Measuring the Efficiency of Public Schools using Data Envelopment Analysis – An Exploratory Study

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Abstract
We explore measuring and comparing the efficiency of selected Abu Dhabi secondary public schools using data envelopment analysis. For better identification and specification, certain scenarios were developed using different combinations of inputs and outputs. Sensitivity analysis was carried out to identify expected reductions (in inputs) or increases (in outputs) needed for inefficient schools to become efficient. The inputs with greatest impact were cost per teacher and cost per students. The outputs with greatest impact were two student tests conducted at the national level. Analysis of variance showed that location and type of school had a significant impact on school efficiencies.
Keywords: School efficiency, Data Envelopment Analysis, Abu Dhabi

1. Introduction

Education is a priority area for Abu Dhabi government. It is important in the performance assessment process to know to what extent schools are achieving their stated missions and expectations. Abu Dhabi schools system has never had a comprehensive performance plan that compares schools relative to each other in an objective and scientific manner. Every year, the results of national exams at the end of secondary school, which are used as entry requirements for higher education, have been made publicly available. These results are usually used to rank the secondary schools by several newspapers, and usually a highly debated issue when it comes to school performance, school choice, and the perverse effects of such simplistic ranking system. Analysis of performance in Abu Dhabi has to be contextualized with the relative maturity of the concept for the country and level of implicit understanding by the stakeholders.

Public schools in Abu Dhabi are non-profit organizations (government funded units). As a result, and as Hu et al. (2009) point out, "government funded schools do not have any motivation to cost accounting and cost minimization". If resource optimization is important, schools should change their policies on the utilization of these resources. On the other hand, with regard to student outcomes, schools were never pressured to do more to raise standards and expectations. Student outcome data was available to the public, but on aggregate basis. As a result, parents could not make a choice of better performing schools for their children. Since 2009, parents could get any information they needed about their children's schools. Performance-based school reform has received much attention in the recent years. Key elements of Abu Dhabi school reform include setting standards for students, teachers and school performance, granting autonomy to local participants in the educational process, and establishing a merit system based on school performance. Performance-based school reform attempts to provide stronger incentives for improving student performance by developing measures of achievement and linking financial and other rewards to those measures. Developing valid and reliable measures of school performance is crucial for both the efforts to establish incentives and to the assessment of management practices.

In the past, evaluating public schools' efficiency and performance in Abu Dhabi were generally hampered by either lack of data or problems with the quality of the data. Only in 2008, a complete student information system (eSIS) was put in place. The eSIS is in its second phase, and the completion of the system might take several years. It is hoped that this study will contribute towards a better understanding of the Abu Dhabi situation in terms of public school performance and to inform the debate on school evaluation, performance improvement, and policy setting.

DEA offers clear advantages over other methods as a source of information in determining the efficiency of organizations that produce multiple outputs (Banker et al., 1989; Banker, et al., 1986; Bowlin, et al.,

1985; Charnes, et al., 1989). DEA is a linear programming based technique which is applied to assess the efficiency of organizations such as universities, schools, bank branches, hospitals, power plants, police stations, tax offices, prisons, and manufacturing units which often use multiple resources (inputs) to achieve multiple goals (outputs). The methodology measures the relative efficiency without prior assumption of input-output weights.

DEA is used in this study as an exploration to examine its applicability to calculate the relative efficiency scores of public schools of Abu Dhabi. A further aim of this study is to give school-wise planning information to improve their efficiency. Because of the lack of clear definition of the factors that reflect the performance of schools and to assess in a more rigorous approach of evaluation, this study will explore using several model variants with available inputs and outputs. Both internal and external factors are considered in these proposed evaluation models. Because of statistical features of the inputs and outputs, only the justified ones would be utilized.

The objective of this paper is to assess the schools' efficiency to some extent in the presence of multiple inputs and outputs by using DEA. Other statistical methods will also be employed to shed light on the understanding of the nature of relationships between the inputs and outputs used in the study. The study would explore the contribution of certain factors to the school efficiencies in Abu Dhabi. The understanding of the nature of these factors should provide a better understanding of the overall production function related to school efficiencies. The main approach of this study could be summarized in the following steps:

1. Identify an appropriate list of input and output variables for evaluating the efficiencies of Abu Dhabi secondary public schools in the urban areas.
2. Assess the relationship between the input and output variables.
3. Assess the relationship among the input variables.
4. Assess the relationship among the output variables.
5. Identify appropriate output/input models of DEA of efficiencies of Abu Dhabi secondary public schools in urban areas.
6. Compute the efficiencies of the Abu Dhabi secondary public schools in urban areas:
   a. analyze the potential improvements for inefficient schools and the contribution percentage of each input or output;
   b. Identify peer schools for each inefficient unit.
7. Perform Post-hoc analysis by conducting statistical significance tests to compare schools based on their efficiencies according to geographic location, school gender, and school type.
8. Identify the effect of inputs and outputs variables on school efficiencies.

As a precaution, it should be understood that study represents only an exploration into the nature of using DEA in measuring the efficiency of public schools in Abu Dhabi. There are many limitations with regard to sample size, specification problems, and other factors. As a result, the outcome from this specific application should be treated with caution. The nature of these limitations will be addressed.

1.1 The Abu Dhabi education system

Public education in Abu Dhabi is divided into three groups: Cycle 1 (Grades 1-5); Cycle 2 (Grades 6-9); and Cycle 3 (Grades 10-12). Abu Dhabi's 296 public schools have been at the center of a transformational reform agenda to elevate student performance and education delivery to international standards. The reform effort spans all areas of education from the physical environment and resources, curriculum, assessment, teaching methods, and health and wellbeing. The public sector reform effort is driven by the Abu Dhabi Education Council's (ADEC) 10-Year Strategic Plan which identifies four main priorities: elevating school quality, improving access to P-12 education, providing affordable options of high-quality private education, and focusing on national identity and career development.

There are three main public school types in Abu Dhabi, public-private partnership (PPP) schools, model schools and government schools. The PPP initiative is designed to use the expertise of private school operators in enhancing public schools operations. Private operator teams work onsite at schools to support enhanced teaching methods and higher curriculum standards. There are 25 Model Schools in the Emirate of Abu Dhabi, covering both primary and secondary education. Model schools have conditions on student achievements, and teacher qualifications. Students are supposed to maintain a certain average every year. However, the new school model aims at unifying these school types in 2-5 years. Since 2009, all urban-secondary-public schools in Abu Dhabi are either PPP or model. However, in 2010, a decision was taken to unify the public school system in Abu Dhabi under one model called the New School Model (NSM). This is implemented in 2011.

In 2011, ADEC initiated its new school model (NSM). All Abu Dhabi schools should be transformed to NSM in 5 years. The NSM is a new approach to learning that will confront existing challenges in the public school sector to drive tangible and specific improvements in education delivery. It is intended as a comprehensive foundation for learning that will enable desired student outcomes by developing major

components of the educational experience: teaching quality, learning environment, school leadership, and parental involvement. Within this model, a new curriculum and new teaching methods will be introduced in order to develop the student as a creative independent thinker and problem-solver. The New School Model (NSM) is grounded in two core beliefs: that all students are capable of learning, and that the teacher is responsible for student learning. This seemingly simple philosophy is the basis for an approach to education that makes educators accountable for ensuring that each and every individual is able to develop to his or her maximum potential through developing specific talents and concentrating on individual areas of improvement.

