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Production Behavior of the Farm Household and Marginal Principles in Postwar Japan

by

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1. Introduction

The objective of the present study is to empirically examine whether there existed differences in the production behavior of the Japanese farm household between the mid-1950s and the mid-1960s. This objective is pursued by testing whether or not the farm household followed marginal principles and faced constant returns to scale in the production during the two time periods. Furthermore, the estimated production elasticities are looked into in order to gain a better understanding of how the production technologies differed in the mid-1950s and the mid-1960s.

The mid-1950s may be characterized as the starting point of the so-called "postwar spurt" in agricultural growth following the chaos of the post World War II era. Agricultural production technology in the mid-1950s may be characterized as relatively bio-chemical (BC technology in short) in the sense that emphasis was placed on developing new varieties and new ways of utilizing chemicals; mechanization of the production processes had just begun. On the other hand, agricultre in the mid-1960s experienced a rapid growth in production as part of the dramatic growth of the Japanese economy as a whole. The production technology in this period may be characterized as relatively mechanical (M technology in short). As is well known, mechanization of agricultural production occurred very rapidly in the 1960s corresponding to the rapid migration of agricultural laborers to non-agricultural sectors.

Furthermore, according to Minami [1970, 1971], the Japanese economy passed the "turning point" in Lewis' [1954] term in the late 1950s and early 1960s. Assuming his statement is correct, the present study is therefore in a position to analyze empirically the production behavior of the farm household before and after the "turning point" of the Japanese economy.

The present study is organized as follows. The methodology is presented in section 2. The statistical procedures and the data of empirical estimations are explained in sections 3 and 4, respectively. These are followed by the empirical results in section 5. Finally, empirical findings are summarized in section 5.

2. The Methodology

Two approaches are employed in this study in order to test the hypotheses described in section 1. They consist of first estimating the production function and then estimating the profit and factor demand functions of the farm household. The details are presented in the following subsections.

2.1 The Production Function Approach

The production function of the farm household is assumed as the following Cobb-Douglas type,

$$(2\text{-}1) \qquad Y = A[\prod_{i=1}^{4} X_i^{\alpha_i}][\prod_{j=1}^{4} K_j^{\beta_j}]\exp[\sum_{\ell=1}^{m} d_\ell D_\ell],$$

where Y is the quantity of total output; X_1, X_2, X_3, and X_4 are the quantities of the variable inputs, i.e., labor, fertilizer, feed, and agri-chemicals, respectively; K_1, K_2, K_3, and K_4 are the amounts of the fixed inputs, i.e., machinery, plants, animals, and farm land, respectively; A is the technical efficiency parameter; and α_i's and β_j's are the production elasticities with respect to the variable inputs and the fixed inputs, respectively. Regional dummy variables D_ℓ and the coefficients d_ℓ (ℓ=1, 2, ..., m)[1] are introduced in order to capture possible differences in the technical efficiency of and differences in climatic effects on farm households in different regions.

It should be noted that K_1, K_2, K_3, and K_4 are assumed to be fixed in equation (2-1). This implies a short run production function in which the farm household can only control the quantities of the variable inputs X_i (i=1, 2, 3, 4).

The first hypothesis tested is whether or not the farm household followed marginal principles in the production during the mid-1950s and mid-1960s. This test may be conducted by comparing the computed values of the marginal productivities of the variable inputs with the respective market prices within the framework of estimating the production function given in (2-1). That is, the null hypothesis to be tested can be written as $H_0 : p_A \frac{\partial Y}{\partial X_i} = q_i'$ or $H_0 : p_A \partial Y / q_i' \partial X_i = 1$ (i=1, 2, 3, 4). Depending on whether or not the null hypothesis is rejected for a variable input, one may say that the farm household followed or did not follow the marginal principle with regard to the level of utilization of that

1) For the mid-1950s and the mid-1960s, 10 and 12 regions are classified respectively, excluding Hokkaidō. Thus, the number of the regional dummy variables(m) introduced in the present study are 9 and 11, for the mid-1950s and the mid-1960s, respectively.

input in the agricultural production.

Next, testing constant returns to scale in the agricultural production of the farm household, within the framework of the Cobb-Douglas production function given in (2-1), can be simply conducted by testing the null hypothesis $H_0 : \sum_{i=1}^{4} \alpha_i + \sum_{j=1}^{4} \beta_j = 1$. If the sum of the elasticities is greater than unity, there are increasing returns to scale. If it is equal to unity, there are constant returns to scale; if it is less than unity, there are decreasing returns to scale.

Finally, differences in the production technologies of the farm household between the two different periods in question may be examined by simply looking at the magnitudes of the estimated production elasticities.

2.2 The Profit Function Approach

At the outset, both conceptual and empirical limitations of the production function approach should be noted. The concept of the marginal product, which is computed under the assumption of ceteris paribus, can be inapplicable since, if the quantity of a variable input changes, the other variable inputs would be expected to change in order to restore the marginal productivity condition. This defect arises from the fact that the quantities of even variable inputs are considered as the exogenous variables in the production function. Furthermore, as is well known, the production function approach entails defect of simultaneous equations bias due to an inplicit assumption of profit-maximizing behavior of the farm household.

These problems may be solved by introducing a more realistic interpretation of the process of production through the profit function. In this approach, the prices of output and variable inputs, and the quantities of the fixed inputs, are considered as exogenously determined. With these restrictions, the farm household is assumed to be maximizing its profits by setting both output and quantities of variable inputs at their optimum levels.

Moreover, tests of the hypotheses of marginal principles, constant returns to scale, and production technologies can easily be formulated within a framework of the profit function.

