increased sharply. Thus, the rates of growth of the factor prices were substantial during the 1969–77 period: 14.9%, 6.6%, 11.2%, 12.8% and 11.6% per year for labor, machinery, intermediate inputs, land and other inputs, respectively. Although the own substitution effect was as large as 4.48%, it was more than offset by the substitution effects with respect to machinery and intermediate inputs. Thus, the complementarity effects with land and other inputs were the major components for the price effect of 1.45% for the period 1969–77.

On the other hand, the annual growth rates of the factor prices became much lower during the 1978–90 period: 3.1%, −0.7%, 0.3%, 2.9% and 0.4% for the five factor inputs. Due to the sharp declines in the growth rates of the factor prices, the absolute values of all the components of the price effect became much lower compared to those for the previous period. In particular, the decreases in the effects of own substitution and substitution for intermediate inputs were found to be substantial.

The substitution effect due to the (labor-saving) bias of technological change, given by μ_{Lt}/S_L, was found to be fairly stable for the entire 1956–90 period: around 1.4–1.6% per year. On the other hand, the (labor-saving) non-homotheticity effect, given by $(\delta_{QL}/S_L)G(Q)$, was fairly significant for the 1956–68 period, namely 0.75% per year. The reason for this could mainly be due to the fairly high rate of growth of output during this period: 2.64% per year. However, due largely to the sharp decline in the growth rate of output from the 1956–68 to 1969–90 periods (2.64–0.27%), the non-homotheticity effect reduced sharply over these two sub-periods. As a result, the total Hicksian biased technological change effect declined from 2.16% for the 1956–68 period to 1.55% for the 1969–90 period.

Turning to the TFP effect, the effect due to technological change decreased consistently over time: 1.43%, 1.25% and 0.86% for the periods, 1956–68, 1969–77 and 1978–90, respectively. The effect due to scale economies was found to be fairly large for the 1956–68 period; it was 0.61% per year which explains 30% of the total TFP effect of 2.04%. However, it became very low for the latter two periods. This was due largely to the sharp decline in the growth rates of output during these periods.

It may be relevant at this point to consider the reasons why the growth rates of output and the rate of technological change decreased from the 1956–68 to the 1969–90 periods. In particular, the sharp decline in the growth rate of output resulted in the rather sharp declines not only in the non-homotheticity effect but also in the scale economies effect.

To begin with, it seems that the farmers' desire to improve management was dampened by the following factors. First, the decline in the growth of the per capita GNP due to the slowdown of the growth of the Japanese economy as a whole after the 'oil crisis' reduced the growth of the demand for agricultural commodities. Second, it is very likely that food consumption reached the saturation level. Third, the government executed fairly strict acreage restriction programs which have imposed uniform rates of restrictions, e.g. 30% set-aside, on rice farmers, whether they are growth-oriented or not. Fourth, the sharp increase in the price of land, especially during the 1970s, as well as persistent attachment to lands as a profitable asset by small-scale farms made it very difficult for growth-oriented farmers to expand their farmland.

On the other hand, although the degrees of supports were substantially reduced, the persistent price support programs for agricultural products by the government impeded competition. This in turn may have caused what Leibenstein (1976) calls a 'slack' or 'X-inefficiency' in farm management.

It may be safe to say that all these factors which are intimately associated have been responsible for the decreases in the growth rate of output as well as for the decline in the rate of technological progress in agricultural production for the years since 1969.

4. Summary and concluding remarks

This paper has shown that using a framework of a non-homothetic and Hicks non-neutral cost function, the growth rate of labor productivity can be decomposed into (1) the total substitution effect which consists of the price effect and biased technological change effect, and (2) the TFP effect which is composed of the effects due to scale economies and technological change. In this manner, the new procedure makes it possible to quantitatively capture the economic factors behind changes in the growth rates of factor intensities and TFP. Using this procedure, the causes for the sharp decline in the growth rate of labor productivity over the 1956–90 period were investigated. The empirical findings of this paper may be summarised as follows:

First, the total substitution effect contributed to the growth of labor productivity much more than the TFP effect did for the entire 1956–90 period as well as for all the sub-periods.

Second, the major cause for the drastic decline in the growth rate of labor productivity from the 1956–68 period to the 1969–90 period was the substantial decrease in the total substitution effect. Above all, the decrease in the price effect was the most important factor.

Third, the TFP effect also declined sharply from the 1956–68 to the 1969–90 periods. The effects due to both scale economies and technological change were responsible for this decline.

At least, two policy instruments may be recommended concerning an increase in the growth rate of labor productivity in the Japanese agriculture.

First, to increase the total substitution effect, policy programs for factor prices, especially for intermediate inputs such as fertilizers and agri-chemicals as well as machinery, have to be carefully designed so as to encourage substitutions of labor for these factor inputs, since, as been empirically proven, these factor inputs are good substitutes for labor.

The price levels of these intermediate inputs in Japan have been almost twice the international levels. It is strongly recommended that agricultural cooperatives take the initiative in organizing collective bargaining with the industries of chemical fertilizers, agri-chemicals, and farm machinery.

