[*Jpn. J. Rural Econ.* Vol. 8, pp. 58-63, 2006]

Productivity and Efficiency Change for Agricultural Cooperatives in Japan: The Case of the Dairy-Farming Region in Hokkaido

Yasutaka Yamamoto,* Katsunobu Kondo† and Jun Sasaki‡

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 (TFP). 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 44 agricultural cooperatives located in the dairy-farming 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 technical progress rather than improvements in technical efficiency. The results also suggest that the goal of a 30 % increase in productivity in agricultural cooperatives by the year 2000 introduced at the 20th Annual Meeting of the Agricultural Cooperatives Association of Japan held in 1994 was unattainable in the case of 44 agricultural cooperatives located in the dairy-farming region of Hokkaido.

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

1. Introduction

Was the goal of a 30% increase in productivity for each agricultural cooperative in Japan by the year 2000 attainable?

Nokyo, the system of agricultural cooperatives in Japan, is distinct from its Western counterparts. 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, i. e., supplies of production inputs and daily necessities, and marketing, i. e., collection, shipment and sales of agricultural products. Many specialized cooperatives of the Western style were established in Japan previously, but most of them either disbanded early or merged with multi-purpose cooperatives (Fujitani [4]). Therefore, multi-purpose agricultural cooperatives (hereafter referred to as merely as "agricultural cooperatives") account for the majority in Japan.

The management performance of Japan's agricultural cooperatives from the beginning of the establishment of their organizations after World War II was unstable mainly due to their small business size. For the purpose of improving their performance, the merger of agricultural cooperatives has been encouraged for more than thirty years as one of the restructuring plans of agricultural cooperatives. The mergers were expected not only to improve efficiency and productivity, but also to enable agricultural cooperatives to utilize

*Hokkaido University
† Asahikawa University
‡ Tokyo University of Agriculture

An earlier version of this paper was presented at the Asia Conference on Efficiency and Productivity Growth held at the Center of Academic Activity, Academia Sinica, Taipei, Taiwan, July 19-20, 2002. Senior authorship is shared.

The authors are grateful to two anonymous referees of this journal for their many constructive comments and suggestions for our earlier version of this paper. However, the responsibility for any errors rests on solely with authors.

their funds effectively in their credit business.

While the profit of both their credit and mutual insurance businesses has increased remarkably through the mergers, the profit of their purchasing and marketing businesses has fallen into a permanent deficit due to the stagnant demand for rice and drinking milk, which are the main marketing products of the agricultural cooperatives. 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 for agricultural cooperatives in Japan.

Since the profitability of the credit business of agricultural cooperatives also deteriorated with the evolution of financial deregulation in Japan during the 1980s, agricultural cooperatives 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 their 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.

With regard to productivity studies of the agricultural cooperative sector in Japan, Jin and Kawamura [6] and Kawamura [7] 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 their technical efficiency. While Kondo and Demura [8] and Kondo, Demura and Yamamoto [9] measured technical efficiency by making use of Data Envelopment Analysis (DEA), they did not measure technical change. Shigeno [11] and Hotta [5] measured technical efficiency change for the merged agricultural cooperatives by Window Analysis of DEA, but they did not measure technical change. Thus, previous studies on the productivity measurement of agricultural cooperatives in Japan have analyzed the technical efficiency change and the technical change of agricultural cooperatives separately, not simultaneously.

The purpose of the paper is to analyze simultaneously the technical efficiency and the technical change of agricultural cooperatives located in the dairy-farming region of Hokkaido in Japan measured by nonparametric output-oriented Malmquist indices of TFP (Färe et al. [3]). The reasons why we focus on the agricultural cooperatives located in this region are as follows. Dairy farmers in Hokkaido currently produce more than 40% of Japan's raw milk (43% in 1998). The agricultural cooperatives located in the dairy-farming region of Hokkaido play important roles in various businesses (financing and supplying agricultural inputs, etc.) for 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 conclusions.