As in the case of the production function approach, the household is assumed to possess the production function given in (2-1). Next, the sum of the elasticities with respect to the variable inputs is assumed to be less than unity, indicating decreasing returns to scale in the variable inputs, i.e.,

$$(2\text{-}2) \qquad \mu \equiv \sum_{i=1}^{4} \alpha_i < 1.$$

If the farm household is assumed to maximize its profits, a profit function corresponds as a dual to the production function given in (2-1).

$$(2\text{-}3) \qquad \Pi = A^* \left[\prod_{i=1}^{4} q_i^{\alpha_i^*} \right] \left[\prod_{j=1}^{4} K_j^{\beta_j^*} \right] \exp\left[\sum_{\ell=1}^{m} \gamma_\ell D_\ell \right],$$

where

$$(2\text{-}4) \qquad A^* \equiv A^{(1-\mu)^{-1}} (1-\mu) \left[\prod_{i=1}^{4} (k_i)^{-\alpha_i (1-\mu)^{-1}} \right] \left[\prod_{i=1}^{4} (\alpha_i)^{\alpha_i (1-\mu)^{-1}} \right],$$

$$(2\text{-}5) \qquad \alpha_i^* \equiv - \alpha_i (1-\mu)^{-1} < 0, \quad i=1, 2, 3, 4,$$

(2-6) $\beta_j^* \equiv \beta_j(1-\mu)^{-1} > 0, \quad j=1, 2, 3, 4.$

Furthermore, q_i is the money price of each variable input, q_i', deflated by the output price, p_A, i.e., $q_i \equiv q_i'/p_A$ (i=1, 2, 3, 4), and Π is the money profit (defined as the total revenue less the total current costs) deflated by the output price, p_A.

By making use of Shephard's [1953] Lemma, the derived demand functions for the variable inputs are given by,

(2-7) $$X_i = -\frac{\partial \Pi}{\partial q_i}, \quad i=1, 2, 3, 4.$$

Multiplying both sides of (2-1) by $-q_i/\Pi$,

(2-8) $$-\frac{q_i X_i}{\Pi} = \alpha_i^*, \quad i=1, 2, 3, 4.$$

The profit function given in (2-4) and the demand functions for the four variable inputs given in (2-8) are the estimating equations for the present study. These five equations are functions only of the deflated prices of the variable inputs and the quantities of the fixed inputs. These variables are normally considered to be determined independently of the farm household's behavior. Econometrically, this implies that they are exogenous variables, and by estimating these functions simultaneously one may avoid the problem of simultaneous equations bias to the extent that it is commonly present in production analysis.

Within the framework of the profit function, the assumption of profit maximization is a maintained hypothesis which is statistically testable. Testing this maintained hypothesis of profit maximization by the farm household is equivalent to testing if the farm household follows the marginal principles with regard to the levels of utilization of the variable inputs, i.e., labor, fertilizers, feeds, and agri-chemicals in its production. This test can be conducted by examining whether or not the α_i*'s in the profit function given in (2-3) are equal to the α_i*'s in the derived demand functions given in (2-8) for all i (=1, 2, 3, 4).[2)]

It should be noted that the introduction of the concept of profits of the farm household, defined as the total revenue less the total current costs in the present model, is possible only if there is a competitive labor market in agriculture.[3)] Although approximately ninety-five percent of labor was family labor in postwar Japanese agriculture, the author assumed that a competitive labor market existed in agriculture and computed the labor costs as part of the total current costs by imputing a market wage rate for family labor.[4)] Therefore, as far as labor input is concerned in the present model, testing the profit maximization hypothesis is tantamount to testing whether or not the

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2) For the details of the derivation of the profit and factor demand functions and of the test procedure of profit maximization, refer to Law and Yotopoulos [1972].

3) This is based on the theory of decomposability of farm households' behavior between the production and consumption sides under the assumption of a competitive agricultural labor market formulated in Sasaki and Maruyama [1966] and applied in empirical studies by Kuroda and Yotopoulos [1978] and Kuroda [1979].

4) The procedure of the imputation is described in more detail in the next section.

imputation of the market wage rate for family labor is valid.

Next, in the present framework, a test of the null hypothesis of constant returns to scale for all inputs in the Cobb-Douglas production function given in (2-1) amounts to testing the null hypothesis, H_0: $\sum_{j=1}^{4} \beta_j^* = 1$, where β_j^*'s are the elasticities of the profit function given in (2-3) with respect to the fixed inputs. If $\sum_{j=1}^{4} \beta_j^* > 1$, there are increasing returns to scale, if $\sum_{j=1}^{4} \beta_j^* = 1$, there are constant returns to scale, and if $\sum_{j=1}^{4} \beta_j^* < 1$, there are decreasing returns to scale.[5)]

Finally, the profit and factor demand functions will be re-estimated with restrictions, if any, based on the results of the abovementioned tests. From this final specification of the profit and factor demand functions, one can immediately compute the production elasticities by making use of the identity equations given in (2-5) and (2-6). These indirectly computed production elasticities will be compared between the mid-1950s and the mid-1960s in order to examine differences in production technologies of the farm household between the two time periods.

3. Procedures for Empirical Estimations

First, in order to estimate the production function given in (2-1) the single equation ordinary least squares method is applied by assuming

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5) Refer to Law and Yotopoulos [1972] for the details of the test procedure.

additive errors with a zero expection and a finite variance for the estimating equation.

Next, for estimating the profit function given in (2-3) and the four factor demand functions given in (2-8), additive erros with a zero expectation and a finite variance for each of the five equations are assumed. The covariances of the errors of the five equations for the same farm household may not be zero, but the covariances of the errors of either equation corresponding to different farm households are assumed to be zero. With these assumptions, an asymtotically efficient method of estimation proposed by Zellner [1962] is used to jointly estimate the five equations. According to this method, the efficiency of estimation can be increased through the imposition of restrictions on the coefficients, if this is required.[6)]

4. The Data and Specifications of the Variables

The main source of data used in the present study is Nōka Keizai Chōsa Hōkoku (Report on the Economic Survey of Farm Households, NKCH hereafter) for 1954, 1955, and 1956 for the mid-1950s and 1965, 1966, and 1967 for the mid-1960s. For the computation of the prices of the variable inputs other than labor, the necessary data was taken from Nōka Butsuzai·Tōkei (Statistical Survey on Commodities of Farm Household, NBT hereafter) for the same years as above. As for the output price,

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6) For a more detailed discussion about the stochastic specification of the profit function model, refer to Kuroda and Yotopoulos [1978].

