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PRODUCTION FUNCTION ANALYSIS ON THE DEVELOPMENT OF DAIRY FARMING IN POST-WAR JAPAN*

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I. Introduction

The dairy industry of Japan is relatively new since milk and dariy products did not begin to enter into general diets until the 1920's and not to any great extent until after World War II.[1] Consequently, in the early 1900's dairy cattles were primarily maintained in urban-suburban areas owing mainly to the advantages claimed for the marketing, with replacements often coming from the more remote areas. And only a small amount of milk was produced in those areas, for so called "superior" goods.

After World War II, especially by the mid-1950's Japanese dairy production, along with other livestock production, had recovered the great damage inflicted by the deficiency of feed during the war and started on a path of rapid growth. And also, in increase in the consumption of dairy products[2] dairy cattles were expanded all over the country in the mid-1960's, even though in the form of "mixed farming" with other crops.

Dairy production location within the country gradually started to shift after the war from traditional suburban areas to more rural or mountainous areas. This was mainly not only due to development in the transportation infrastructure which permitted to be hauled economically over much greater distances but also due to technological advantages of farming condition in their areas. Especially Hokkaido, northern island of Japan, produced a small amount of milk in the country in 1960's; now that area

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1 Improved breeds of dariy cattle, such as Holstein or Jersey, were introduced into Japan during the period of Tokugawa (1603–1867), probably by the Dutch. But, the early period milk was mainly used by evaporating it and ingesting the concentrate as a drug for treating tuberculosis and syphilis.

2 Per capita consumption of diary products has increased continuously from 22.2 kg in 1960 to 53.3 kg in 1975 and 67.1 kg in 1984.

has the largest one-third of all production.[3] In briefly, the development process of Japanese dairy production has been often described as "milking oriented or non-cultivated dairying" during the Pre-War, and as "truly dairy farming" in the Post-War by some writers in Japan. It is also worth noticing that after war dairy production is mostly performing by family farming. This is also remarkable because dairy farms are, for the most part, located in the areas where grazing land is more abundant.

The great changes on the dairy farms have taken place in the past few years for, while in 1975 the total number of farms had fallen to 160 thousand with 11.2 head per farm (from 410 thousand farms with 2.0 head in 1960) only 9 years later in 1984 the number of farms had decreased by 45 percent to just 87 thousand units, but with on average of 24.3 head per farm. Total dairy cattle numbers in the meantime have been growing rapidly and continuously, from 1.3 million head in 1965 to 2.1 million head in 1984. Distribution of dairy cattle on farms has changed in convert with average inventory per farm increasing rapidly. In 1965 almost exactly two-thirds of the dairy cattle were on farms with 1–4 head; by 1984 those very small units had fallen to less than a fourth part of the total. In 1975 only 10.9 percent of the farms had 20 head or more; by 1984, 34.7 percent of all farms had more than 20 head including 20.1 percent of the farms which had 30 or more head.[4] Moreover, these appearence of increase in the number of dairy cattles vary in different localities.

Japan's dairy production is changing dramatically, both in practices and structure in the recent years. As indicated above, many large scale dairy farms have emerged, and the heaviest concentration of farms is found geographically. Changes will continue to take place, but dairy industry can be also considered as virtually mature one. In fact, the early to 1980's, when the products had gone on a oversupply, could be called the "age of specialization" in the Japanese dairy production.[5]

The information about the development process of dairy farming is interesting, and more illuminating is how economic factors had been related to those phenomena. That is, we believe that the changes had a significant correlation with the difference in "returns to scale" or "productivity" positively. Because both are very important factors in explaining the incentive of the enlargement of scale or the allocation of producing areas in the country. This paper will provide some insights for interpreting the development of dairy farming in Post-War Japan, using the production function analysis, and thereby will give some policy implications for the

[3] Another major locations are such prefectures as Chiba, Gumma, Iwate, Tochgi, Aichi, Nagano, Hyogo, Ibaragi, Kumamoto, and so on.

[4] The source of numerical values is the *Abstract of Statistics on Agriculture, Forestry, and Fisheries* (1960–1984) conducted by MAFF, Japan.

[5] The self-sufficiency ratio for milk and milk products have stayed in the high 80 percent in 1960–1983.

future development of it.

A few attempts have been made to explain the development process of dairy farming in estimating the production function as a method of quantitative analysis. These empirical studies were based on the analysis with data abstracted from such sources as aggregate tabulations or restricted regional farm records. In consequence, the results are either too national-wide or too sectional, even though the purposes differ from each other.

Dairy production, like other livestock subsectors, is a specific field of agriculture. Dairy farms do not behave in a generally passive way when faced with an arrey of possible inputs. The differences in dairy production technology have an direct effect upon the formation of dairying type. Accordingly, some special difficulties arise in the estimation of dairy production functions.

