Efficiency of Secondary Education in Selected OIC Countries

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Abstract

The purpose of this study is to investigate the level of technical efficiency of secondary education in 16 selected Organisation of Islamic Conference (OIC) countries (including West Bank and Gaza). Educational efficiency has become an important issue given many countries' pressing levels of public deficit and debt. Since the educational sector always receives high priority in budget allocations, an evaluation of whether the allocations made for education have been technically efficient is important. With budget constraints and the public's high expectation to see a continuous improvement in students' academic achievement, the educational sector has been put under pressure to deliver. The study employs TIMSS 2011 data, involving 40 countries. The technique used to calculate the level of technical efficiency is data envelopment analysis (DEA). Almost all of the 16 selected OIC members are technically inefficient in utilising their educational resources to achieve better TIMSS results in comparison with the non-OIC countries. Even after controlling for environmental factors, secondary education in the OIC countries remains technically inefficient.

Keywords

technical efficiency, secondary education, OIC countries, data envelopment analysis, TIMMS

Introduction

The purpose of this study is to investigate the level of technical efficiency of secondary education in the Organisation of Islamic Conference (OIC) member countries in comparison with other countries. Educational efficiency has become an important issue given many countries' pressing levels of public deficit and debt. Since the educational sector always receives high priority in budget allocations, an evaluation of whether the allocations made for education have been technically efficient is important. With budget constraints and the public's high expectations to see a continuous improvement in students' academic achievement, governments have been put under pressure to deliver higher educational outcomes.

With cross-country data, the level of technical efficiency in the OIC countries' educational sectors can be assessed against those of other countries (among the OIC and non-OIC countries). The findings of the study

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are important in that they provide information about these countries' level of efficiency in resource utilisation when it comes to promoting student academic achievement. In order to remain competitive, the members of the OIC need to address the issue of the existing educational gap. According to the UN 2010 Millennium Development Goals (United Nation, 2010), there has been a significant gap in the distribution of students' academic achievement, especially between the first-tier (i.e. Australia, South Korea, Singapore, and Taiwan) and the second-tier economies (i.e. Indonesia, Iran, Jordan, Kazakhstan, Lebanon, Malaysia, Morocco, Syria, Tunisia, and Turkey). The gap, according to the Report, needs to be reduced, given the constricted resources.

The focus of this study is on secondary education. Schultz (1963) points out that while primary education might suffice for basic production of goods and services, workers with secondary education can use technology in the workplace, while tertiary education is considered important in the process of inventing and innovating technology. In other words, the level of economic advancement needs to be backed up with a proportionally qualified workforce. Since most of the OIC countries fall under the category of "developing economy," secondary education remains a crucial stage for the OIC members to develop their human capital as a natural progression towards becoming a developed economy. For that matter, an evaluation of whether the investments made in these countries' secondary education systems are efficient merits further scrutiny.

For the study, secondary students' achievements in mathematics and science on the Trends in International Mathematics and Science Study (TIMSS) are employed. TIMSS is an international mathematics and science examination involving students in the fourth and eighth grades from countries all over the world. It provides reliable and comparable data to measure countries' performance in mathematics and science. TIMSS data have been collected in 1995, 1999, 2003, 2007, and 2011. In 2011, more than 60 countries participated in TIMSS, involving more than 500,000 students. An international assessment such as TIMSS offers a unique opportunity to compare the performance of students from each participating country at a global standard, since the students sat for the same examination (Martin et al., 2008). With such data, a comparison can be made to know, for example, how efficient each of the OIC countries has been in utilising its educational resources, given the performance of its students at a global stage. Results from this analysis can provide valuable feedback in current efforts to improve mathematics and science instructions in the OIC countries to global standards of excellence.

High achievements in both subjects are considered an important ingredient for a nation to progress. Low performance, by contrast, in the subjects may hamper OIC members' levels of competitiveness. Again, according to the UN 2010 MDG, a failure to reduce the gap in mathematics and science achievements between the second-tier and the first-tier economies could slow the pace of convergence for the developing countries.

The organization of the paper is as follows. The concepts of efficiency and productivity in an educational sector are first discussed in Section

2. This section is crucial because it provides a perspective on how the concepts of educational efficiency and productivity, as economists view them, can be understood. A review of the theories and models of data envelopment analysis (DEA) is presented in Section 3. Also in the section is a discussion of the application of DEA models in education. In Section 4, I provide descriptions of the data used for analysis. Results of the analysis are discussed in Section 5. Some concluding remarks are presented in Section 6.

How Do the OIC Countries Fare Internationally?

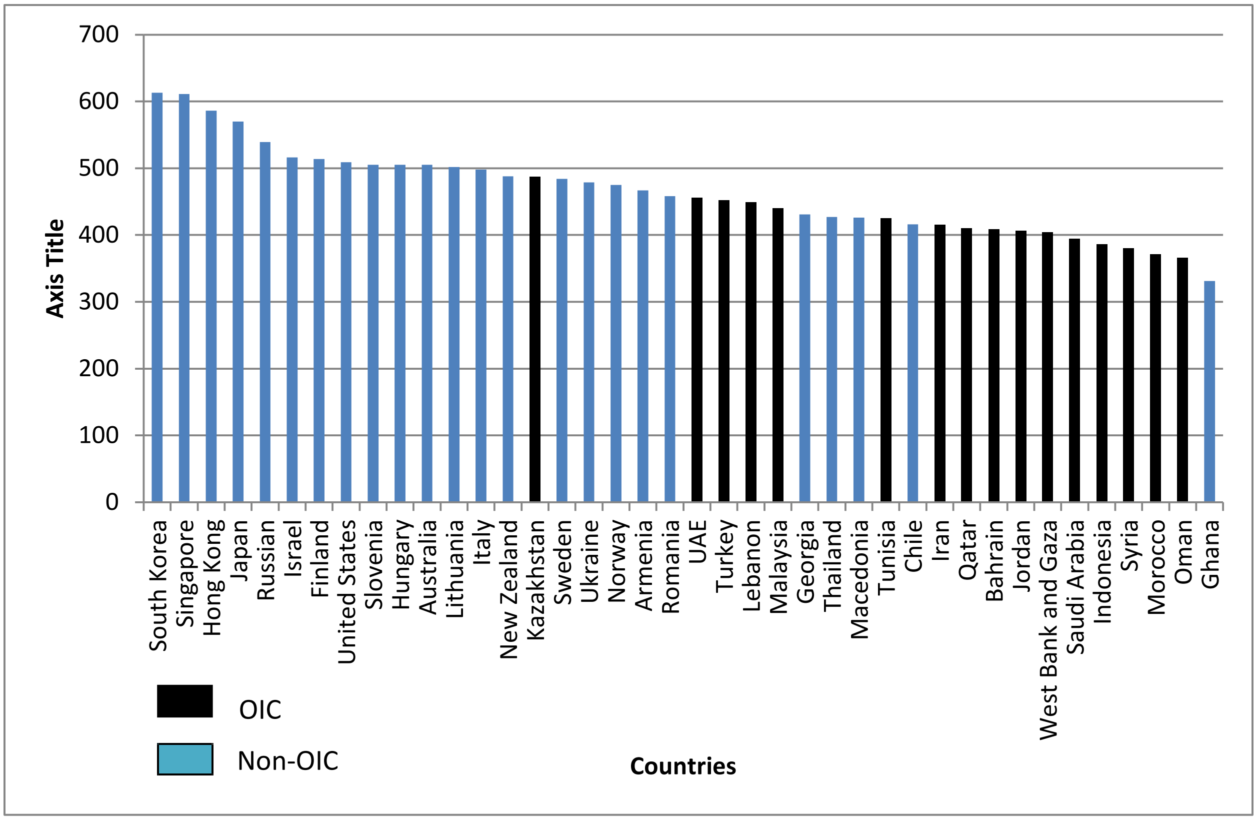
To evaluate the educational achievement of the OIC countries internationally, the researcher analysed a cross-sectional dataset of 40 countries that participated in TIMSS 2011. The two educational outputs used for the analysis are each country's eighth-grade average scores in science and each country's eighth-grade average scores in mathematics. The source of the data is the World Bank's database on Education Statistics[1] and the Statistical, Economic and Social Research and Training Centre for Islamic Countries (SESRIC).[2] The analysis is limited to the 40 countries because only these countries participated in TIMSS 2011 for the eighth grade. In fact, among the OIC countries, there were only 16 countries that participated in TIMSS 2011, and the remaining 24 were the non-OIC countries. The number of the participating countries therefore limits the sample.

