Chapter 7
Effectiveness and Other Models of DEA

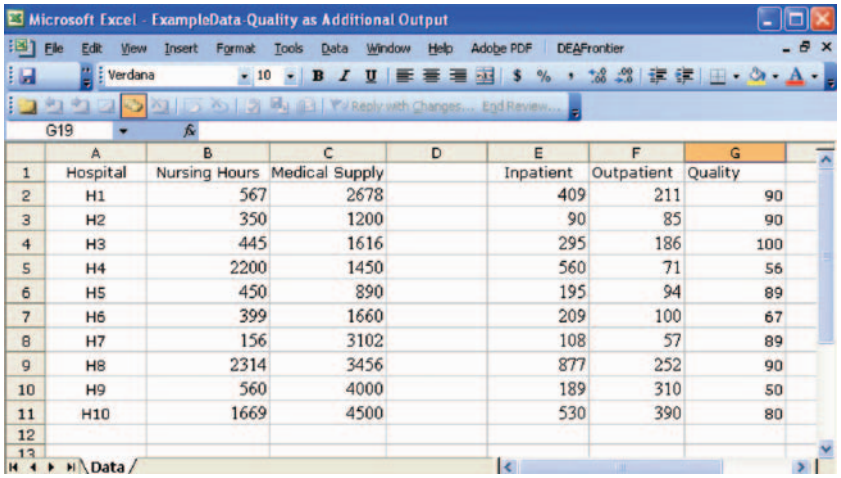
7.1 Incorporation of Quality into DEA Models

The two components of health care facility performance, efficiency and effectiveness quality), were introduced in Chap. 1. In this chapter, a closer examination of the effectiveness component is provided. Sherman and Zhu (2006) introduce quality-adjusted DEA applied to bank branches. In this discussion, they incorporate quality into DEA benchmarking in two different models. The first model adds a quality variable as an additional output into the standard DEA model. They demonstrate that, using this approach, the model may exhibit a quality/efficiency tradeoff. Of course in health care, managers would not welcome such a tradeoff sacrificing quality for efficiency. The second approach, which avoids such tradeoffs, is an evaluation of quality and efficiency independently. Using the hospital example, we illustrate these concepts below.

7.2 Quality as an Additional Output

Hospital quality for this example is measured using data from the Hospital Quality Alliance (HQA) for the purpose of public reporting on the Hospital Compare Website. The data include information about clinician adherence to clinical guidelines for patients with three conditions including pneumonia, acute myocardial infarction and congestive heart failure (HQA, 2007). The data was coded to produce a total hospital quality score by providing a dichotomous measure of whether the hospital performed above (1) or below (0) the national average for each individual measure, and then dividing this score by the number of measures the hospital reported. This resulted in the range of scores from zero to 100, with 100 indicating perfect adherence to clinical guidelines in these measures.

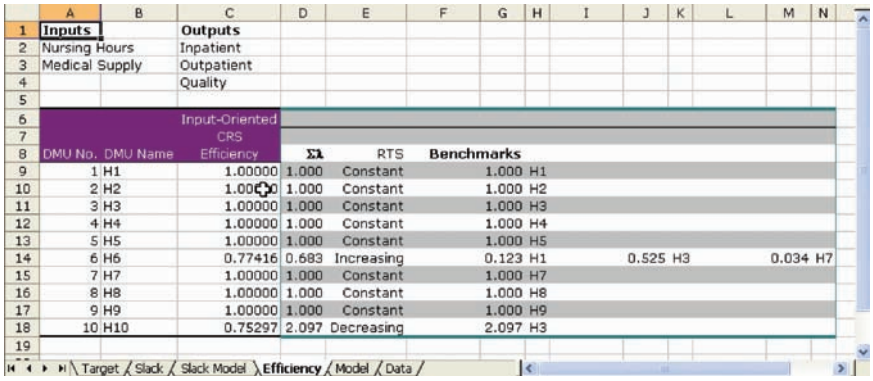
The setup for our ongoing hospital example with quality as an additional output is shown in Fig. 7.1. As the number of variables (one additional output) increased in this model compared to the basic CRS model, one can expect more hospitals