In this paper I intend to estimate "operationally meaningful" production function, and shall present the results of an analysis applied to the individual dairy farm data which selected from Milk Production Cost Records during the period 1965–1980 in eight distinctive regions (prefectures) such as Hokkaido, Iwate, Chiba, Aichi, Kyoto, Osaka, Ehime, and Kumamoto. The analysis is based on estimating of production functions in some groups, which are classified according to the dairying type. The general Cobb-Douglas production function model is selected for the analysis.

The order of presentation is as follows. After the Introduction, Section two presents the model and variables for the analysis, and then explains some economic aspects of the production technology. In Section three, the results of the production function analysis are discussed. Finally, Section four provides a summary and conclusions for the study.

II. Methods

The unrestricted Cobb-Douglas production function form, that is, an equation linear in the logarithms of the variables, is widely used in agriculture partly for its ease of manipulation and interpretation, but mainly for its good fit to the data.[6] When estimated from cross-section data, especially, this function is often interpreted as the long-run production function for farms in the sample, on grounds that inputs fixed on individual will vary among farms. Ideally, inputs and outputs are measured as service flows provided or produced over the appropriate time period.[7] This analysis

[6] Other forms are such as the "transcendental" and CES function in particular.

[7] In the Cobb-Douglas form, which is estimated from a cross-section sample, the usual assumptions of the economist are (1) a given percentage increase in input results in the same percentage increase in output for all farms, that is, the production coeffi-

has chosen the C-D function after due consideration of all conventional inputs for the milk production process. The model of this attempt at defining and defining a production function are reported later.

1. Model and Variables

The model to be estimated is as follows.

$$Y_j = A_0 \prod_k X_{kj}^{\beta_k} U_j$$

where the dependent variable Y_j is some measure of output, X_{kj} are independent variables representing some measure of inputs, A_0 is a costant term, and β_k $(k = 1, 2, \ldots, 6)$ are unobserved population parameters that are assumed to be positive. U_j is the unobserved random error. And subscript j represents the farm number.

The variables were measured as flows during the milk production cost accounting period (from July 1 to June 30 of next year). The actual total product (Y) are given in physical terms like as X_3 And this is calculated in terms of "standard milk fat rate (3.2 percent)" (M/T). The factor labor (X_3) is measured by the total number of hours labor, i.e., hired labor as well as family labor. There is also converted female labor into the adult man labor. And the other expenses are measured in terms of money (,000 yen).

X_1 represents concentrate costs, and X_2 stands for roughage costs. X_4 represents building and machinery costs, consists of depreciation on the value of building and machine capital, repairs and maintenance, and other tools purchased.[8] In particular, X_5 stands for the value of dairy cattles based on the depreciation. And X_6 represents current operating expenses like some veterinary expense, fuel, oil, gas, water, special expense, and miscellaneous. Costs of cattle maintenance form more than a half of these especially. It is realized that the choice of these variables is to a certain degree arbitrary and could easily be replaced by another classification.[9]

2. Economic Aspects of Production Technology

In this part we discuss some economic features in the Cobb-Douglas type production function through the estimation of cross-section data, in that we assume two groups of production function: (1) $y_1 = b_{01}x_1^{b_{11}}x_2^{b_{21}}$; and (2) $y_2 = b_{02}x_1^{b_{12}}x_2^{b_{22}}$. In an attempt to clarify the concept of production

cients are identical for all farms, (2) each individual farm maximizes profit, and (3) all farms face the same input and output prices. (Nerlove 1965)

[8] There is no problem in the aggregation of two variables as a single input, because machinery services arising mainly from facilities incidental to building.

[9] On the aggregation of inputs, the two general rules are held (Heady and Dillon 1961): (1) The inputs within an individual category should be as nearly perfect substitutes or perfect complements as possible. (2) Relative to each other, the categories of inputs should be neither perfect substitutes nor perfect complements.

technology, I shall present five kinds of aspects as will be discussed.

First, the difference between two groups are represented by "constant term" (b_{01} and b_{02}). This indicates that a group is considered relatively more production-efficient than another, if, given the same quantities of measurable inputs, under the elasticities of production are also all identical, it produces a larger output. That is, group 1 is more production-efficient than group 2 if $b_{01} > b_{02}$.

Second is the elasticities of output (b_{11}, b_{21}, b_{12}, and b_{22}) with respect to inputs. The elasticity means the proportion of the increasing rate in quantity of input to the increasing rate in output.[10] Consequently, these elasticities are also a contribution rate of factor inputs with respect to output respectively.

Third is the relative ratio of factor elasticity such as b_{11}/b_{21} and b_{12}/b_{22}. In view of the optimum ratio of factor combination, Group 1 is "factor X_1-using (factor X_2-saving)" than group 2 if $b_{11}/b_{21} > b_{12}/b_{22}$.[11] Generally, it is pointed out that the change in the optimum combination of factor inputs is not only due to technical change simply but also due to changes in relative factor price among inputs. This relative ratio of elasticity is consequently, as it were, an index of the difference in optimum ratio of factor combination among the groups.