The summary statistics of the selected countries' performance on TIMSS 2011 are shown in Table 1. The scale of TIMSS achievement levels is as follows: (i) advanced—score above 625; (ii) high—score between 550 and 625; (iii) intermediate—score between 475 and 550; and low—score between 400 and 475.[3] As shown in the table, the average scores of the OIC countries in both mathematics and science are lower than the sample averages. Further, a more concerning point can be observed between the performance of the OIC and the non-OIC countries. The performance of students from the OIC countries is significantly lower than their non-OIC counterparts. As shown in Table 1, the highest scoring OIC country in both mathematics (at 487, that is Kazakhstan) and science (490, also Kazakhstan) are lower than the overall average of the non-OIC countries for both subjects (494 and 498 points, respectively). The gap is a clear indication of how far behind the OIC countries are in terms of meeting global educational standards.

Table 1: Summary statistics of students' performance on TIMSS 2011

	All		OIC		Non-OIC	
Statistics	**Mathematics**	**Science**	**Mathematics**	**Science**	**Mathematics**	**Science**
Average	462.63	473.18	415.63	436.69	493.96	497.5
Std dev	66.0752	59.0918	33.87797	30.80848	63.97994	61.30537
Minimum	331	306	366	376	331	306
Maximum	613	590	487	490	613	590
Observations	40	40	16	16	24	24

Figure 1: Students' performance in mathematics on TIMSS 2011, 8th Grade (mean scores)

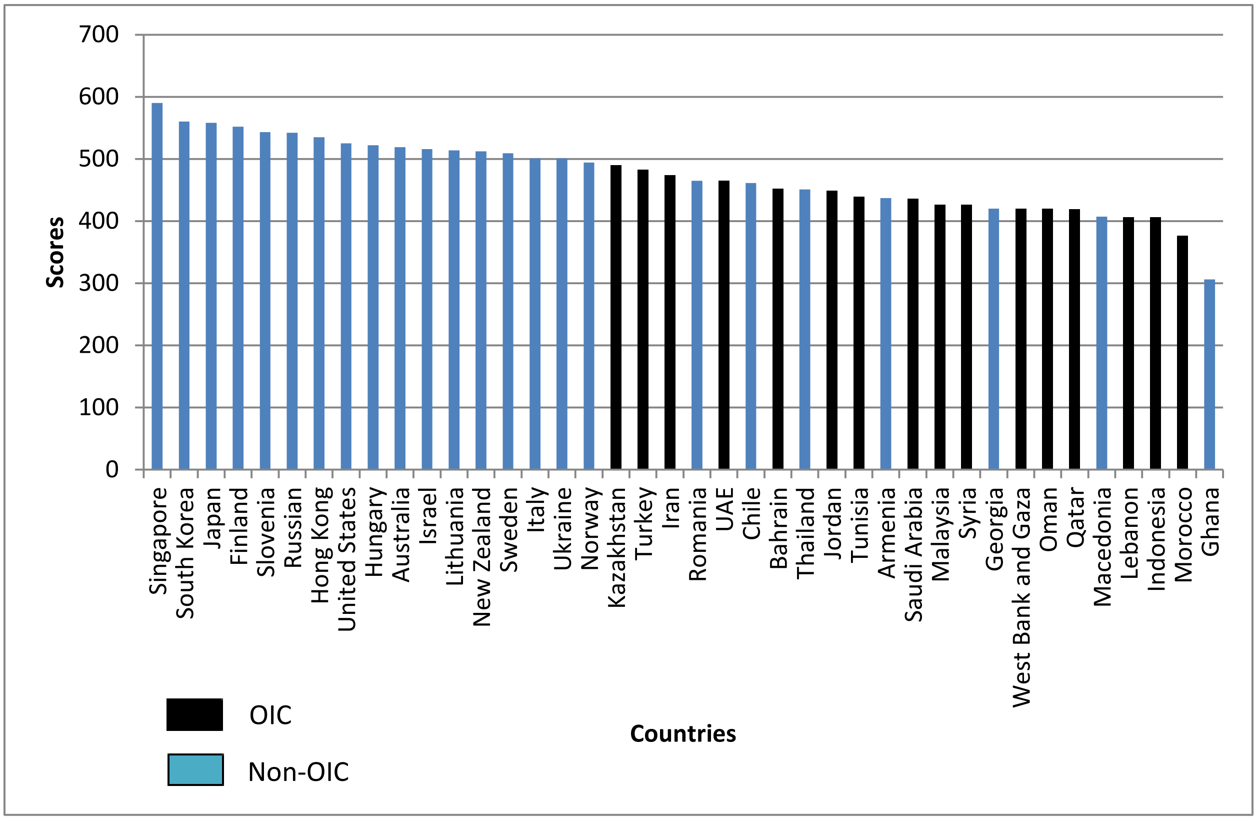


In Figure 1, each country's performance in mathematics is graphed in order of highest to lowest scores. As indicated by the darkened bar chart, in general, all of the OIC countries achieved lower scores as compared to many of the non-OIC countries. Kazakhstan is the country with the highest score in mathematics among the OIC countries, while Oman records the lowest score for the OIC countries. In science, the OIC countries also performed poorly. As illustrated in Figure 2, all of the OIC countries participating in TIMSS 2011 are on the lower side of the chart. Kazakhstan, again, scored the highest, while Morocco got the lowest score among OIC countries.

Both figures show a clear gap between the OIC nations and countries that performed well on TIMSS 2011, such as South Korea, Singapore, Japan, and Hong Kong. Looking back at history, one way in which those high-achieving countries managed to transform their economies and become high-income nations was through efforts to improve educational quality. Science and mathematics were subjects considered particularly vital to human capital development throughout those countries' processes of transformation. Given the existing gap between the OIC countries and those high-performing nations, serious efforts to reduce this gap need to be undertaken if the OIC countries are serious about brighter futures.

In order to understand the low performance of the OIC countries in both mathematics and science, the discussion now turns to analysing allocated educational inputs. If the allocation of educational inputs by the OIC countries is relatively proportional to those of high-achieving countries, then inefficiency in inputs utilisation could be one reason for the failure to translate the allocated inputs into higher student academic achievement.

