CHAPTER 8

INVESTIGATION ON THE MALMQUIST PRODUCTIVITY INDEX MEASURE

8.1 INTRODUCTION

The Malmquist index was introduced by Caves, Christensen and Diewert (CCD) (1982) and developed further in the context of performance assessments by Fare et al. (1994). They named these indices after Malmquist, who had earlier proposed constructing input quantity indices as ratios of distance functions. In recent years, the Malmquist index has become the standard approach to productivity measurement over time within the non-parametric literature. This popularity can be attributed to several factors. The Malmquist productivity index has the advantage that it can be constructed from quantity data only. Caves et al, argued that the empirical usefulness of the Malmquist productivity index was limited by the need to estimate the parameters of the underlying technology.

In the later years, Fare, Grosskopf, Lindgren and Roos (FGLR) (1992, 1994) provided the foundation by showing how to use linear programming techniques to calculate a Malmquist productivity index. The Malmquist productivity index is based on distance functions, output distance functions for an output-oriented index and input distance functions for an input-oriented index. The FGLR approach is an adaptation of the Charnes et al (1978), Banker et al (1984), oriented DEA models designed to construct non—parametric Debreu (1951) and Farrell (1957) radial efficiency measures.

Distance functions are reciprocals of radial efficiency measures, and so the FGLR technique can be used to construct a non—parametric Malmquist productivity index. The index is usually applied to the measurement of productivity change over time, and can be multiplicatively decomposed into an efficiency change index and a technological change index.

In this chapter, the primary focus is on the measurement and decomposition of the Malmquist Productivity Index using DEA.

8.2 MULTIFACTOR PRODUCTIVE INDEXES

The productivity of a firm is measured by the quantity of output produced per unit of input. In the single-output, single-input case, it is merely the ratio of the firm's output and input quantities. Thus if in period 0 a firm produces output y_0 from input x_0, its productivity is,

$$\Pi_0 = \frac{y_0}{x_0} \tag{8.1}$$

Similarly, in period 1, when output y_1 is produced from input x_1, the productivity is,

$$\Pi_1 = \frac{y_1}{x_1} \tag{8.2}$$

Moreover, the productivity index in period 1 with period 0 as the base is,

$$\pi_1 = \frac{\Pi_1}{\Pi_0} = \frac{y_1/x_1}{y_0/x_0} = \frac{y_1/y_0}{x_1/x_0} \tag{8.3}$$

This productivity index shows how productivity of the firm has changed from the base period. The rate of productivity growth is the difference in the growth rates of the output and input quantities respectively.

When multiple inputs and/or outputs are involved, one must replace the simple ratios of the output and input quantities in (8.3) by a ratio of quantity indexes of output and input. In this case, the index of multifactor productivity is

$$\pi_1 = \frac{\prod_1}{\prod_0} = \frac{Q_y}{Q_x} \tag{8.4}$$

where Q_y and Q_x are the output and input quantity indexes of the firm in period 1 with period 0 as the base.

8.3 MALMQUIST PRODUCTIVITY INDEX

Consider that in time period t, the DMU is using input X^t to produce Y^t. The input distance function $D\left(X^t, Y^t\right)$ is defined on the technology ϕ^t, as the maximal feasible contraction of X^t that still enables the production of Y^t

$$D\ \left(X^t, Y^t\right) = \max\left\{\lambda : \left(\frac{X^t}{\lambda}, Y^t\right) \in \phi^t\ \right\} \tag{8.5}$$

The technology of production ϕ^t consists of all input–output vectors that are technically feasible for a certain production process. The work by Fare et al (1994) showed that the distance function is the reciprocal of Farrell's (1957) measure of technical efficiency. This opened the possibility for using DEA models to compute the Malmquist index.

Fare et al (1994), defined an input-oriented productivity index as the geometric mean of the two Malmquist indices. It referred to the technologies at time periods *t* and *t* + 1, yielding the following Malmquist-type measure of productivity:

$$\left[M^{t,t+1} = \left[\frac{D^{t}\left(X^{t+1},Y^{t+1}\right)}{D^{t}\left(X^{t},Y^{t}\right)} . \frac{D^{t+1}\left(X^{t+1},Y^{t+1}\right)}{D^{t+1}\left(X^{t},Y^{t}\right)} \right]^{1/2} \right] \tag{8.6}$$

Another achievement showed (Fare et al 1994) how to decompose the index $M^{t,t+1}$ into an index, reflecting the change in technical efficiency and an index reflecting the change in the frontier of the production possibility set (i.e., an index of technological change). These components are obtained by rewriting the index in (8.6) as follows:

$$M^{t,\ t+1} = \frac{D^{t+1}\left(X^{t+1},Y^{t+1}\right)}{D^{t}\left(X^{t},Y^{t}\right)} \left[\frac{D^{t}\left(X^{t+1},Y^{t+1}\right)}{D^{t+1}\left(X^{t+1},Y^{t+1}\right)} . \frac{D^{t}\left(X^{t},Y^{t}\right)}{D^{t+1}\left(X^{t},Y^{t}\right)} \right]^{1/2} \tag{8.7}$$

The ratio outside the bracket measures the input technical efficiency change (TEC) between time period *t* and *t* + 1. The geometric mean of the two ratios inside the bracket captures the technological change (TC) (or shift in technology) between the two periods, evaluated at the input–output levels $\left(X^{t},Y^{t}\right)$at time period *t* and the levels $\left(X^{t+1},Y^{t+1}\right)$ at time period *t* + 1. In relation to the returns to scale assumption used for the estimation of the distance functions, constant returns to scale should be used in the first instance, as the Malmquist index provides an inaccurate productivity measure when it is evaluated under variable returns to scale.