Fourth is the sum of the coefficients in the function. This sum, $b_{11}+b_{21}$, is often called the "elasticity of production". Scale economy is also represented by its size, there is an indication of economies of scale if $b_{11} + b_{21} > 1$. Taking this economic opportunity, dairy farms will take a course of increasing in scale.

Last is the estimated total products, that is, stands for an amounts of product after due consideration of all inputs ($\hat{y}_1 = b_{01}\, \bar{\bar{x}}_1^{b_{11}} \bar{\bar{x}}_2^{b_{21}}$, $\hat{y}_2 = b_{02} \bar{\bar{x}}_1^{b_{12}} \bar{\bar{x}}_2^{b_{22}}$: $\bar{\bar{x}}$ = total mean of x in the groups). This is an efficiency index which is measured by a same level of all inputs considered.

3. Grouping of the Data

The data were selected from the Milk Production Cost Records by the ministry of agriculture, forestry, and fishery (MAFF) in Japan (see Table 1).

As mentioned above, when estimated from cross-section data, we assume that the production coefficients are identical for all farms. This indicates the data have need of homogeneous ideally. And dairy farms, however rice technology is common to call homogenous approximately

[10] Elasticity b also means;

$$b_1 = \lim_{\Delta X_1 \to 0} \frac{\Delta Y/Y}{\Delta X_1/X_1}, \quad b_2 = \lim_{\Delta X_2 \to 0} \frac{\Delta Y/Y}{\Delta X_2/X_2}$$

[11] A term of "using" or "saving" is originated by Hicks (1965). Kislev and Peterson (1982) explained factor ratio changes by changes in factor prices without reference to technical change or economies of scale.

TABLE 1 Distribution of Sample Data

	Hokkaido	Iwate	Chiba	Aichi	Kyoto	Osaka	Ehime	Kumamoto
1965	59	34	47	27	19	18	19	24
1970	78	48	45	25	7	8	13	27
1975	72	49	28	19	10	10	9	18
1980	76	46	20	14	9	5	10	15

Note: Figures indicate the number of farms.

among farms, have a quite different technology respectively in their farming situation such as environmental factors, locations, markets, etc.; and their production activities affect the formation of the dairying type. Some problems remain for production function analysis using cross-section samples, but there is no magic rule which will tell us which is the appropriate estimation in the empirical study. Whereas, in practice, the grouping is often utilized for a method of homogenization in different samples for the consistant or meaningful model estimated.

On estimating the production function in this analysis, the data classified into five groups respectively on two categories; regional type and farm type (dairying type), as follows.

For the regional types, following five groups were prepared according to the difference in the structure of raw milk price and production cost among the areas; (1) Hokkaido type: farms in Hokkaido, (2) Tohoku type: farms in Iwate, (3) Kanto type: farms in Chiba and Aichi, (4) Kinki type: farms in Kyoto and Osaka, and (5) Shikoku-Kyushu type: farms in Ehime and Kumamoto.

Next, for the farm types, following five groups were selected according to the farm size and "feed structure"[12] apart from some groups which have small samples; (1) Small Scale-Purchased Feeds type (all farms excluding Hokkaido): farms which are small scale and also mainly depend upon the purchased feeds, (2) Small Scale-Self Sufficing Feeds type (Hokkaido): farms which are small scale and also mainly depend upon the self-sufficing feeds, (3) Small Scale-Self Sufficing Feeds type (all farms excluding Hokkaido): same as (2), (4) Large Scale-Purchased Feeds type (all farms excluding Hokkaido): farms which are large scale and also mainly depend upon the purchased feeds, and (5) Large Scale-Self Sufficing Feeds type (Hokkaido): farms which are large scale and also mainly depend upon the self-sufficing feeds.[13] In this classification, all farms ex-

[12] "Feed structure" stands for the concept of a serial process from the production to the utilization through all feeding system.

[13] In practice, I selected the feeds self-sufficing ratio (own-produced / purchased) for the feed structure. Consequently, the groups were classified by the arithmetical mean of total. And farm size was seperated by the number of cattles, that was 7 head in 1965, 10 head in 1970, 15 head in 1975, and 20 head in 1980, considered as the scale of self-farming farm.

cluding Hokkaido means four areas such as Chiba, Aichi, Kyoto, and Osaka. These prefectures possess a character for the urban areas.

The number of samples are distributed from 20 to 60 on an average in a group (ten cross-sections). In next section, after estimating the production function model in use of the data, we will discuss the results of the production function analysis.