Figure 2: Students' performance in science in TIMSS 2011, 8th Grade (mean scores)



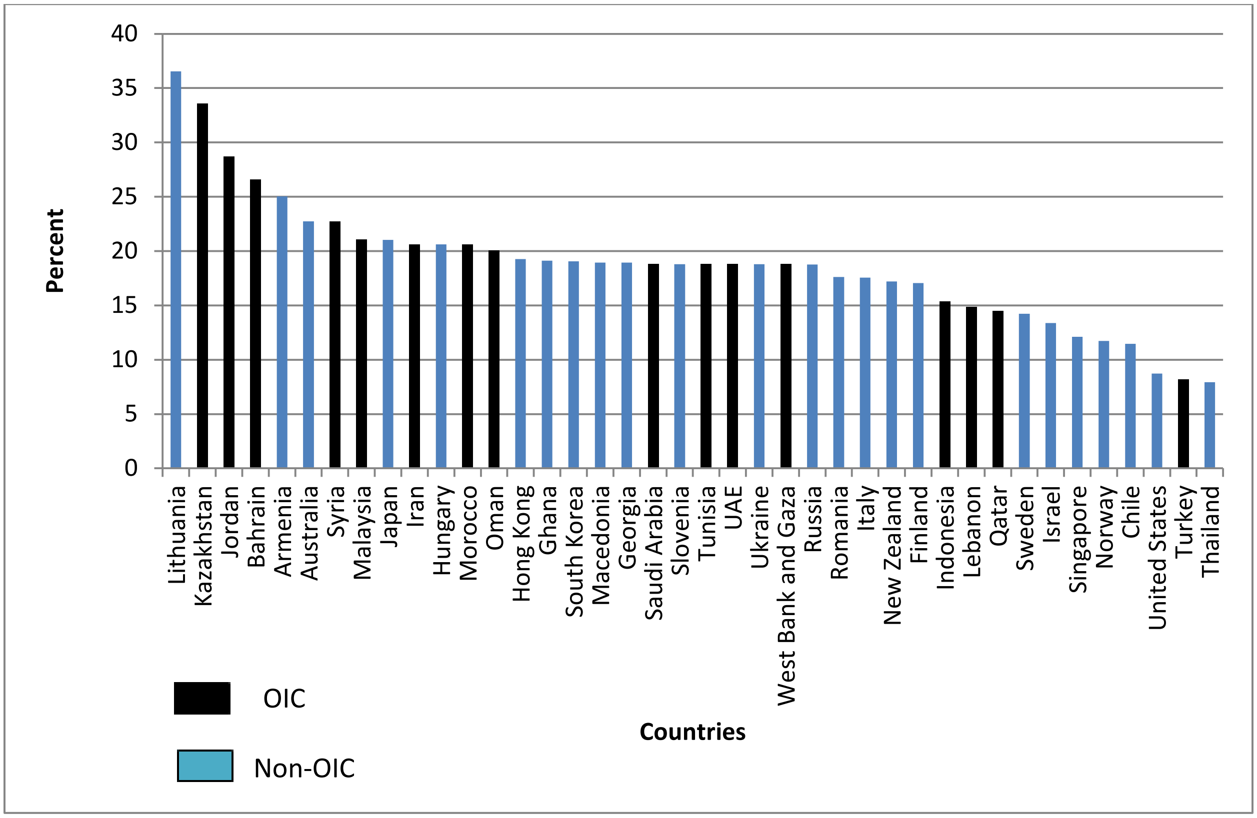
Two sets of input-related data are considered: the average percentage distribution of current public expenditure to lower secondary education[4] from 2008 to 2011, and the average student-teacher ratio in secondary education from 2008 to 2011. These inputs are discretionary educational inputs because they are under the direct control of Ministries of Education. In the study of educational production function, systematic associations have been found between these two inputs and students' academic achievement. Educational expenditure has a positive effect on students' achievement (Hedges et al., 1994), while there is a negative relationship between student-teacher ratio and students' achievement (Finn et al., 2003).

For both inputs, the average figures are considered for three reasons. First, the figures represent the commitment of each country from the time of the last TIMSS (in 2007) to the recent TIMSS (in 2011). Second, the lag in policy effectiveness is overcome by using the average data. Third, the average data solves the problem of some missing data on the inputs.

Table 2: Summary statistics of educational inputs to secondary education (average from 2008 to 2011)

Statistics	All		OIC		Non-OIC	
	Percentage distribution of public current expenditure to lower secondary education	Student-teacher Ratio	Percentage distribution of public current expenditure to lower secondary education	Student -teacher Ratio	Percentage distributio n of public current expenditur e to lower secondary education	Student-teacher Ratio
Average	18.71	13.66	20.12	15.27	18.17	12.52
Std dev	5.93	4.73	6.18	4.94	5.62	4.44
Minimum	7.92	6.85	8.15	9.15	7.92	6.85
Maximum	36.54	25.26	33.58	25.26	36.54	22.14
Observations	40	40	16	16	24	24

Figure 3: Percentage distribution of public current expenditure to lower secondary education (average from 2008 to 2011)



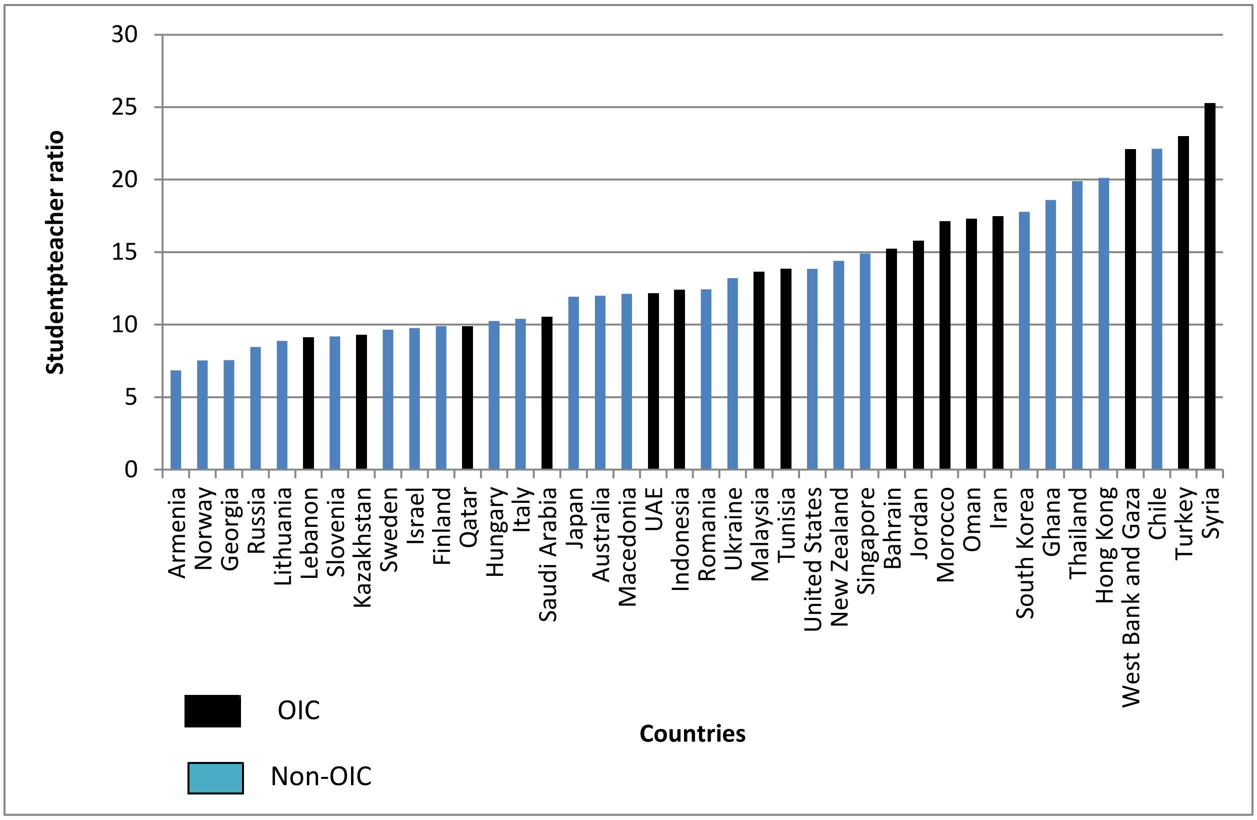
Summary statistics of the inputs data are presented in Table 2. As shown in the table, for the sample, the average financial allocation to lower secondary education is 18.71 percent, with a standard deviation of 5.93. The average financial allocation by the OIC countries is 20.12 percent, which is higher than the sample and the non-OIC countries' average. In general, the commitment of the OIC countries to improving their educational standards can be seen in terms of higher financial allocation made to lower secondary education. Their poor performance in TIMSS, however, may be attributed to inefficiency in utilizing the allocated financial resources. Further investigation of this claim will follow in Section 5.

