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Abstract

Since the 1970s, the policy of Indian government has been to promote dairy development on the basis of the cooperative organisations. During the 1990s the dairy industry in India was liberalised. This study examines the impact of the liberalisation policy on the cooperative dairy plants in India. Data envelopment analysis (DEA) and the Fisher index approach are applied to measure economic efficiency and total productivity changes, respectively. The data involves 65 observations from a complete panel of 13 cooperative dairy plants from 1992/93 to 1996/97. The empirical results show that the deregulation and liberalisation of the dairy industry alone is not the answer.

Key Words: productivity, efficiency, Fisher index, Indian dairy processing.

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1. Introduction

Dairy cooperatives have played a prominent role in the development of dairy industry in India. A huge amount of money has been spent on the creation of infrastructure and provision of facilities for the cooperative dairies. The dairy cooperative has a four-level structure, which consists of National Dairy Development Board (NDDB), state federations, milk unions and dairy cooperative societies operating at the national level, state level, district level and village level, respectively. The milk unions of dairy cooperative societies operate dairy plants, and the dairy plants are the focus of this study.

In 1991 a new delicensing dairy policy was introduced. As a result of this new policy, milk plant numbers have increased in the private sector. The impact of the new market policy on the cooperatives needs to be assessed. The main objective of the present study is to estimate the overall impact of the new policy on the performance of milk plants operating in the cooperative sector. From the point of view of present study, it is useful to know that very few studies have been carried out in the dairy processing sector as reported by Singh, Coelli and Fleming (1999). The efficiency literature may be lacking studies of dairy processing units because of the unavailability of required data.

Performance of firms are generally measured in terms of economic efficiency (decomposed into technical and allocative efficiency) and total factor productivity. These concepts, which are widely accepted as measures of performance of the firm,

have not been applied in milk processing on a large scale, as in other areas, such as production. This study makes an attempt to measure cost efficiency and total factor productivity of the cooperative sector by covering many multi-input and multi-output dairy plants in two states of India.

In this study, data envelopment analysis (DEA) and Fisher index approach are employed to measure cost efficiency and total factor productivity, respectively. The estimation of efficiency measures is a useful first step to improve the productivity of dairy plants. Both producers and consumers can be benefited by efficiency improvement.

The remainder of the paper is organised into four sections. The data are described in section 2. In section 3, the DEA method and its results are presented. Section 4 covers the Fisher index method and its results. Section five provides some conclusions.

2. Data

An effort is made to collect data across milk plants and over a time in the cooperative sector. Primary data were collected from milk plants operating in Punjab and Haryana states through interviews and questionnaires. Information was collected on outputs and inputs. A questionnaire was designed to obtain information from the milk plants.

Data were collected from 13 cooperative milk plants. Of these 13 milk plants, four operate in the in Haryana state and nine operate in Punjab state. The data involve a combined total of 65 observations of annual data covering the period from 1992/93 to 1996/97. All cooperative milk plants operating in these two states are covered in the study.

Variables

One output and four input variables are used in analytical models. These variables are listed below.

- Output — aggregate output quantity of the milk products produced by the dairy plant.

- Raw material — aggregate quantity of milk and other products used as raw material by the dairy plant.

- Labour — total labour involved in the dairy plant.

- Capital — the costs of depreciation, repairs and maintenance and interests of the machinery and building of the dairy plant.

- Other inputs — other costs of dairy production inputs (administration cost, fuel, power and insurance) excluding raw material, labour and capital.

The information on these variables were provided in value terms. Implicit quantities (at constant prices) are calculated by dividing the values in current prices by the corresponding price index. Price indices were obtained from the Directorate of Economics and Statistics, Government of India, New Delhi.

3. Data Envelopment Analysis (DEA) Method

Before describing DEA method, input-oriented efficiency measures are discussed, which are used in the present study. Farrell (1957) used a two-input and single-output constant returns-to-scale example to demonstrate his ideas.

In Figure 1, two inputs, X_1 and X_2, are represented on the horizontal and vertical axes, respectively. $SS^/$ is an isoquant representing various combinations of inputs (X_1 and X_2) used to produce a certain quantity of output (Y). All points on this isoquant reflect technically efficient production. An effort is made to measure the efficiency of a particular firm, which is operating at a point P. At this point (P), the particular firm produces the same level of output (Y) as produced on isoquant, $SS^/$. To define the technical efficiency of the observed firm, a line is drawn from the origin to the point P. This line crosses the isoquant at the point Q. In the case of a technically efficient firm, the same amount of output (Y) is produced using inputs (X_1 and X_2) defined by the point Q. Inputs are not used efficiently by observed firm P. So the technical efficiency of the observed firm is defined as the ratio of the distance from the point Q to the origin, over the distance of the point P from the origin:

TE = OQ/OP.