Microsoft Excel - ExampleData-Quality as Additional Output

	A	B	C	D	E	F	G
1	Hospital	Nursing Hours	Medical Supply		Inpatient	Outpatient	Quality
2	H1	567	2678		409	211	90
3	H2	350	1200		90	85	90
4	H3	445	1616		295	186	100
5	H4	2200	1450		560	71	56
6	H5	450	890		195	94	89
7	H6	399	1660		209	100	67
8	H7	156	3102		108	57	89
9	H8	2314	3456		877	252	90
10	H9	560	4000		189	310	50
11	H10	1669	4500		530	390	80
12							
13							

Fig. 7.1 Setup for quality as an additional output



	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	**Inputs**		**Outputs**											
2	Nursing Hours		Inpatient											
3	Medical Supply		Outpatient											
4			Quality											
5														
6			Input-Oriented											
7			CRS											
8	DMU No.	DMU Name	Efficiency	Σλ	RTS	**Benchmarks**								
9	1	H1	1.00000	1.000	Constant	1.000	H1							
10	2	H2	1.00000	1.000	Constant	1.000	H2							
11	3	H3	1.00000	1.000	Constant	1.000	H3							
12	4	H4	1.00000	1.000	Constant	1.000	H4							
13	5	H5	1.00000	1.000	Constant	1.000	H5							
14	6	H6	0.77416	0.683	Increasing	0.123	H1			0.525	H3		0.034	H7
15	7	H7	1.00000	1.000	Constant	1.000	H7							
16	8	H8	1.00000	1.000	Constant	1.000	H8							
17	9	H9	1.00000	1.000	Constant	1.000	H9							
18	10	H10	0.75297	2.097	Decreasing	2.097	H3							
19														

Fig. 7.2 Results of CRS input-oriented model with a quality output

to become efficient while keeping the number of hospitals in this evaluation the same, ten.

Figure 7.2 displays the results of the CRS input-oriented envelopment model with an additional quality variable. As expected, compared to the basic model, two more hospitals became efficient. Compared to the basic model, hospitals H2 and H7 are classified as best performers. In order to examine the performance of the hospitals, it is prudent not only to compare the basic DEA model with the modified DEA model with additional quality output, but also to compare the original raw quality scores of the hospitals.

Figure 7.3 provides this comparison. As can be observed, the average performance of the hospitals increased from 0.909 to 0.953, as an additional variable was introduced to the DEA model. We also may have introduced some tradeoffs between efficiency and quality, as suggested by Sherman and Zhu (2006). However, the more

	Basic Model	Quality as additional output	
DMU Name	Input-Oriented CRS Efficiency	Input-Oriented CRS Efficiency	Raw Quality Score
H1	1.00000	1.00000	90
H2	0.61541	1.00000	90
H3	1.00000	1.00000	100
H4	1.00000	1.00000	56
H5	1.00000	1.00000	89
H6	0.75780	0.77416	67
H7	0.96852	1.00000	89
H8	1.00000	1.00000	90
H9	1.00000	1.00000	50
H10	0.75297	0.75297	80
Average	0.90947	0.95271	80

Fig. 7.3 Comparison of DEA models and quality score

important observation here is whether the additional quality variable provides the needed performance information for managerial decision-making.

Upon closer examination of the last two columns of Fig. 7.3, we observe that the two hospitals, H2 and H7, which are now among the best performers, have raw quality scores of 90 and 89, respectively. This score may be acceptable, assuming that 90 is a good raw quality score, yet with other hospitals, such as H4 and H9, despite their perfect DEA scores, display raw quality scores of 50 and 56, nowhere near acceptable levels.