In Figure 3, all countries' financial allocation to lower secondary education is graphed from the highest to the lowest. As shown in the figure, three OIC countries, namely Kazakhstan, Jordan, and Bahrain, have allocated more than 25 percent of their current public expenditures to lower secondary education. Their performance on TIMSS 2011, however, is far from being impressive (see the position of these countries in Figures 1 and 2). Perhaps, had the allocated financial resources been utilised fully, these countries could have achieved better results. Caution, however, needs to be exercised when comparing countries using this percentage data. High-income countries, for example, may have small percentage allocations, but in terms of absolute value, the figures can be higher than for a low-income country with high percentage allocation. By using the percentage figure for the analysis, countries' educational allocations are normalized and more comparable.

For the second input, readers should refer to Table 2 and Figure 4. The average student-teacher ratio of the OIC countries (15.27) is higher than the sample (13.66) and the non-OIC countries' (12.57) averages, as shown in Table 2. The high number of students per teacher may result in disturbance of the knowledge transmission process, thus providing one explanation for the OIC countries' low performance on TIMSS as compared to the non-OIC countries.

As shown in Figure 4, the student-teacher ratios in OIC countries are fairly distributed, with countries such as Kazakhstan, Lebanon, and Qatar having low student-teacher ratios (10 or fewer students per teacher); Saudi Arabia, UAE, Indonesia, Malaysia, Tunisia, Bahrain, Jordan, Morocco, Oman, and Iran having moderate ratios (more than 10 but fewer than 20 students per teacher); and West Bank and Gaza, Turkey, and Syria having high ratios (more than 20 students per teacher). Although countries such as Kazakhstan, Lebanon, and Qatar have lower student-teacher ratios than the other OIC countries, these countries' performance on TIMSS is still low as compared to the non-OIC countries with relatively proportional student-teacher ratios. Such an outcome could be attributed to technical inefficiency—for example, many teachers may not be able to engage in computer-aided learning. In order to understand how the concepts of efficiency and productivity are applied in the educational sector, further discussion is provided in the next section.

Figure 4: Student-teacher ratio (secondary level, average from 2008 to 2011)



The Concepts of Efficiency and Productivity in Education

According to Worthington (2001), technical efficiency in education deals with the best use of educational inputs, such as school resources, to improve student academic achievement. Allocative efficiency, he states, concerns the optimal combinations of educational inputs needed (for example, teacher instruction and computer-aided learning), in order to produce a given level of educational output at minimal cost. In other words, allocative efficiency is about choosing the right combination of educational inputs, and must take into account the relative costs of the inputs employed, assuming outputs are constant. The study here evaluates the level of technical efficiency, since the primary concern is whether the resources allocated to the secondary educational sector have been utilized fully. Productivity in education, according to Rolle (2004), is related to the issue of how to achieve the efficient production of educational outcomes. Rolle (2004) further states that in the context of public educational institutions, educational productivity debates cover the matters of how to: minimise costs; maximise the utilisation of available resources; meet increased and diversified educational objectives; and become accountable to the public for the expenditure of resources.

In order to apply the concepts of productivity and efficiency to the field of education, Duyar et al. (2006) emphasise the need to establish the relationship between educational inputs and outputs. One way to understand that relationship is by estimating an educational production function. Once the relationship is clear, a production frontier of the best-practice educational institutions (i.e. schools) can be estimated, where the estimated frontier stands as a benchmark in the process of evaluating the efficiency (relative) of other educational institutions. For the study, the construction of the production function of education is based on a technique called data envelopment analysis (DEA). The construction of a production function based on DEA takes a piecewise linear production frontier. Economists have applied the frontier production approaches to measure the technical, allocative, and cost efficiency of schools. This study will only evaluate technical efficiency levels in several selected countries. Technical efficiency alone is estimated because in order to estimate allocative efficiency, data on educational resource prices are required, and those data are not available. In order to investigate the efficiency level of resource utilization by the OIC countries, DEA is employed. The next sections review the models of DEA to be applied for the analysis.

Data Envelopment Analysis (DEA)

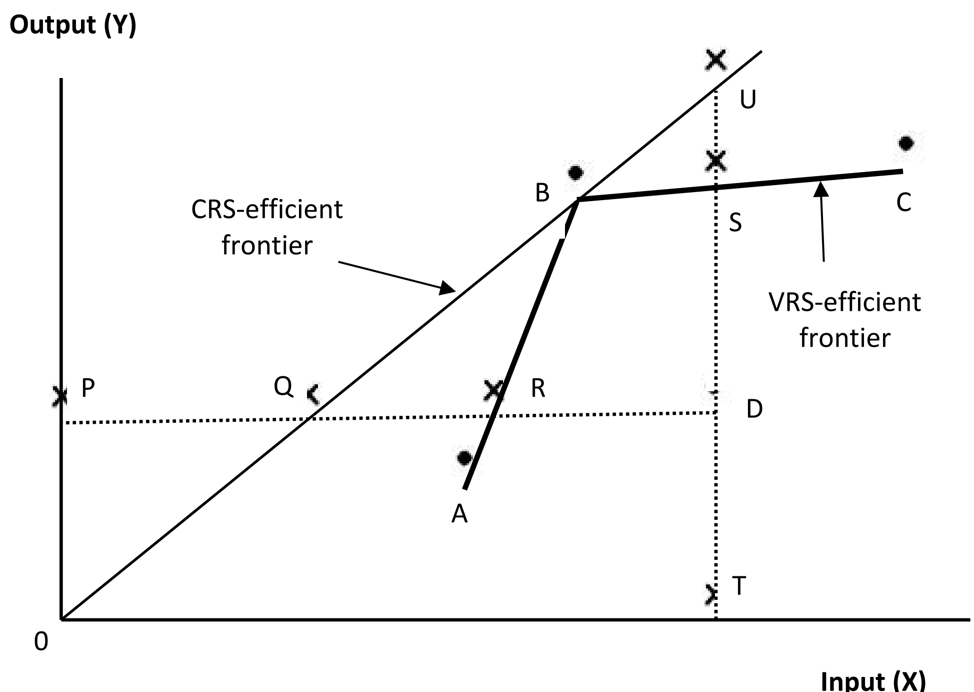
Theoretical Framework of DEA

Two basic DEA models have been widely applied: (i) the constant returns to scale (CRS) model of Charnes, Cooper, and Rhodes (1978); and (ii) the variable returns to scale (VRS) model of Banker, Charnes, and Cooper (1984). In Figure 5, I illustrate the theoretical idea behind the two principal approaches to DEA frontier analysis and the derivation of technical efficiency measures based on the DEA frontier. The figure is constructed based on a single-input, single-output case. The simplification enables the production process to be described in a simple two-dimensional diagram.