III. Results of Production Function Analysis

In the preceding section we have specified the model, defined some related variables, and discussed the economic features of Cobb-Douglas type production function. And the grouping of samples has carried out in order to estimate "operationally meaningful" production functions in the context of farm-level, cross-section data analysis. In this section we firstly estimate the production function, and discuss the results of analysis one by one.

1. Results of Production Function

The results of production function estimated are reported in Table 2 and 3. Table 2 shows the various estimators of production function parameters in five regional types (from A1 to A5), and also Table 3 shows the estimators in five dairying types (from F1 to F5).

The production functions estimated displayed a very high degree of significance, the null hypothesis about the coefficients of production function, i.e., $\beta_1 = \beta_2 = \ldots\ldots = \beta_k = 0$, was rejected at the one percent level of F-test. Under the significance test of coefficients, most of estimators were statistically significant at more than ten percent level of T-test. And R^2 of the equations also appeared very high. According to the tests for the homogeneity of coefficients among the estimated functions (from A1 to A5 and F1 to F5), it is manifested that the coefficients are significantly distinguished each other (.05 level in F-test).[14] This is an evidence that dairy farming have a different technology between the groups. In the following, the results of production function analysis are discussed in order.

Production Efficiency and Returns to Scale

As examined above, the estimates of each production functions did not have the equality assumptions among the groups. This means the difference of production efficiency in them would not be grasped in the meaning of technical neutrality. Therefore, it is difficult to compare the efficiency among the groups as for a term of constant. There is a significant relationship between the production efficiency and the factor combination

[14] See Bolch and Huang (1974).

TABLE 2 Parameter Estimates of C-D Type Dairy Production Functions by Regional Types

Year	Region	Constant	Coefficients of						$\Sigma\beta_k$ (Sum of coefficients)	R^2
			X_1 (Concen- trates)	X_2 (Roughage)	X_3 (Labor)	X_4 (Building & machinery)	X_5 (Dairy cattle)	X_6 (Current expenses)		
1965	A1	0.1464	0.0901	0.1833*	0.2003*	0.1284**	0.3072**	0.0512	0.9605	0.9104
	A2	0.0920	0.2489**	0.3332**	0.1683*	0.0370	0.0811	0.1167*	0.9851	0.8983
	A3	0.0755	0.4576**	0.1032**	0.1965*	0.0560	0.1005*	0.1333**	1.0472	0.9737
	A4	0.0489	0.4070**	−0.0480	0.3936**	0.1187*	0.0558	0.1321**	1.0592	0.9636
	A5	0.1172	0.2462**	0.2834**	0.1537*	0.0742	0.1491**	0.0762*	0.9827	0.8523
1970	A1	0.1369	0.1805**	0.3666**	0.1404*	0.0600	0.1155*	0.1330*	0.9961	0.9453
	A2	0.0716	0.2677**	0.1671*	0.2833**	0.0322	0.0743	0.1471*	0.9717	0.9304
	A3	0.0775	0.5313**	0.0425*	0.2105**	0.0200	0.1373*	0.0967*	1.0103	0.9718
	A4	0.0515	0.3472**	−0.0352	0.4160**	0.0296	0.1379*	0.1924*	1.1057	0.9808
	A5	0.1233	0.2511*	0.1113*	0.2243**	0.1248*	0.2017**	0.0642	0.9775	0.9489
1975	A1	0.0701	0.2221**	0.1943**	0.2056**	0.0789*	0.1815**	0.1623**	1.0448	0.9429
	A2	0.0434	0.4425**	0.0715	0.2254*	0.0269	0.1783**	0.1053*	1.0499	0.9520
	A3	0.0259	0.5990**	0.0417	0.2815**	0.0709*	0.0140	0.0844*	1.0814	0.9754
	A4	0.0207	0.3330*	0.0728**	0.4148**	0.1216**	0.1573**	0.0411	1.1406	0.9856
	A5	0.0962	0.3062**	0.1569*	0.1623*	0.1531**	0.0729	0.1274*	0.9787	0.9819
1980	A1	0.0284	0.3340**	0.2434**	0.2566**	0.0083	0.0843*	0.1747**	1.1014	0.9537
	A2	0.0589	0.5357**	0.2156**	0.1063	0.0289	0.0684	0.0203	0.9751	0.9512
	A3	0.0235	0.6170**	0.1510**	0.2102*	0.0635*	0.0078	0.0383	1.0873	0.9756
	A4	0.0146	0.4161**	0.1123**	0.3573*	0.0609*	0.1025**	0.1196**	1.1687	0.9836
	A5	0.0799	0.3316**	0.0547*	0.1568**	0.1623**	0.1522*	0.1336**	0.9912	0.9905

Notes: 1) Coefficients with * indicate the statistical significance at the 10 percent level; ** indicate significant at the 1 percent significance level.