Torris's [1971] estimate was utilized, again for the same years as above.

The numbers of sample observations used for empirical estimations are 50 and 70 for the mid-1950s and the mid-1960s, respectively. The difference in the sample sizes are due to the differences in the classifications of regions and size classes between the two time periods. Ten regions and five size classes are classified for each year in the mid-1950s and twelve regions and six size classes for each year in the mid-1960s, with Hokkaidō being excluded in both cases because of its different size classification.

It should be noted that although the production function given in (2-1) is expressed in quantity terms, mainly for the convenience of the derivation of the profit function given in (2-3), the standard method of estimating gross output production functions in value terms are made use of in the present study. The dependent variable is the value of gross agricultural output. As for the independent variables, the expenditures on fertilizers, feeds, and agri-chemicals are used for X_2, X_3, and X_4, respectively. For the fixed variables K_j's, the flows of these capital services in value terms, defined in Kuroda [1979], are employed. These variables are all expressed in 1,000 yen per year. As for labor, the man-equivalent family labor days are used.[7] The detail of the specification of this variable will be presented in the following paragraphs.

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7) To summarize, the follwoing gross output production function is used for the actual estimation.

$$P_A Y = A x_1^{\alpha_1} \left[\prod_{i=2}^{4} (q_i' X_i)^{\alpha_i} \right] \left[\prod_{j=1}^{4} K_j^{\beta_j} \right] \exp \left[\prod_{\ell=1}^{m} d_\ell D_\ell \right]$$

The specifications of the variables in the profit and factor demand functions are mostly the same as in the previous studies [Kuroda and Yotopoulos, 1978 and Kuroda, 1979]. They are therefore not repeated here except for the quantity and price of farm labor for which some corrections are made for the present study.

The amount of labor expended on the farm is defined as the sum of family labor, exchange labor, and hired labor. Hired labor consists of both temporary and annual-contract hired labor. It should be noted that there are two kinds of quality differences between these categories of labor. One is between male and female labor, and the other is between temporary and annual-contract hired labor. The following methods of conversions are applied to yield the man-equivalent family labor days.

First, in each category of labor, the ratio of the wage rate of female temporary hired labor to that of male temporary hired labor, 0.8 on the average for the years in question,[8] was used to convert female labor days to man-equivalent days. Next, the quality of family labor and annual-contract hired labor was assumed to be the same, while the quality of exchange labor and temporary hired labor was assumed to be the same. Assuming that the difference between the wage rates of temporary and annual-contract hired labor reflects the difference in the quality of labor in the two categories of hired labor, the ratio of the wage rate of the latter was computed for the relevant years in question. The average

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8) The data was from Nōson Bukka Chingin Chōsa Hōkoku-Sho (Survey Report on Prices and Wage Rates in Farm Villages) for the periods 1954 - 1956 and 1963 - 1967 to obtain the conversion rate, 0.8.

ratio for 1954, 1955, 1956, 1965, and 1966 was around 1.4.[9)] This value was employed to convert exchange and temporary hired labor to family-equivalent man-days.

Next, the farm household-specific price of man-equivalent family labor (q_1') and the total labor cost were obtained as follows.[10)] First, the family labor cost was obtained by imputing the wage rate of annual-contract hired labor, while the exchange labor cost was computed by imputing the wage rate of temporary hired labor.[11)] The family labor cost and exchange labor cost were then added to the wage bills for temporary and annual-contract hired labor reported in NKCH in order to ontain the total labor cost. This total labor cost was used to compute money profits.

For the price of labor, a geometrically weighted average wage rate was computed for each farm household. The procedure was as follows. The share of the cost of exchange and temporary hired labor and that of

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9) For this computation, the data was taken from Appendix Table 3 in Minami [1977]. Although this table does not present the wage rates for 1967, assumption of the same conversion coefficient 1.4 for 1967 may not be far from the reality.

10) Wage rates are expressed in 1,000 yen per day and labor costs in 1,000 yen per year.

11) The wage rate of temporary hired labor was obtained by dividing the wage bill for temporary hired labor by the man-equivalent temporary hired labor days. For farm households which employ annual-contract labor, the wage rate was computed by dividing the wage bill for annual-contract labor by the man-equivalent annual-contract labor days. However, for farm households which do not employ annual-contract hired labor, the wage rate of temporary hired labor was multiplied by the conversion coefficient 0.7 to yield the wage rate of annual-contract hired labor. The constant 0.7 was simply the reciprocal of the conversion rate 1.4 in note 9).

the cost of family and annual-contract hired labor in the total labor cost were obtained. These shares were then used as weights to compute the geometric average of the wage rates of temporary and annual-contract hired labor. Since, in postwar Japanese agriculture, on an average, more than ninety-five percent of labor is family labor, the farm household-specific wage rate so obtained is very close to the wage rate of annual contract hired labor. Finally, this price of labor, denoted by q_l', was deflated by the output price, p_A, to obtain q_l which was used in the estimation of the profit and factor demand functions.

5. Empirical Results

5.1 Estimates of the Production Elasticities and Tests of Hypotheses

The estimated production elasticities are reported in Table 4-1.[12] Most of the estimated elasticities are statistically significant and stable for the respective periods of time. Furthermore, the R^2 is large enough for each year.

First of all, by comparing the corresponding production elasticities between the mid-1950s and the mid-1960s, one may find that the production elastcities of labor and working capital in the 1950s are systematically

12) Fertilizers, feeds, and agri-chemicals were aggregated as working capital in order to avoid either negative coefficients in insignificant coefficients for individual variables. For the same reason, plants and and animals were aggregated as one variable.

larger than those in the 1960s.13) However, the production elasticity of land in the 1950s is smaller than that in the 1960s. As for the production elasticites of machinery and plants and animals, one does not see any clear differences between the two periods.

From these findings it may concluded that the farm household employed production technology in the 1950s which contributed to a relative increase in values of the production elasticites of labor and working capital. On the other hand, production technology employed in the 1960s was such that there was a relative increase in the production elasticity of land.

