Measuring Total Factor Productivity Change for Agricultural Cooperatives in Japan: A Nonparametric Malmquist Indices Approach

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Abstract

The purpose of this paper is to analyze the productivity change for agricultural cooperatives in Japan measured by nonparametric output-oriented Malmquist indices of total factor productivity. The productivity change is decomposed into technical change and technical efficiency change. Linear programming techniques are used to calculate the productivity change using a panel data set for 49 agricultural cooperatives located in the paddy-field region of Hokkaido in Japan over the period 1982-1991. The results suggest that the pattern of TFP changes tends to be driven more by improvements in technical efficiency rather than technical progress.

Key words: agricultural cooperatives, Japan, Malmquist indices, technical change, technical efficiency, TFP

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Introduction

The major organizational form of agricultural cooperatives in Japan is multi-purpose agricultural cooperatives. Japan's multi-purpose agricultural cooperatives operate simultaneously in many areas of businesses including credit, mutual insurance, purchasing (supplies of production inputs and daily necessities), and marketing (collection, shipment and sales of agricultural products). Many specialized cooperatives were established in Japan previously, but most of them either disbanded early or merged with multi-purpose cooperatives (Fujitani (1991)). Therefore, multi-purpose agricultural cooperatives (hereafter referred to merely as "agricultural cooperatives") account for the majority in Japan.

A financial structure in which the profits from the credit and insurance businesses subsidize the losses from the purchasing and marketing businesses has become the norm in Japan for agricultural cooperatives[1]. Since 1980s, the profitability of the credit business of agricultural cooperatives also deteriorated with the evolution of financial deregulation in Japan, they have been confronted with a more competitive business environment. Given this situation, agricultural cooperatives began to think that it would be difficult for them to survive without improving business performance. Thus, the goal of a 30% increase in labor productivity for each agricultural cooperative by the year 2000 was introduced at the 20th Annual Meeting of the Agricultural Cooperatives Association of Japan held in 1994. From this viewpoint, examining how the productivity of agricultural cooperatives has changed over time is a necessary task in order to facilitate the improvement of their productivity.

The purpose of this paper is to analyze technical efficiency and TFP change of agricultural cooperatives located in the paddy-field region of Hokkaido in Japan measured by nonparametric output-oriented Malmquist indices of TFP (Färe *et al.* (1994)). We focus on agricultural cooperatives located in the Hokkaido prefecture because it has the highest share of rice production in Japan (7% in 2001). The agricultural cooperatives located in the paddy-field region of Hokkaido play important roles in various businesses (financing and supplying agricultural inputs, etc.) serving member farmers.

The structure of this paper is as follows. In the following section we outline the methodology of Malmquist TFP indices. The third section describes the data used in the analysis. In the fourth section a discussion of the empirical results of our analysis is presented. In the final section we provide summary and implications.

1 Godo (2001) analyzes business performance of agricultural cooperatives in Japan. His results suggest the government's protection allowed agricultural cooperatives in Japan to count on stable profits from credit and insurance businesses.

Methodology

With regard to productivity studies of the agricultural cooperative sector in Japan, Jin *et al.* (1998) and Kawamura (2000) measured Total Factor Productivity (TFP) by making use of estimated cost functions. Since they assumed that inefficiency in agricultural cooperatives did not exist, they measured only the technical change in agricultural cooperatives, and not technical efficiency. While Kondo *et al.* (1996) and Kondo *et al.* (1997) measured technical efficiency using Data Envelopment Analysis (DEA), they did not measure technical change. Shigeno (1997) and Hotta (1998) measured technical efficiency change for the merged agricultural cooperatives by using Window Analysis of DEA, but they did not measure technical change. Yamamoto *et al.* (2006) analyzed simultaneously the technical efficiency change and the technical change of agricultural cooperatives located in the dairy-farming region of Hokkaido in Japan using nonparametric output-oriented Malmquist indices of TFP. In this study we apply the nonparametric output-oriented Malmquist TFP indices to agricultural cooperatives located in the paddy-field region of Hokkaido in Japan.

