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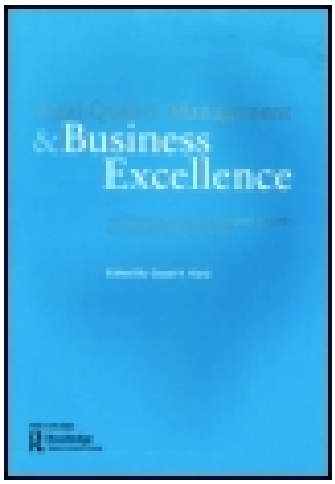

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A study on the efficiency evaluation of total quality management activities in Korean companies

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A study on the efficiency evaluation of total quality management activities in Korean companies

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ABSTRACT *Total quality management (TQM) can be considered as a system that has input processes and output processes. 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) is proposed. AHP is employed to quantify the weights of success factors for TQM. The proposed methodology is applied to the sample of 101 Korean firms. The firm-specific TQM efficiency level is presented, and the surplus and dual prices for the firms with and without ISO certification and large and small-sized firms are analysed. Several findings are expected to provide a new perspective for the evaluation of TQM.*

Introduction

TQM is a managerial system to improve an organization's competitiveness. Kanji & Asher (1993) said that 'TQM is about continuous performance improvement of individuals of groups and of organizations'. As it is imperative to evaluate the performance of the TQM activity, and to set up the appropriate strategy to achieve the desired goal based on the evaluation, the importance of the proper evaluation of TQM cannot be overemphasized. Several studies on the performance measurement of TQM are available (for an excellent survey, see Black & Porter, 1995). Most studies have devoted their attention to finding important factors for successful TQM with factor analysis (see, for example, Saraph *et al.*, 1989). Other studies tend to illustrate 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 have a common strategy of depending on the simple aggregated sum of numerous factors (Black & Porter, 1995).

In this paper, 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; a data generating process incorporating the Analytical Hierarchy Process (AHP) to provide relevant weight and a Data Envelopment Analysis (DEA) to evaluate efficiency.

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DEA is a linear programming technique for the construction of a non-parametric, piecewise linear convex hull to the observed set of input and output data; see, for example, Charnes *et al.* (1994) for a discussions of the methodology. Since the path-breaking paper of Charnes *et al.* (1978), there have been numerous applications in the field of efficiency measurement. DEA outperformed other alternative methods to measure the efficiency, especially when there are not definite physical units and/or a market price for the input and output.

The implication of the DEA efficiency results is to derive the efficiency level of a firm's TQM activity from the observed performance of peer firms. It also helps identify the benchmarking firms, which would be valuable information for improving the TQM performance.

Unlike other DEA applications, in this paper AHP will provide the input and output data for the DEA model. AHP is the process of making a weighted sum of factors involving multiple criteria. In this paper, the experts' opinion on TQM to determine the plausible weights in AHP is considered, which permits us to avoid arbitrariness in setting the weights. The seven different factors concerning TQM; five input factors and two output factors, are derived from the survey data. The factors will be used in the DEA model to evaluate the efficiency of TQM activity.

This paper is expected to provide the following policy implications. First, the firm-specific TQM efficiency level is evaluated, and the best-practice firm with respect to TQM is identified. Second, the managerial strategy to improve the TQM efficiency, which is customized to the firm's characteristics using the information about the slack variables and dual prices, is analysed.

This paper is organized into five subsections. The AHP approach to generate the data for efficiency evaluation reflecting qualitative and judgemental factors is presented in the next section. In the third section, discussion centres on the mathematical formulation of the DEA model and the implications that can be derived from results. In the fourth section, a summary is given of primary results obtained from the surplus and dual prices analysis, and the strategic implications of this are summarized. The final section provides conclusions and implications.

Data generating process

The factors involved in TQM are generally difficult to quantify because they are often complicated and subjective. In this paper, AHP is employed to analyse the weight given to multi-layered TQM factors, in order to generate in turn the relevant input and output data for efficiency evaluation.

To provide plausible weights to the relevant factors in TQM, the AHP for TQM consists of three stages; the principles of decomposition, comparative judgements, and synthesis of priorities.

The empirical procedure for the data generating process in this paper 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. The selection of critical success factors was based on literature reviews, and a content analysis was performed through several meetings by an expert group consisting of 23 quality managers and professors. The collected data were processed by a computer program for AHP, and the relative importance weights on the critical success factors were obtained.