All schools are government funded. ADEC is responsible for recruiting and hiring staff, principals and teachers. The ADEC strategic plan outlines many student achievement outcomes along with resources utilized as KPI's. Currently, ADEC decides (as a regulator and operator) on resources for each school. However, the strategic plan is calling for ADEC to have a regulatory role only in few years. ADEC has put many plans and initiatives to provide government schools with the know-how to gradually take the operation responsibility from ADEC. It should be noted that the resources available to each schooling system varies. These variations are hypothesized to affect student achievements, and hence, school efficiencies.

The sources for school inefficiency could vary from school to another. These sources might include inputs, outputs, or misallocation of resources. In this paper, we explore school efficiencies (or inefficiencies) from an empirical perspective.

2. Background and review

2.1 School efficiency measurement: The DEA approach

DEA was developed by Charnes et al. (1978) to evaluate public sector and not-for-profit organizations. DEA compares each decision-making unit (DMU) with all other DMUs in a set of DMUs, and calculates an aggregate performance measure based on a ratio of outputs and inputs. DEA can deal with multiple inputs and outputs for measuring the performance of each DMU. With this information, the DEA model determines the observed frontier of performance, based on the units with 100 per cent performance – all those units that perform better relative to all others in the set of units. DEA can also identify areas for improvement of performance for each unit (relative to the observed performance at the frontier), comparing the practice of the units on the frontier with the practice of the units below it (Sarrico et al., 2010). The sharing of the best practice of the units on the frontier with the units below it allows an opportunity for the units with worse performance to improve and, thus, improve the performance of the whole set. The repeated use of DEA helps to establish an environment of organizational learning.

Many studies report on using DEA to measure performance of schools (Coelho et al., 2007; Mayston, 2003; Dyson, 2000). In fact, DEA was used in many countries to measure the efficiency of schools. Most studies concluded that DEA is applicable to efficiency measurement of schools in the sense that it detects differences among schools and its results are fairly robust (i.e., USA [Bessent and Bessent, 1980; Bessent et al., 1982, 1983, 1984; Ludwin and Guthrie, 1989; Fare et al., 1989; Sengupta, 1987; Sengupta and Sfeir, 1986, 1988; Ray, 1991; Ganley and Cubbin, 1992; Ruggiero, 1996, 1999, 2004; Engert, 1996; Duncombe et al., 1997; Chalos and Cherian, 1995; Chalos, 1997; Grosskopf et al., 1999; Grosskopt et a., 2001; Rassouli-Currier, 2007; Christie et al., 2010]; [UK (Jesson et al., 1987; Mayston, 1996; Mancebon and Mar-Molinero, 2000; Bradley et al., 2001; Thanassoulis and Dunstan, 1994; Bates, 1997)]; [Norway (Bonesrqnning and Rattsq, 1992, 1994)]; [Finland (Kirjavainen and Loikkanen, 1998)]; [Spain (Muniz, 2002)]; [Sweden (Waldo, 2007)]; [Portugal (Sarrico et al., 2010)]; [Cyprus (Soteriou et al., 1998)]; [China (Hu et al., 2009; Ng and Li, 2009)]; and [Tunisia (Essid et al., 2010)].

Some studies went beyond just measuring school efficiencies. Bradley et al. (2001) calculated the technical efficiencies of all secondary schools in England over the period 1993-1998, and estimated models to examine the determinants of efficiency in a particular year and the change of efficiency over the period. They also found that competition was an important determining factor of school efficiency over time. Fare et al., (1989) used DEA to assess the performance of school districts in Missouri. They did not only allow for variable returns-to-scale by employing the Banker et al (1984) formulation, but also used 'jack-knifing' techniques to reduce the impact of outliers on efficiency measures. Ng and Li (2000) used DEA to examine the effectiveness of China Education Reform in the mid-1980 with the data from 84 institutions, and outlined a different efficiency change pattern.

2.2 Input variables

The literature on educational inputs is plentiful. The inputs are divided into two categories. These are endogenous inputs that can be controlled by schools and exogenous inputs that cannot be controlled by schools. It seems that human and school resources are the two main endogenous determinants affecting school efficiency emerging from studies on school efficiency. The operating expenses and the teaching staff are the most frequently selected inputs for educational processes (Ruggiero, 1998; Madaus et. al. 1979; Mancebon & Bandres,

1999; Mancebon and Banders, 2001). Rutter and Maughan (2002) provide a more comprehensive list of inputs. They involve school management that includes good leadership that provides strategic vision, staff participation with a shared vision and goal, and appropriate rewards. They also involve ethos qualities such as an orderly atmosphere, attractive working environment, shared high expectations and good teacher-student relationships. In addition, other factors include effective monitoring that means regular measurement of student performance, assessment of teacher efficiency and evaluation of overall school performance. Other components include good classroom management that is efficient lessons, clarity of purposes and contents in these lessons; and the pedagogic qualities such as effective teaching, active participation from students, maximization of learning time and the like. Thanassoulis (1999) and Rutter and Maughan (2002) agree to the decisive importance of this category of inputs to student performance. Sammons et al (1996) find that these factors such as student prior attainment, gender, ethnicity and free school meals are statistically significant, contributing about 44.5% of the variation in student academic achievement. Mancebon and Badres (1999) suggest the inclusion of 'socio-economic component', 'human capital component' and 'aspiration component' for the estimation of school efficiency, which account for 74% of the variance in student academic achievement. However, Rutter and Maughan (2002) report that the influence of school related factors can have a stronger impact on academic performance than those of student related factors.

In addition to direct teaching inputs, several studies have attempted to incorporate non-labor inputs, often with the dollar value of non-teaching expenditure. For example, Smith and Mayston (1987) divided total expenditure into a teaching and non-teaching component, while Deller and Rudnicki (1993) used categories of instructional, administrative, operational and busing expenditure. The division of expenditures into finer categories is likely to illuminate particular aspects of educational efficiency that deserve attention. Sengupta and Sfeir (1988) used average teaching salaries for the price of labor and Barrow (1991) specified a re-pricing index for educational expenditure. Ray (1991) for example, specified the number of classroom teachers, support and administrative staff as inputs into the high school education process.

2.3 Output variables

One of the obstacles encountered by studies on school efficiency is the conceptualization and measurement of outputs (Soteriou et al., 1998; Waldo, 2007). However, most studies established the importance of academic performance in this efficiency evaluation (Madaus et. Al. 1979, Mancebon & Bandres, 1999). Mancebon and Bandres (1999) suggest that the variables selected for academic performance must reflect both the quantity and quality of the academic standards achieved by schools. For quantity, one of the suggestions is the proportion of students passing an examination. The marks obtained by students in the subjects that form the curriculum is the variable most supported in the literature for quality. Charnes et al (1981) and Bessent et al. (1982) reported that the preferred specification of educational outcomes in most of the empirical literature has been student test scores. Senupta (1987) used average test scores in reading, mathematics, writing and spelling, McCarty and Yaisawarng (1993) specified passing students in mathematics, reading and writing proficiency, and Chalos and Cherian (1995) and Chalos (1997) employed verbal and math test scores. Studies by Ruggiero (1996) of New York State schools also specified social studies test scores, and Ray (1991) who added language and arts performance in an analysis of Connecticut high schools. However, the specification of output also varies enormously according to the chosen educational context. For instance, Diamond and Medewitz (1990) evaluated an economic education program using the 'Test for Economic Literacy', while most U.K. studies have concentrated upon the percentage of school leavers attaining 'A' levels and graded 'O' levels [see, for example, Smith and Mayston (1987), Ganley and Cubbin (1992) and Bates (1997)].