At the same time, it must be noted that it is very likely that the persistent price support programs for farm products have consistently given excuses to these industries to raise the prices or, at least, to maintain the high price levels of these inputs. Thus, relaxation of the price support programs of farm products by the government may offer weaker chances to these industries to maintain high prices of fertilizers, agri-chemicals, and machinery. Furthermore, such relaxation of price supports will in turn give strong incentives to profit-oriented farmers to make greater efforts in reducing production costs.

Second, in order to increase the TFP effect through raising the rates of output growth and technological change, strong incentives have to be given to farmers to increase output by improving management. Along this line of thought, regulations such as acreage restrictions for rice production and restrictions on farmland utilization and transactions have to be relaxed or withdrawn to a large extent.

An important limitation of this study is the implicit assumption of the constancy of the coefficients of the translog cost function over the sample period. This limitation may be overcome by introducing the translog cost function with time-varying parameters as developed by Stevenson (1980) and Greene (1983). In this case, however, a substantial number of observations is required.

Another important limitation is inadequate treatments of quality changes in factor inputs. First, human capital concepts were not taken into accounts for labor input due to shortage of data. It appears that the level of education of farmers has increased during the postwar years. If so, the quantity of labor in this study might have been underestimated.

Furthermore, the vintages of farm machinery and automobiles were note valuated in this study due simply to lack of data. Clearly, the quality of them has increased. This implies that the quantity of machinery capital input might also have been underestimated.

Finally, land input in this study does not reflect quality differences between different regions. However, it is hard to tell whether the quantity of land input in the present study is over or underestimated.

All these limitations may have caused biases in the empirical results. However, no one could tell a priori how significant and which directions the biases are.

Appendix 1

Data [8]

The variables required to estimate the cost function model are the total cost, the revenue, the quantity of total output, and the prices and cost shares of the five factors of production; labor, intermediate inputs, machinery, land, and other inputs. The data were collected and processed for the Japanese agricultural sector for the period 1956–90.

The quantity and price indexes of total output (Q and P) were computed by the Törnqvist (1936) approximation method of the Divisia index. For this computation, eleven categories of farm products were distinguished, from among crop and livestock products as well as agricultural services. The base year of these and the following indexes were set at 1985.

The sources of data for the values of products are: (a) for 1956–59, Long-Term Economic Statistics of Japan since 1868 (LTES [9]), and (b) for 1960–90, National Accounts of Agriculture and Food-Related Industries (NAAF, 1992 [10]). The data obtained from LTES were linked to the data from the NAAF at 1960.

The data sources for the price indexes of products are: (a) for 1956–59, Survey Report on Prices and Wages in Rural Villages (PWRV [11]), and (b) for 1960–90, the NAAF (1992). The PWRV data were linked to the NAAF data at 1960.

The quantity and price indexes of labor input (X_L and P_L) were obtained in the following manner. The number of work-hours per year of male and female agricultural workers were obtained using Yamada's method (Yamada, 1982). The sources of data for this computation are various issues of the Statistical Yearbook of the Ministry of Agriculture, Forestry, and Fisheries (SY [12]) and the Survey Report on Farm Household Economy (FHE [13]), published annually by the Japanese Ministry of Agriculture, Forestry, and Fisheries (MAFF). Dividing the total numbers of work-hours per male and female workers for the agricultural sector by the numbers of work-hours per day obtained from the FHE, the total numbers of work-days per year were ob-

[8] The data set will be provided on request.

[9] Choki Keizai Tokei 9, Noringyo [Agriculture and Forestry], edited by K. Ohkawa, M. Shinohara and M. Umemura, 1966. Toyo Keizai Shinposha, Tokyo.

[10] Nogyo-Shokuryo Kanrensangyo no Keizai Keisan (various issues) Statistical Bureau of the Ministry of Agriculture, Forestry, and Fisheries, Tokyo.

[11] Noson Bukka Chingin Chosa Hokoku (various issues) Statistical Bureau of the Ministry of Agriculture, Forestry, and Fisheries, Tokyo.

[12] Norinsho Tokeihyo (various issues) Statistical Bureau of the Ministry of Agriculture, Forestry, and Fisheries, Tokyo.

[13] Noka Keizai Chosa Hokoku (various issues) Statistical Bureau of the Ministry of Agriculture, Forestry, and Fisheries, Tokyo.

tained for male and female workers separately (X_L^m and X_L^f).

For the prices of male and female labor, the daily wage rates of temporarily-hired workers were obtained from the PWRV. These wage rates were then inflated by the boarding rates which were obtained by Izumida (1987) separately for male and female labor. These inflated wages were designated as P_L^m and P_L^f. The cost of labor was obtained as $P_L X_L = P_L^m X_L^m + P_L^f X_L^f$. This and the following factor costs are expressed in billion yen per year. Next, the quantity and price indexes of labor input (X_L and P_L) were computed by the Törnqvist approximation method using the quantity and price data of male and female labor.

The cost of intermediate inputs ($P_I X_I$) was obtained by adding up the expenditures on seed, fertilizer, feed, agri-chemicals, fuels and electricity, other intermediate inputs, and agricultural services. The Törnqvist quantity and price indexes of intermediate inputs (X_I and P_I) were obtained using the set of data on the expenditures and price indexes of the above seven items of intermediate inputs. The sources of data are the same as in the case of the quantity and price indexes of total output.