In other words, it may be said that farmers employed BC technologies in the 1950s in order to increase the contribution of labor and working capital to agricultual production. On the other hand, rapid farm mechanization during the 1960s worked in such a way that the contribution of land to agricultural production increased compared with that of 1950s.

Next, in order to investigate whether or not the farm household followed marginal principles in its production with regard to the variable inputs, the marginal productivities of labor and working capital were computed for each year in question and compared with the respective market prices. The results are reported in Tables 4-2 and 4-3.

The marginal productivety of labor was compared with two kinds of

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13) The production elasticity of labor for 1966 turns out to be much larger than those for 1965 and 1967. However, according to the author's estimation of the same production function for each year of the 1963 - 70 period, the elasticity ranges from 0.20 to 0.31. Thus, the elasticity for 1966 seems to be exceptional.

Table 4-1

Estimates of the Production Elasticities for the Two Periods, 1954-1955 and 1965-1967

Variable	1954	1955	1956	1965	1966	1967
Constant	1.228*	1.410*	2.716*	1.634*	1.137*	1.512*
Labor	0.431*	0.352*	0.102	0.200*	0.404*	0.206*
Working capital	0.546*	0.626*	0.558*	0.367*	0.352*	0.309*
Machinery	0.114*	-0.041	0.113*	0.169*	0.128*	0.149*
Plants and Animals	-0.012	0.033	0.094*	0.030	0.047**	0.003
Land	-0.049	0.078*	0.087*	0.254*	0.140**	0.386*
R^2	0.994	0.996	0.994	0.994	0.992	0.996
Sum of Elasticities	1.030	1.048	0.954	1.020	1.071	1.053

Notes:
1. The specified production function is a Cobb-Douglas type.
2. The coefficients of the regional dummy variables and the computed t-ratios are excluded in order to save space.
3. Working capital are composed of fertilizers, feeds, and agri-chemicals.
4. Coefficients with * and ** are statistically significant at the 5 and 10 percent levels, respectively.

market wage rates, market wage rates I and II. Market wage rate I is a geometrically weighted average of the market wage rates of annual-contract and temporary hired labor. As mentioned in Section 4, this is almost equal to the market wage rate of annual-contract hired labor. On the other hand, market wage rate II is that of temporary hired labor.

For comparisons a t-test was applied. As a result, it is found that the farm household behaved so as to equate the marginal productivity of labor to market wage rate I instead of market wage rate II both in the mid-1950s and in the mid-1960s. The latter is paid mainly during the peak seasons. On the other hand, the former may be considered as an annually averaged wage rate. Thus, market wage rate I is considered to be more appropriate than market wage rate II for comparison with the marginal productivity of labor, which is also an annual average.

In this sense, the author concludes that an average farm household followed the marginal principle with regard to the level of utilization of labor in its production both in the mid-1950s and in the mid-1960s.

Since the dependent variable (i.e., the gross output) and working capital are expressed in value terms, the test of the marginal principle with respect to working capital amounts to testing whether or not the marginal productivity of working capital is equal to unity.

The results in Table 4-3 show a clear distinction between the mid-1950s and the mid-1960s. That is, the marginal productivity of working capital in the mid-1950s is consistently larger than unity while that in the mid-1960s is equal to unity. This implies that the farm household did not follow the marginal principle with respect to

Table 4-2

Marginal Productivity of Labor and the Market Wage Rates

(unit: yen/man-day, in current prices

Year	Marginal productivity of labor (1)	Market wage rate I (2)	Market wage rate II (3)	Ratio I (2)/(1)	Ratio II (3)/(1)
1954	278 (60)	270 (35)	350 (61)	0.97	1.26
1955	318 (71)	277 (34)	356 (55)	0.87	1.12
1956	314 (66)	294 (30)	383 (50)	0.94	1.22
1965	542 (124)	614 (103)	903 (151)	1.13	1.67
1966	630 (152)	678 (120)	997 (177)	1.07	1.58
1967	741 (168)	804 (192)	1,182 (282)	1.08	1.60

Notes:
1. For the computation of the marginal productivity of labor, simple averages of the labor production elasticities of 1954 and 1955 and of 1965, 1966, and 1967 reported in Table 4-1 were respectively used for the years in the 1950s and in the 1960s.
2. Market wage rate I is a geometrically weighted average of the market wage rates of annual contract and temporary hired labor. See text for details of computation.
3. Market wage rate II is the market wage rate of temporary hired labor. See text for the details of computation.
4. Figures in parentheses are computed standard deviations. The sample sizes are 50 and 72 for the years in the 1950s and in the 1960s, respectively.

Table 4-3

Marginal Productivity of Working capital

(unit: yen/yen)

	1954	1955	1956	1965	1966	1967
Marginal prod. of Working capital	4.41 (0.88)	4.71 (0.86)	4.15 (0.75)	0.95 (0.33)	0.97 (0.37)	1.04 (0.43)

Notes: 1. For the computation of marginal productivity of working capital the simple averages of the production elasticities of working capital of 1954, 1955, and 1956 and of 1965, 1966, and 1967 reported in Table 4-1 were respectively used for the years in question.

2. Figures in parentheses are computed standard deviations. The sample sizes are 50 and 72 for 1954, 1955, and 1956 and for 1965, 1966, and 1967, respectively.

working capital in the mid-1960s, but it did in the mid-1960s.

This may be interpreted as follows. As mentioned earlier, the agricultural production technology during the mid-1950s was characterized by an increased utilization of chemical fertilizers and agri-chemicals, and a rapid introduction of new varieties. Under such a situation, farmers might not have adjusted themselves fully to the new production technology. As time passed, however, they were now abte to adjust themselves to the new technology and became exonomically rational in the utilization of working capital during the mid-1960s.