Following Färe *et al.* (1994), the Malmquist output-oriented TFP index $M_O(x^{t+1}, y^{t+1}, x^t, y^t)$ between years t and $t+1$ is as follows:

(1)
$$M_o\left(x^{t+1}, y^{t+1}, x^t, y^t\right) = \left[\frac{D_O^t\left(x^{t+1}, y^{t+1}\right)}{D_O^t\left(x^t, y^t\right)} \frac{D_O^{t+1}\left(x^{t+1}, y^{t+1}\right)}{D_O^{t+1}\left(x^t, y^t\right)}\right]^{\frac{1}{2}}$$

An alternative way in which to represent the Malmquist index (1) is the following:

(2)
$$M_o\left(x^{t+1}, y^{t+1}, x^t, y^t\right) = \frac{D_O^{t+1}\left(x^{t+1}, y^{t+1}\right)}{D_O^t\left(x^t, y^t\right)} \times \left[\frac{D_O^t\left(x^{t+1}, y^{t+1}\right)}{D_O^{t+1}\left(x^{t+1}, y^{t+1}\right)} \frac{D_O^t\left(x^t, y^t\right)}{D_O^{t+1}\left(x^t, y^t\right)}\right]^{\frac{1}{2}}$$

where the ratio outside the brackets measures the change in technical efficiency between years t and $t+1$. The geometric mean of the two ratios inside the brackets captures the shift in technology between the two periods evaluated at x^t and x^{tt1}. Therefore, the Malmquist TFP index is expressed as the product of a technical efficiency change index (*EFFCH*) and a technical change index (*TECHCH*):

(3)
$$EFFCH = \frac{D_O^{t+1}\left(x^{t+1}, y^{t+1}\right)}{D_O^t\left(x^t, y^t\right)}$$

(4) $$TECHCH = \left[\frac{D_o^t\left(x^{t+1}, y^{t+1}\right)}{D_o^{t+1}\left(x^{t+1}, y^{t+1}\right)} \frac{D_o^t\left(x^t, y^t\right)}{D_o^{t+1}\left(x^t, y^t\right)} \right]^{\frac{1}{2}}$$

The technical efficiency change index (*EFFCH*) is greater than, equal to, or less than unity according to whether technical efficiency change is improving, unchanging or declining between years *t* and *t+1*. The technical change index (*TECHCH*) is greater than, equal to, or less than unity according to whether technical change is progressing of technology, unchanging of technology, or regressing of technology between years *t* and *t+1*. The Malmquist TFP index (*M*) is greater than, equal to, or less than unity according to whether TFP change is improving, unchanging, or declining between years *t* and *t+1*.

Although it is not necessary, we follow Färe *et al.* (1994) for the purpose of consistency and impose constant returns to scale (CRS) technology for the calculation of these indices.[2] We use linear programming techniques to calculate these indices.

Data

The data used in the analysis are taken from *The Hokkaido Nogyo-Kyodo-Kumiai Yoran* (*The Data Handbook on Agricultural Cooperatives in Hokkaido*), hereafter DHACH, issued by the Hokkaido Government over the period 1982-1991 (ten years).[3] To conduct the analysis we constructed a balanced panel. Agricultural cooperatives located in the paddy-field region of Hokkaido whose share of rice sales (the annual sales of rice / the annual sales of total agricultural products) of each cooperative was greater than 40 percent over the entire period 1982-1991 were used in our study. For this period 49 cooperatives remained in the survey. Of course while it is desirable to use the most recent data available, the increase in mergers among agricultural cooperatives in Hokkaido after 1992 prevented us from obtaining a sufficient number of sample cooperatives for measurement.

The period 1982-1991 seemed to be a difficult time economically for the

2 This assumption may be relaxed by restricting the sum of the intensity variable to unity, which allows technology to exhibit increasing, constant and decreasing returns-to-scale. For estimating the Malmquist TFP index, this introduces the possibility, however, that no solution to the mixed-period problems may exist. Assuming constant return-to-scale eliminates that problem (Grosskopf, 1993, Umetsu *et al*., 2003).

3 The total number of agricultural cooperatives in Hokkaido is 248 in 1991 (*The Hokkaido Nogyo-Kyodo-Kumiai Yoran*).

agricultural cooperatives located in the paddy-field region of Hokkaido because of the downward trend in rice prices due to the stagnant demand and the excess supply for the rice, the beginning of financial deregulation and the intense pressure for the import liberalization of agricultural products.