Figure 1:   Technical and allocative efficiencies in input-oriented measures
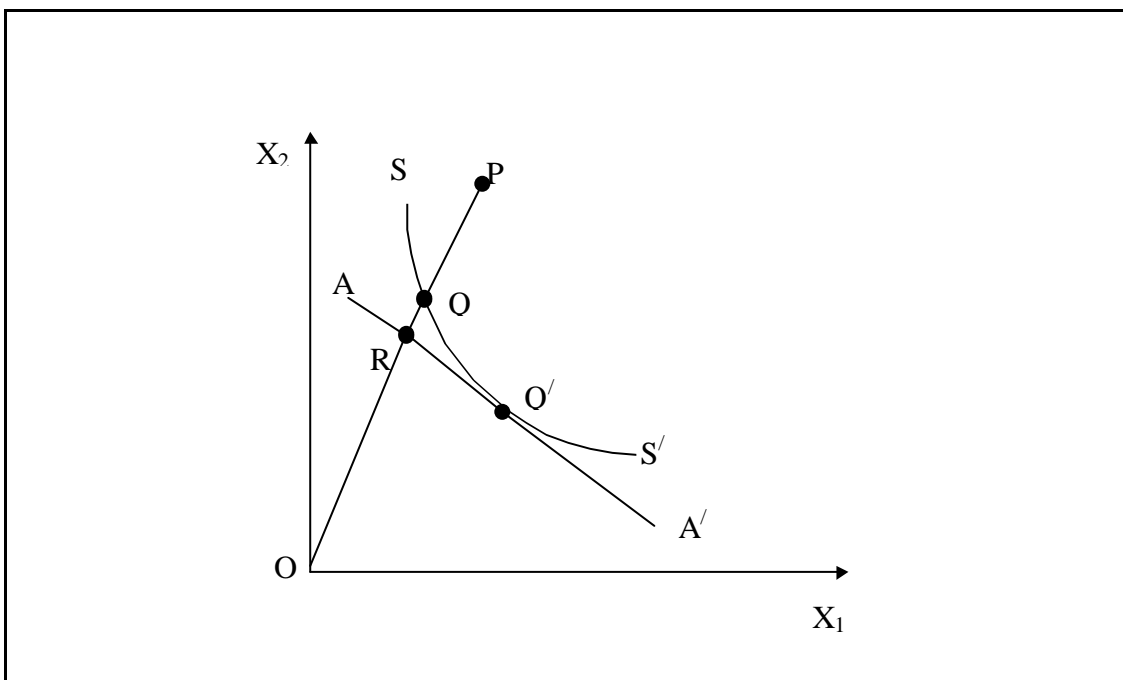
If the input prices are available, allocative efficiency could also be defined. An isocost line, $AA^{/}$, is drawn tangential to the isoquant, $SS^{/}$, at the point $Q^{/}$, which intersects the line OP at the point R. For the output quantity produced at the point Q, the best use of inputs is at the point $Q^{/}$ because it incurs the minimum cost. Therefore, the point Q is not an optimal point because the distance, RQ (cost), can be reduced without any reduction in output. Allocative efficiency is defined as the ratio of the distance of the point R to the origin over the distance of the point Q from the origin:

AE = OR/OQ.

Economic efficiency is the product of technical efficiency and allocative efficiency:

EE = (OQ/OP)(OR/OQ) = OR/OP.

Technical, allocative and economic efficiencies are calculated using DEA methods. Technical efficiency is calculated using the input-oriented variable returns to scale (VRS) DEA model. The VRS model is discussed below. This is followed by a discussion of the DEA-Cost model. The exposition, which follows, is based upon Coelli, Rao and Battese (1998).

3.1 Technical Efficiency

Suppose data are available on K inputs and M outputs in each of N firms. Input and output vectors are represented by the vectors, x_{it} and y_{it}, respectively, for the i-th firm in t-th time period. The data for all firms may be denoted by the K×NT input matrix (X) and the M×NT output matrix (Y). The envelopment form of the input-oriented VRS DEA model is specified as follows:

$\min_{\theta, \lambda} \theta,$

st $\quad -y_{it} + Y\lambda \geq 0,$

$$\theta x_{it} - X\lambda \geq 0,$$

$$N1' \times \lambda = 1$$

$$\lambda \geq 0, \quad\quad\quad\quad\quad\quad\quad\quad\quad\quad (1)$$

where θ is the input technical efficiency measure having a value $0 \leq \theta \leq 1$. If the θ score is equal to one, it indicates that the firm is on the frontier. The vector λ is an $NT \times 1$ vector of weights which defines the linear combination of the peers of the i-th firm in the t-th period. The linear programming problem needs to be solved NT times, providing a value of θ for each firm in the sample.