Finally, the null hypothesis of constant returns to scale was tested for each year in the two periods in question. A t-test was applied for each year. The results are presented in Table 4-4. For all the years in the mid-1950s and 1964, the null hypothesis could not be rejected. However, in 1966 and 1967 the null hypothesis was rejected at either the one percent level or the five percent level. Since the computed sum of the production elasticities for these years are respectively 1.07 and 1.05, this result indicates that increasing returns to scale existed in the agricultural production during the mid-1960s.

This clear difference between the two periods (i.e., constant returns to scale in the mid-1950s and increasing returns to scale in the mid-1960s) is considered to be strongly related to the differences in the agricultural production technologies of the two periods. That is to say, production technology in the mid-1950s, which was characterized by a BC technology did not allow farmers to enjoy economies of scale. On the other hand, an M technology made it possible for farmers to enjoy economies of

Table 4-4

Results of Test for Constant Returns to Scale

	1954	1955	1956	1965	1966	1967
Computed t	0.44	0.99	-1.46	0.76	2.61	2.56
Result	Accept	Accept	Accept	Accept	Reject	Reject

Notes: 1. The degrees of freedom for 1954, 1955, and 1956 and for 1965, 1966, and 1967 are 33 and 59, respectively.

2. The critical $t_{0.05(33)}$ and $t_{0.05(59)}$ are respectively ± 2.03 and ± 1.67 and the critical $t_{0.01(33)}$ and $t_{0.01(59)}$ are ± 2.74 and ± 2.39, respectively.

scale in the mid-1960s. A casual examination of statistical data on the numbers of farm households in different size classes supports the above result. There was no significant and consistent change in the numbers of farm household in different size classes in the 1950s. However, in the 1960s the number of relatively large scale farm households increased while that of relatively small scale farm households declined.

5.2 Tests of Hypotheses through the Estimation of the Profit Function

The profit and factor demand functions were first estimated for 1954, 1955 and 1956 and for 1965, 1966 and 1967 with no restriction on coefficients of the price variables. The results are reported in Tables 4-5 and 4-6, respectively. Based on the estimated results, the null hypotheses of profit maximization and constant returns to scale were statistically tested. The results are given in Table 4-7. Finally, by making use of the results of the tests of the null hypotheses, the profit and factor demand functions were reestimated, this time with restrictions.

Although one may derive many findings from the estimates of the cofficients of the profit and factor demand functions presented in Tables 4-5 and 4-6,[14] the author only points out differences between the two periods in the coefficients of machinery and land and in the coefficients of demand functions for labor, fertilizers, and feeds. However, these

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14) For example, one may discuss differences in the elasticities of factor demands and output supply between the two periods. However, that is not the major purpose in the present study.

Table 4-5

Cobb-Douglas Profit and Factor Demand Functions for 1954, 1955 and 1956 by Zellner's Efficient Estimation Method

Variable	Parameter	1954 No Rest.	1954 1 Rest. CRTS	1954 5 Rest. CRTS Equalities	1955 No Rest.	1955 1 Rest. CRTS	1955 5 Rest. CRTS Equalities	1956 No Rest.	1956 1 Rest. CRTS	1956 5 Rest. CRTS Equalities
Profit Function										
Constant	lnA*	7.438*	7.365*	5.840*	5.919*	5.359*	5.755*	4.378*	4.629*	6.077*
		(6.118)	(6.209)	(20.34)	(6.806)	(7.088)	(43.20)	(5.188)	(5.717)	(29.42)
$\ln q_1$	α_1^*	-1.339*	-1.284*	-1.189*	-0.610**	-0.377	-0.960*	0.229	0.243	-1.104*
		(-2.505)	(-2.470)	(-6.418)	(-1.750)	(-1.267)	(-10.93)	(0.685)	(0.726)	(-10.33)
$\ln q_2$	α_2^*	1.982*	1.923*	-0.223*	0.038	0.016	-0.186*	0.625**	0.708*	-0.219*
		(3.368)	(3.384)	(-10.63)	(0.093)	(0.038)	(-18.47)	(1.716)	(2.011)	(-19.09)
$\ln q_3$	α_3^*	-0.159	-0.205	-0.109*	0.200	0.195	-0.093*	-0.193	-0.233	-0.131*
		(-0.353)	(-0.493)	(-4.203)	(0.880)	(0.847)	(-7.266)	(-0.585)	(-0.695)	(-5.582)
$\ln q_4$	α_4^*	0.287	0.299	-0.027*	0.088	0.094	-0.022*	-0.175	-0.119	-0.029*
		(1.359)	(1.519)	(-4.136)	(0.762)	(0.802)	(-13.05)	(-1.308)	(-0.906)	(-16.22)
$\ln K_1$	β_1^*	0.766*	0.765*	0.642*	0.816*	0.743*	0.771*	0.554*	0.631*	0.773*
		(5.201)	(5.669)	(2.801)	(6.633)	(7.241)	(6.872)	(4.266)	(6.426)	(4.615)
$\ln K_{23}$	β_{23}^*	0.202	0.186	0.183	0.215	0.283*	0.206*	0.246*	0.179	0.095
		(1.216)	(1.232)	(0.697)	(1.639)	(2.367)	(1.969)	(1.897)	(1.627)	(0.533)
$\ln K_4$	β_4^*	-0.071	0.049	0.176	-0.098	-0.026	0.023	0.290*	0.190**	0.132**
		(-0.579)	(0.459)	(0.846)	(-0.666)	(-0.194)	(0.175)	(2.254)	(1.716)	(1.701)
$\sum_j \beta_j^*$		0.897	1.000	1.000	0.933	1.000	1.000	1.090	1.000	1.000
Labor Demand Function	α_1^*	-1.577*	-1.577*	-1.189*	-1.039*	-1.039*	-0.960*	-1.247*	-1.247*	-1.104*
		(-7.666)	(-7.666)	(-6.418)	(-11.11)	(-11.11)	(-10.93)	(-11.15)	(-11.15)	(-10.33)
Fert. Demand Function	α_2^*	-0.264*	-0.264*	-0.223*	-0.194*	-0.194*	-0.186*	-0.234*	-0.234*	-0.220*
		(-11.83)	(-11.83)	(-10.63)	(-18.36)	(-18.36)	(-18.47)	(-20.14)	(-20.14)	(-19.09)
Feed Demand Function	α_3^*	-0.157*	-0.157*	-0.109*	-0.101*	-0.101*	-0.093*	-0.153*	-0.153*	-0.131*
		(-5.645)	(-5.645)	(-4.203)	(-7.689)	(-7.689)	(-7.266)	(-6.375)	(-6.375)	(-5.582)
Ag. Ch. Demand Function	α_4^*	-0.032*	-0.032*	-0.027*	-0.022*	-0.022*	-0.022*	-0.031*	-0.031*	-0.029*
		(-11.18)	(-11.18)	(-4.136)	(-13.76)	(-13.76)	(-13.05)	(-16.77)	(-16.77)	(-16.22)