In order to obtain the quantity and price indexes of machinery inputs, the Jorgenson (1974) service price model was applied. Machinery inputs in this paper consists of farm machinery and farm automobiles. According to Jorgenson, the service price of each component of this category of capital assets (P_t) is yielded by

$$P_t = q_t(r_t + \delta_t) \qquad (A.1)$$

where q_t, r_t, and δ_t are the asset price, interest rate, and depreciation rate at time t. Here, capital gain was ignored as being unimportant, since a farm machine, once it is bought by a farmer, is usually used for a specific purpose of agricultural production with little or no aim at obtaining capital gain.

The rate of depreciation is computed from the following identity:

$$K_t = K_{t-1} + I_t - \delta_t K_{t-1} \qquad (A.2)$$

where K_{t-1} is capital stock at the end of period $t-1$ and I_t is gross investment at time period t. Using the interest rate r_t and the rate of depreciation δ_t together with the asset price index q_t, the service price of this component of machinery capital assets can now be obtained by (A.1).

The flow of services for each capital component is assumed to be proportional to the stock K_t,

$$V_t = P_t K_{t-1} \qquad (A.3)$$

where V_t is the value of service flow at t.

Using this formula, the cost of machinery ($P_M X_M$) was obtained by adding the values of service flows of farm machinery and farm automobiles. Next, using the series of computed service prices and values of service flows of these capital assets, the Törnqvist quantity and price indexes of machinery inputs (X_M and P_M) were computed.

The same procedure was applied in order to obtain the cost ($P_O X_O$) and the quantity and price indexes (X_O and P_O) of other inputs. The other inputs are composed of large plants, animals, and farm buildings and structures.

The following procedures were applied to obtain the capital stocks and gross investments for the 1960–90 period. The capital stock of farm machinery was obtained by the perpetual inventory method. Those of farm automobiles, plants, and animals were computed by the physical stock valuation method. However, the data of farm automobiles for the 1956–66 period could not be obtained for lack of data. For the capital stocks of farm buildings and structures, the benchmark year method was applied. The major sources of data for these computations are the Statistical Yearbook of Farm Machinery [14], Agricultural Survey [15], Statistics of Farm Products [16], and Statistics of Livestock Products [17], published annually by the MAFF. The detail of the sources of

[14] Nogyo Kikai Nenkan (various issues) Statistical Bureau of the Ministry of Agriculture, Forestry, and Fisheries, Tokyo.

[15] Nogyo Chosa (various issues) Statistical Bureau of the Ministry of Agriculture, Forestry, and Fisheries, Tokyo.

[16] Sakumotsu Tokei (various issues) Statistical Bureau of the Ministry of Agriculture, Forestry, and Fisheries, Tokyo.

[17] Chikusan Tokei (various issues) Statistical Bureau of the Ministry of Agriculture, Forestry, and Fisheries, Tokyo.

data and the computational procedures are given in Izumida (1987). The amounts of the gross investments of these capital items were directly obtained from the NAAF. The data for the 1956–59 period were taken from Yamada (1984) and linked at 1960.

The asset price indexes were obtained from the NAAF (1963 and 1992 issues). The market interest rate used here is the rate for loan trust taken from the Japan Statistical Yearbook [18].

The quantity and price indexes of land input are obtained in the following manner. The planted area of paddy and upland fields were multiplied by the respective prices per unit of land to obtain the total values of paddy and upland fields. In order to obtain the values of the service flows of paddy and upland fields, these total land values were multiplied by the same market interest rate r_t as used in obtaining the service flows of the capital assets. The cost of land ($P_B X_B$) was obtained by summing up these service flows. Using the prices of paddy and upland fields, and the respective values of the service flows, the Törnqvist quantity and price indexes of land input (X_B and P_B) were computed.

The source of data for the planted areas of paddy and upland fields is the SY (various issues). The prices of land were taken from the Survey Report on Prices and Rents of Paddy and Upland Fields, published annually by the Japan Real Estate Institute. These prices are for medium-quantity paddy and upland fields which are for farming purposes and are in general located in farming areas.

The total cost (C) was calculated as

$$C = P_L X_L + P_M X_M + P_I X_I + P_B X_B + P_O X_O \tag{A.4}$$

The revenue share and the cost share of each component were then obtained respectively by the following formulae

$$R = PQ/C \tag{A.5}$$

$$S_i = P_i X_i / C \tag{A.6}$$

$i = L, M, I, B, O.$

[18] Nihon Tokei Nenkan (various issues) Bureau of Statistics, Office of the Prime Minister, Tokyo.

Finally, the Törnqvist index of total input (F) was computed using the Törnqvist price and quantity indexes, P_L, P_M, P_I, P_B, and P_O, and X_L, X_M, X_I, X_B and X_O. Using the Törnqvist quantity indexes of total output (Q) and total input (F), the Törnqvist quantity indexes of labor and total factor productivities were computed as Q/X_L and Q/F.

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