3.2 Economic Efficiency

The cost-minimising vector of input quantities for the i-th firm in the t-th time period is calculated using the cost minimisation DEA model. The model is specified below.

$$\min_{\lambda, x_{it}^{E}} x_{it}^{E} w_{it}$$

st $\quad -y_{it} + Y\lambda \geq 0,$

$$x_{it}^{E} - X\lambda \geq 0,$$

$$N1'\lambda = 1$$

$$\lambda \geq 0, \quad\quad\quad\quad\quad\quad\quad\quad\quad\quad (2)$$

where w_{it} is a vector of input prices for the i-th firm in the t-th time period and x_{it}^{E} is the cost-minimising vector of input quantities for the i-th firm in the t-th time period.

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Economic efficiency is calculated by dividing minimum cost by observed cost.

Economic efficiency = minimum cost/observed cost

or

$$EE = w_{it}{}^{E}x_{it} / x_{it}w_{it} \qquad\qquad (3)$$

3.3 Allocative Efficiency

Allocative efficiency is calculated by dividing economic efficiency by technical efficiency.

Allocative efficiency = economic efficiency/technical efficiency

or

$$AE = EE/TE, \qquad\qquad (4)$$

where TE is the θ obtained from equation (1). Efficiency scores are obtained using the computer program, DEAP Version 2.1, described in Coelli (1996).

3.4 Results and Discussion

In this section, the measures of technical, allocative and cost efficiency obtained using VRS DEA and cost minimisation DEA models are discussed. The technical, allocative and cost efficiency scores of the cooperative plants for the five years involved are reported in Table 1. The mean values of technical, allocative and cost efficiency are 0.912, 0.731 and 0.667, respectively. These results suggest that there is significant scope to increase efficiency levels in the cooperative plants. The mean cost could be reduced by about 37 per cent.

Table 2 reports information about the efficiency scores over time in the cooperative plants. These efficiency scores are based on the variable returns to scale assumption. There was an increase in allocative and cost efficiencies over the five year period, while technical efficiency declined to some extent. The improvements in allocative and cost efficiencies may be due to the increased competition from the growing number of private plants putting pressure upon the cooperatives to allocate their resources properly.

Table 1: Mean technical, allocative and cost efficiency scores of cooperative plants, 1992/93-1996/97

Dairy Plant	Technical efficiency	Allocative efficiency	Cost efficiency
Plant A	0.973	0.875	0.851
Plant B	0.969	0.755	0.731
Plant C	0.902	0.783	0.705
Plant D	0.837	0.649	0.523
Plant E	0.772	0.904	0.698
Plant F	0.865	0.580	0.498
Plant G	0.929	0.627	0.581
Plant H	0.968	0.933	0.904
Plant I	0.895	0.406	0.362
Plant J	0.893	0.587	0.523
Plant K	0.975	0.938	0.915
Plant L	0.975	0.782	0.765
Plant M	0.907	0.682	0.616
Minimum	0.772	0.406	0.362
Maximum	0.975	0.938	0.915
Average	0.912	0.731	0.667

Table 2: **Efficiency scores of cooperative plants during 1992/93 to 1996/97**

Year	Technical efficiency	Allocative efficiency	Cost efficiency
1992/93	0.937	0.688	0.647
1993/94	0.955	0.687	0.654
1994/95	0.904	0.726	0.658
1995/96	0.867	0.791	0.689
1996/97	0.899	0.762	0.688

4. The Fisher Index

The productivity index is defined as the ratio of an output index to an input index. We calculate these indices using the Fisher index. The Fisher quantity index (Q_{st}^{F}) is a geometric mean of the Laspeyres and Paasche indices. Its formula is:

$$Q_{st}^{F} = \sqrt{Q_{st}^{L} \times Q_{st}^{P}}, \tag{5}$$

where

$$\text{Laspeyres index} = Q_{st}^{L} = \frac{\sum_{i=1}^{N} p_{it} q_{is}}{\sum_{i=1}^{N} p_{is} q_{is}} = \sum_{i=1}^{N} \frac{p_{it}}{p_{is}} \times w_{is} \; ; \text{and} \tag{6}$$

$$\text{Paasche index} = Q_{st}^{P} = \frac{\sum_{i=1}^{N} p_{it} q_{it}}{\sum_{i=1}^{N} p_{is} q_{it}} = \frac{1}{\sum_{i=1}^{N} \frac{p_{is}}{p_{it}} \times w_{it}}. \tag{7}$$

In equations (5) and (6), p_{is} is price of the i-th commodity in the s-th year and p_{it} is the price of i-th commodity in the t-th year. The notations, q_{is} and q_{it}, represent quantities of the i-th commodity in the s-th year and t-th year, respectively. Furthermore, w_{is} is the value share of the i-th commodity in the base period, s, and w_{it} is the value share of the i-th commodity in period t.