Notes:
1. The coefficients of the nine regional dummy variables are excluded in order to save space.
2. For restrictions, CRTS implies constant returns to scale, i.e., $\sum_j \beta_j^*$, and equalities implie $\alpha_i^* = \alpha_i^*$ (i=1,2,3,4).
3. Figures in parentheses are computed t-ratios.
4. Coefficients with * and ** are statistically significant at the 5 and the 10 percent levels, respectively.

Table 4-6

Cobb-Douglas Profit and Factor Demand Functions for 1965, 1966, and 1967 by Zellner's Efficient Estimation Method

Variable	Parameter	1965 No Rest.	1965 4 Rest. Equalities	1966 No Rest.	1966 4 Rest. Equalities	1967 No Rest.	1967 4 Rest. Equalities
Profit Function							
Constant	ℓnA^*	1.145* (2.477)	1.435* (6.986)	1.217* (2.787)	1.638* (8.849)	0.432 (0.746)	0.388 (1.547)
ℓnq_1	α_1^*	-0.137 (-0.691)	-0.549* (-22.30)	-0.107 (-0.545)	-0.500* (-24.35)	-0.186 (-0.738)	-0.470* (-10.27)
ℓnq_2	α_2^*	-0.086 (-1.166)	-0.125* (-29.80)	-0.094 (-1.335)	-0.114* (-32.75)	-0.111 (-1.262)	-0.102* (-9.042)
ℓnq_3	α_3^*	-0.100 (-0.448)	-0.266* (-11.11)	-0.133 (-0.631)	-0.243 (-11.31)	-0.105 (-0.425)	-0.239* (-6.482)
ℓnq_4	α_4^*	-0.003 (-0.036)	-0.042* (-20.93)	-0.030 (-0.414)	-0.038* (-23.89)	0.078 (0.874)	-0.042* (-25.03)
ℓnK_1	β_1^*	0.092 (1.031)	0.281* (7.013)	0.110 (1.312)	0.290* (8.031)	0.193* (2.585)	0.380* (7.268)
ℓnK_2	β_2^*	0.074* (2.574)	0.104* (3.092)	0.074* (2.724)	0.099* (3.257)	-0.021 (-0.564)	0.016 (0.385)
ℓnK_3	β_3^*	0.049 (1.666)	0.028 (0.812)	0.038 (1.365)	0.024 (0.779)	0.011 (0.309)	0.023 (0.644)
ℓnK_4	β_4^*	0.896* (7.413)	0.732* (26.22)	0.875* (7.664)	0.705* (28.06)	0.994* (9.351)	0.806* (27.55)
$\sum_j \beta_j^*$		1.111	1.145	1.097	1.118	1.177	1.225
Labor Demand Function	$\alpha_1^{*\prime}$	-0.579* (-22.75)	-0.549* (-22.30)	-0.521* (-24.69)	-0.500* (-24.35)	-0.539* (-10.64)	-0.470* (-10.27)
Fert. Demand Function	$\alpha_2^{*\prime}$	-0.128* (-32.14)	-0.125* (-29.80)	-0.116* (-35.00)	-0.114* (-32.75)	-0.117* (-9.553)	-0.102* (-9.042)
Feed Demand Function	$\alpha_3^{*\prime}$	-0.292* (-11.87)	-0.266* (-11.11)	-0.263* (-11.94)	-0.243* (11.31)	-0.291* (-7.218)	-0.239* (-6.482)
Ag.Ch. Demand Function	$\alpha_4^{*\prime}$	-0.043* (-28.16)	-0.042* (-20.93)	-0.039* (-30.19)	-0.038* (-23.89)	-0.043* (-28.72)	-0.042 (-25.03)

Notes:
1. The coefficients of the 11 regional dummy variables are excluded in order to save space.
2. For restriction, equalities imply $\alpha_i = \alpha_i$ (i=1,2,3,4).
3. Figures in parentheses are computed t-ratios.
4. Coefficients with * and ** are statistically significant at the 5 and 10 percent levels, respectively.

differences will be discussed in a more economically meaningful manner later in this subsection where the production elasticities are computed indirectly by making use of the results of restricted estimations.

It may be more interesting at this point to look into the results of the tests of the null hypotheses in Table 4-7. First, the null hypotheses of profit maximization, which is a joint hypothesis, was tested for each year in the two periods. An F-test was applied to this test and the results are given in the sixth line in the table. According to the results, the null hypothesis was rejected for 1954 and 1956 at either the one or five percent level of statistical significance. However, it could not be rejected for 1955 at either level of statistical significance. On the other hand, this null hypothesis could not be rejected for any of the years in the mid-1960s at the one percent level. In summary, the farm household failed to maximize its profits with regard to the levels of utilization of the variable inputs in the mid-1950s, while it maximized its profits in the mid-1960s.

One should note that the theory of profit and factor demand functions requires that the null hypothesis of profit maximization be tested jointly as equalities between the coefficients of the price variables and the corresponding coefficients of the factor demand functions. However, the author proceeded to test the equality for each pair of the coefficients with respect to the variable inputs (i.e., labor, fertilizers, feeds and agri-chemicals). For example, for labor the test was conducted to examine the equality between the coefficient of the profit function with respct to the wage rate (i.e., α_1*) and the coefficient of the labor demand function (i.e., α_1*). The same method was applied to the other variable inputs. This procedure will help offer ideas on which variable input farmers failed to follow the marginal principle. The results of these equality tests are shown in lines one through four in Table 4-7.