In Figure 5, points *A*, *B*, *C*, and *D* represent the observed performance of four decision-making units (called DMUs—the DMUs in this study are those countries that participated in TIMSS), given their levels of input and output and production technology. The CRS model is represented by the thin line extending from the origin of Figure 5 through point *B*, where the DMU *B* is chosen to maximise the angle of the ray. The thin line is the production frontier as identified under the CRS model. Based on the CRS model, the DMU *B* is identified as the most efficient DMU since it lies on the frontier. Point *B* is, therefore, CRS-efficient. Other DMUs (*A*, *C*, and *D*), which lie below the frontier, are inefficient under the CRS model.

Still referring to Figure 5, the VRS model is illustrated by the solid thick lines that connect points *A* and *B*, and *B* and *C*. The solid lines depict the so-called “VRS production frontier.” The VRS model has its production frontier spanned by the convex hull of the DMUs (from point *A* to *B*, and *B* to *C*). The frontier is piecewise linear and concave. The VRS frontier assumes variable returns to scale where: (i) increasing returns to scale occur in the first solid line (*AB*) segment, and (ii) decreasing returns to scale occur in the second segment (*BC*) (Cooper et al., 2006). Note that points *A*, *B*, and *C* are on the frontier and are therefore VRS-efficient. Point *D*, on the other hand, is the inefficient DMU because it lies below the frontier (Cooper et al., 2000).

Figure 5: The best-practice reference frontier



* Source: Based on Coelli et al. (2005)

Given the CRS-efficient and VRS-efficient frontiers, an inefficient DMU has two major projection paths to improve its performance; namely, (i) an input-oriented path, and (ii) an output-oriented path (Cooper et al., 2000). The input-oriented path aims at reducing the input amounts by as much as possible while keeping the present output levels unchanged. The output-oriented path aims at maximising output levels under the given input consumption. For this study, an output-oriented path is adopted because in the context of public education, allocations to schools are made with expectations of full utilisation of the allocations provided, together with high student academic achievement. Conservation of inputs is not the objective of public education, and as a result, an analysis based on the input-oriented path is not appropriate.

Referring to Figure 5, the output-oriented model identifies technical efficiency as a proportional augmentation of output for a given level of input. Under the VRS model, the inefficient DMU *D* can improve its performance by a movement to point *S*. The movement to point *S* means DMU *D* needs to increase its output level given the amount of inputs it has. As such, the VRS technical efficiency of DMU *D* under the output-oriented path (OTE_{VRS}) is given by:

$$OTE_{VRS} = SD/ST \qquad (1)$$

With the understanding of the theoretical concept of DEA in mind, I discuss the mathematical linear programming of DEA in the next sub-section.

Mathematical Linear Programming of DEA

A case of multiple-output, multiple-input DEA is now discussed. I start the discussion by defining some notation to be used in this section. The dataset is assumed to consist of *J* DMUs (*j*=1, ..., *J*). Each DMU *j* employs x_n inputs (for n = 1, ..., *N*) in order to produce y_m outputs (for m = 1, ..., *M*). The envelopment form of an output-oriented linear programming problem under constant returns to scale (CRS) assumption is set out as:

For each *j*, $\max_{\phi_j,\lambda}\ \phi_j$ (2)

subject to:

$$-\phi_j y_{mj} + \sum_{j=1}^{J} \lambda_j y_{mj} \geq 0, \text{ for } m = 1, ..., M$$

$$x_{nj} - \sum_{j=1}^{J} \lambda_j x_{nj} \geq 0, \text{ for } n = 1, ..., N$$

$$\lambda_1, ..., \lambda_J \geq 0$$

where ϕ_j is the output weight of the *j*th DMU to be maximised, λ's refer to the value of weights for each DMU under the solution of the *j*th linear programming. The first constraint implies that the output produced by the observed DMU *j* must be less than or equal to the sum of output weights of all the DMUs. The value of ϕ_j is $1 \leq \phi_j < \infty$. The measure of technical efficiency for the *j*th DMU is given by $1/\phi_j$ [Coelli, 1996]. The second constraint states that the inputs of the observed DMU *j* minus the sum of input weights of all the DMUs must be greater than or equal to zero, and the last constraint is to ensure that the value of λ is non-negative. The weights for outputs and inputs are estimated as the best advantage for each DMU to maximise its relative efficiency.

By adding a convexity constraint, $\sum_{j=1}^{J} \lambda_j = 1$, to equation (2), the CRS linear programming is now modified to a variable returns to scale (VRS) linear programming, as set out below:

For each *j*, $\max_{\phi_j,\lambda}\ \phi_j$ (3)

subject to:

$$-\phi_j y_{mj} + \sum_{j=1}^{J} \lambda_j y_{mj} \geq 0, \text{ for } m = 1, ..., M$$

$$x_{nj} - \sum_{j=1}^{J} \lambda_j x_{nj} \geq 0, \text{ for } n = 1, ..., N$$

$$\sum_{j=1}^{J} \lambda_j = 1$$

$$\lambda_1, ..., \lambda_J \geq 0$$

where the purpose of the convexity constraint, according to Coelli et al. (2005, p. 172), is to "... form a convexity hull of intersecting planes that envelope the data point more tightly than the CRS conical hull and thus provides technical efficiency scores that are greater than or equal to those obtained using the CRS model..." The convexity constraint also ensures that each DMU is only benchmarked or compared with DMUs of relatively similar scale. If the *j*th DMU is technically efficient (θ_j is equal to one), the weight of its λ_j is one, while the weights of λ's for the other DMUs are zero. In a case when the observed *j*th DMU is technically inefficient, the weights of λ's for any (or some) of the other DMUs (known as peers to the *j*th DMU) must be positive—a peer with higher value of λ signifies a greater position as an exemplar (relative to the other peers) to DMU *j*.

Further, the values of λ (peer weights) can for DMU *j*. The measures of input and output targets for DMU *j* are calculated as:

m^{th} output target:

$\lambda_1 y_{m1} + \ldots + \lambda_J y_{mJ}$, for m = 1, …, M,

n^{th} input target:

$\lambda_1 x_{n1} + \ldots + \lambda_J x_{nJ}$, for n = 1, …, N (4)

The input and output targets can be used by DMU *j* to improve its efficiency. With the knowledge of how to calculate the CRS and VRS technical efficiencies in mind, I explain the calculation of scale efficiency in the next sub-section.

Scale efficiency for each DMU can be calculated when both the CRS and the VRS technical efficiencies are obtained. A difference between the CRS and VRS technical efficiency scores for a particular DMU indicates that the DMU has scale inefficiency. To describe the concept of scale efficiency, Figure 5 is once again employed for expositional purposes (the CRS and VRS frontiers are illustrated in the figure). Notice that the distance *PQ* gives the input technical efficiency under constant returns to scale for DMU *D*. Under the VRS model, however, the input-oriented technical efficiency for DMU *D* is given by the distance *PR*. The difference between the two distances, *QR*, is due to scale inefficiency. A ratio efficiency expression for scale efficiency (*SE*) based on Figure 5 is given by:

$$SE = PQ/PR \quad (5)$$

where the measure is bounded between zero and one. Scale inefficiency, therefore, is given by one less *SE*:

$$\text{Scale inefficiency} = 1 - SE = QR/PR \quad (6)$$

Another way to calculate scale efficiency is given by

$$TE_{CRS} = TE_{VRS} \text{ x } SE \quad (7)$$

be used to calculate the input and output targets because

$$\frac{PQ}{PD} = \left(\frac{PR}{PD}\right)\left(\frac{PQ}{PR}\right) \quad (8)$$

From equation (8), the CRS technical efficiency can be decomposed into two parts: (i) the VRS technical efficiency (which is also known as "pure" technical efficiency), and (ii) the scale efficiency (Coelli et al., 2005).

