The Efficiency Evaluation of Total Quality Management in the Korean Industry with Data Envelopment Analysis[1)]

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Abstract

As all the other managerial activities, total quality management (TQM) has also inputs into and outputs from the process. Therefore, the principal managerial efficiency criteria of maximum outputs with minimum inputs should be applied to TQM. In this paper, the methodology for the performance evaluation of TQM by Data Envelopment Analysis (DEA) was proposed. DEA is used to measure the efficiency of TQM for each firm with the input and output data obtained by questionnaire. It is found that there are not significant differences between the firms with and without ISO9000 certification and between the large and small-sized firms with respect to the TQM efficiency.

1. Introduction

Global competition has become the state of nature in recent years. Pressure from strong competitors has forced managers to regard the quality as the main strategic factors to survive. A well-developed quality management will create a new corporate culture centered at the quality itself, and will refresh the employee's perception about the quality, which will eventually make the corporate more competitive.

As in many other managerial activities, it is imperative to evaluate the effectiveness of the activity in quality management, and to set up the appropriate strategy to achieve the desired goal based on the evaluation. Thus, the importance of proper evaluation of quality management cannot be overemphasized.

Several studies on the performance measurement of total quality management are available. Saraph interviewed 162 corporate managers and exacutives responsible for the quality management, and classified the important factors for successful TQM by factor nalysis technique[Saraph et. al., 1989].

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Benson et al. illustrated the relationship between corporate structural characteristics and the weight given by the managers concerning the product quality[Benson et. al., 1991]. Despite the large body of empirical research into the evaluation of TQM, most of the studies has concentrated on the simple aggregated sum of numerous factors[Black, 1995].

In this article, TQM activity is examined in the context of efficiency, which implies that more output should come out from less input if TQM is operated efficiently. A unified framework is proposed to facilitate efficiency evaluation of TQM. The suggested framework contains two individual modules; an Analytical Hierarchy Process (AHP) and a Data Envelopment Analysis (DEA).

DEA is a linear programming technique for the construction of a non-parametric, piece-wise linear convex hull to the observed set of input and output data[Charnes et. al., 1994]. Since the path-breaking DEA paper, there has been numerous applications in the field of efficiency measurement. DEA outperformed the other alternative method to measure the efficiency, especially when there are not definite physical units and/or market price for the input and output[Banker, 1993].

The implication of the DEA efficiency results is to derive the efficiency level of firm's TQM activity from the observed performance of peer firms. It also renders to identify the benchmaking firms, which would be the valuable information in order to improve the TQM performance[Ali et. al., 1995].

In this paper, the seven different factors concerning TQM; five input factors and two output factors, are derived through literature reviews. The factors will be used in DEA model to evaluate the efficiency of TQM activity. The input and output data for DEA model will be given by AHP. AHP is the process to make an weighted sum of factors involving multiple criteria. The opinion of the quality experts was referred in order to determine the plausible weights in AHP, which permit me to avoid the arbitrariness in setting the weights.

This paper is expected to provide the following policy implications. First, the firm-specific TQM efficiency level is evaluated, and the best-practiced firm with respect to TQM is identified. Second, the relationship between firm characteristics and TQM efficiency is examined. This entails the comparison of TQM efficiency between the firms with and without ISO-9000 certification. Another efficiency comparison will be executed between the large and small-sized firms. These efficiency comparisons between characteristic groups will provide a possible solution to questions whether the firms with ISO certification or large firms do better than those without ISO certification or small-sized firms. Lastly, the managerial strategy to improve the TQM efficiency is suggested.

This paper is organized in five subsections. The AHP approach to generate the data for efficiency evaluation reflecting qualitative and judgmental factors is presented in the next section. In the third section, discussion centers on the mathematical formulation of DEA model and the implications which can be derived from results. In the fourth section, the summary of primary results obtained from the empirical analysis and their policy implications are presented. The last section provides the summary and concluding remarks.