Of course, all of these output measures concentrate on intermediate educational outcomes, though there is an increasing tendency to specify longer-term educational benefits in more recent work. For example, Fare et al. (1993) followed up their study with post-secondary grades, incomes and education, Engert (1996) included post-secondary college entrance, and Haksevevr and Muragishi (1998) viewed starting salaries and the employment of graduating students as the most appropriate output for the MBA programs. The study by Fare et al., (1993) 'High School and Beyond' program simultaneously assessed the performance of schools in generating educational opportunities, as well as intermediate and long-term educational achievement. Educational outcomes were proxied in the short-term by the number of classes taken and extracurricular activity, by follow-up test scores in the intermediate term, and by post-secondary income and educational attainment in the long-term. Engbert (1996) also used a temporal 'value-added' approach to educational output by including basic competency, diploma attainment and college entrance in a study of New York schools. Another set of frontier efficiency measurement studies that deserves particular attention is the instances where educational outputs are jointly produced with (strictly) non-educational outcomes (Johnes and Johnes, 1993, 1995; Beasley, 1990, 1995; Madden et al., 1997). Other studies suggest that school beautification activities, sports and other co-curriculum activities are also desirable outputs (Thanassoulis, 2001; Thanassoulis & Dunstan, 1994, Lovell et al, 1993).

Following studies such as Bessent et al. (1980; 1982), Sengupta (1987), Diamond et al, (1990), and

Beasely (1995), the current study has considered school related variables as inputs and test scores as outputs. To assess the intuitive picture of performance and to measure the dependency of efficiency on different variables we consider several models with different input-output combinations. The guiding principle in construction of these models is to proceed from simple one (with less number of input-output variables) to more complicated ones (with greater number of variables). This strategy of running several models enables testing the robustness of the results since the DEA methodology does not have a statistical method for testing hypotheses. The utilization of DEA in measuring school performance is highly dependent on the availability of data that, frequently, is not available. It is important to note that a performance measurement model such as DEA will assure the consistency and comparability of the standards used: and the validity values of the educational performance measures for each school compared across schools.

3. Methods

3.1 Data and study sample

Data for the academic year 2009-2010 on Abu Dhabi public schools was collected from the ADEC's database of public schools, from its ERP system, and from the electronic student information System (eSIS). Since there are many distinguishing features among Abu Dhabi schools, the study established a set of requirements to make the list of schools (DMU's) more homogeneous. The study focused on schools that met the following four criteria:1) An Abu Dhabi public school; 2) secondary level (or high schools); 3) located in urban areas of the three education zones in Abu Dhabi (Abu Dhabi zone, Al Ain zone, and Al Gharbiah zone); and 4) has been in existence for at least 5 years.

There were 22 schools that met all four requirements. Table 1 provides some details regarding these schools according to location, school type and student gender. The Table shows that average cost per student is highest in Al Ain, for model schools and for male schools. Average cost per teacher is highest in Al Ain, for model schools and for male schools. The unutilized teacher load average is highest in Al Ain, for PPP schools and female schools. The unutilized class capacity of 25 students per class is highest in Al Ain, and for model schools. With regard to outputs, results show that on average, Abu Dhabi scores are the highest. With regard to school type, model schools outperformed PPP's, and male averages are higher than female averages.

Table 1. School Sample Characteristics (22 schools)

School feature	Zone			School Type		Gender	
	Abu Dhabi	Al Ain	Gharbiah	Model	PPP	Male	Female
Frequency	13	8	1	2	20	11	11
Average cost/student	39020.104	58899.156	49249.611	37917.130	47593.497	50589.548	42838.107
Average cost/teacher	201404.54	245183.01	181265.17	225155.79	215533.83	234104.55	198712.57
Teacher load average unit?	0.2588764	0.3371315	0.2500000	0.2848230	0.2871400	0.2695716	0.3042871
Class capacity average	16.404363	22.556393	21.111111	27.537879	17.987161	18.882722	18.828094
Student/teacher ratio	9.3616683	8.7282734	9.4666667	9.4464286	9.1050842	10.327989	7.9442419
CEPA? Average	140.10502	157.41545	156.46667	175.82307	144.27547	158.72191	135.56495
G12 Thanawyiah	68.906154	80.33875	82.790000	88.435000	72.220500	79.606364	67.782727
EMSA G10 English reading	488.85449	497.07563	557.51000	583.04814	486.15636	522.47732	467.45208
EMSA G10 mathematics	469.17942	550.78696	545.28571	554.66473	497.07922	556.18239	448.44614
EMSA G1 Arabic reading	467.65968	554.6976	544.19178	555.53334	497.51409	554.17489	451.40223
EMSA G11 English reading	493.48604	578.59349	564.21739	590.24722	521.38947	581.58814	473.7104
EMSA G11 mathematic	471.96272	489.91713	557.40541	560.62644	474.55025	562.16704	402.58368
EMSA G12 Arabic reading	481.30083	573.53122	560.38824	577.73591	512.50385	573.44147	463.42659
EMSA G12 English reading	503.77391	584.44747	569.1413	603.45532	529.34356	593.81093	478.35106

3.2 Methods and design

For ADEC secondary public schools, several outputs related to student outcomes are available (Figure 1 and Table 2). These outputs include the following:

- The 12th grade average exit exam results (called *Thanawiah*). All students in Abu Dhabi, who finish their secondary school, have to sit for an exam at the end of the academic year. This compulsory exam is administered by the Ministry of Education (jointly with ADEC for Abu Dhabi Schools). The results are usually taken by higher education institutions in the UAE as criteria for entering specific colleges and major disciplines.
- The Common Educational Proficiency Assessment (CEPA) average score. CEPA is a joint venture between the National Admissions and Placement Office (NAPO) in the Ministry of Higher Education and Scientific Research and the Federal Higher Education Institutions in the United Arab Emirates. CEPA consists of two tests - an English test and a Math test. For those students who are expected to apply for federal higher education institutions in the UAE, CEPA is required.

- English, Math, Science and Arabic (EMSA) average scores. EMSA test has been used to provide a benchmark to measure actual student progress against the standards and performance levels expected at each grade level. The results are expected to provide information and guidance for individual students, school faculty and administration on their performance relative to other students and schools throughout the Emirate of Abu Dhabi. EMSA is administered by ADEC for all grade levels starting from the 4th grade.