The null hypothesis of equality for labor could not be rejected for 1954 and 1955 at either the one or five percent level of statistical significance. However, it was rejected for 1956 at either level. In the case of fertilizers, the null hypothesis was rejected for 1954 and 1956 at the five percent level of statistical significance, but it could not be rejected at either level for 1955. As for feeds and agri-chemicals, the null hypotheses of equalities could not be rejected for any of the years in the mid-1950s at either the one or five percent level. On the other hand, none of the null hypotheses could be rejected for any of the years in the 1960s, again at either level of statistical significance.

These results may be interpreted as follows. The farm household followed, on the whole, the marginal principle in the mid-1950s with regard to the utilization of labor, feeds and agri-chemicals. However, it failed to follow the marginal principle in the case of chemical fertilizers during the mid-1950s. Mainly because of this, the farm household failed, on the whole, to maximize its profits during the mid-1950s.[15)]

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15) However, this statment needs a qualification since the null hypothesis of equality for fertilizers could not be rejected for 1955 at either level of statistical significance and for 1956 at the one percent level. Moreover, the equality for labor was rejected in 1956. Thus, in order to confirm the above statement it would be necessary to estimate the same profit and factor demand functions at least for, say, 1953 and 1957.

On the other hand, the farm household followed fully the marginal principles in the production of agricultural commodities.

It should be noted at this point that the wage rate used in the profit and factor demand functions is q_1' (or market wage rate I) which is a geometrically weighted average of the wage rates of annual-contract and temporary hired labor. As mentioned earlier, this wage rate is almost equal to the wage rate of annual-contract hired labor. Thus, the above result of the test of equality for labor implies that the farm household behaved in its production so as to equate the marginal productivity of labor to the wage rate of annual-contract hired labor both in the mid-1950s and in the mid-1960s. This result supports the finding by the production function approach that the farm household followed the marginal principle with regard to labor both in the mid-1950s and in the mid-1960s.

Next, the null hypothesis of constant returns to scale was tested for each year of the two periods. This test was executed with and without the condition of profit maximization. Actually, only the former method is appropriate by the theory of profit function where profit maximization is assumed and hence it is a maintained hypothesis. Yet, the latter method is also employed for reference.

The test results are presented in lines 5 and 7 in Table 4-7. The null hypothesis of constant returns to scale could not be rejected for any of the years in the mid-1950s, at either the one or five percent level of statistical significance, using either of the test methods. On the other hand, the null hypothesis was rejected for all the years in

Table 4-7

Test Statistics

Hypothesis		Degrees of Freedom 1950s ν_1	ν_2	Critical Value $F_{0.01}$	$F_{0.05}$	Actual Value 1954	1955	1956	Degrees of Freedom 1960s ν_1	ν_2	Critical Value $F_{0.01}$	$F_{0.05}$	Actual Value 1965	1966	1967
1. Equality	$\alpha_1^* = \alpha_1^*$	1	229	6.73	3.88	0.18	1.45	18.07	1	336	6.72	3.87	2.12	3.15	1.99
2. Equality	$\alpha_2^* = \alpha_2^*$	1	229	6.73	3.88	15.11	0.33	5.72	1	336	6.72	3.87	0.33	0.10	0.004
3. Equality	$\alpha_3^* = \alpha_3^*$	1	229	6.73	3.88	0.000	1.80	0.02	1	336	6.72	3.87	0.76	0.39	0.59
4. Equality	$\alpha_4^* = \alpha_4^*$	1	229	6.73	3.88	2.37	0.94	1.19	1	336	6.72	3.87	0.28	0.01	1.99
5. CRTS	$\sum_j \beta_j^* = 1$	1	229	6.73	3.88	0.36	1.70	2.81	1	336	6.72	3.87	8.17	5.29	11.13
6. Equalities	$\alpha_i^* = \alpha_i^* (i=1,,4)$	4	229	3.40	2.40	16.74	1.94	17.58	4	336	3.37	2.40	2.68	3.09	2.60
7. CRTS conditional on equalities	$\sum_j \beta_j^* = 1$ conditional on $\alpha_i^* = \alpha_i^* (i=1,,4)$	1	234	6.73	3.88	0.31	0.91	3.14	1	340	6.72	3.87	59.05	48.75	81.67

Note: 1. CRTS stands for constant returns to scale.

the mid-1960s at either level of significance using either method of statistical test. These results imply that economies of scale did not exist in the mid-1950s, whereas they did exist in the mid-1960s.[16)] This supports the finding obtained through the production function approach discussed earilier in this section.

Finally, the profit and factor demand functions were reestimated with restrictions based on the results of tests of the null hypotheses of profit maximization and constant returns to scale. For the year 1954, 1955 and 1956, the restriction of constant returns to scale was introduced for the reestimation. For 1965, 1966, and 1967, the equality restriction was used. Moreover, another estimation was carried out for 1954, 1955, and 1956 with the restrictions both of equalities and constant returns to scale in order to gain an understanding of how the farm household would have behaved if it had maximized its profits during the mid-1950s. The results of the restricted estimations are presented in Tables 4-5 and 4-6 respectively for the mid-1950s and for the mid-1960s.

As mentioned earlier, it may be more interesting to examine the indirectly estimated production elasticites compared with their direct estimates. By making use of equations (2-5) and (2-6), the production elasticities were computed. For this computation, estimates of the profit and facor demand functions, with the restrictions of equalities and constant returns to scale, were used for 1954, 1955, and 1956. On the

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16) Refer to Kuroda [1979] for details of the test result of increasing returns to scale in the mid-1960s.