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The factors concerning TQM are divided into primary and secondary factors—the former being the aggregated measure of the latter. The weights derived from AHP for TQM are presented in Table 1.

The results presented in Table 1 indicate that 'New product development' is the most important primary factor of TQM (16.21%). Other factors to be identified as important, having a weight of more than 10%, are 'Quality performance' (15.95%), 'Customer satisfaction' (14.76%), 'Leadership and organization for quality' (11.15%) and 'Human resources management' (10.75%). Meanwhile, the weights given to 'Environmental and safety management' (5.15%) and 'Information analysis' (3.79%) seem to be relatively small. We know that there is a wide variety of weights among factors of TQM, since factor weights of more than 10% are given only to five out of ten primary factors. There is also a large difference among

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

Primary critical success factors (weight)	Secondary critical success factors	Weight for secondary factors
Leadership and organization for quality (0.1115)	1. Leadership of top management	0.537 (0.0599)
	2. Management for quality	0.269 (0.0230)
	3. Social responsibility	0.194 (0.0216)
Strategic quality planning (0.0630)	1. Long and short-term quality policy	0.151 (0.0095)
	2. Quality policy deployment	0.319 (0.0201)
	3. Review of policy output	0.530 (0.0034)
Information analysis (0.0379)	1. Establishment of information system	0.199 (0.0075)
	2. Comparative analysis and benchmarking	0.573 (0.0217)
	3. Implementation of computer system	0.228 (0.0086)
New product development (0.1621)	1. Product quality design	0.294 (0.0477)
	2. Technology for new product development	0.706 (0.1144)
Process management (0.0915)	1. Quality assurance system	0.386 (0.0353)
	2. Purchasing and outsourcing management	0.141 (0.0129)
	3. Production management	0.192 (0.0176)
	4. Facilities management	0.144 (0.0132)
	5. Quality assessment	0.137 (0.0125)
Human resource management (0.1075)	1. Human resources planning	0.198 (0.0213)
	2. Education and training	0.520 (0.0559)
	3. Employee welfare and incentives	0.282 (0.0303)
Organizational involvement (0.0677)	1. Team activities	0.273 (0.0185)
	2. Suggestion activities	0.386 (0.0261)
	3. Quality circle	0.341 (0.0231)
Environmental and safety management (0.0515)	1. Environmental management	0.545 (0.0281)
	2. Safety management	0.455 (0.0234)
Customer satisfaction management (0.1476)	1. Customer needs survey	0.562 (0.0829)
	2. Customer management	0.221 (0.0326)
	3. Customer satisfaction survey	0.217 (0.0320)
Quality performance (0.1595)	1. Quality improvement level compared to domestic companies	0.385 (0.0614)
	2. Quality improvement level compared with foreign companies	0.615 (0.0981)

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secondary factors. The consistency ratio among factors reaches 2.2%, which implies that the reliability of resulting weights is very high.

The factors in AHP are divided into inputs and outputs according to their nature and relative importance in factor weights. 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 with domestic companies (O1); and Quality improvement level compared with foreign companies (O2). Other factors, such as strategic quality planning, information analysis, organizational involvement, and environmental and safety management, are not considered as input or output factors, since their weights are relatively small. Note that the O1 and O2 are considered separately from the secondary factors on the grounds that the products for the domestic and international market can be different from each other and the systems for quality management for the two markets can also be different.

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DEA model for measuring the TQM efficiency

Assume that there are K firms indexed by $k = 1, 2, \ldots, K$. Let the inputs and outputs for TQM of firm k be $X_k = (x_k^1, x_k^2, \ldots x_k^n)$ and $Y_k = (y_k^1, y_k^2, \ldots y_k^m)$, respectively. The TQM efficiency can be calculated by solving the following fractional programming equation (1) for each firm.

$$\begin{aligned} &\text{Maximize } h_k = \frac{\mu^{\mathrm{T}} Y_k}{v^{\mathrm{T}} X_k} \\ &\text{s.t. } h_i = \frac{\mu^{\mathrm{T}} Y_i}{v^{\mathrm{T}} X_i} \leqslant 1, \quad i = 1, \ldots, n \\ &\mu^{\mathrm{T}} \geqslant 0 \quad \text{and} \quad v^{\mathrm{T}} \geqslant 0 \end{aligned} \tag{1}$$

This ratio model is designed to determine, for each firm, the best non-negative set of input multipliers (v^{T}) and output multipliers (μ^{T}) such that the ratio of the total weighted outputs to the total weighted input is maximized. This is done subject to the constraint that the corresponding ratio for each firm, including the one in question, does not exceed 1. The values of v^{T} and μ^{T} show, respectively, the marginal effect of inputs X and output Y on the TQM efficiency, i.e. they provide information on the relative importance of inputs and outputs in the efficiency evaluation.