Input and output variables[4] for measuring Malmquist TFP indices are selected following Kawamura (2000). Two inputs for cooperatives are specified (to 1000 yen units). Labor input is measured in labor expenses. Capital input is measured in other expenses (the total expenses minus labor expenses), which mainly consist of capital expenses. The five outputs are specified (to 1000 yen units) with the gross profits for credit, insurance, purchasing, marketing and other business.[5]

In order to obtain the input and output data in real value terms, it is necessary to convert the nominal value data into real value data by using deflators (1990 = 100). We make use of the same deflators as Kawamura (2000).[6]

A summary of the statistics for the cooperatives by year is listed in Table 1. All yen values are expressed in 1990 constant yen. The mean yen value of the labor expenses in 1991 was 383.5 million Yen with a range from 38.2 million Yen to 782.3 million Yen. The mean yen value of the capital expenses in 1991 was 149.0 million Yen. The mean yen value of the gross profit for credit business in 1991 was 145.4

4 In terms of the measurement of technical efficiency using DEA, Chambers *et al.* (1998) emphasize that there should always be at least three times as many observations as there are inputs and outputs.

5 We deleted ten cooperatives because they reported negative values of some outputs. For the sample period, 49 cooperatives remained in the survey.

6 The deflators employed in this study are as follows.

(1) Labor input: index numbers of wages for temporary agricultural employment of male and female from *Noson Bukka Chingin Tokei* (*Statistics of Price and Wages in Rural Areas*, hereafter SPWRA) issued by the Ministry of Agriculture, Forestry and Fisheries. In order to aggregate both index numbers, we took the arithmetic mean of index numbers on wages of male and female.

(2) Capital input: index numbers of materials price for building from SPWRA.

(3) Outputs of credit, insurance and other businesses: GDE deflators from *Kokumin Keizai Keisan Nempo* (*Annual Report on National Accounts*) issued by the Economic Planning Agency.

(4) Output of purchasing business: index number of materials price for agricultural production and index number of commodities price for living from SPWRA. In order to aggregate both index numbers, we used the share of annual purchasing sale on goods for agricultural inputs and the share of annual purchasing sale on goods for members' daily life from DHACH as weights.

(5) Output of marketing business: index numbers of agricultural products from SPWRA. In order to aggregate index numbers, we used the shares of annual marketing sale on agricultural products from DHACH as weights. Also see Kawamura (2000, pp. 358-360).

million Yen with a standard deviation of 80.9 million Yen. The means of the gross profits for insurance, purchasing, marketing and other businesses in 1991 were 82.7, 235.7, 81.9, and 44.6 million Yen, respectively.

Table 1. Summary statistics of cooperatives' real values of inputs & outputs, 1982-91