8.4 RESULTS AND DISCUSSION

The Malmquist productivity index is calculated for two different periods 2003/04 and 2004/05. The results of Malmquist indices for the electricity utilities in each state are reported in Table 8.1. It shows the multiplicative decomposition of the Malmquist productivity index into technical efficiency change. That is, the movement towards the production frontier is termed as the 'catching up' effect and the pure technological change for the period 2003/04 and 2005/06. The result in Table 8.1 clearly indicates the positive change in the overall electricity sector. Here, the numbers greater than ‘one’ indicate productivity growth, while the numbers smaller than ‘one’ show regress.

It is evident from Table 8.1 that, the positive change in the productivity of the distribution utility may be either due to the technical change (reduction in losses, reduction in failure etc.) or due to technology change (replacement of analog meters by static meters, mechanism to reduce theft and pilferage, providing 100% metering in the 11kV feeder, 100% consumer metering etc.). The states which have been unbundled in the earlier years showed MPI greater than or equal to one. Fourteen states (Andhra Pradesh, Assam, Delhi, Gujarat, Haryana, Karnataka, Madhya Pradesh, Maharashtra, Orissa, Rajasthan, Tripura, Uttar Pradesh, Uttranchal and West Bengal) have started their restructuring from 1996. Except Gujarat and Orissa which have MPI less than 1, all the other states have a higher value of MPI. Another 7 states (Bihar, Himachal Pradesh, Jharkhand, Kerala, Meghalaya, Punjab and Tamilnadu) are half way through in the process of unbundling. Still, there are quite a lot of potential improvements which need the attention of the policy makers if the power sector of the country aims at excellence.

In this work, MPI is investigated for the two year period. This is also can be calculated over period more than two years. DEA based productivity index only gives an idea about the increase in the productive growth which is based on parameters, but this could not exploit about the load forecasting, generation planning etc. But the long term planning such as generation planning, transmission planning could be possible if the idea of DEA is combined with Fuzzy logic.

Table 8.1 Malmquist productivity index

Sl.No.	State owned electric utility	Tech. eff. change	Technology change	MPI
Northern Region				
6	Delhi	1	1	1
9	Haryana	1.08116	1.041778	1.126332
10	Himachal Pradesh	1.00689	0.985176	0.991966
11	Jammu and Kashmir	1.03894	1.031443	1.071605
22	Punjab	1.06644	1.027483	1.095748
23	Rajasthan	1.04502	0.991793	1.03644
27	Uttar Pradesh	1.09537	1.002711	1.098343
28	Uttaranchal	1.15449	1.027209	1.185907
Eastern Region				
4	Bihar	0.79885	0.924539	0.738572
12	Jharkhand	1.01657	1.075081	1.092895
21	Orissa	0.85931	0.925412	0.795214
24	Sikkim	1.07075	0.993986	1.064279
29	West Bengal	1.1236	1.02689	1.153809
Western Region				
5	Chattisgarh	1.36129	1.10918	1.50991
7	Goa	1.33761	1.06713	1.427408
8	Gujarat	1	0.978059	0.978059
15	Madhya Pradesh	1.13012	1.01678	1.149079
16	Maharashtra	1	1	1
Southern Region				
1	Andhra Pradesh	1	1	1
13	Karnataka	1.02596	1.011003	1.037245
14	Kerala	1	1	1
25	Tamil nadu	0.98206	0.968517	0.951144
North Eastern Region				
2	Arunachal Pradesh	0.86287	0.943426	0.814054
3	Assam	0.97845	0.98701	0.965738
17	Manipur	0.448	0.973534	0.436143
18	Meghalaya	0.93961	1.008365	0.947469
19	Mizoram	0.87106	0.951828	0.829094
20	Nagaland	0.88584	0.957949	0.848587
26	Tripura	1.33553	1.045427	1.396194

8.4 SUMMARY

The Malmquist productivity Index reported in this chapter for the two year period gave a clear idea about the productivity change experienced by the individual change. The decomposition of MPI as technical efficiency change and technology change gives an overview whether the changes are due to technology or due to technical enhancement. It is observed from the analysis that the SOEUs which have participated in the reforms and restructuring in the earlier years shown the growth in productivity. Even though the SOEU Orissa accepted the restructuring process earlier, the productivity did not show any good results because a few major areas still need to be identified for the improvement.