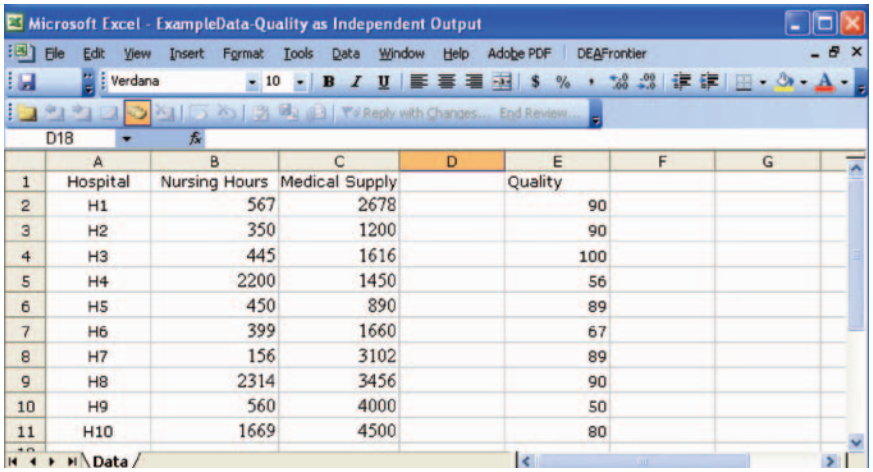
Thus, this illustration shows one of the shortcomings for inclusion of quality variables into the benchmark model as an additional output.

7.3 Quality as an Independent Output

In this section we examine the impact of quality as an independent output in a separate DEA model and make comparisons between the basic DEA model, quality-adjusted DEA model, and raw quality scores. This way we have two independent DEA evaluations, one for efficiency and one for quality.

Using our example again, Fig. 7.4 shows the setup for quality as an independent output DEA model. As the reader can observe, there is only one output variable, quality.

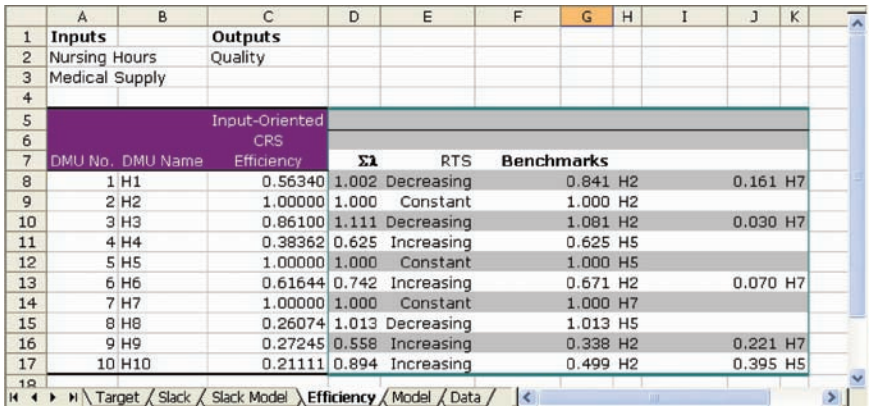
The result of the CRS input-oriented DEA model, where quality is only output are shown in Fig. 7.5. This model, along with the basic DEA model, will provide two independent dimensions of performance to the health care managers.



Microsoft Excel - ExampleData-Quality as Independent Output

	A	B	C	D	E	F	G
1	Hospital	Nursing Hours	Medical Supply		Quality		
2	H1	567	2678		90		
3	H2	350	1200		90		
4	H3	445	1616		100		
5	H4	2200	1450		56		
6	H5	450	890		89		
7	H6	399	1660		67		
8	H7	156	3102		89		
9	H8	2314	3456		90		
10	H9	560	4000		50		
11	H10	1669	4500		80		