2. Data generating process

The critical success factors involved in TQM are generally difficult to quantify because they are often complicated and subjective. The selection of critical success factors was based on literature reviews, and a content analysis was performed through several meetings by expert group[Hanjoo, 1997]. Additionally, AHP is employed to analyze the weight given to multi-layered TQM factors, and is used to generate the relevant input and output data for efficiency evaluation.

To provide plausible weights to the critical success factors in TQM, the following three stages for AHP are applied; the principles of decomposition, comparative judgements, and synthesis of priorities. The empirical procedure for the data generating process is as follows; Survey questionnaires were mailed to a target sample of 540 firms in Korea. These firms were selected from a directory provided by KSA (Korea Standard Association). Both primary and follow-up mailings were carried out. In order to supplement the results from the questionnaires, structured interviews were held with quality managers. Questionnaire data collected by mail cover 101 different firms. Collected data was processed by the computer program for AHP and the relative importance weights on the critical success factors were obtained. The weights derived from AHP for TQM are presented in the following Table 1[Hanjoo, 1998].

The critical success factors of TQM were divided into input and output factors according to their characteristics. The inputs are selected as the following five factors; Leadership and organization for quality (I1), New product development (I2), Process management (I3) Human resources management (I4), Customer satisfaction management (I5). Outputs are selected as Quality improvement level compared to domestic companies (O1) and Quality improvement level compared to foreign companies (O2). Other factors such as strategic quality planning, information analysis, organizational involvement, and environmental and safety management are not considered as input nor output factors, since their weights are relatively small. Note that the O1 and O2 are considered separately on the grounds that the products for domestic and international markets can be different from each other and the systems for quality management for the two market can also be different.

3. DEA Model for measuring the TQM efficiency

Assume that there are K firms indexed by $k=1,2,\cdots,K$. Let the inputs and outputs for TQM of firm k as $Xk=(x_k^1,x_k^2,\cdots x_k^n)$ and $Yk=(y_k^1,y_k^2,\cdots y_k^m)$ respectively. The TQM efficiency can be calculated by solving the following linear programming problem for each firm:

$$\begin{aligned} &\textit{Maximize} \quad \phi_k \\ &s.t. \quad Y_i\lambda \geq \phi Y_k \\ &\qquad X_i\lambda \geq X_k, \quad i=1,\cdots,n \\ &\qquad \lambda \geq 0 \end{aligned}$$

where λ is the intensity vector indicating the degree of utilization of each firm. The intensity vector, λ, enables to expand existing output level with given input level, for the purpose of constructing unobserved but nonetheless feasible activities. It will be used to identify the best-practiced firms in determining the TQM efficiency of firm k.

The optimal ϕ_k indicates a TQM efficiency score in a manner that it takes a value of one if the unit's own technology is 'best' and larger than one if combinations of alternative technologies are indicated as efficient. The larger the value of ϕ_k, the less efficient the *k*th firm is in performing TQM activity.

4. Empirical results

4.1 Efficiency Estimator of TQM activity

Table 2 sets out the TQM efficiency measures computed for 101 firms using data generated through the data generating process described above.

Table 3 displays the summary statistics for the information contained in Table 2. The firms with and without ISO certification are denoted as ISO and NISO respectively. Also, LARGE and SMALL denote the groups consisting of large and small-sized firms.

Table 1 Relative weights on the critical success factors of TQM in Korean companies