The Fisher index needs price and quantity information on each variable for each year. It is also known as the Fisher Ideal index because it satisfies a large number of important properties. According to Diewert (1992), there are 21 tests that are satisfied by the formula, which illustrates its versatility. Some of these tests are listed below.

Positivity: The index number is positive.

Continuity: The index is a continuous function of the prices and quantities.

Proportionality: When there is any proportional price change in all prices (p_{it}), then Q_{st}^{F} is also changed by the same proportion.

It is invariant to changes in units of measurement.

Time reversal test: For two periods s and t:

$$Q_{st}^{F} = 1/Q_{ts}^{F}.$$

Mean value test: The quantity index lies between the respective minimum and maximum price changes at the commodity level.

Factor reversal test: If the same formula is used for price and quantity indices, their product is equal to the value ratio.

Although many of these properties appear fundamental, many other index numbers (e.g. Laspeyres and Paasche) do not satisfy all of these tests. Furthermore, as noted by Diewert (1992), the Fisher index is a "superlative" index, because it is exact for the quadratic functional form, which is a flexible functional form (where a "flexible" form is one that provides a second-order approximation to an arbitrary twice continuously differentiable functional form).

Results and Discussion

On an individual plant basis, the Fisher-EKS TFP indices are also calculated for all cooperative plants operating in Haryana and Punjab for the period from 1992/93 to 1996/97. The results are presented in Table 3.

In Table 3, the total factor productivity level of Plant A in 1992/93 is set at 1.00 in 1992/93 and the total factor productivity changes for Plant A in other years of the study period and for other plants are observed against Plant A in 1992/93 as the base. Total factor productivity indices show that there were large variations in productivity among plants.

In 1992/93, Plant B had the lowest productivity level of 0.86 and Plant G had the highest productivity level of 1.51, showing a 43 per cent (0.86/1.51 = 0.57) difference in productivity level among dairy plants. The maximum productivity differences are 0.35, 0.43, 0.36 and 0.37 per cent among dairy plants in 1993/94, 1994/95, 1995/96 and 1996/97, respectively.

Plant B achieved the highest rise in TFP of 29 per cent from 1992/93 to 1996/97. Plant F exhibited the largest decline of 27 per cent over the study period.

When we compare the TFP results from the index number method with technical efficiency results from the DEA analysis for the cooperative plants. These two methods use the same data. The TFP change is equal to the sum of technical change, technical efficiency change and scale change. We could assume that there has been no technical change and that the scale effect should be minimal given that firm sizes have not changed noticeably. Therefore, the technical efficiency change measured by DEA should be roughly equal to the TFP change measured using the Fisher indices. The TFP change and technical efficiency change results are similar. Technical efficiency in the cooperative dairy plants declined over the study period in the DEA analysis. TFP in cooperative plants also declined over the study period.

Table 3:   **Indices of total factor productivity change for individual dairy plants, 1992/93-1996/97**

Dairy Plant	Year				
	1992/93	1993/94	1994/95	1995/96	1996/97
Plant A	1.00	1.00	1.00	0.95	0.96
Plant B	0.86	1.06	1.14	1.08	1.11
Plant C	1.35	1.12	1.03	1.00	1.03
Plant D	0.98	0.94	0.84	0.77	0.76
Plant E	0.88	0.86	0.75	0.83	0.83
Plant F	1.22	1.32	1.11	0.94	0.89
Plant G	1.51	1.31	1.11	1.20	1.17
Plant H	1.00	1.28	0.99	1.04	1.05
Plant I	0.98	1.09	1.03	1.12	1.21
Plant J	0.99	1.12	1.05	0.98	1.07
Plant K	0.93	1.04	1.07	1.20	0.95
Plant L	1.29	1.26	0.94	0.92	1.05
Plant M	1.19	1.17	1.31	1.14	1.12
Average	1.09	1.12	1.03	1.01	1.02

5. Conclusions

Our analysis of cooperative dairy plants shows that there were variations in efficiency and total factor productivity scores among plants. Our results also indicate that the TFP change and technical efficiency change declined from 1992/93 to 1996/97. However, there were improvements in allocative and cost efficiencies over the study period, which could be due to increased competition among plants.

Our efficiency results indicate that there is significant scope for efficiency improvement in the dairy industry. The mean cost could be reduced by 37 per cent. However, privatisation alone is not the answer to higher performance in the processing sector of the industry. Plant managers and public policy makers should make efforts to achieve higher performance through actions on both the demand and supply side of the milk and milk products industry.

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