2) Regional type (A1–A5) represents respectively as follows; A1 for Hokkaido, A2 for Tohoku, A3 for Kanto, A4 for Kinki, and A5 for Shikoku-Kyushu.

TABLE 3 Parameter Estimates of C-D Type Production Functions by Farm Types

Year	Farm type	Constant	Coefficients of X_1 (Concen-trates)	X_2 (Roughage)	X_3 (Labor)	X_4 (Building & machinery)	X_5 (Dairy cattle)	X_6 (Current expenses)	$\Sigma\beta_k$ (Sum of coefficients)	R^2
1965	F1	0.0396	0.6042**	0.0685**	0.2188**	0.0462	0.0641	0.1031**	1.1049	0.9008
	F2	0.0451	0.1508*	0.3097**	0.3200**	0.0142	0.1620*	0.1114*	1.0681	0.9041
	F3	0.0419	0.2313*	0.4610**	0.1795*	0.0471	0.1124*	0.0871	1.1184	0.9188
	F4	0.0626	0.4999**	0.0202*	0.3293**	0.0729*	0.0186	0.0680*	1.0088	0.9520
	F5	0.1605	0.3692**	0.1652**	0.0974	0.0834*	0.1841*	0.0640	0.9633	0.9025
1970	F1	0.0470	0.4675**	0.0511	0.2424*	0.0579	0.1644**	0.1069*	1.0902	0.8984
	F2	0.0882	0.1213*	0.2682**	0.2986*	0.0461	0.0899	0.1509*	0.9750	0.9524
	F3	0.0217	0.3870**	0.2960**	0.2667*	0.0585	0.1576*	0.0512	1.2170	0.9354
	F4	0.1117	0.6033**	0.0301	0.1821*	0.0856*	0.0305	0.0371	0.9686	0.9601
	F5	0.1010	0.3167**	0.2111*	0.1202	0.1313**	0.1613*	0.1207*	1.0614	0.9284
1975	F1	0.0212	0.5315**	0.0328	0.3269**	0.0512	0.0443	0.1080*	1.0947	0.9109
	F2	0.0311	0.1080*	0.2551*	0.3310**	0.1332*	0.1050*	0.1840*	1.1163	0.8863
	F3	0.0386	0.4149**	0.0338	0.2925*	0.0231	0.1792**	0.0981	1.0416	0.9263
	F4	0.0948	0.5503**	0.0466**	0.1757*	0.0363	0.0554	0.0574	0.9208	0.9475
	F5	0.1591	0.2424**	0.2786*	0.0924*	0.0840**	0.0806	0.1567**	0.9347	0.9025
1980	F1	0.0117	0.5415**	0.1076**	0.3072**	0.0172	0.0683	0.1457*	1.1875	0.9077
	F2	0.0300	0.2390**	0.2671**	0.2523*	0.0791*	0.0682	0.1932*	1.0978	0.9369
	F3	0.0445	0.5607**	0.0341	0.2373*	0.0480	0.0772	0.0315	0.9888	0.9416
	F4	0.0644	0.5037**	0.1175**	0.1423*	0.0530*	0.0774*	0.0925*	0.9864	0.9285
	F5	0.0910	0.2934**	0.2088**	0.2184**	0.0824*	0.0930*	0.0666	0.9625	0.9156

Notes: 1) Coefficients with * indicate the statistical significance at the 10 percent level; ** indicate significant at the 1 percent significance level.
2) Farm type (F1–F5) represents respectively as follows; F1 for Small Scale-Purchased Feeds type (all farms excluding Hokkaido), F2 for Small Scale—Self Sufficing Feeds type (Hokkaido), F3 for Small Scale—Self Sufficing Feeds type (all farms excluding Hokkaido), F4 for Large Scale—Purchased Feeds type (all farms excluding Hokkaido), and F5 for Large Scale—Self Sufficing Feeds type (Hokkaido).

patterns. At this point, this part will mainly discuss some results about the changes in scale economies.

But, concerning the analyses it is worth noticing that the size of constant terms is negatively correlated with the sum of elasticities of the production functions. Especially we notice the evidences among the regional types such as Kanto, Kinki, and Shikoku-Kyushu. That is, there is a slight tendency that the constant term is large while the sum of elasticities is relatively small in Shikoku-Kyushu area, but the results in Kanto or Kinki area are just opposite to it. This means the total factor products, in other words, total outputs after due consideration of all factor inputs, of small-scale farm in Shikoku-Kyushu area is relatively high than that in Kanto and Kinki area; the total factor products of large-scale farm is relatively high in Kanto or Kinki area "vice versa".

The differences in the levels of production efficiency among the groups will be presented in the part of the results of total products in detail.

A casual examination of evidence generally shows that, during the postwar years, the number of dairy farms with small-scale has been decreasing while the number of dairy farms with larger farm operations has been increasing. This is "prima facie" evidence for the existance of economies of scale in dairy production during the postwar years. On estimating the production function, a statistical test of the null hypothesis of constant returns to scale, that is, linearity test, will provide a definite answer to this question.