Table 2. Output details for schools

School name	G10 Eng. Read. EM.	G10 Math EM.	G11 Ar. Read. EM.	G11 Eng. Read. EM.	G11 Math EM.	G12 Ar. Read. EM.	G12 Eng. Read. EM.	G12 Math EM.	Gr12	CEPA
S1: K Bin Zayed (AA)	560.59	552.49	550.98	575.09	557.92	568.14	589.94	577.24	76.93	153.8
S2: Mereijeb Second.	569.48	548.61	553.27	580.05		564.87	577.57	569.64	83.10	164.2
S3: Al Qadesyah	570.44	543.35	545.79	576.99	550.09	557.43	580.43	569.78	78.50	166.6
S4: Qatr Al Nada	557.51	545.29	544.19	564.22	557.41	560.39	569.14	571.22	82.79	156.5
S5: K. Bin Zayed (AD)	575.74	561.64	552.19	588.07	563.46	573.12	607.58	583.84	75.27	162.4
S6: Umm Ammar	573.61	545.93	553.50	577.03	552.49	565.16	597.14	579.70	83.07	166.8
S7: Al Mawaheb	592.08	561.44	561.23	604.65	566.59	581.95	610.72	596.40	89.03	179.6
S8: Al Manaseer	562.76	545.98	553.77	577.63	551.37	568.27	579.71	570.78	80.68	164.8
S9: Zayed Al Awwal	557.59	544.35	551.50	569.05	554.34	572.24	586.06	582.83	82.59	155.5
S10: Al Maahad Islami	582.84	568.75	576.57	602.72	584.55	570.78	593.71	592.50	77.42	152.4
S11: Al Ittihad	574.01	547.89	549.84	575.84	554.67	573.52	596.19	577.74	87.84	172.1
S12: Al Sarooj	570.50	552.92	550.13	572.13	550.39	568.56	586.34	577.85	84.40	163.5
S13: Mohd. Bin Khalid	574.51	564.78	551.26	588.07	559.14	563.46	611.23	589.63	79.85	163.4
S14: Al Mutanabbi	590.66	563.25	564.43	594.45	560.79	587.15	610.15	594.80	80.80	163.3
S15: Darwish B. Karam	569.53	557.08	547.20	569.45	565.28	563.93	594.57	573.93	73.74	162.0
S16: Al Montaha	571.31	544.38	550.97	572.07	550.04	560.74	570.93	570.62	79.14	164.2
S17: Palestine	574.28	545.01	552.58	586.03	550.04	570.33	589.87	573.12	84.90	165.0
S18: Al Ain Secondary		534.66	546.08	568.27	552.73	597.14	569.93	567.17	78.35	149.7
S19: Abu Dhabi	588.94	564.57	550.58	582.67	562.93	560.14	580.23	573.14	83.64	155.9
S20: Khaled Bin Wald.	572.84	558.54	555.28	583.81	568.03	578.24	592.32	582.74	79.24	155.4
S21: Hanen Secondary	563.30	536.19	543.04	571.90	545.26	551.82	569.48	564.47	81.06	165.8
S22: Aish. B. A. Baker	583.45	559.59	570.79	594.14	560.24	587.03	603.80	581.59	85.59	170.1

With respect to the input variables, for ADEC secondary public schools, there are many cost related variables that are available. After careful discussion and considerations with the office of Strategic Plan in ADEC, two cost-related variables are usually used as KPI's by ADEC, and they will be considered in this study. Other non-monetary variables related to class capacity, teacher to student ratio, and teacher load will be considered too. The list of input variables, as shown in Table 3, and they include:

- Average student cost per school.
- Average teacher cost per school (it should be added here that the average teacher cost per school is a figure added already in the average per student cost per school).
- Class capacity utilization. The policy established by ADEC recommends secondary schools to fulfill class capacity to 25 students.
- The teacher – student ratio in the school. The policy established by ADEC recommends secondary schools to fulfill a ratio of 13 students per teacher.
- Teacher load. The policy established by ADEC recommends secondary schools to fulfill a teacher load of 24 hours per week.

It should be mentioned that ADEC has other inputs and outputs that are directly measureable but were not utilized in the current analysis due to various reasons. These indicators include parent satisfaction scores, teacher satisfaction scores, number of licensed teachers and their satisfaction scores, average ILETS scores of teachers, other cost figures for each school, size of the school, number of students, and other indicators. With regard to satisfaction scores' data (parents, teachers, and licensed teachers), all scores correspond to the academic year 2010-2011. Prior scores were not school-specific, but they were of a general nature. The full utilization of the services of licensed teacher occurred more in 2010-2011. As a result, using the data for analysis prior to 2010-2011 might not reflect the true application. ILETS scores were not readily available when this study was conducted. Finally, school size and number of students data were not utilized since the numbers were reflected more objectively through other variables such as teacher/student ratio, and class utilization. It should be mentioned that most of those indicator variables would be utilized in future studies.
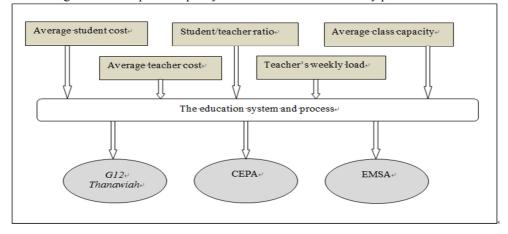
In DEA, usually two rules of thumb should guide the analyst in the specification of the model. The first is parsimony. The analyst should avoid the "kitchen sink" approach when selecting inputs and outputs

(Thanassoulis, 2001; Cooper et al., 2000). The more inputs and outputs for a given number of DMUs, the greater proportion of units classified as efficient. This is so because the DMUs are compared to each other on the basis of inputs and outputs. Idiosyncratic levels of inputs or outputs of a DMU will cause a DMU to be "unique" and thus only comparable to it; hence, be labeled as efficient. The second rule of thumb is to avoid the use of highly correlated inputs and highly correlated outputs. The issue is whether the variables are truly distinct. For example, the teacher-student ratio and the expenditure per student may not truly reflect two distinct resource utilization measures. Moreover, the first rule of thumb is enhanced by minimization of somewhat redundant inputs and outputs. The vast majority of the literature on education production relationships was estimated with multiple regression analysis which provides an extensive examination of appropriate input and output measures. These carry over to desired DEA input and output measures.

Golany and Roll (1989) note that the number of DMUs should be at least twice of the total number of input and output factors considered when applying the DEA model. In this study the number of DMUs was 22, while the total (available) inputs (5 inputs) and outputs (9 outputs) is 15, which means that we need to be extra careful in selecting the right combination of outputs and inputs for the DEA to yield high construct validity. Through further statistical analysis, an appropriate list of inputs and outputs would be outlined.

Table 3. Input details for schools

School name	Cost per teacher	Cost per Student	Teacher load	Class size	student teacher ratio
School 1	244691	43685.35	22.99	13.19	28.69
School 2	267221	64063.23	39.29	13.92	43.72
School 3	254970	43226.81	14.18	12.17	14.04
School 4	181265	49249.61	25.00	21.11	40.83
School 5	267182	49446.45	17.15	10.00	18.57
School 6	242664	51041.47	27.30	10.35	29.03
School 7	229059	40216.00	44.68	27.58	46.65
School 8	268504	58978.94	29.17	21.37	39.24
School 9	224502	48205.23	18.18	27.08	35.19
School 10	230899	60566.30	54.59	20.77	52.90
School 11	221253	35618.26	12.28	27.50	30.95
School 12	270242	61780.72	36.84	16.67	42.03
School 13	248971	55822.64	30.92	13.33	32.59
School 14	227990	49931.43	40.27	0.93	32.70
School 15	234408	42597.13	27.54	20.00	23.08
School 16	235373	46480.79	28.57	9.79	29.59
School 17	236540	56181.59	31.82	18.84	39.78
School 18	227439	87144.07	38.84	56.92	66.13
School 19	219848	36698.78	3.96	7.46	0.34
School 20	227966	46769.40	29.80	10.53	32.00
School 21	222867	51310.92	38.86	17.33	42.33
School 22	213516	58904.67	19.01	37.97	46.16

Figure 1. The input – output system of Abu Dhabi secondary public schools

3.3 Analysis methods

It should be noted that defining inputs and outputs is crucial in any study. The validity of the results rests on the quality of the data used to perform the analysis. Again, since this kind of analysis is new to the Abu Dhabi school system, it should be obvious that this is only an exploratory study of better understanding the advantages of DEA, and its shortcomings. In these circumstances, the authors were not clear at all on what output and input variables they were supposed to be using. There is just a long list with variables described and without link among them. However, the ADEC authorities participating in the study suggested looking at DEA programs output with various scenarios of different input and output combinations to explore their usefulness. This kind of scenario analysis will provide a clearer idea of the variable used and why they were used and why only some combinations have been used.