2. Malmquist TFP Indices

Following Färe et al. [3], 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:

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

where $D_o^t(\cdot)$ indicates output-based distance function in year t,[1)] x^t input vector in year t, and y^t output vector in year t.

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

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

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^{t+1}. Therefore, the

Malmquist TFP index is expressed as the product of a technical efficiency change index (*EFFCH*) and a technical change index (*TECHCH*):

$$EFFCH = \frac{D_o^{t+1}(x^{t+1}, y^{t+1})}{D_o^t(x^t, y^t)} \quad (3)$$

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

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, unchanging, or regressing between years t and $t+1$. The Malmquist TFP index (M_o) is greater than, equal to, or less than unity according to whether TFP change is improving, unchanging, or declining between years t and $t+1$.

We follow Färe et al. [3] for the purpose of consistency and impose the constant returns to scale (CRS) technology for the calculation of these indices. We use linear programming techniques to calculate these indices.

3. Data

The data used in the analysis are taken from *Hokkaido Nogyo-Kyodo-Kumiai Yoran* (*Data Handbook on Agricultural Cooperatives in Hokkaido*, hereafter DHACH) issued by the Hokkaido Government over the period 1982-1991 (ten years). To conduct the analysis we constructed a balanced panel. In our study, we used agricultural cooperatives located in the dairy-farming region of Hokkaido whose share of raw milk, calf and cattle turnover in the marketing business of each cooperative was greater than 40 percent over the entire period 1982-1991. 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. Our final sample consists of 44 agricultural cooperatives. 2)

The period 1982-1991 seemed to be a difficult time economically for the agricultural cooperatives located in the dairy-farming region of Hokkaido because of the downward trend in milk prices due to the stagnant demand for drinking milk, the beginning of financial deregulation and the intense pressure for the import liberalization of dairy products.

Input and output variables for measuring Malmquist TFP indices are selected following Kawamura [7]. Two inputs for cooperatives are specified. 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 with the gross profits for credit, insurance, purchasing, marketing and other business.

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 [7]. 3)

4. Results and Interpretation

1) Technical efficiency estimates

Before the Malmquist TFP results are reported, it is useful first to consider the measures of technical efficiency. The results of estimating the technical efficiency output-oriented CRS specifications are presented in Table 1. The geometric mean of technical efficiency scores across the entire sample period for all cooperatives is around 0.95 which suggests that there is nearly a 5% margin for improvement in terms of converting inputs into outputs.

While the mean efficiency score for agricultural cooperatives located in the dairy-farming region of Hokkaido in this study is 0.95,

Table 1. Technical efficiency scores of agricultural cooperatives: CRS output-orientation, 1982-91

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	Mean
Mean	0.932	0.936	0.946	0.956	0.949	0.950	0.960	0.949	0.937	0.945	0.946

Notes : a) Sample size is 44. b) The sample mean is a geometric mean.

Kondo, Demura and Yamamoto [9] estimated the mean technical efficiency of agricultural cooperatives located in the same region to be 0.869 for 1982 and 0.840 for 1991. The reasons why the mean technical efficiency scores in Kondo, Demura and Yamamoto [9] are lower than in our study seem to be: (1) we added gross profit of other business as one more output variable[4)] and (2) we employed labor expenses rather than the number of employees as a labor input variable.

Correlation analysis was used to examine which cooperative characteristics were related to technical efficiency. The Pearson correlation coefficient estimates between technical efficiency scores and cooperative characteristics are shown in Table 2. A positive sign on the correlation coefficient indicates that a change in that variable has a positive relationship with technical efficiency. Business size (number of full-member households)[5)] is selected as a variable 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.

Table 2 suggests that there is no statistically significant relationship between business size and technical efficiency scores. This finding is consistent with Shigeno [10], Kondo, Demura and Yamamoto [9], and Sueyoshi et al. [12], 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. [1], who determined that technical and allocative efficiency increase with business size for grain marketing and farm supply cooperatives in the Great Plains of the United States over the period 1988-92, with agricultural cooperatives with larger business size allocating inputs more efficiently.