	Inputs		Outputs				
	Labor	Capital	Credit	Insurance	Purchasing	Marketing	Others
1982Mean	412.799	151.319	169.017	76.019	226.871	53.290	56.976
St. Dev.	217.045	69.716	95.367	38.994	121.646	29.119	38.112
Minimum	43.477	8.368	18.042	5.215	23.674	4.425	1.913
Maximum	990.285	359.753	445.997	164.070	515.063	139.031	203.921
1983Mean	405.637	148.737	182.877	76.517	226.551	48.731	41.086
St. Dev.	210.577	68.583	100.907	38.420	123.497	27.236	35.789
Minimum	44.231	7.488	19.720	5.130	24.098	4.931	0.789
Maximum	946.976	355.963	449.901	159.280	546.960	123.383	200.157
1984Mean	407.632	148.787	189.462	79.274	228.432	57.336	38.356
St. Dev.	210.705	69.886	102.222	39.705	125.081	34.042	32.119
Minimum	43.720	10.868	19.673	5.537	23.606	5.164	0.067
Maximum	948.445	367.232	504.099	162.895	564.065	157.903	171.534
1985Mean	408.517	150.569	183.908	80.894	230.877	62.999	40.617
St. Dev.	211.316	71.399	100.447	40.389	124.857	35.376	35.686
Minimum	42.749	11.977	17.145	5.617	23.846	5.980	0.187
Maximum	914.748	367.062	474.141	171.097	577.694	168.819	193.466
1986Mean	408.114	159.037	185.765	81.575	245.145	62.440	44.196
St. Dev.	207.291	76.518	96.568	40.614	134.251	35.030	35.285
Minimum	41.641	11.376	18.176	5.773	24.636	5.690	0.471
Maximum	889.548	399.794	429.688	167.947	630.469	171.689	190.350
1987Mean	392.494	158.104	172.933	82.451	241.616	58.799	46.436
St. Dev.	193.295	73.905	89.587	40.790	131.371	30.328	34.350
Minimum	41.142	11.389	18.119	6.201	23.570	5.269	2.743
Maximum	836.831	359.837	398.658	168.724	661.476	138.040	190.423
1988Mean	386.683	152.018	156.286	83.762	232.096	70.560	56.591
St. Dev.	187.455	69.863	84.612	41.013	125.764	37.211	37.246
Minimum	40.432	11.738	16.271	6.350	21.885	5.900	1.896
Maximum	801.874	321.326	349.625	172.717	651.880	153.784	182.425
1989Mean	380.088	150.753	166.322	81.899	222.002	72.487	55.573
St. Dev.	181.908	74.468	86.663	39.799	118.912	39.598	42.490
Minimum	37.382	10.465	15.300	6.469	20.356	5.876	2.028
Maximum	778.327	320.642	366.808	169.002	600.336	176.663	216.905
1990Mean	383.602	143.495	157.329	81.311	226.059	77.433	46.120
St. Dev.	178.986	65.834	83.575	38.645	122.180	41.602	34.386
Minimum	39.104	10.448	16.495	6.556	20.627	6.139	1.825
Maximum	776.076	303.768	388.862	166.458	649.920	171.164	169.180
1991Mean	383.496	149.043	145.387	82.728	235.695	81.899	44.606
St. Dev.	179.763	70.467	80.927	40.291	130.588	42.820	34.122
Minimum	38.154	11.006	13.212	6.944	21.072	6.894	1.598
Maximum	782.263	317.796	401.157	167.863	695.827	172.842	162.617

Note: Unit = 1 million yen.

Empirical Results

Technical Efficiency

Before the Malmquist TFP results are reported, it is useful first consider the measures of technical efficiency.[7] The results of estimating the technical efficiency output-oriented CRS specifications are presented in Table 2. Mean technical efficiency scores for the ten year period range from 0.849 in 1983 to 0.935 in 1991. The mean technical efficiency score across the entire sample period for all cooperatives is around 0.89 which suggests that there is nearly an 11% margin for improvement in terms of converting inputs into outputs. The minimum technical efficiency score across the entire sample period for all cooperatives is 0.602 in 1983.

Table 2. Technical efficiency scores: CRS output orientation, 1982-91

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	mean
Mean	0.860	0.849	0.879	0.884	0.883	0.897	0.863	0.901	0.909	0.935	0.886
St. Dev.	0.104	0.113	0.104	0.096	0.101	0.094	0.104	0.091	0.088	0.072	0.088
Minimum	0.635	0.602	0.603	0.655	0.621	0.620	0.619	0.638	0.662	0.741	0.640
Maximum	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

While the mean efficiency score for agricultural cooperatives located in paddy-field region of Hokkaido in this study is 0.89, Kondo *et al.* (1996) estimated the mean technical efficiency of agricultural cooperatives located in the same region to be 0.901 for 1982 and 0.915 for 1991. Yamamoto *et al.* (2006) estimated the mean technical efficiency of agricultural cooperatives in the dairy-farming region in Hokkaido to be 0.932 for 1982 and 0.945 for 1991. Ferrier *et al.* (1991) reported a mean technical efficiency score of 0.543 for milk processing cooperatives in the United States in 1972. Ariyaratne *et al.* (2000) estimated the pure technical efficiency of grain marketing and farm supply cooperatives in the Great Plains of the United States over the period 1988-1992. Their results show mean pure technical efficiency ranged from 0.76 in 1991 to 0.90 in 1992.