To help in identifying a shorter list of inputs and outputs for the DEA, two main analysis methods were employed. First, multiple regression was used to assess the relationships between the input and output variables. The output variables were treated as dependent variables with all input variables being independent variables. This method would allow understanding the contributing input variables with each of the output variables. Second, correlation analysis was used to better understand the relations among the input variables. It was also used to establish correlations among the output variables.

DEA models (scenarios) would attempt to incorporate variables that have low correlations. The scenarios would represent the explorations of their usefulness to school decision-makers. The issue of returns to scale concerns what happens to schools' outputs when they change the amount of inputs that they are using to produce their outputs. Since this study is only an exploration, DEA with constant return to scale would be assumed. Under the assumption of constant returns to scale a school's efficiency is measured relative to efficiency of other schools of different scale sizes. As a result no school will obtain a lower efficiency score using variable returns to scale than it achieves using constant returns to scale and some schools are likely to achieve higher efficiency results.

For the DEA, both input minimization and output maximization are available as options. However, since school efficiencies with respect to costs of each school were a major determinant, the input minimization option will be used. It is concerned with "given the level of outputs that schools produce, how much could their use of inputs have been reduced while maintaining their current level of outputs?" In addition, sensitivity analysis would identify potential improvements. It would show how much inefficient schools need to reduce their inputs or increase their outputs in order to become efficient. As a result, such exploratory investigation would answer two questions: "how efficient the schools are?" and "how much could they improve?" Such analysis might suggest performance targets for each inefficient school. It also would identify the units which were performing best and; therefore, their operating practices could be examined to establish a guide to "best practice" for other schools to emulate.

Since several scenarios would be explored and run using DEA (i.e., DEA under different combinations of inputs and outputs), average efficiency scores for each school would be calculated. Using efficiency scores as dependent variable, regression analyses would be run to better understand the significant input and output variables. Separate and individual regressions would be run on all inputs for each of the outputs one at a time because of the small sample size of schools. Some limitations with using this method would be addressed later in the study.

To evaluate statistical differences between schools based on their calculated efficiencies, ANOVA would be utilized. Since a one-way ANOVA with small sample sizes may not have sufficient power to detect any significant difference among the samples, the analysis would be utilized to only suggest future directions for this study.

3.4 The DEA model

The model designed here is a simple CCR model, which is probably the most widely used and best known DEA model (Banker et al., 1989; Charnes et al., 1993). A constant return to scale relationship is assumed between inputs and outputs. It was the first DEA model to be developed, named CCR after Charnes, Cooper and Rhodes who introduced this model in an article published in the European Journal of Operational Research (1978, Vol. 2 pp. 429-444). This model calculates the overall efficiency for each unit, where both pure technical efficiency and scale efficiency are aggregated into one value. The primal CCR model and its primal version used are explained here.

DMU_j : The j th Decision Making Unit $(j = 1, 2, \cdots, n)$

x_{ij} : The amount of the i th input of the j th DMU

$$x_{1j}, x_{2j}, \cdots, x_{mj}$$

y_{ij} : The amount of the i th output of the j th DMU

$$y_{1j}, y_{2j}, \cdots, y_{sj}$$

v_i : The weight assigned to the i th input $(i = 1,2,\cdots m)$

u_r : The weight assigned to the r th output $(r = 1,2,\cdots s)$

Maximize $\theta = \dfrac{u_1 y_{1k} + u_2 y_{2k} + \cdots + u_s y_{sk}}{v_1 x_{1k} + v_2 x_{2k} + \cdots + v_m x_{mk}}$

subject to $\dfrac{u_1 y_{1j} + \cdots + u_s y_{sj}}{v_1 x_{1j} + \cdots + v_m x_{mj}} \leq 1$ $(j = 1,2,\cdots, n)$ (1.2)

$$v_1, v_2, \cdots, v_m \geq 0, \qquad u_1, u_2, \cdots, u_s \geq 0$$

Maximize $\theta = u_1 y_{1k} + \cdots + u_s y_{sk}$

subject to $v_1 x_{1k} + \cdots + v_m x_{mk} = 1$

$$u_1 y_{1j} + \cdots + u_s y_{sj} \leq v_1 x_{1j} + \cdots + v_m x_{mj}$$

$$v_1, v_2, \cdots, v_m \geq 0, \qquad u_1, u_2, \cdots, u_s \geq 0$$

An Optimal Solution : (v^*, u^*, θ^*)

$$R_k = \left\{ j : \sum_{r=1}^{s} u_r^* y_{rj} = \sum_{i=1}^{m} v_i^* x_{ij}, \ j = 1, \cdots, n \right\}$$

The reference set R is given by
The primal problem becomes:

Maximize $\displaystyle\sum_{r=1}^{s} u_r y_{rk}$

subject to $-\displaystyle\sum_{i=1}^{m} v_i x_{ij} + \sum_{r=1}^{s} u_r y_{rj} \leq 0$

$$\sum_{i=1}^{m} v_i x_{ik} = 1$$

$$v_i \geq 0 \ \text{and} \ u_r \geq 0$$

And the dual problem becomes:

Minimize θ

subject to $-\displaystyle\sum_{j=1}^{n} x_{ij} \lambda_j + \theta x_{ik} \geq 0$

$$\sum_{j=1}^{n} y_{rj} \lambda_j \geq y_{rk}$$

$$\lambda_j \geq 0 \ \text{and} \ \theta : unrestricted$$

4. Results

4.1 Relationship between input and output variables

Regression analysis is performed of input and output variables. Each output variable is treated as a dependent variable with all input variables being independent variables. As a result, a total of 10 regression analyses were run, one for each output variable. Again, it should be noted that the only justification for doing such analysis was to explore dependency of variables on each others. The analysis calculated the values for the standardized beta,

and t-value for only those variables that portray less than (0.10) level of significance. Results show that only several output variables showed some sensitivity to certain input variables. CEPA scores were impacted significantly by only two inputs: average cost per teacher, and average cost per student. Thanawiyah scores were also impacted by the two cost factors. The other output variables related to EMSA scores were not significantly impacted by any of the cost variables.

The analyses provide some justifications for the possible impact of two main input variables: average cost per teacher and average cost per student. Other non-cost variables had some impacts on the EMSA scores but not on the CEPA and Thanawiyah scores. Analyses also point to the importance of three output variables: Thanawiyah scores, CEPA scores, and Grade 12 EMSA Math scores. These three variables mostly were impacted by cost variables.

4.2 Variable candidates and scenarios

The number of schools (DMU's) is 22 schools with a possible list of 15 input/output variables available. As a result, the DEA would be useless if all inputs and outputs were to be considered. Correlation analyses were performed on the set of inputs and the set of outputs to reduce the total number; and to find the best combination mix of inputs and outputs. Several scenarios could result. Table 4 provides correlation coefficients with regard to the candidate inputs. There are several conclusions that could be made. There is a low correlation between cost per teacher, and the other 4 input variables. As a result, *cost per teacher* is a good candidate to be a representative input variable. It could be a part of all scenarios. If *average cost per student* is an important input variable, it should be noted that it enjoys high correlation with *teacher load* and *average student/teacher ratio*. In addition, *Class capacity* is highly correlated with *student/teacher ratio*. Other inputs listed here could be used, but due to the above reason they will not be include n the final analysis.