This problem cannot easily to solved due to the difficulties associated with the fractional programming; it therefore needs to be linearized. For output-augmenting efficiency, the problem can be linearized by restricting the numerator of the objective function to unity, and then adding it as another constraint. In this way, the original problem is transformed to a problem of maximizing the total weighted quality outputs in the presence of the normalized total weighted inputs and the remaining constraints, as seen in equation (2).

$$\begin{aligned} &\text{Minimize } v^{\mathrm{T}} X_k \\ &\text{s.t. } \mu^{\mathrm{T}} Y_k = 1 \\ &\mu^{\mathrm{T}} Y_i - v^{\mathrm{T}} X_i \leqslant 0, \quad i = 1, \ldots, n \\ &\mu^{\mathrm{T}} \geqslant 0 \quad \text{and} \quad v^{\mathrm{T}} \geqslant 0 \end{aligned} \tag{2}$$

The dual representation of equation (2) is given by,

$$\begin{aligned} &\text{Maximize } \phi_k \\ &\text{s.t. } Y_i\lambda \geqslant \phi Y_k \\ &X_i\lambda \leqslant X_k, \quad i = 1, \ldots, n \\ &\lambda \geqslant 0 \end{aligned} \tag{3}$$

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

The optimal ϕ_k in equation (3) indicates a TQM efficiency score such 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 kth firm is in performing TQM activity.

From the DEA model we obtain the slack value from the dual problem, and the shadow price, μ^{T} and v^{T}, from the primal problem for each inputs outputs. The slack value tells us whether a specific factor restriction is binding or not. The shadow price will inform us of the variation in the efficiency level, ϕ_k, resulting from the unit variation of a specific input or output factor. If there is slack, the shadow price for that factor will become zero. The ratio of shadow prices between factors implies the marginal rat of substitution. From this information, the information concerning the relative importance among input or output factors of TQM is obtained. See Charnes *et al.* (1994) and Seiford (1996) for more technical details about the DEA model.

Empirical results

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. LARGE and SMALL denote the groups consisting of large and small-sized firms, respectively.

The mean value of TQM efficiency over 101 firms suggests that the average inefficiency is 21.1%, which implies that we can obtain 21% more output with the same level of effort in TQM activity. 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 also appear less efficient than the small firms (23.3% versus 16.9%).

The entire efficiency distribution for TQM activity is presented in Fig. 1.

From Fig. 1, we know that a large proportion of sample firms show a TQM efficiency of less than 1.400 (40% inefficiency), and a relatively small number of firms appear efficient. This implies that there is not the problem of a loss of discriminating power, and the data utilized in DEA model is reasonable.

Best-practice firms in TQM efficiency

The DEA model to measure TQM efficiency permits us to identify the reference firms which are the benchmarks in determining the firm's efficiency. This would be a critical piece of

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Table 2. *TQM efficiency estimator*

Firm no.	Characteristics		TQM Eff.	Firm no.	Characteristics		TQM Eff.	Firm no.	Characteristics		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 numbers 1 and 2 in the ISO column denote the firms with and without ISO certification, respectively.
[b]The numbers 1 and 2 in the Size column denote the firm size, with 1 for large and 2 for small 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

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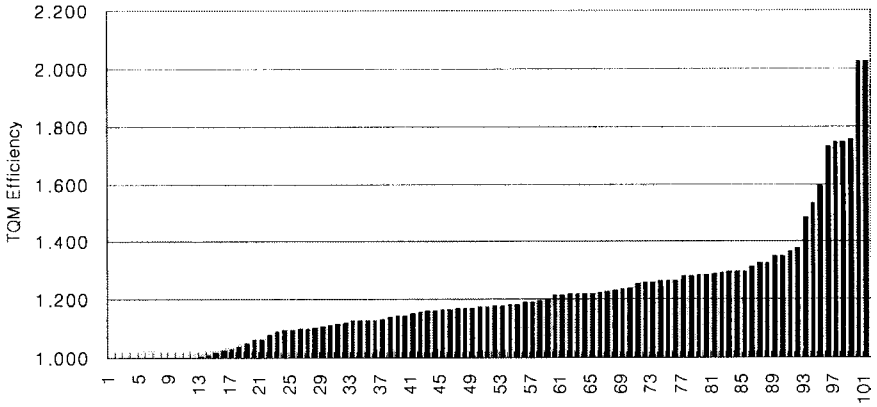