2) Malmquist TFP results

The Malmquist TFP results for the whole sample of agricultural cooperatives are reported in Table 3. Over the whole of the sample period TFP increased at an average rate of 1.9% per cooperative annually and has grown by 18.5% in the sample period (ten years). The pattern of TFP changes tends to be driven more by technical progress at an annual

Table 2. 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	0.0666	0.0861	0.1632	0.1086	0.1197	0.1274	0.0722	0.1983	0.1688	0.1280

Notes : a) Business size is number of full-member households. b) Sample size is 44. c) * and ** represent the statistical significance at 5% and 1%, respectively.

Table 3. Annual efficiency, technical and Malmquist TFP changes for 44 agricultural cooperatives, 1982-91: sample geometric means

Year	Efficiency change	Technical change	TFP change
1982/83	1.005	1.050	1.055
1983/84	1.010	0.997	1.007
1984/85	1.011	0.992	1.003
1985/86	0.992	1.023	1.015
1986/87	1.002	1.052	1.053
1987/88	1.010	1.011	1.021
1988/89	0.989	1.021	1.009
1989/90	0.988	0.997	0.984
1990/91	1.009	1.013	1.022
Mean	1.002	1.017	1.019

average rate of 1.7% rather than improvements in technical efficiency at an annual average rate of 0.2%.

Table 3 shows that TFP growth has been volatile with few apparent trends. The changes in TFP growth closely follow changes in technical progress, with changes in technical efficiency having had little impact on TFP. The variation in the estimates reported in Table 3 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 1990 TFP change appears to have fallen by 1.6% when compared to the previous year. However, in 1991 the measured TFP increased by 2.2%.

The only cooperative-level results comparable to those presented here were reported by Kawamura [7]. He 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.

5. Conclusion

The purpose of this paper is to analyze technical efficiency and TFP change of agricultural cooperatives located in the dairy-farming 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 0.95 and this suggests that there is nearly a 5% 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, over the whole of the sample period TFP increased at an average rate of 1.9% per cooperative annually and has grown by 18.5% in the sample period. Fourth, the pattern of TFP changes tends to be driven more by technical progress at an average rate of 1.7% rather than improvements in technical efficiency at an average rate of 0.2%.

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 1.9%[6), the growth rate of TFP would be only 7.8% from 1994 to 2000. Even if we use the largest average annual rate of TFP growth of the samples, the growth rate of TFP (29.1%) is below 30% from 1994 to 2000. Therefore, the results of this study suggest that the goal of a 30% increase in productivity in agricultural cooperatives located in the dairy-farming region of Hokkaido by the year 2000 was unattainable.

1) The output-based distance function in year t, $D_o^t(x^t, y^t)$, can be interpreted as a reciprocal of Farrell's measure of output-based technical efficiency in year t and calculated as by-product in the measurement of the Malmquist TFP indices.

2) We deleted twelve cooperatives because they reported negative values of some outputs. We also deleted one cooperative because they reported only one employee. For the sample period, 44 cooperatives remained in the survey.

3) 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 an-

nual 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 [7, pp. 358-360].

4) In terms of the measurement of technical efficiency using DEA, Chambers et al. [2] emphasize that there should always be at least three times as many observations as there are inputs and outputs.

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

6) Due to limitations of data availability, we could not 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.

References

[1] Ariyaratne, C. B., A. M. Featherstone, M. R. Langemeier and D. G. Barton. "An Analysis of Efficiency of Midwestern Agricultural Cooperatives," *the Western Agricultural Economics Association Selected Paper of the 1997 Annual Meeting*, July 13-16, 1997, Reno/Sparks, Nevada, USA, pp. 1-13.

[2] Chambers, R. G., R. Färe, E. Jaenicke and E. Lichtenberg. "Using Dominance in Forming Bounds on DEA Models: The Case of Experimental Agricultural Data," *Journal of Econometrics*, Vol. 85, 1998, pp. 189-203.