The debate was to select most appropriate non-cost variables. Regression results did not show significant effect for most non-cost variables on any of the outputs. However, both student/teacher ratio and teacher load provided significant effects with regard to the different outputs. Since teacher load and student/teacher ratio are both highly correlated ($P = 0.742$); and student/teacher ratio is correlated with class size ($P = 0.749$), more discussion were required. As a result, these facts were presented to a panel consisting of ADEC executive members. Such overall results would lead to the recommendation of possibly not using any of the non-cost inputs.

Table 4. Correlation coefficients for inputs (significance level)

	Cost per teacher	Cost per student	Teacher load	Student/teacher ratio	Class capacity
Cost per teacher	1.000				
Cost per student	0.293	1.000			
Teacher load	0.067	0.513	1.000		
Student/teacher ratio	-0.300	0.618	0.742	1.000	
Class capacity	-0.174	0.147	-0.002	0.749	1.000

Table 5 provides the correlation between the output variables. There are several conclusions that could be made. Both *CEPA* and *G12 Thanawiyah* have relatively low correlations with all other variables. However, *CEPA* and *G12 Thanawiyah* are highly correlated. Recommended that either one could be a candidate for inclusion in the analysis. However, they should not be a part of the same model (or scenario). EMSA variables are correlated with each other. As a result, only one of them could be included in the analysis. The one with the lowest correlation with *CEPA* or with *G12 Thanawiyah* is *EMSA Grade 12 Math*.

Table 5. Correlation coefficients for outputs (add significance level)

	EMSA G10 English Reading	EMSA G10 Math	EMSA G11 Arabic Reading	EMSA G11 English Reading	EMSA G11 Math	EMSA G12 Arabic Reading	EMSA G12 English Reading	EMSA G12 Math	Grade 12 Than.	CEPA
EMSA G10 English Reading	1.000									
EMSA G10 Math	0.712	1.000								
EMSA G11 Arabic Reading	0.633	0.638	1.000							
EMSA G11 English Reading	0.826	0.723	0.820	1.000						
EMSA G11 Math	0.494	0.827	0.673	0.631	1.000					
EMSA G12 Arabic Reading	0.527	0.512	0.713	0.633	0.408	1.000				
EMSA G12 English Reading	0.609	0.690	0.535	0.703	0.457	0.717	1.000			
EMSAG12 Math	0.613	0.751	0.708	0.771	0.660	0.725	0.834	1.000		
Grade 12 (Than.)	0.289	-0.140	0.114	0.176	-0.251	0.307	0.078	0.118	1.000	
CEPA	0.358	-0.152	0.024	0.262	-0.323	0.242	0.332	0.094	0.568	1.000

Results from regression and correlation analyses reduced the number of outputs to three (CEPA, Thanawiyah, and EMSA Grade 12 Math). The analyses also reduced the number of possible inputs to three (class size, average cost per student, and average cost per teacher). However, because of the correlation between some of those selected variables, some variables were recommended not to be used in the same model. The suggested models (or scenarios) were the following:

Scenario 1. Average cost per student and (CEPA and EMSA Grade 12 Math).
Scenario 2. Average cost per student and (Thanawiyah and EMSA Grade 12 Math).
Scenario 3. Average cost per teacher and (CEPA and EMSA Grade 12 Math).
Scenario 4. Average cost per teacher and (Thanawiyah and EMSA Grade 12 Math).

Table 6. Efficiency of schools under different scenarios

	Scenario 1 CEPA - EMSA Cost/ Student	Scenario 2 Than. – EMSA Cost/student	Scenario 3 CEPA – EMSA Cost/teacher	Scenario 4 Than – EMSA Cost/teacher	Average Overall
School 1	81.46	81.46	74.86	74.86	78.16
School 2	54.82	54.82	71.17	68.09	62.23
School 3	81.26	81.26	75.68	70.91	77.28
School 4	71.51	71.51	100.0	100.0	85.76
School 5	72.79	72.79	70.40	69.43	71.35
School 6	70.02	70.02	79.61	75.81	73.87
School 7	92.43	91.43	90.82	85.10	89.95
School 8	59.56	59.66	71.09	67.46	64.44
School 9	74.54	74.54	82.38	82.38	78.46
School 10	60.31	60.31	81.43	81.43	70.87
School 11	100.0	100.0	90.09	86.92	94.25
School 12	57.66	57.66	70.08	68.38	63.45
School 13	65.12	65.12	76.02	75.15	70.355
School 14	73.44	73.44	82.96	82.79	78.16
School 15	83.07	83.07	80.05	77.70	80.97
School 16	75.69	75.69	80.80	76.93	77.28
School 17	62.89	62.89	80.79	78.58	71.29
School 18	40.13	40.13	79.13	79.13	59.63
School 19	96.28	96.28	82.73	83.30	89.65
School 20	76.82	76.82	81.12	81.12	78.97
School 21	67.82	67.82	86.17	80.37	75.55
School 22	60.87	60.87	92.27	87.77	75.45

Than (Thanawiyah scores - Grade 12 exit exams)
EMSA (test of English, Math, Science and Arabic – the Math portion only)

4.3 School relative efficiencies under various scenarios

School efficiencies are calculated under the six scenarios suggested, given the conclusions reached with regard to the regression and correlation analyses. Each scenario is associated with different combinations of inputs and/or outputs. This form of analysis could be thought of as an exploration of the sensitivity of the model to different inputs and outputs. In other words, how would the efficiencies change given a change in the combination on inputs and outputs? For both input minimization and output maximization analyses with constant returns to scale, the efficiencies for each of the scenarios were analyzed and are given in Table 6. The last row shows the average efficiency scores under each scenario.

There are several obvious results that could be summarized here:

- For the 4 scenarios, only 2 schools reach the 100% efficiency score at least once (School 4 and School 11).
- The first and second scenarios provided almost identical results.
- Using cost/student or cost/teacher significantly affected the efficiency of several schools.
- The correlation between the third and fourth scenario is 0.882, significant and high.
- The correlation between either the first or second scenario with either third or fourth scenarios is low (around 0.228).
- Either cost/student or cost/teacher were used in any of the scenarios because of the high correlation between the two (many members of the consulting or advisory group preferred using average cost per teacher because of the variation in teacher cost from one school to another).
- A preference was given to the third and fourth scenarios dealing with cost/teacher.

The results indicate that changing the combinations of outputs and inputs affected and hence, significantly altered the school rankings with regard to efficiency. Selecting one of the scenarios to conduct sensitivity analysis would yield outcomes unique to that scenario. For the input minimization analysis, DEA provided actual and targets for each resource (the input variables). As a result, each school gets the potential improvement it could achieve to be efficient in comparison with its efficient peer (s). The analyses with regard to the fourth scenario is shown in Table 7.