Table 4-8

Indirect Estimates of the Production Elasticities for the Two Periods, 1954-1956 and 1965-1967

Variable		1954	1955	1956	1965	1966	1967
Labor	(α_1)	0.466	0.424	0.445	0.277	0.264	0.253
Fertilizer	(α_2)	0.087	0.082	0.088	0.063	0.060	0.055
Feed	(α_3)	0.043 } 0.141	0.041 } 0.133	0.053 } 0.153	0.134 } 0.218	0.128 } 0.208	0.129 } 0.207
Ag. Chem.	(α_4)	0.011	0.010	0.012	0.021	0.020	0.023
Machinery	(β_1)	0.252	0.341	0.312	0.142	0.153	0.205
Plants	(β_2)	0.072	0.091	0.038	0.066 } 0.080	0.052 } 0.065	0.008 } 0.020
Animals	(β_3)				0.014	0.013	0.012
Land	(β_4)	0.069	0.010	0.053	0.369	0.372	0.435
Sum of Elasticities		1.000	1.000	1.000	1.086	1.062	1.120

Notes: 1. The elasticities were computed indirectly based on the estimates reported in Tables 4-6 and 4-7. For 1954, 1955, and 1956 the estimates with five restrictions and for 1965, 1966, and 1967 the estimates with one restriction were used, respectively. For the computation method, refer to text.

other hand, the estimates with the equality restrictions were used for 1965, 1966, and 1967. The indirectly computed production elasticities are given in Table 4-8.

As was expected, the indirectly estimated production elasticities in the mid-1960s are very similar to the corresponding elasticities directly estimated which are reported in Table 4-1. This similarity may be considered to naturally derive from the results that the farm household was found to behave so as to maximize its profits with regard to the levels of utilization of the variable inputs during the mid-1960s either by the production function approach or by the profit function approach.

On the other hand, the production elasticities in the mid-1950s estimated indirectly under the assumption of profit maximization are fairly different from those directly estimated (given in Table 4-1). In particular, under the assumption of profit maximization, the working capital production elasticity became much smaller than that directly estimated. Furthermore, the machinery production elasticity under the profit maximization assumption turned out to be larger than that directly estimated. These results might have been because farmers in the mid-1950s could not adjust themselves fully to the new production technologies which were characterized by a rapid introduction of chemical fertilizers and the early state of mechanization of production processes.

6. <u>Summary</u>

The findings in the present study are summarized as follows.

(1) From the production function approach, the farm household followed the marginal principle in its production with regard to the level of utilization of labor both in the mid-1950s and in the mid-1960s. This finding was supported on the whole by the estimation of the profit and factor demand functions. It should be noted that the farm household equated the marginal productivity of labor to a geometrically weighted average of the wage rates of annual-contract and temporary hired labor, which was almost equal to the wage rate of annual-contract hired labor.

(2) The farm household did not, however, utilize working capital, especially fertilizers, to the extent that the marginal productivity of fertilizers is equated to the market price during the mid-1950s. Because of this, the farm household failed to maximize its profits with regard to the levels of utilization of the variable inputs during this period. On the other hand, the farm household behaved so as to equate the marginal productivity of each component of working capital to its market price in the mid-1960s.

(3) Constant returns to scale existed in the agricultural production during the mid-1950s. However, farmenrs faced increasing returns to scale in the mid-1960s.

(4) The production technology during the mid-1950s worked to increase the production elasticities of labor and working capital. On the other hand, farmers employed a production technology during the mid-1960s which increased the production elasticity of land.

References

[1] Kuroda, Y. and P. A. Yotopoulos [1978], "A Microeconomic Analysis of Production Behavior of the farm Household in Japan — A Profit Function Approach — ," Keizai Kenkyū (The Economic Review), Vol.29, No.2, pp.116 - 129.

[2] Kuroda, Y. [1979], " A Study of the Farm Firm's Production Behavior in the Mid-1960's in Japan — A Profit Function Approach —," Kikan Riron Keizai-Gaku (The Economics Studies Quarterly), Vol.30, No.2, pp.107 - 122.

[3] Lau, L. J. and P. A. Yotopoulos [1972], " Profit, Supply and Factor Demand Functions," American Journal of Agricultural Economics, Vol.54, No.1, pp.11 - 18.

[4] Lewis, W. A. [1954], "Economic Development with Unlimited Supplies of Labour," Manchester School of Economic and Social Studies, Vol.22, No.2, pp.139 - 191. Reprinted in A. N. Agarwala and S. P. Singh (eds.), The Economics of Underdevelopment, Oxford University Press, London, 1958, pp.400 - 449.

[5] Minami, R. [1970], Nihon Keizai no Tenkanten (The Turing Point of the Japanese Economy), Sobunsha, Tokyo.

[6] Minami, R. [1971], The Turning Point in Economic Development: Japan's Experience, Kinokuniya Bookstore Co., Tokyo.

[7] Nōrin-Suisan-Shō [annual edition], Nōka Butsuzai Tōkei (Statistical Survey on Commodities of Farm Households), 1954 - 1956 and 1965 - 1967.

[8] Nōrin-Suisan-Shō [annual edition], Nōka Keizai Chōsa Hōkoku (Report on the Economic Survey of Farm Households), 1954 - 1956 and 1965 - 1967.

[9] Nōrin-Suisan-Shō [annual edition], Nōson Bukka Chingin Chōsa Hōkoku-sho (Survey Report on Prices and Wage Rates in Farm Villages), 1954 - 1956 and 1963 - 1067.

[10] Sasaki, K. and Y. Maruyama [1966], "Kotei-teki Shigen no Kazoku Nokigyō ni-taisuru Eikyō (impacts of the Fixed Inputs on the Family Farm-Firm)," Nogyō Keizai Kenkyū (Journal of Rural Economics), Vol.38, No.1, pp.110 - 117.

[11] Shephard, R. W. [1953], Cost and Production Functions, Princeton University press, Princeton.

[12] Torii, Y. [1971], "Nōsan-Butsu Kakaku no Sokutei (Estimation of Farm Output Prices)," Mita Gakkai Zasshi (Keio University), Vol.64, No.1, pp.17 - 28.

[13] Zellner, A. [1962], "An Efficient Method for Estimating Aggregation Bias," Journal of the American Statistical Association, Vol.57, pp.348 - 368.