Empirical Strategy

Measuring the level of technical efficiency under the CRS and VRS assumptions can be done by solving equations (2) and (3). The solutions involve two strategies: (i) no control is made on the effects of the environmental factors, and (ii) control is made on the environmental factors. Caution needs to be exercised when interpreting the results based on the first strategy because of the possibility of biased estimates. Differences in environmental factors create a cross-sectional heterogeneity across countries, where some countries may perform better than others due to socio-economic advantage. Favourable environmental factors (better socio-economic conditions such as higher income, lower corruption level, and better health quality, just to mention a few) may have positive effects on technical efficiency, while non-favourable environmental factors may have negative effects on technical efficiency. The factors that constitute socio-economic heterogeneity in the production environment, therefore, need to be considered when comparing the efficiency scores; hence, the relevance of the second strategy.

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Table 3: Summary statistics of the outputs and inputs according to high-income and middle-income countries' divisions

	High-income countries				Middle-income countries			
	Man	**Std dev**	**Min**	**Max**	**Mean**	**Std dev**	**Min**	**Max**
Outputs								
Math	495.47	69.18	366	613	432.91	47.48	331	539
Science	506.74	48.62	419	590	442.81	51.41	306	542
Inputs								
% current exp. to lower secondary level	17.48	4.25	8.72	7.541	19.83	7.03	7.92	36.54
Secondary student-teacher ratio	12.47	3.39	26.55	20.13	14.73	5.54	6.85	25.26

To control for the environmental factors, the sample is divided into high- and middle-income countries. To avoid low number of observations due to the sub-division of the middle-income countries into upper-middle and lower-middle categories, countries in these categories, together with one low-income country (only West Bank and Gaza), are placed into a middle-income group. The divisions are based on the World Bank's classification.[5] Separate estimates for high- (19 countries) and middle-income (21 countries) countries, therefore, have been undertaken.[6] The division provides some socio-economic homogeneity in the production environment of countries in each division. As such, countries are relatively more comparable in terms of their socio-economic conditions within their respective groups.

Based on the division, summary statistics of the outputs and inputs of education are presented in Table 3. As shown in the table, the average performance of high-income countries is significantly higher for both mathematics and science as compared to the middle-income countries. In terms of inputs, the high-income countries on average have lower financial allocation to lower secondary education as compared to the middle-income countries. The student-teacher ratio for the high-income countries, however, is lower than that of the middle-income countries. Given the differences between the level of inputs and outputs, an analysis of technical efficiency will shed light on the extent to which the resources have been properly utilised. In the next section, I turn to the discussion of the results of DEA.

Results

The efficiency scores based on an output-oriented DEA are calculated using cross-sectional data from 40 countries that participated in TIMSS 2011. A panel data analysis was not employed because construction of a panel dataset would result in a lower number of observations, since a country might participate in TIMSS one year, but not in the other years. A software package called DEAP 2.1 was used for the efficiency scores computation.[7] Results of DEA involving all 40 countries (no controlling for environmental variables) are first discussed. Then, the discussion proceeds with

Table 4: Summary statistics of DEA efficiency scores involving all 40 countries

Statistics	CRS Technical Efficiency	VRS Technical Efficiency	Scale Efficiency
Average	0.70	0.86	0.80
Std dev	0.20	0.12	0.14
Minimum	0.37	0.54	0.51
Maximum	1	1	1

the results obtained after controlling for the environmental variables.

Summary statistics of the DEA results for all 40 countries are presented in Table 4. As shown in the table, on average, the CRS-technical efficiency for all the countries is 70 percent. The VRS-technical efficiency, on the other hand, is 86 percent, with a standard deviation of 12 percent. The minimum technical efficiency score under the CRS assumption is 37 percent, while under the VRS assumption, it is 54 percent. The difference between the CRS and VRS efficiency scores exists due to a large-scale difference, as shown by the average scale efficiency of 80 percent.

In Table 5, details of each country's score and ranking are shown. Ghana is the country with the lowest VRS technical efficiency score, which stands at only 54 percent. Ghana, in other words, has failed to realise its potential educational outputs in terms of higher TIMSS results, due to technical inefficiency of 46 percent. Armenia, Norway, and the United States, by contrast, have each recorded a CRS-technical efficiency score of 100 percent. Nine countries, however, have the maximum score of 100 percent under the VRS assumption: Armenia, Norway, the United States, Russia, Turkey, Singapore, Thailand, Finland, and South Korea. These countries form the VRS frontier against which the performance of the other countries is evaluated.

For all nine VRS-technically efficient countries, the number of times each of them acts as a peer (exemplar) is also identified. The objective of this exercise is to discriminate between superior and inferior peers among the identified efficient countries. Singapore, for example, appears 29 times (the highest peer count) as a peer to the other countries, with relatively the same level of inputs. Other countries with high peer count are Russia (20 counts), Norway (five counts), South Korea (two counts), Finland (two counts), United States (one count) and Armenia (one count). Although Turkey and Thailand have VRS efficiency scores of one, the peer count for these countries is zero, meaning that they form part of the VRS frontier, but do not stand as peers to the other countries. This is because these countries' positions are at the lower end (near to the origin—recall Figure 5) of the frontier, and no other countries are relatively comparable to them in terms of inputs. Although they form parts of the frontier, their exclusion from the sample will not affect the efficiency scores of the other countries.

The results in Table 5 also show that Turkey is the only OIC country that is technically efficient under the VRS assumption. As mentioned above, although Turkey forms part of the VRS frontier, it does not become a peer (exemplar) to other countries. Based on VRS scores, the remaining OIC countries dominated the bottom 20 positions of the ranking (refer to

Table 5: Efficiency scores and rankings of all 40 countries

Countries	CRS	VRS	Scale	Returns to scale	CRS Rank	VRS Rank
Armenia	1	1	1	crs	1	1
Norway	1	1	1	crs	2	2
United States	1	1	1	crs	3	3
Russia	0.985	1	0.985	drs	4	4
Turkey*	0.984	1	0.984	irs	5	5
Singapore	0.977	1	0.977	drs	6	6
Thailand	0.946	1	0.946	irs	7	7
Finland	0.852	1	0.852	drs	12	8
South Korea	0.699	1	0.699	drs	19	9
Slovenia	0.903	0.992	0.91	drs	9	10
Japan	0.752	0.987	0.763	drs	18	11
Israel	0.915	0.98	0.933	drs	8	12
Hong Kong	0.632	0.956	0.661	drs	24	13
Sweden	0.835	0.953	0.876	drs	13	14
Lithuania	0.886	0.943	0.939	drs	10	15
Hungary	0.778	0.94	0.827	drs	15	16
Australia	0.662	0.913	0.725	drs	22	17
Italy	0.756	0.9	0.84	drs	17	18
Kazakhstan*	0.81	0.894	0.906	drs	14	19
Georgia	0.872	0.876	0.995	drs	11	20
New Zealand	0.649	0.873	0.743	drs	23	21
Ukraine	0.616	0.868	0.709	drs	27	22
Lebanon*	0.777	0.855	0.909	drs	16	23
UAE*	0.597	0.816	0.731	drs	28	24
Romania	0.623	0.814	0.766	drs	26	25
Iran*	0.499	0.803	0.621	drs	33	26
Chile	0.669	0.799	0.837	drs	21	27
Saudi Arabia*	0.632	0.782	0.808	drs	25	28
Qatar*	0.686	0.778	0.882	drs	20	29
Bahrain*	0.453	0.766	0.591	drs	34	30
Jordan*	0.434	0.761	0.57	drs	36	31
Tunisia*	0.534	0.754	0.709	drs	31	32
Malaysia*	0.514	0.737	0.698	drs	32	33
Macedonia	0.557	0.734	0.758	drs	30	34
Syria*	0.367	0.722	0.508	drs	40	35
Oman*	0.452	0.712	0.635	drs	35	36
West Bank and Gaza*	0.427	0.712	0.6	drs	37	37
Indonesia*	0.584	0.711	0.822	drs	29	38
Morocco*	0.409	0.637	0.641	drs	38	39
Ghana	0.37	0.54	0.686	drs	39	40

Note: * to indicate the OIC countries; crs denotes constant returns to scale; irs denotes increasing returns to scale; drs denotes decreasing returns to scale.