In this analysis, the sum of elasticities of the production function was nearly identical to one for the most part. But in the results of F-test, in Kinki of 1975–1980 (.01 level) and Hokkaido of 1980 (.10 level), it was significantly greater than one, and seemed to imply substantial economies of scale, and for particular there exsisted increasing returns to scale in the small-scale farm groups. This indicates, in other words, diseconomies of small-scale, and that could be put this way, too; it is a good evidence for explaining the economic enducements that the small-scale farm has increased in its scale during the period.[15] In fact, relatively large-scale dairy farms within the country locate in these areas. Farms in Kinki or Kanto area have some advantages of marketing for the urban areas. Especially Hokkaido farmers could easily expand to much larger production for their abundant pasture land.

Elasticities of Production Function and Factor Combination Ratio

The estimated elasticities of the production functions are subject to wide fluctuations among the groups. The distributions of the elasticities are

[15] On estimating the Cobb-douglas production function, there is also a question about the omission of variables such as "management" if $\Sigma \beta_k > 1$. See Cho (1979) in detail.

from 0.1 to 0.6 in Concentrates, 0.02 to 0.4 in Roughage, 0.1 to 0.4 in Labor, 0.02 to 0.15 in Building and Machinery, 0.02 to 0.3 in Dairy Cattle, and 0.02 to 0.2 in Current Expenses. And the elasticities of production for concentrates, roughage, and labor are relatively large, indicating that the dairy production is strongly influenced by changes in such factor inputs.

In the results there seems to be much difference in three regional types such as Hokkaido, Kanto and Kinki, and Shikoku-Kyushu, and also in two groups of period such as 1965–1970 and 1975–1980.

First, on the output elasticities of feedstuff, the concentrates increase in its elasticity in all groups but the roughage's have many-sided changes. In Hokkaido the elasticity of roughage increased during the period of 1965–1970, and the use of feedstuff was relatively roughage-using. But in 1975–1980 period the roughage-using technology has gradually turned to the roughage-saving, according as the elasticity of concentrate relatively increases. In Shikoku-Kyushu, it has also turned to the concentrate-using in the early 1970. Kanto and Kinki, while use relatively large amounts of concentrates, have become to roughage-using from the period of 1975.

For the results according to the farm types, there is a little difference in using the feedstuff among the groups in purchased feed type, but in self-sufficing type the large-scale farms are relatively concentrate-using. This indicates that the production technology in dairy farming get changed into concentrate-using in increasing the farm size.

Most interesting technological change in the production function analysis is the difference between labor and some capital inputs. In this analysis it is represented by the relative ratio of the elasticities between labor and building-machinery. The elasticity of labor is high in Kinki area, and small-scale farm's is high as compared with large-scale's. On the periodical changes in the elasticities of labor input, we found that the elasticities changed significantly between the two time period such as 1965–1970 and 1975–1980. That is, in 1965–1970 period there is an increasing tendency in all groups except Hokkaido, in 1975–1980 that is in the opposite direction. On the other hand, the changes in the elasticities of building and machinery show an opposing tendency toward the changes in the labor's. The consequences of this facts can be explained fairly in the context of factor substitution.[16] Especially farms in Hokkaido have had a building and machinery-using technology in 1965–1970 period, but it has converted to labor-using in 1975–1980; the other farms were in the opposing direction in that time period.

2. Results of Estimated Total Products

As mentioned above, the estimated production functions were significantly

16 This interpretation would be fully examined using the context of the changes in the elasticity of substitution.

TABLE 4 ESTIMATED TOTAL PRODUCTS BY REGIONAL TYPES

Year	Region	Estimated total product
	A1	17.023(96.9)
	A2	15.117(86.0)
1965	A3	18.477(105.1)
	A4	19.229(109.4)
	A5	17.308(98.5)
	average	17.576(100.0)
	A1	33.711(104.3)
	A2	23.027(71.3)
1970	A3	35.968(111.3)
	A4	39.774(123.1)
	A5	31.557(97.6)
	average	32.316(100.0)
	A1	52.957(108.5)
	A2	46.062(94.4)
1975	A3	47.030(96.3)
	A4	44.499(91.2)
	A5	49.066(100.5)
	average	48.815(100.0)
	A1	75.914(105.4)
	A2	70.392(97.7)
1980	A3	68.729(95.4)
	A4	65.943(91.6)
	A5	71.019(98.6)
	average	72.015(100.0)

Notes: 1) Estimated total product is given in physical term (M/T); $\hat{Y} = A_0 \Pi \bar{X}_k^{\beta_k}$.
2) Figures in parentheses are the relative ratios, which are measured by weighted mean of number of samples.
3) Regional types are same as Table 2.

distinguished each other, then it is difficult to compare the productivity among them directly. At this point of the analysis, next part will use a term of total products that is, $\hat{Y}$, in the context of estimated total products after due consideration of all conventional inputs for the dairy production. And we give a definition for the level of total products to the meaning of the relative level of its success in producing an output from a given set of inputs, under the estimated production function.