Primary Critical Success Factors (Weight)	Secondary Critical Success Fsctors	Weights for Secondary Factors
Leadership and Organization for Quality (0.1115)	① Leadership of Top Management ② Management for Quality ③ Social Responsibility	0.537(0.0599) 0.269(0.0230) 0.194(0.0216)
Strategic Quality Planning (0.0630)	① Long and Short-Term Quality Policy ② Quality Policy Deployment ③ Review of Policy Output	0.151(0.0095) 0.319(0.0201) 0.530(0.0334)
Information Analysis (0.0379)	① Establishment of Information System ② Comparative Analysis and Benchmarking ③ Implementation of Computer System	0.199(0.0075) 0.573(0.0217) 0.228(0.0086)
New Product Development (0.1621)	① Product Quality Design ② Technology for New Product Development	0.294(0.0477) 0.706(0.1144)
Process Management (0.0915)	① Quality Assurance System ② Purchasing and Outsourcing Management ③ Production Management ④ Facilities Management ⑤ Quality Assessment	0.386(0.0353) 0.141(0.0129) 0.192(0.0176) 0.144(0.0132) 0.137(0.0125)
Human Resources Management (0.1075)	① Human Resources Planning ② Education and Training ③ Employee Welfare and Incentives	0.198(0.0213) 0.520(0.0559) 0.282(0.0303)
Organizational Involvement (0.0677)	① Team Activities ② Suggestion Activities ③ Quality Circle	0.273(0.0185) 0.386(0.0261) 0.341(0.0231)
Environmental and Safety Management (0.0515)	① Environmental Management ② Safety Management	0.545(0.0281) 0.455(0.0234)
Customer Satisfaction Management (0.1476)	① Customer Needs Survey ② Customer Management ③ Customer Satisfaction Survey	0.562(0.0829) 0.221(0.0326) 0.217(0.0320)
Quality Performance (0.1595)	① Quality Improvement Level Compared to Domestic Companies ② Quality Improvement Level Compared to Foreign Companies	0.385(0.0614) 0.615(0.0981)

Table 2 TQM efficiency estimator

Firm No.	Characteristics		TQM Eff..	Firm No.	Characteristic		TQM Eff.	Firm No.	Characteristic		TQM Eff.
	ISO[a]	Size[b]			ISO	Size			ISO	Size	
1	1	2	1.010	35	1	2	1.092	69	1	1	1.324
2	1	1	1.217	36	2	1	1.163	70	1	1	1.051
3	1	1	1.005	37	2	1	1.150	71	1	1	1.263
4	1	1	1.280	38	1	1	1.231	72	2	1	1.000
5	1	1	2.025	39	1	1	1.188	73	1	1	1.278
6	1	2	1.093	40	1	1	1.159	74	1	1	1.263
7	1	1	1.000	41	1	1	1.000	75	1	1	1.109
8	1	1	1.744	42	1	1	1.000	76	1	1	1.166
9	2	2	1.023	43	1	1	1.176	77	2	1	1.142
10	1	1	1.172	44	1	1	1.178	78	1	1	1.379
11	1	1	1.157	45	1	1	1.594	79	2	2	1.263
12	2	1	1.728	46	1	1	1.000	80	1	1	1.324
13	1	1	2.025	47	1	1	1.000	81	1	1	1.214
14	2	2	1.015	48	2	2	1.131	82	1	1	1.256
15	2	1	1.189	49	2	2	1.235	83	2	2	1.145
16	1	1	1.312	50	1	1	1.219	84	2	2	1.211
17	2	1	1.125	51	1	1	1.288	85	2	2	1.194
18	1	1	1.078	52	1	1	1.281	86	1	1	1.216
19	1	1	1.126	53	1	1	1.532	87	1	1	1.000
20	1	1	1.350	54	1	1	1.171	88	1	1	1.028
21	1	2	1.297	55	1	1	1.257	89	2	1	1.167
22	1	1	1.101	56	1	2	1.116	90	1	2	1.140
23	1	1	1.097	57	2	1	1.255	91	1	2	1.125
24	1	1	1.061	58	2	1	1.284	92	2	2	1.295
25	1	2	1.180	59	1	1	1.000	93	2	2	1.098
26	1	1	1.126	60	1	1	1.217	94	1	2	1.483
27	1	1	1.177	61	1	1	1.202	95	2	2	1.239
28	1	1	1.219	62	1	1	1.297	96	2	2	1.226
29	2	1	1.088	63	2	2	1.365	97	2	2	1.000
30	1	1	1.168	64	1	1	1.104	98	2	2	1.289
31	1	1	1.161	65	2	1	1.061	99	1	1	1.000
32	1	1	1.744	66	2	1	1.039	100	1	2	1.000
33	1	1	1.755	67	1	1	1.350	101	1	2	1.165
34	1	2	1.120	68	1	1	1.000	-	-	-	-

Note

a) The number 1 and 2 in the column named ISO denote the firms with and without ISO certification, respectively.

b) The number 1 and 2 in the column entitled Size denote the firm size with 1 for large and 2 for small-size based on the operating gross revenue.