VRS ranking column of Table 5). After Turkey, the second most efficient OIC country is Kazakhstan, with an efficiency level of 89 percent. Morocco is ranked 39th (second to last), with a technical efficiency score of 64 percent. In what has become a central issue in the Middle East, Israel is 98 percent technically efficient. Israel manages to outperform almost all of the OIC countries (except Turkey); not just in TIMSS, but also in technical efficiency. The findings suggest that due to technical inefficiency, educational resources in most of the OIC countries were not being utilised fully for the realisation of higher TIMSS scores. An improvement in technical aspects of how the existing resources can be fully utilized is key for the OIC nations to achieve better TIMSS results, and to avoid wasting resources. The study, however, does not investigate factors that may explain the inefficiency. It could be a possible topic for future research.

Since the analysis is based on an output-oriented DEA, the objective of the linear programming problem is to assess how much a country should improve its output given the allocated level of inputs. As shown in Table 6, in the case of Malaysia, for example, the projected outputs are 597 for mathematics and 581 for science—the calculation is based on equation (4). The projected outputs are obtained from the piecewise linear frontier constructed by joining the identified efficient countries (recall Figure 5). The percentage difference between the projected and the original outputs shows the percentage improvement in mathematics and science Malaysia needs to achieve in order to be technically efficient. In other words, the projected outputs stand as the key performance indicators for Malaysia to improve its performance internationally. To offer another example, given the allocated resources, a country such as Ghana needs to improve both mathematics and science average scores by 85 percent from the present results in order to be technically efficient. For the OIC, Morocco is the country that requires the most improvement in both subjects (65 percent improvement in mathematics and 57 percent improvement in science) in order to be fully efficient.

So far in the analysis, I have not controlled for the effects of environmental factors on technical efficiency. As discussed in Section 4.3, to control for environmental factors, the 40 countries are divided into high- and middle-income nations. Due to the division, two separate DEA models are estimated.

In Table 7, summary statistics of the efficiency scores obtained under each division are presented. After controlling for the environmental factors, the average VRS efficiency score for the high-income countries is 92 percent, while the middle-income countries' is 87 percent. The high-income countries' scale efficiency, however, is only 81 percent, while the middle-income countries' score is 88 percent. The findings suggest that scale inefficiency is more prevalent among the high-income countries than it is in the middle-income countries.

Table 6: Projected outputs for all the countries

Country	2011 mean math for 8th grade	Projected math score	% difference	2011 mean science for 8 grade	Projected science score	% difference
Armenia	467	467	0	437	437	0
Australia	505	578	15	519	568	10
Bahrain*	409	611	49	452	590	31
Chile	416	591	42	461	577	25
Finland	514	514	0	552	552	0
Georgia	431	492	14	420	487	16
Ghana	331	613	85	306	566	85
Hong Kong	586	613	5	535	560	5
Hungary	505	559	11	522	555	6
Indonesia*	386	583	51	406	571	41
Iran*	415	611	47	474	590	24
Israel	516	526	2	516	531	3
Italy	498	561	13	501	556	11
Japan	570	578	1	558	568	2
Jordan*	406	611	50	449	590	31
Kazakhstan*	487	548	13	490	548	12
South Korea	613	613	0	560	560	0
Lebanon*	449	525	17	406	531	31
Lithuania	502	544	8	514	545	6
Macedonia	426	580	36	407	569	40
Malaysia*	440	597	36	426	581	36
Morocco*	371	611	65	376	590	57
New Zealand	488	605	24	512	586	14
Norway	475	475	0	494	494	0
Oman*	366	611	67	420	590	40
Qatar*	410	527	28	419	538	28
Romania	458	583	27	465	572	23
Russia	539	539	0	542	542	0
Saudi Arabia*	394	562	43	436	557	28
Singapore	611	611	0	590	590	0
Slovenia	505	547	8	543	547	1
Sweden	484	512	6	509	534	5
Syria*	380	611	61	426	590	38
Thailand	427	427	0	451	451	0
Tunisia*	425	599	41	439	582	33
Turkey*	452	452	0	483	483	0
Ukraine	479	592	24	501	577	15
UAE*	456	581	27	465	570	23
United States	509	509	0	525	525	0
West Bank & Gaza*	404	611	51	420	590	40

Note: * to indicate the OIC countries

In Table 8, the efficiency score and ranking of the 19 high-income countries are presented. Based on VRS efficiency, all five OIC countries that fall under the high-income category are at the lowest five positions; namely, UAE (82 percent), Qatar (79 percent), Saudi Arabia (78 percent), Bahrain (77 percent), and Oman (71 percent). As shown in Table 8, Norway, the United States, Singapore, Slovenia, Finland, Japan, and South Korea are the most efficient countries under the VRS assumption. These countries form the VRS frontier against which the performance of other countries is evaluated; these highly technically efficient countries also stand as exemplars for the OIC countries as they seek to improve technical efficiency.

Table 7: Summary statistics of DEA efficiency based on the division of the DMUs into high- and middle-income countries

Statistics	19 high-income countries			21 middle-income countries		
	CRS	VRS	Scale	CRS	VRS	Scale
Average	0.75	0.92	0.81	0.77	0.87	0.88
Std dev	0.17	0.10	0.12	0.18	0.11	0.12
Min	0.45	0.71	0.59	0.49	0.61	0.63
Max	1	1	1	1	1	1

Table 8: Efficiency scores and rankings of 19 high-income countries

Countries	CRS	VRS	Scale	Returns to scale	VRS Rank	CRS Rank
Norway	1	1	1	crs	1	1
United States	1	1	1	crs	2	2
Singapore	0.977	1	0.977	drs	3	3
Slovenia	0.903	1	0.903	drs	4	5
Finland	0.852	1	0.852	drs	5	6
Japan	0.759	1	0.759	drs	6	10
South Korea	0.699	1	0.699	drs	7	11
Israel	0.915	0.995	0.919	drs	8	4
Hong Kong	0.632	0.956	0.661	drs	9	15
Sweden	0.835	0.953	0.876	drs	10	7
Hungary	0.781	0.952	0.821	drs	11	8
Italy	0.76	0.931	0.817	drs	12	9
Australia	0.668	0.914	0.731	drs	13	13
New Zealand	0.649	0.873	0.743	drs	14	14
UAE*	0.597	0.817	0.731	drs	15	17
Qatar*	0.686	0.788	0.871	drs	16	12
Saudi Arabia*	0.632	0.783	0.807	drs	17	16
Bahrain*	0.453	0.766	0.591	drs	18	18
Oman*	0.452	0.712	0.635	drs	19	19

Note: * to indicate the OIC countries; crs denotes constant returns to scale; irs denotes increasing returns to scale and drs denotes decreasing returns to scale.