The estimated total products of the groups are presented in Table 4 and 5. And the relative levels, which are measured by weighted mean of number of sample, are declared in parentheses.

In the results among the regional types, the level of measured total products is changed with the lapse in time period. In the period of 1965–1970 the total product was a high level such as Kinki > Kanto > Hokkaido > Shikoku-Kyushu > Tohoku, in order, but in 1980 it has changed as Hokkaido > Shikoku-Kyushu > Tohoku > Kanto > Kinki. This

TABLE 5 ESTIMATED TOTAL PRODUCTS BY FARM TYPES

Year	Farm type	Estimated total product
1965	F1	15.862(93.0)
	F2	15.255(89.4)
	F3	13.537(79.3)
	F4	20.578(120.6)
	F5	19.234(112.7)
	average	17.063(100.0)
1970	F1	27.688(92.0)
	F2	26.792(89.1)
	F3	27.069(90.0)
	F4	35.899(119.3)
	F5	32.565(108.2)
	average	30.085(100.0)
1975	F1	39.073(83.0)
	F2	38.951(82.8)
	F3	42.274(89.8)
	F4	51.170(108.8)
	F5	55.949(118.9)
	average	47.052(100.0)
1980	F1	65.627(88.5)
	F2	69.180(93.2)
	F3	61.157(82.4)
	F4	75.805(102.2)
	F5	85.348(115.0)
	average	74.192(100.0

Notes: 1) Estimated total product is given in physical term (M/T); $\hat{Y} = A_0 \Pi \bar{X}_k^{\beta_k}$.
2) Figures in parentheses are the relative ratios, which are measured by weighted mean of number of samples.
3) Farm types are same as Table 3.

fact is, as it were, an evidence that the productivity level of dairy production has relatively shifted from urban areas to rural distant areas in the recent years.

In the farm types, the total products of large-scale farms are relatively high than small-scale's, especially Hokkaido farm with large-scale has made startling progress in its products. These results are similar to the findings related to the existance of economies of scale in the preceding part.

3. Some Implications for the Technological Change

Let us here discuss some implications connected with the analysis. We have already examined some economic features of the production function analysis. More especially, the results have provided empirical evidence of differences in technology and in changes among the different farm types,

TABLE 6 Labor Hours per a Cattle of Dairy Farming, 1965–80

		Hokkaido		All farms excluding Hokkaido	
		For milking	Total	For milking	Total
Year	1965	148	376	192	494
	1970	113	237	138	315
	1975	87	175	103	229
	1980	74	145	87	187
Farm size	1–4 head	127	256	126	303
	5–9	110	211	106	235
	10–14	93	190	101	212
	15–19	90	163	88	181
	20–29	83	157	82	165
	30–	63	128	60	132

Source: MAFF, *Milk Production Cost Records*

thereof over time and in the process of development. In this part, on the basis of the results some related implications are presented.

On the estimated production functions, the factors observed increase in average products were labor (increased about 3 times as much in the period of 1965–1980) and dairy cattle (increased about 2 times as much in the period). Other factors' were as it is or decreased. The increase in average productivity of factor inputs only means dairy farms economize on that factor required in unit output.

As mentioned above, the increase in average products of labor input, while capital's is on the decrease, also indicates a tendency that dairy farms use more capital inputs rather than labor.

Table 6 shows the changes in labor hours per a cattle of dairy famring during the period of 1965–1980. Labor hours per a head has become to decrease from 494 hours in 1965 to 187 hours in 1980 in the farms excluding Hokkaido. On the contrary, capital inputs increased from 580 thousand yen to 1,120 thousand yen during the period. (This is not appeared in the table.)

In the analysis we have compared the relative ratios of elasticities in order to clarify the relationship between the factors. Although these ratios could not be fully comparable to our results, they are still suggestive in the analysis. Two points were clear from these ratios. First, in respect to feedstuffs it is pointed out that roughage is substituted for concentrate according to the increase in farm size. Second, there is a slight substitution between labor and building and machinery especially in Shikoku-Kyushu area.