Fig. 7.4 Setup for quality as an independent output



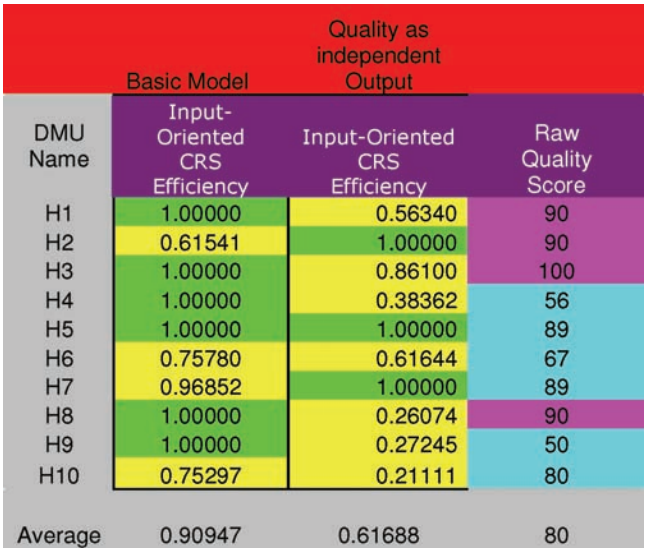
	A	B	C	D	E	F	G	H	I	J	K
1	**Inputs**		**Outputs**								
2	Nursing Hours		Quality								
3	Medical Supply										
4											
5			Input-Oriented								
6			CRS								
7	DMU No.	DMU Name	Efficiency	Σλ	RTS	**Benchmarks**					
8	1	H1	0.56340	1.002	Decreasing	0.841	H2		0.161	H7	
9	2	H2	1.00000	1.000	Constant	1.000	H2				
10	3	H3	0.86100	1.111	Decreasing	1.081	H2		0.030	H7	
11	4	H4	0.38362	0.625	Increasing	0.625	H5				
12	5	H5	1.00000	1.000	Constant	1.000	H5				
13	6	H6	0.61644	0.742	Increasing	0.671	H2		0.070	H7	
14	7	H7	1.00000	1.000	Constant	1.000	H7				
15	8	H8	0.26074	1.013	Decreasing	1.013	H5				
16	9	H9	0.27245	0.558	Increasing	0.338	H2		0.221	H7	
17	10	H10	0.21111	0.894	Increasing	0.499	H2		0.395	H5	

Target / Slack / Slack Model / Efficiency / Model / Data /

Fig. 7.5 Results of CRS input-oriented model with an independent quality output

The independent quality evaluation using DEA shows that only three hospitals H2, H5 and H7 perform well (at 1.0 level). Of course, this is an independent quality evaluation, and should be compared to raw quality scores for validation of this model. The reader can observe that H5, which was identified as an efficient hospital in the basic-DEA model, is also an excellent performer in quality dimension. On the other hand, hospitals H2 and H7 that were identified as inefficient in the basic DEA model are now identified as excellent performers once quality is considered.

Figure 7.6 provides the comparison of both the basic DEA, independent quality models, and the raw quality scores. While we can validate that hospital H5 is both efficient and effective in both DEA models, it has near acceptable raw quality score. However, we cannot validate a quality DEA score for hospitals H1, H3 and H8.



	Basic Model	Quality as independent Output	
DMU Name	Input-Oriented CRS Efficiency	Input-Oriented CRS Efficiency	Raw Quality Score
H1	1.00000	0.56340	90
H2	0.61541	1.00000	90
H3	1.00000	0.86100	100
H4	1.00000	0.38362	56
H5	1.00000	1.00000	89
H6	0.75780	0.61644	67
H7	0.96852	1.00000	89
H8	1.00000	0.26074	90
H9	1.00000	0.27245	50
H10	0.75297	0.21111	80
Average	0.90947	0.61688	80

Fig. 7.6 Comparison of DEA-models and quality score

These hospitals had good raw quality scores but the quality DEA model resulted in poor performance on quality.

This introduces the dilemma of how to incorporate quality into DEA models. In these examples we used only one quality variable. Other dimensions of the quality certainly would change the results of these evaluations. Because this is a fertile area of research in health care management, and many operations and health services researchers are examining this issue as more public data becomes available in quality of care, better models would be built and validated for health care managers' use.

This begs the question of how to evaluate the two dimensions of performance, efficiency and effectiveness (quality) in the mean time. Actually, this is not that problematic, as long as health care managers have access to quality data.