Table 7. Actual and targets under the 4th scenario (Minimization of inputs)

School name	Efficiency	EMSA		Cost per teacher		Thanawiyah	
		Actual	Target	Actual	Target	Actual	Target
School 1	74.86	577.24	577.24	244,691	183,175	76.93	83.66
School 2	68.09	569.64	573.36	267,222	181,943	83.10	83.10
School 3	70.91	569.78	569.78	254,970	180,808	78.50	82.58
School 4	100.0	571.22	571.22	181,265	181,265	82.79	82.79
School 5	69.43	583.84	583.84	276,182	185,269	75.27	84.62
School 6	75.81	579.70	579.70	242,664	183,955	83.07	84.02
School 7	85.10	596.40	614.27	229,059	194,927	89.03	89.03
School 8	67.46	570.78	570.78	268,504	181,125	80.68	82.73
School 9	82.38	582.83	582.83	224,502	184,949	82.59	84.47
School 10	81.43	592.50	592.50	230,899	188,017	77.42	85.87
School 11	86.92	577.74	606.06	221,253	192,321	87.84	87.84
School 12	68.38	577.85	582.33	270,242	184,790	84.40	84.40
School 13	75.15	589.63	589.63	248,971	187,107	79.85	85.46
School 14	82.79	594.80	598.80	227,990	188,747	80.80	86.21
School 15	77.70	573.93	573.93	234,408	182,124	73.74	83.18
School 16	76.93	570.62	570.62	235,373	181,074	79.14	82.70
School 17	78.58	573.12	585.78	236,540	185,884	84.90	84.90
School 18	79.13	567.17	567.17	227.439	179.979	78.35	82.20
School 19	83.30	573.14	577.08	219,848	183,126	83.64	83.64
School 20	81.12	582.74	582.74	227,966	184,920	79.24	84.46
School 21	80.37	564.47	564.47	222,867	179,123	81.06	81.81
School 22	87.77	581.59	590.54	213,516	187,395	85.59	85.59
Average	78.80	578.22	582.03	226,325	176,464	81.27	84.33
% change required		+0.659%		-22.03%		+3.76%	

In a presentation to the executive committee in ADEC, much of the discussions focused around the fourth scenario. The scenario concentrates on the Thanawiyah score and the EMSA Math scores. Both scores are major KPI's in ADEC's strategic plan. In addition, the fourth scenario incorporates average cost per teacher. For each school, Table 7 shows the actual and the targets for each of the resources used and the output produced under the fourth scenario (such analysis could be carried out for each of the four scenarios). Under the fourth scenario, school 4 maintains 100% efficiency; as a result, no improvements are necessary. Results show that some schools require extensive improvements if they are to reach 100% efficiency. On average, cost per teacher could improve 22.03%, and the Thanawiyah scores could improve 3.76%. The most inefficient schools require more improvements.

4.4 Regression analysis

Regression analysis was run where the efficiency scores of the fourth scenario was treated as the dependent variables, and the three variables of average teacher cost, EMSA Math, and Thanawiyah as independent variables. The model yields an adjusted R-square of 0.977, with an significant F value of 302.961. The regression coefficients are given in Table 8. Results show that all four independent variables are significant.

Table 8. Regression analysis results

Variables	Unstandardized coefficients		Standardized coefficients	t-value	Sig.
	B	Standard error	Beta		
Constant	77.236	17.006	----	4.542	.0001
Cost/teacher	.000	.000	-0.942	-27.722	.0001
EMSA Math	.112	.028	.1318	3.961	.001
Thanawiyah	.221	.068	.1119	3.246	.004

It should be noted however with caution that to identify the determinants of efficiency, the authors used the efficiency scores as the dependent variable and the inputs and outputs as independent variable (Table 8). Among these independent variables were those which had been used to calculate efficiency scores. This might pose certain specification problem of the regression model (see for example the work of Simar and Wilson, 2007). However, this study has an exploratory feature only. Results would only enhance our understanding of DEA to decision-makers in public schools in Abu Dhabi.

4.5 Testing differences

Analysis of variance is performed where the school efficiency related to the fourth scenario is tested with regard to school location, gender, and type.

With regard to school type (PPP vs. model schools), the ANOVA results show that the F-ratio is 5.82047, with a P-value of the F-test of 0.0256, meaning that there is a statistically significant difference between the mean school efficiency from one level of school type to another at the 95.0% confidence level. We should note too that the efficiency mean for model schools is 95.9108 and for PPP schools are 82.2715. We need to be careful when interpreting this result because there are only 20 PPP schools, while there are only 2 Model schools.

With regard to school location, the ANOVA results provide an F-ratio of 6.77151 with a P-value of 0.006, meaning that there is a statistically significant difference between the mean efficiency from one level of school location to another at the 95.0% confidence level. The efficiency mean of Abu Dhabi schools is 86.6562, the Al Ain School is 76.8935, and the Gharbiah schools are 95.5731. We need to note that there are 13 schools located in Abu Dhabi, 8 in Al Ain, and only 1 in Gharbiah.

With regard to school gender, the ANOVA results provide an F-ratio of 0.32 with a P-value of 0.5779, meaning that there is no statistically significant difference between the mean efficiency from one level of school gender to another at the 95.0% confidence level. The efficiency mean of male schools is 84.5478, while for female schools is 82.4571. There are 11 male schools and 11 female schools in the analysis.

The results show that the factors of school type, gender, and location are significant when examining schools' efficiencies. Such results indicate that the schools are not homogeneous. In future efficiency analysis, such exogenous factors should be considered too. Separate DEA analysis for each of those categories might be more effective given that the sample size is justified.

5. Discussions

As presented earlier, DEA was utilized in measuring school efficiencies in many countries (Coelho et al., 2007; Ng and Lee, 2009; Muniz, 2002). Abu Dhabi public school settings present a unique setting with distinct features. These included the fact that it was going through a reform where many schools were to experience changes in its school management and decision-making practices.

Since the number of available input and output variables (15) was large relative to the number of schools (22) in the analysis, it was necessary to reduce the number of variables. Correlation analysis indicated high correlations among many variables. The results and further analysis justified utilizing only 3 output variables and 1 input variable to be retained for further analysis. However, each DEA model were run using only 3 total variables. The number of DMU's and the number of input/output variables adhered to the acceptable combination rule suggested by others (Colany and Roll, 1989; Cooper et al., 2000).

As in other studies, the current study utilized output variables related to student performance scores ((Du, 2004; Cherchye et al., 2010; Bates, 1997). Two cost related inputs were selected, average cost per teacher and average cost per student. However, because of their high correlation, only a single one was used in each of the models developed. Analysis justified using only one input variable dealing with class capacity standard as a non-cost input variables. According to Mancebon and Molinero (2000), administrative resource allocation and achievements of students, inspired lots of economic studies of educational production, efficiency and cost issues. However, during the discussion of panel of experts, many concerns were raised with regard to this variable. It was decided to omit it from further considerations.

Regression analysis of output variables being dependent while input variables being independent, showed that two cost-related input variables were noticeably significant: average cost per teacher and average cost per student. The expenditure/cost inputs being significant contributors to education outputs is consistent with other studies (Ruggiero and Vitaliano, 1999; Hu et al., 2009). Regression results, also utilized by other studies (Waldo. 2007; Soteriou et al., 1989; Rassouli-Currier, 2007), provided further suggestions that average annual teacher costs have significant effects on school efficiencies. Moreover, it showed that this cost-related variables effected efficiencies in a negative manner.

The current study examined also school's non-cost variables as suggested by others (Thanassoulis, 1999; Mancebon and Badres, 1999; Rutter and Maughan, 2002). However, it was noted that the schools did not have control over many of those factors as they were significantly affected by other factors such as school

location. The only variable considered was class size. Further analysis and discussions led to use only cost-related factors.

Similar to other studies (Ruggeiro and Vitaliano, 1999), test scores were main output variables for the DEA models used in this study. A total of four scenarios were tested with different combinations of inputs and outputs. The scenario with the lowest estimated mean efficiency of 40.13% was related to the first and second scenarios of one input (average cost per student), and either of two combination of outputs (CEPA and E12Math or Thanawiyah and EMSA E12Math). The analysis and the panel of expert discussions led to selecting the fourth scenario as the one more reflective of the realities on the ground among Abu Dhabi urban public schools.