In Table 9, the efficiency scores of the 21 middle-income countries, together with their rankings, are shown. Ghana once again has the lowest CRS and VRS efficiency scores, and thus is positioned last (21st). Six countries are technically efficient under the VRS assumption: Armenia, Russia, Thailand, Turkey, Lebanon, and Georgia. Of the six efficient countries, Russia has the highest peer count (15 counts), followed by Turkey (three counts) and Thailand (one count). These three countries are the superior peers, and the inefficient countries may learn from them. Although Armenia, Lebanon, and Georgia form the VRS frontier, these countries do not stand as exemplars to any of the inefficient countries, making them inferior peers. Although they form parts of the frontier, their exclusion from the sample will not affect the efficiency scores of the other countries.

From the estimated VRS technical efficiency, Turkey and Lebanon are the only OIC countries with maximum efficiency scores. Kazakhstan scored 90 percent, Iran 88 percent, Jordan 83 percent, Malaysia 82 percent, Tunisia 81 percent, Indonesia 79 percent, Syria 79 percent, West Bank and Gaza 78 percent, and Morocco 69 percent. These inefficient OIC countries are also found to be in the state of decreasing returns to scale (DRS). In other words, a proportional change in the inputs of education results in less than a proportional change in the outputs of education.

As an expositional purpose, we now turn to the case of Indonesia. Given its VRS technical efficiency of 79 percent, Indonesia needs to improve. For that matter, the country may learn from its peers; namely, Russia (peer weight = 0.684), Thailand (peer weight = 0.218), and Turkey (peer weight = 0.098). Since Russia's peer weight is the highest, Indonesia should learn most from that country. Had Indonesia been technically efficient, given its level of educational inputs, the country should have scored 506 in mathematics and 516 in science. Those are the projected outputs for the nation to improve its technical efficiency (refer to Table 10).

In Table 10, the projected outputs for the high- and middle-income countries are presented. The projected outputs are obtained using equation (4). The projected outputs in Table 10 are different than those in Table 6 because the figures in Table 10 are obtained after controlling for environmental factors.

Table 9: Efficiency scores and rankings of the middle-income countries

Countries	CRS	VRS	Scale	Returns to scale	VRS Rank	CRS Rank
Armenia	1	1	1	crs	1	1
Russia	1	1	1	crs	2	2
Thailand	1	1	1	crs	3	3
Turkey*	1	1	1	crs	4	4
Lebanon*	0.983	1	0.983	irs	5	5
Georgia	0.882	1	0.882	irs	6	7
Lithuania	0.903	0.948	0.952	drs	7	6
Ukraine	0.825	0.924	0.893	drs	8	8
Chile	0.821	0.919	0.893	drs	9	10
Kazakhstan*	0.822	0.904	0.909	drs	10	9
Iran*	0.67	0.875	0.766	drs	11	16
Romania	0.817	0.868	0.941	drs	12	11
Jordan*	0.517	0.828	0.625	drs	13	19
Malaysia*	0.671	0.816	0.822	drs	14	15
Tunisia*	0.712	0.81	0.88	drs	15	14
Macedonia	0.724	0.79	0.916	drs	16	13
Indonesia*	0.784	0.786	0.997	drs	17	12
Syria*	0.495	0.786	0.63	drs	18	20
West Bank & Gaza*	0.577	0.775	0.744	drs	19	17
Morocco*	0.54	0.694	0.778	drs	20	18
Ghana	0.493	0.614	0.804	drs	21	21

Note: * to indicate the OIC countries; crs denotes constant returns to scale; irs denotes increasing returns to scale and drs denotes decreasing returns to scale.

Table 10: Projected outputs for high-income and middle-income countries

High-income country	2011 mean math for 8 grade	Projected math score	% difference	2011 mean science for 8 grade	Projected science score	% difference
Australia	505	555	10	519	568	9
Bahrain*	409	611	49	452	590	31
Finland	514	514	0	552	552	0
Hong Kong	586	613	5	535	560	5
Hungary	505	531	5	522	549	5
Israel	516	518	0	516	524	2
Italy	498	535	7	501	538	7

Japan	570	570	0	558	558	0
South Korea	613	613	0	560	560	0
New Zealand	488	601	23	512	586	14
Norway	475	475	0	494	494	0
Oman*	366	611	67	420	590	40
Qatar*	410	520	27	419	531	27
Saudi Arabia*	394	526	34	436	557	28
Singapore	611	611	0	590	590	0
Slovenia	505	505	0	543	543	0
Sweden	484	512	6	509	534	5
UAE*	456	558	22	465	569	22
United States	509	509	0	525	525	0
Middle-income country	**2011 mean math for 8 grade**	**Projected math score**	**% difference**	**2011 mean science for 8 grade**	**Projected science score**	**% difference**
Armenia	467	467	0	437	437	0
Chile	416	479	15	461	501	9
Georgia	431	431	0	420	420	0
Ghana	331	539	63	306	542	77
Indonesia*	386	506	31	406	516	27
Iran*	415	539	30	474	542	14
Jordan*	406	539	33	449	542	21
Kazakhstan*	487	539	11	490	542	11
Lebanon*	449	449	0	406	406	0
Lithuania	502	539	7	514	542	5
Macedonia	426	539	27	407	542	33
Malaysia*	440	539	23	426	542	27
Morocco*	371	539	45	376	542	44
Romania	458	530	16	465	536	15
Russia	539	539	0	542	542	0
Syria*	380	539	42	426	542	27
Thailand	427	427	0	451	451	0
Tunisia*	425	539	27	439	542	23
Turkey*	452	452	0	483	483	0
Ukraine	479	539	13	501	542	8
W. Bank & Gaza*	404	539	33	420	542	29

Note: * to indicate the OIC countries

Conclusion

This study investigated the level of technical efficiency of secondary education in 40 countries that participated in TIMSS 2011. Central to the analysis was the assessment of OIC countries' technical efficiency in utilizing the allocated educational resources. The technique employed for the analysis was data envelopment analysis (DEA). For the DEA analysis, each country's mean scores in TIMSS 2011mathematics and science were employed as the educational outputs, while the inputs were represented by the percentage distribution of current public expenditure on lower secondary education and secondary school student-teacher ratios.

From the analysis, the OIC countries, in general, were technically inefficient in utilising their educational resources to achieve better TIMSS results in comparison with the non-OIC countries. Although Turkey and Lebanon managed to achieve 100 percent VRS efficiency scores (refer to Table 9), they were still inferior exemplars. Had the OIC countries been technically efficient, they would have achieved better TIMSS results. To improve, the OIC countries may learn from their identified superior peers. Experience of the superior peers in utilising their educational resources should be carefully studied, particularly in areas to better enhance teaching and learning processes, to provide more effective educational technologies and to adopt best-practice education management system.

Notes

1. The database is retrievable for free at http://databank.worldbank.org/ddp/home.do
2. Input data for the OIC countries are obtained from SESRIC database at http://www.sesrtcic.org/baseind-step1.php
3. Source: http://www.centerforpubliceducation.org/Libraries/Document-Library/Achievement-Levels/Description-of-TIMSS-Achievement-Levels.html
4. These data represent a direct allocation to lower secondary education, where the eighth-grade students fall. Although data such as percentage educational expenditure for secondary schools as a percentage of GDP are available, this allocation made covers both the lower and upper secondary levels of education. Such data is less specific to capture the government's effort on the lower secondary level.
5. Refer to the World Bank's world databank at: http://databank.worldbank.org/ddp/home.do.
6. Refer to Maragos & Despotis (2003) for an example of this method in research to evaluate schools' technical efficiency.
7. The software package is downloadable for free from The Centre of Efficiency and Productivity Analysis (CEPA) at http://www.uq.edu.au/economics/cepa/deap.htm

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