7.4 Combining Efficiency Benchmarks and Quality Scores

The health care managers can use the power of the DEA benchmarks from the efficiency models and the quality scores as shown in Fig. 7.7. The next step for the manager is to decide cut-off points for high and low efficiency and quality dimensions of the performance. For illustrative purposes, let us suppose that the manager decided to use 1.0 for high efficiency provided by DEA score. Any hospital that did not achieve the score of one will be considered low in efficiency. Similarly, the health care manager can set the high and low values for the quality scores. Let us assume a score of 90 or above (out of 100) represents high quality. With this

DMU Name	Basic Model: Input-Oriented CRS Efficiency	Raw Quality Score
H1	1.00000	90
H2	0.61541	90
H3	1.00000	100
H4	1.00000	56
H5	1.00000	89
H6	0.75780	67
H7	0.96852	89
H8	1.00000	90
H9	1.00000	50
H10	0.75297	80
Average	0.90947	80

Fig. 7.7 Benchmark and quality scores

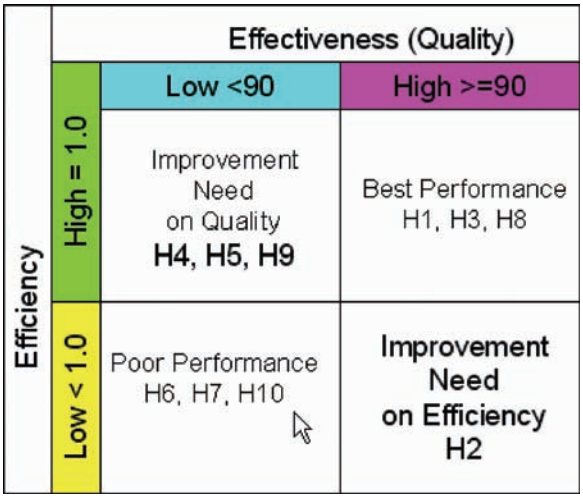


Fig. 7.8 Combined performance

information we can construct the quadrants of low/high efficiency and quality as shown as combined performance in Fig. 7.8.

Best performing hospitals are shown in the upper right quadrant of the Fig. 7.8.

These include hospitals H1, H3 and H8, which all had a perfect efficiency score, and 90 or better on their quality scores. The other three efficient hospitals H4, H5 and H6 appear on the upper left quadrant, indicating that they need to improve their quality. Although hospital H2 has high quality score, its efficiency is low, thus

causing H2 to appear in lower right quadrant, indicating that it needs improvement on efficiency.

The poor performance on both dimensions, efficiency and quality, is identified in the lower left quadrant. The hospitals H6, H7 and H10 are identified as poor performers, hence they not only need to improve their efficiency, but also their quality at the same time.

Using these combined performance models, health care managers of the hospitals lacking performance on efficiency would have information on how to improve efficiency by examining targets provided by DEA solutions. Similarly, health care managers who know the quality scores will be able take the necessary actions to improve that dimension.

7.5 Other DEA Models

The DEA field has grown tremendously during the past three decades. Besides the most frequently used models presented in this book, there are other models of DEA. These more specific models provide solutions to specific conditions. We will briefly describe them here, and the interested reader can further inquire from the following texts listed in the references: Zhu (2003), Cooper et al. (2007). We will list few of them below, which can be applied to problems in health care organizations.

7.5.1 Congestion DEA

If in a situation in which a reduction in one or more inputs generates an increase in one or more outputs (the reverse can also occur), congestion might be present. Fare and Grosskopf (1983) developed models to handle conditions that arise from these situations. Zhu (2003) also provides solutions using slack-based congestion models.

7.5.2 Super Efficiency DEA Models

This model, among other purposes, can identify extreme-efficient DMUs. To evaluate the super efficiency, the DMU under evaluation is not included in the reference set (benchmarks) of the envelopment models. More explanations for these models can be found in Andersen and Petersen (1993), Zhu (2003), Cooper et al. (2007).

7.5.3 Economies of Scope

This DEA model can be used to evaluate whether a health care organization might produce different services by spinning them off as separate organizations. Similarly,

one can test whether separate organizations delivering the services might be better off by consolidating under one umbrella. Economies of scope provide some answers to many capacity related questions using DEA. For further details of effects of divestitures and mergers, the interested reader is referred to Fare et al. (1994), and Cooper et al. (2007).

7.6 Summary

This chapter examined the effectiveness (quality) dimension of performance and illustrated how different evaluations can yield unexpected scores. More specifically, DEA models with quality variables may produce results that may not be valid. Thus, it is safer to evaluate efficiency and effectiveness dimensions independently to make managerial decisions in performance assessment and devise necessary improvement strategies.