[3] Färe, R., S. Grosskopf, M. Norris and Z. Zhang. "Productivity Growth, Technical Progress, and Efficiency Change in Industrialized Countries," *American Economic Review*, Vol. 84, 1994, pp. 66-83.

[4] Fujitani, C. "Japan's Agricultural Cooperatives," in the Committee for the Japanese Agriculture Session, XXI IAAE Conference, ed., *Agriculture and Agricultural Policy in Japan*. Tokyo: University of Tokyo Press, 1991, pp. 223-243.

[5] Hotta, K. "Koiki-Gappei-Nokyo no Marketing-Koritsu to Eino-Shido Hanbai-Jigyo no Soshiki-Saihen-Hoko (The Marketing Efficiency of Merged Agricultural Cooperatives and the Direction of the Reorganization of Sales and Farm Management Guidance Activities)," *Nogyo Keiei Kenkyu* (*Japanese Journal of Farm Management*), Vol. 36, 1998, pp. 1-15.

[6] Jin, S. H. and T. Kawamura. "Sogo-Nokyo no Seisansei no Suii to sono-Yoin: Total Factor Productivity (TFP) niyoru Bunseki (Trend and Decomposition of Productivity of Multipurpose Agricultural Cooperatives: Total Factor Productivity Approach)," *1998-Nendo Nihon-Nogyo-Keizai-Gakkai Ronbunshu* (*Journal of Rural Economics, Special Issue 1998*), 1998, pp. 52-57.

[7] Kawamura, T. "Sogo-Nokyo no So-Yoso-Seisansei no Keisoku to sono-Yoin ni kansuru Jisshoteki-Kenkyu (Measurement of Total Factor Productivity of Agricultural Cooperatives)," *Kyodokumiai Shorei Kenkyu Hokoku* (*Research Report on Agricultural Cooperatives for Young Researchers*), Vol. 25, 2000, pp. 343-380.

[8] Kondo, K. and K. Demura. "Kome-Seisan-Chosei-Ki niokeru Sogo-Nokyo no Keiei-Koritsusei to sono-Keieiteki-Tokushitsu (Management Efficiency of Agricultural Cooperatives and their Management Characteristics in a Period of Rice Production Control)," *Hokkaido Daigaku Nokei-Ronso* (*Review of Agricultural Economics, Hokkaido University*), Vol. 52, 1996, pp. 75-89.

[9] Kondo, K., K. Demura and Y. Yamamoto. "Hokkaido no Rakuno-Chitai niokeru Sogo-Nokyo no Keiei-Koritsusei to sono-Yoin (The Technical Efficiency of Agricultural Cooperatives in Hokkaido's Dairy-farming Region)," *Hokkaido Daigaku Nokei-Ronso* (*Review of Agricultural Economics, Hokkaido University*), Vol. 53, 1997, pp. 55-59.

[10] Shigeno, R. "Nokyo-Keiei no Gijutsu-Koritsusei to sono-Yoin (The Technical Efficiency of Agricultural Cooperatives in Japan)," *Nogyo-Keizai-Kenkyu* (*Journal of Rural Economics*), Vol. 63, 1991, pp. 91-99.

[11] Shigeno, R. "Nokyo-Gappei no Keizai-Bunseki (Mergers and Economic Efficiency: A Case Study of Japanese Agricultural Cooperatives)," *1997-Nendo Nihon-Nogyo-Keizai-Gakkai Ronbunsyu* (*Journal of Rural Economics, Special Issue 1997*), 1997, pp. 247-251.

[12] Sueyoshi, T., T. Hasebe, F. Ito, J. Sakai and W. Ozawa. "DEA-Bilateral Performance Comparison: An Application to Japan Agricultural Co-operatives (Nokyo)," *Omega, International Journal of Management Science*, Vol. 26, 1998, pp. 233-248.

(Received November 4, 2005; accepted January 6, 2006)