Figure 1. *Efficiency distribution for the total sample.*

Table 4. *Firms on the efficient facet*

Firm no.	Characteristics		Number of appearances	Firm no.	Characteristics		Number of appearances
	ISO	Size			ISO	Size	
7	1	1	53	68	1	1	10
41	1	1	11	72	2	1	7
42	1	1	15	87	1	1	2
46	1	1	3	97	2	2	86
47	1	1	4	99	1	1	26
59	1	1	44	100	1	2	9

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information when a firm is to improve efficiency, since the reference firms become models to follow. Table 4 presents the reference firms and their characteristics.

The 97th firm appeared most frequently as the reference firm, and the seventh firm follows. From the table, we know that 10 out of 12 efficient firms are large-size firms with ISO certification. This implies that while ISO certification and large size is not a sufficient condition, it is a necessary condition for efficient TQM activity. Therefore, if a firm simultaneously has ISO and NISO firms as its reference firms, it would be advisable to learn TQM practice from ISO firms. The same argument also applies for the large firms.

To investigate the characteristic features of best-practice firms, Fig. 2 presents the input and output data for the 97th and seventh firms, and sample mean.

The 97th and seventh firms dominate the sample mean, except for I5 of the seventh firm. This implies that the two firms obtain more quality output with less resources or effort than the sample mean, which implies an efficient TQM activity.

Surplus and dual prices

The DEA model defines a linear-segmentation to envelope the whole sample data, and uses radial expansion or contraction to measure the efficiency (Ali *et al.*, 1995). Therefore, more often than not, there remains a room for Pareto improvement. This additional increase in outputs and a reduction in inputs will appear as slack. From a strategic viewpoint, the firm

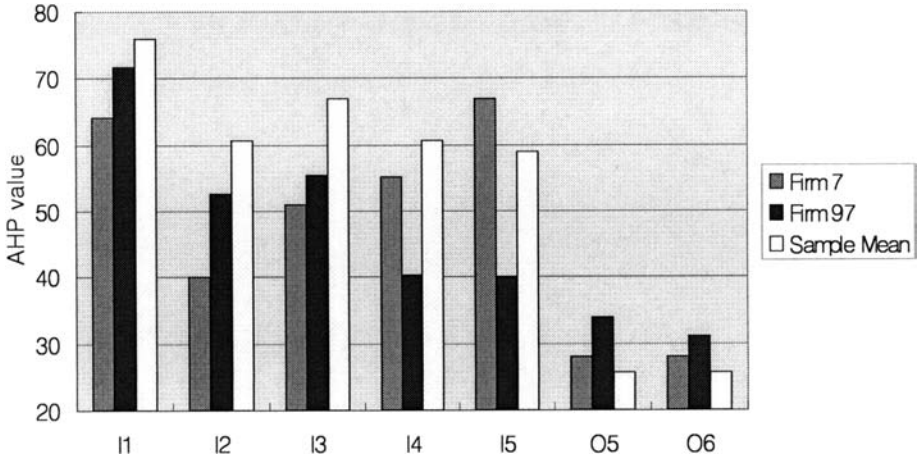

Figure 2. *Input and output data for 97th and seventh firm, and sample mean.*

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should concentrate its attention on reducing this slack. The descriptive statistics for the slack of the whole sample and for characteristic groups are summarized in Table 5.