As an illustration, further analysis was carried out on the 4th scenario since it contained all variables that are included in the KPI list of ADEC's strategic plan. Under this scenario, results show that schools could reduce average teacher cost by 22.03% and still produce the same output. In addition, inefficient schools could increase their student outcome in Thanawiyah by 3.76%. Results of the fourth scenario identified four schools that attained high efficiency scores (above 85%). Results also identified four schools that were relatively underperforming (below 70%). Only one school attained perfect efficiency of 100%, and identified as best performing school. The results need to be analyzed with caution since other non-cost variables related to schools or socio-economic and environment settings were not included in the analysis.

In 2012, ADEC recognized the four most efficient schools in a major event attended by all Abu Dhabi public school principals. Results confirm that some lower-spending schools are considered to be operating with the best practices, while any extra spending is generally interpreted as a measure of school inefficiency. Groskopf et al., (2001) noted that inefficiency among schools could be reduced by increasing competition amongschools districts. Deller and Rudnicki (1993) suggested that competitive pressure within highly concentrated areas results in a better school performance. Hoxby (2000) founded that competition between private and public schools can increase public schools' productivity without increasing expenditure.

Since ADEC will gradually provide schools with more responsibilities and control, optimal allocation of resources would become a major force in school performance in the future. As Hu et al., (2009) hints that accountability would become a major phenomenon in the future for publicly funded schools – especially if efficiency is a core school KPI. ADEC intends to publicized student outcomes for each school by end of 2012. This plan would let parents make better informed decision with regard to the school that they might select for their children. It also intends to reward the schools based on their performance.

Utilizing multiple inputs and outputs to calculate school efficiencies would provide a more objective way to assess efficiencies (Beasely, 1995; Brockett et al., 2005; Charnes et al., 1993). DEA, as a benchmarking tool, avoids specification error between the inputs and outputs. As a result, more practitioners could utilize it (Johnes and Johnes, 1995; Hanushek, 1986). The cross efficiency in DEA allows for effective discrimination between niche performers and good overall performers. Moreover, evaluating the performance of schools over time (window analysis) by treating them as a different entity in each period will allow the school to be compared to itself over time.

Analysis of variance results showed that school location and school type have significant effects on school efficiencies. Location of the school was also a major factor in other studies (Du, 2004; Hanushek, 1986; Sarrico et al., 2010; Roggiero, 2004)). This result might have major implications for ADEC. ADEC has invested a significant amount of resources in PPP schools. However, model schools provided superior efficiency results. To be more objective, model schools accept students who are better achievers than other type of schools. Nevertheless, ADEC needs to extensively evaluate PPP performance based on the results obtained in this study. An essential objective of the school reform process in ADEC is to reduce student outcome variations between schools regardless of any other factors. In 2010, a roadmap is recommended where only one school type would exist in Abu Dhabi by 2016 (the New School Model).

6.   Conclusion

This study utilized a non-parametric method named DEA to evaluate relative efficiency for 22 schools in Abu Dhabi Emirate. There are many advantages of using DEA to analyze efficiency of comparable units which make it an attractive tool for both public and private organizations. The most important one is that it is able to handle multiple inputs and outputs without prior weights. In this study, there were15 input and output variables for only 22 schools. Correlation analysis and other judgmental processes reduced the number to a total of 4 variables only. DEA is particularly suitable for analyzing the efficiency of schools, where it is difficult or impossible to assign prices to many of the outputs. Hence, student performance is used. Another benefit is that DEA does not require a functional form that relates inputs and outputs. DEA can also optimize each individual observation and compare it with the 'best practice' observations, because it can produce a single measure for every DMU which can be easily compared with other DMUs.

The Abu Dhabi school reform has fundamentally changed the conditions under which public education is operated. The responsibility for providing education is gradually being decentralized from ADEC to schools.

One of the aims with the reform was to increase efficiency in education. This paper estimated efficiency for the school year of 2010-2011 using DEA. ADEC's policy makers could optimally utilize DEA in evaluating schools by performing the following tasks:

- Resource allocation between schools: reallocating from the inefficient school to the efficient school.
- Identification of "best practices" in school operations.
- Identification of "poor practices" in school operations.
- Setting targets for inefficient schools.
- Monitoring school efficiency changes over time.
- Giving rewards for good performing schools.

Today, school managers and policy makers have to cope with and make sense of an enormous amount of data relating to their schools' operations. The challenge is to somehow derive useful insights from all these numbers that will lead to improvements in the performance of the schools. For ADEC, which has an estimated 300 public schools, the goal of management is to ensure that each school achieves the best possible performance; however, the challenge is deciding on what "the best possible performance" exactly means and the best method to measure it. The outputs of the schools such as student outcomes can be studied and compared. Similarly, a school's inputs, such as, costs and staff, can be measured. All these attempts to measure performance may; however, produce no overall clear picture as schools may exhibit considerable variation depending on the performance indicator chosen. In other words, it might be difficult to have a homogenous group of comparable schools across the country. This is where DEA helps as it provides a more comprehensive measure of efficiency by taking into account all the important factors that affect a school's performance.

For ADEC, which is going through a rigorous reform, an important topic for future research is the source of school inefficiencies. ADEC has to have a better grasp of why schools in Abu Dhabi differ in their efficiency scores. As noted by others (Ruggiero and Vitaliano, 1999; Hu et al., 2009), not knowing the sources of inefficiencies in public schools would lead to failures when adopting the various structural reforms being put forward on grounds of greater efficiency. Future research should expand the list of input and output candidates and examine their inclusion in the analysis. Some of the output candidates might include stakeholders' satisfaction (parents' satisfaction results, principals' satisfaction results, teachers' satisfaction results, etc.). Other variables could be the number of teacher aides and teacher assistants per student, number of computers and classrooms per student, and proportion of teachers with at least a certain amount of training. Future studies could incorporate some discretionary input as suggested by some studies (Muniz, 2002; Ruggiero, 1996), such as student related background.

A major implication of this research for Abu Dhabi is the awareness of the upper management that the operating expenses' data should be available for each school in details if better reflective score efficiencies are to be measured. Almost all operating expenses were available but on aggregate level (i.e., money spend by schools on professional development, extracurricular activities, stationeries, public events, library expenses, laboratory expenses, etc.). The availability of detailed and school-specific operating expenses will also allow schools, regardless of their size, location, type, and gender to be evaluated all together. As pointed out by others (Charnes et al., 1993; Banker et al., 1989; Bates, 1997; Hu et al. 2009), the availability of data will better lead to the selection of truly representative inputs and outputs for efficiency analysis. The creation of a new financial data system for Abu Dhabi schools will certainly provide many data elements for much better efficiency calculations.

Defining inputs and outputs is crucial in any study. A production process is an economic model and need to be specified properly. Knowledge of the system and of the production process would lead to a theoretically founded model (or few models that compete). Future studies should better identify specific variables to better understand the production process related to schools in Abu Dhabi. This would lead to testable hypothesis about the production process. The study was limited to using a CRS model of DEA. Future studies should not be limited to CRS only. Returns to scale are important as they allow one to determine the school optimal size. It should be mentioned also that in terms of practical application, the presence of different types of schools along with other differences may result in biased comparisons due to data heterogeneity. In view of the applied nature of this work, future studies should be able to avoid the challenge of heterogeneity since all schools will follow one model only. It might be recommended too that the inclusion of a benchmark school (an ambitious school) in the analysis might provide better efficiency scores relative to the expected benchmark rather than an existing school.

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