Table 3 TQM efficiency results

Statistics	ISO	NISO	LARGE	SMALL	Total Sample
Mean	1.195	1.183	1.232	1.169	1.211
Max.	2.025	1.728	2.025	1.483	2.025
Mini.	1.000	1.000	1.000	1.000	1.000
Standard Dev.	0.197	0.145	0.219	0.118	0.201

The mean value of TQM efficiency from over 101 firms suggests that the average inefficiency is 21.1%, which implies that 21% output with the same level of TQM activity effort can be obtained more. The firms in the ISO group seem slightly less efficient than the firms in the NISO group (19.5% versus 18.3% of inefficiency). The large firms appear also less efficient than small firms (23.3% versus 16.9%).

4.2 Statistical Tests for The Firm Characteristics

The assumption of half-normal for the TQM efficiency is adopted, and F-test following procedure is performed. If the TQM efficiency, ϕ_i (i=1,2), for two group G_1 and G_2 are half-normally distributed, such as $|N(0,\sigma_i)|$ then the squared sum of TQM efficiency divided by deviation, $\sum_j(\frac{\phi_j}{\sigma_j})^2$, $j \in G_i$, will follow chi-square distribution with n_i degree of freedom. Therefore, under the null hypothesis $H_0 : \sigma_i = \sigma_2$, it is possible to test the null hypothesis H_0 using the test statistics $\left[\sum_j(\varepsilon_j)^2/n_1\right] / \left[\sum_k(\varepsilon_k)^2/n_2\right]$ relative to the F-distribution with (n_1, n_2) degrees of freedom[Banker, 1996].

F-statistics calculated for ISO versus NISO and LARGE versus SMALL are F(73, 28) = 1.0859 and F(74, 27) = 1.1273, respectively.

For both cases, the probabilities to reject the hypothesis that there are significant difference exceed 99%[DeGroot, 1985]. Therefore, it can be said that the TQM efficiency of firms in the ISO and LARGE group are not different from those of firms in the NISO and SMALL group with 99% of statistical significance. These test results contrast with the traditional perception that the firms with ISO 9000 certification or large firms do the quality management more efficiently. These results can be partly explained by noting that the ISO certification itself focuses on the procedure of quality management rather than the efficiency as the ratio of quality output to input. With the same postulation, it can be said that the large firms generally focus on the input side to manage the quality problem, not on the efficiency of quality activity.

5. Summary and conclusions

This paper introduced an unified framework to evaluate the TQM activity based on the efficiency concept. The proposed framework integrates the two distinctive methodologies serially; one is a data generating process incorporating AHP and the other is the DEA approach.

The first step of this process was to identify the appropriate input and output factors for TQM. As realized by many researchers, the factors involved in TQM are difficult to quantify, since they often contain qualitative and subjective judgments.

In this paper DEA was employed to compute a single measure of TQM efficiency utilizing the input and output data generated data generating process utilizing AHP in the first stage.

Empirical application to the 101 sample firms provided the firm-specific TQM efficiency measure and identified best-practiced firms that would be a valuable piece of information for benchmarking in TQM activity. Moreover, the comparisons between the firms with and without ISO certification and between large and small-sized firms were performed based on the resulted TQM efficiency measure. Formal statistical tests showed that there are not significant differences between groups in terms of TQM efficiency.

The efficiency perspective employed in this paper is expected to provide another insight in analyzing the performance of TQM. Considering that TQM is also a part of managerial activity, more research should be devoted to the evaluate the TQM efficiency and to address relevant strategies to improve it.

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