Table 5 indicates that the slack for I4 (Human resources management) and O1 (Quality improvement level compared with domestic companies) is relatively larger than any other factors. This result also applies to the ISO and LARGE group. On the contrary, the slack for I5 (Customer satisfaction management) is relatively large in the NISO and SMALL group. The above observation indicates that effort should be devoted to reducing I4 and to

Table 5. *Surpluses for inputs and outputs*

	Input 1	Input 2	Input 3	Input 4	Input 5	Output 1	Output 2
(Total Sample)							
Mean	1.018	4.229	3.585	6.728	4.723	2.105	0.475
Max.	20.959	23.825	24.994	25.245	45.750	18.613	17.525
Standard Dev.	2.882	6.554	6.341	7.303	9.769	3.767	2.078
(ISO)							
Mean	0.475	3.856	4.165	7.005	3.003	2.375	0.362
Max.	17.525	23.825	24.994	25.245	45.750	18.613	17.525
Standard Dev.	2.078	6.308	6.964	7.415	7.854	4.106	2.161
(NISO)							
Mean	2.208	4.790	1.431	5.222	9.205	1.402	0.769
Max.	20.959	23.001	9.943	19.179	37.798	8.573	6.677
Standard Dev.	4.364	7.203	2.797	6.459	12.731	2.702	1.891
(LARGE)							
Mean	0.832	3.763	3.937	6.972	3.923	2.285	0.146
Max.	12.372	23.001	24.994	25.245	32.438	18.613	3.851
Standard Dev.	2.245	6.253	6.754	7.433	8.855	4.084	0.652
(SMALL)							
Mean	1.452	5.213	3.269	5.311	8.664	1.337	0.751
Max.	20.959	23.825	20.083	18.285	37.798	8.573	6.677
Standard Dev.	4.183	7.348	5.043	6.154	11.926	2.477	1.960

Table 6. *Dual prices for inputs and outputs*

	Input 1	Input 2	Input 3	Input 4	Input 5	Output 1	Output 2
(Total Sample)							
Mean	0.010	0.003	0.002	0.001	0.003	−0.006	−0.029
Max.	0.026	0.022	0.022	0.025	0.051	0.000	0.000
Standard Dev.	0.007	0.005	0.005	0.003	0.007	0.011	0.014
(ISO)							
Mean	0.011	0.002	0.002	0.001	0.002	−0.004	−0.030
Max.	0.026	0.017	0.022	0.025	0.027	0.000	0.000
Standard Dev.	0.006	0.004	0.005	0.003	0.005	0.009	0.012
(NISO)							
Mean	0.006	0.006	0.005	0.001	0.003	−0.010	−0.026
Max.	0.017	0.022	0.020	0.006	0.025	0.000	0.000
Standard Dev.	0.006	0.007	0.006	0.002	0.007	0.013	0.016
(LARGE)							
Mean	0.010	0.002	0.002	0.001	0.003	−0.004	−0.032
Max.	0.026	0.022	0.022	0.007	0.051	0.000	0.000
Standard Dev.	0.007	0.005	0.005	0.001	0.008	0.009	0.012
(SMALL)							
Mean	0.008	0.004	0.003	0.002	0.001	−0.012	−0.022
Max.	0.017	0.017	0.020	0.025	0.027	0.000	0.000
Standard Dev.	0.007	0.007	0.005	0.005	0.005	0.014	0.016

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increasing O1 for the firms in the ISO and LARGE group, while effort should especially be given to reducing I5 for the firms in the NISO and SMALL group.

In Table 6, the descriptive statistics of dual prices for each input and output are presented. Note that the dual prices for inputs take a negative value, while the shadow prices for outputs take a positive value.

The relative ratio of shadow prices among inputs is 10 : 3 : 2 : 1 : 3 and between outputs it is 6 : 29, for the whole sample. It can be observed that the same pattern prevails in the ISO and LARGE group. For NISO and SMALL, the shadow value of I1 (leadership) takes a relatively low value.

The shadow price ratio between outputs illustrates another implication for TQM strategy. This ratio for the ISO and LARGE group is nearly 1 : 5, while it is 1 : 2 for the NISO and SMALL group. This implies that the effort to increase O1 would be more valuable in NISO and SMALL than in ISO and LARGE.

Conclusions and implications

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

This paper employs DEA to compute a single measure of TQM efficiency by utilizing the input and output data that were generated by AHP in the first stage.

Empirical application to the 101 sample firms provides a firm-specific TQM efficiency measure, and reveals best-practice firms, which is a valuable piece of information for TQM

benchmarking. Moreover, insights concerning strategies to improve the TQM efficiency can be gleaned from analysis of the slack and dual prices.

The efficiency perspective employed in this paper provides another insight to analysing the performance of TQM. Considering that TQM is also a part of managerial activity, more research should be devoted to evaluating TQM efficiency and to addressing relevant strategies to improve it.

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