However, these findings may not mean that agricultural cooperatives located in the paddy-field region of Hokkaido are superior to those in the United States in management performance. Higher mean scores for technical efficiency in Hokkaido than in the United States were inferred from smaller differences of management performance among agricultural cooperatives in Hokkaido.

7 A new frontier is estimated each year using 49 observations of the agricultural cooperatives to determine the each year’s technical efficiency.

Correlation analysis was used to examine which cooperative characteristics were related to technical efficiency.[8] The Pearson correlation coefficient estimates between technical efficiency scores and cooperative characteristics are shown in Table 3. A positive (negative) sign on the correlation coefficient indicates that a change in that variable has a positive (negative) relationship with technical efficiency. Business size (number of full-member households)[9] and labor productivity (total gross profit / labor expenses) are selected as variables for cooperative characteristics.

In Japan, attention is often given to business size in the merger debate concerning agricultural cooperatives. The merger of agricultural cooperatives has been encouraged as one of the restructuring plans concerning agricultural cooperatives for more than thirty years. Improvement in labor productivity has also been one of the goals of the restructuring plans since 1994.

Table 3 suggests that there is no statistically significant relationship between business size and technical efficiency scores. This finding is consistent with Shigeno (1991), Kondo *et al.* (1996), Sueyoshi *et al.* (1998), and Yamamoto *et al.* (2006), suggesting that the expansion of business size by merger does not contribute to the improvement of management performance. However, this finding contrasts with that of Ariyaratne *et al.* (2000), who determined that technical efficiency increases with business size in the United States.

Table 3 suggests that there is a positive relationship between labor productivity and technical efficiency. This finding is statistically significant at the 5% level, implying that high labor productivity is related to greater efficiency.

8 The causality between technical efficiency and cooperative characteristics is generally unknown. Therefore, a bivariate correlation analysis is used in this study. However, if the issue is whether there is some multiple correlation relationship rather than just a bivariate correlation, the regression framework such as Tobit (Ariyaratne *et al.*, 2006) gives more information regarding the relationship between technical efficiency and cooperative characteristics.

9 Generally in Japan, the business size of an agricultural cooperative is shown as the number of full-member households.

Table 3. Correlation coefficients between CRS output-oriented technical efficiency scores and cooperative characteristics, 1982-91

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Business Size	-0.0842	-0.2020	-0.0668	-0.0563	-0.0626	-0.1288	-0.0575	-0.1739	-0.0185	-0.0821
Labor Productivity	0.5606**	0.4839**	0.3929**	0.4208**	0.4175**	0.3123**	0.4354**	0.3078*	0.2995*	0.2930*

Notes: Business Size=Number of full-member households, Labor Productivity=Total gross profit / Labor expenses.
** =Significant at 1%, *=Significant at 5%.

Malmquist TFP

The Malmquist TFP results for the whole sample of agricultural cooperatives are reported in Tables 4 and 5. Over the whole of the sample period TFP increased at an average rate of 1.3% per cooperative annually and has grown by 12.3% in the sample period (ten years). The pattern of TFP changes tends to be driven more by improvements in technical efficiency at an annual average rate of 1.0% rather than technical change at an annual average rate of 0.3%. The maximum annual rates of improvements in technical efficiency, technical progress, and TFP changes across the entire sample period for all cooperatives are 3.2%, 3.2% and 4.6%, respectively.

Table 4. Summary statistics of average annual change in productivity and its components, 1982-91

Summary Stastistics	Technical Efficiency Change	Technical Change	Productivity Change
Geo. Mean	1.010	1.003	1.013
St. Dev.	0.011	0.012	0.017
Minimum	0.984	0.975	0.971
Maximum	1.032	1.032	1.046

Table 5 shows that TFP growth has been volatile with few apparent trends. Except for the year 1987/88, the changes in TFP growth tend to follow changes in technical efficiency, with technical change having had little impact on TFP. The variation in the estimates reported in Table 5 may also mean that we could alter significantly the way in which we report on efficiency change, technical change and TFP growth. For example, in 1983 TFP change appears to have fallen by 2.1% when compared to the previous year. However, in 1984 the measured TFP increased by 4.8%.