Dairy production, like as other livestock subsectors, is a specific field of agricultural production in the respect of feedstuffs-use. And the technology in use of feedstuffs have also a special meaning. That is, factor combination method between roughage and concentrate is not only limited

TABLE 7 FORAGE LAND AND PRODUCTION, 1970–80

Item	1970	1975	1980
		1,000 ha	
Total land for grazing and forage cultivation	666	840	1003
Permanent pastures	279	377	452
Annual grassland	194	311	336
Land for forage cultivation	173	152	215
		1,000 metric tons	
Total forage production	24,466	32,217	38,490

Note: Annual grassland includes paddy and other land which is double cropped.
Source: MAFF, *Statistics on Livestock*, 1985.

by the farmer's economical desire, but also by the physical desire of cattle.[18] Therefore, it is an important factor that restrict in farmer's decision making. But because of the dairy farms, some farms except in Hokkaido, have a small land for forage cultivation, there is no farm which has a perfect technical substitution between them.

In the recent years, many dairy farms in which use large amount of roughage for their own use emerged. And many dairy farms have kept to increase in the number of dairy cattles, mainly due to an expansion of grass land which was converted from rice paddy field.[19] Paddy field becomes an another source of feestuffs, especially for roughage. It is also anticipated that farms with roughage-use will continue to increase in the next some years. Table 7 shows the forage land and production during the period of 1970–80.

IV. Summary and Conclusions

The Japanese dairy farming has been undergoing major changes for the past three decades. The greatest changes on dairy farm are generally summarized as such two aspects; one is the increase in its size, the other is the changes of its location. This paper was beginning to indicate the existance of the differences in production technology through the production process. On estimating the general C-D production function in use of cross-section data, formerly the grouping was carried out. The results presented in the preceding section raise several important issues and problems for the future development of dairy farming. The findings gained from the production function analysis can be summarized as follows.

(1) There exist increasing returns to scale especially in Hokkaido

[18] In physiological restraints on the feed mix vector, the reasonable ratio between roughage and concentrate is from 30:70 to 70:30.

[19] Rice over production has become a serious problem in Japan since 1970 and, consequently, there has been official pressure put to divert paddy field to other uses or simply to allow it to remain fallow.

and Kinki area in 1975–1980. This finding is consistent with the statistical trend that the number of larger scale dairy farms has been increasing while the number of small scale farms has been decreasing in those areas relatively.

(2) The differences in the factor-use technology among farms were manifested by the relative ratio of production elasticities between roughage and concentrate, and labor and capital inputs. Especially there was a tendency that the technology gradually changes into concentrate-using in increasing the farm size.

(3) The differences in the productivity of dairy production were estimated in a term of estimated total products after due consideration of all inputs. The level of total products was relatively high as in order as Kinki > Kanto > Hokkaido > Shikoku-Kyushu > Tohoku during the period of 1965–70, but in 1980 it has changed as Hokkaido > Shikoku-Kyushu > Tohoku > Kanto > Kinki. This fact is an evidence that the productivity level of dairy production has relatively shifted from urban areas to rural distant areas in the recent years.

Concerning the findings, more studies are needed to further explain the so called "unmeasurable factors" which apparently cause the change in productivity.

REFERENCES

Bolch, B. W. and C. J. Huang, (1974), *Multivariate Statistical Methods for Business and Economics*, Prentice-Hall, Inc.

Cho, S.J., (1979), Managerial Ability and Estimation of Individual Firm Production Function: An Application to Dairy Industry in Hokkaido, Japan, Unpublished Ph.D. Dissertation, University of Hokkaido, Japan.

Dillon, J. L., (1977), *The Analysis of Response in Crop and Livestock Production*, 2nd ed., Oxford: Pergamon Press.

Heady, E. O. and J. L. Dillon, (1961), *Agricultural Production Functions*, Oxford: Pergamon Press.

Johansen, L., (1972), *Production Functions: An Integration of Micro and Macro, Short and Long Run Aspects*, North-Holland Pub. Co.

Johnstone, J., (1972), *Econometric Methods*, 2nd ed., McGraw-Hill Inc.

Kim, J. H., (1986), *Economic Analysis on the Development of Dairy Farming in Post-War Japan*, Unpublished Ph.D. Dissertation, (written in Japanese), Kyoto University, Japan.

Kim, J. H., (1986), "Production Function Analysis of Dairy Farming in Post-War Japan", (written in Japanese), *Japanese Journal of Farm Management*, Vol. 23, No. 3.

Kislev, Y. and W. Peterson, (1982), "Prices, Technology and Farm Size," *Journal of Political Economy*, Vol. 90, No. 3.

Nerlove, M., (1965), *Estimation and Identification of Cobb-Douglas Production Function*, Chicago: Rand McNally & Co.

Upton, M., (1976), *Agricultural Production Economies and Resource Use*, London:

Oxford University Press.

Yori, T. and S. Inamoto, (1967), "Production Function Analysis of Technological Change in Rice Farming", *Journal of Rural Problem,* (written in Japanese), Vol. 3, No. 1.

Yotopoulos, P. A. and J. B. Nugent, (1976), *Economics of Development: Empirical Investigations,* Happer & Row, Pub. Co.

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