Table 5. Annual efficiency, technical and Malmquist total factor productivity changes for 49 agricultural cooperatives, 1982-91: sample geometric means

Year	Efficiency change	Technical change	Productivity change
1982/83	0.987	0.992	0.979
1983/84	1.037	1.011	1.048
1984/85	1.007	1.020	1.027
1985/86	0.998	0.995	0.994
1986/87	1.016	0.987	1.003
1987/88	0.961	1.102	1.058
1988/89	1.046	0.973	1.018
1989/90	1.009	0.992	1.001
1990/91	1.031	0.964	0.994
Mean	1.010	1.003	1.013

The cooperative-level results comparable to those presented here were reported by Kawamura (2000), Ariyaratne *et al.* (2006), and Yamamoto *et al.* (2006). Kawamura (2000) used prefecture-level data for agricultural cooperatives in Japan to estimate TFP change from 1966 to 1996. He estimated that TFP and technical change increased by 1.18% and 2.25% respectively on average annually from 1985 to 1990, although he found technical regress during the period 1990-1996.

Ariyaratne *et al.* (2006) estimated TFP, technical change, pure efficiency change and scale change of grain marketing and farm supply cooperatives in the Great Plains of the United States. Their results show TFP change was mainly due to technical progress rather than improvement in pure efficiency or scale. TFP, technical change, pure efficiency change and scale change from 1990 to 1992 were 6.1%, 11.2%, -3.8% and -0.9% on average, respectively. TFP, technical change, pure efficiency change and scale change from 1996 to 1998 were 12.1%, 6.3%, 4.6% and 0.9% on average, respectively.

Yamamoto *et al.* (2006) estimated Malmquist TFP change of agricultural cooperatives in the dairy-farming region of Hokkaido in Japan from 1982 to 1991. Their results show the pattern of TFP changes tends to be driven more by technical progress at an annual average rate of 1.7% rather than improvements in technical efficiency at an annual average rate of 0.2%.

Summary and Implication

The purpose of this paper is to analyze technical efficiency and TFP change of agricultural cooperatives located in the paddy-field region of Hokkaido in Japan measured by nonparametric output-oriented Malmquist indices of TFP.

Our results are summarized as follows. First, the mean technical efficiency score across the entire sample period for all cooperatives is around 0.89 and this suggests that there is nearly an 11% margin for improvement in terms of converting inputs into outputs. Second, there is no relationship between business size and technical efficiency scores and this suggests that the expansion of business size by mergers does not contribute to the improvement of their management performance. Third, there is a positive relationship between labor productivity and technical efficiency scores with a 5% statistical significance and this suggests that high labor productivity is related to greater efficiency. Fourth, over the whole of the sample period TFP increased at an average rate of 1.3% per cooperative annually and has grown by 12.3% in the sample period. Fifth, the pattern of TFP changes tends to be driven more by improvements in technical efficiency at an average rate of 1.0% rather than technical change at an average rate of 0.3%.

Finally, we would like to discuss the goal of a 30% increase in labor productivity in each agricultural cooperative by the year 2000 introduced at the 20th Annual Meeting of the Agricultural Cooperatives Association of Japan in 1994. Strictly speaking the Malmquist TFP is not the same as the labor productivity, but we would like to use Malmquist TFP change as a proxy indicator of labor productivity change. If we use our estimate of the average annual rate of TFP as 1.3%,[10] the growth rate of TFP would be only 5.3% from 1994 to 2000. Even if we use the largest average annual rate of TFP growth of the samples, the growth rate of TFP (19.7%) is below 30% from 1994 to 2000. Therefore, the results suggest that the goal of a 30% increase in labor productivity by the year 2000 was certainly an ambitious one.

Since this study does not use data from 1994, no evidence is provided to suggest whether the goal of a 30% increase in labor productivity by the year 2000 was met or not. It would be a fruitful avenue for future research to examine this issue through measurement of the Malmquist TFP indices by pooling data from other regions to obtain data on cooperatives from 1992.

10 Due to limitations of data availability, we were not able to estimate the growth rate of TFP from 1994 to 2000. Instead, we assumed that the annual TFP growth rate over the period 1994-2000 is the same as the annual TFP growth rate over the period 1982-1991.

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