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How Efficient is Malaysia's Secondary Education?
(Bagaimanakah Keberkesanan Pendidikan Menengah di Malaysia)

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ABSTRACT

The purpose of this study is to investigate the level of technical efficiency of Malaysia's secondary education in comparison with other countries. Education efficiency has become an important issue given the pressing levels of public deficit and debt of many countries. Since the educational sector always receives high priority in budget allocations, an evaluation of whether the allocations made for education has been technically efficient is important. With budget constraints and high expectation by the public to see a continuous improvement in students' academic achievement, the educational sector has been put under pressure to deliver. The study employs TIMSS 2007 data, involving 44 countries. The technique used to calculate the level of technical efficiency is Data Envelopment Analysis (DEA). Malaysia is found technically inefficient in terms of utilising its educational resources to achieve better TIMSS results in comparison with the other countries. Even after controlling for the environmental variable, Malaysia's secondary education remains technically inefficient.

Keywords: TIMSS, Secondary education, Data envelopment analysis, Efficient

ABSTRAK

Tujuan kajian ini adalah untuk menyiasat tahap kecekapan teknikal pendidikan menengah di Malaysia berbanding dengan negara-negara lain. Kecekapan pendidikan telah menjadi satu isu penting dalam suasana tahap defisit dan hutang kebanyakan negara yang semakin menekan. Berikutan sektor pendidikan sentiasa menerima peruntukan yang tinggi dalam bajet, penilaian sama ada peruntukan yang dibuat telah digunakan dengan cekap adalah penting. Dalam keadaan kekangan belanjawan dan berserta harapan tinggi oleh masyarakat untuk melihat peningkatan berterusan dalam pencapaian akademik pelajar, tahap penyampaian Kementerian Pendidikan perlu dipertingkatkan. Kajian ini menggunakan data TIMSS 2007 yang melibatkan 44 negara. Teknik yang digunakan untuk mengira tahap kecekapan teknikal adalah Data Envelopment Analysis *(DEA). Malaysia didapati tidak cekap secara teknikal dari segi menggunakan sumber-sumber pendidikan untuk mencapai keputusan TIMSS yang lebih baik berbanding dengan negara-negara lain. Walaupun selepas mengawal pemboleh ubah persekitaran, pendidikan menengah Malaysia kekal tidak cekap.*

Keywords: TIMSS, Pendidikan menengah, data Pembangunan analisis data*, Keberkesanan*

INTRODUCTION

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

With a cross country evaluation, the level of technical efficiency of Malaysia's educational sector can be assessed against other countries. Findings of the study are important in providing information of Malaysia's level of efficiency in resource utilisation to achieving high students' academic achievement. If Malaysia wants to remain competitive, it needs to address the issue of educational gap. According to the UN 2010 Millennium Development Goal (MDG) report, the Asian region has a significant gap in the distribution of students' academic achievement between the first-tier Asian economies (i.e. the Republic of Korea, Singapore and Taiwan) and the second-tier countries (i.e. Indonesia, Malaysia and Thailand). The gap, according to the report, needs to be reduced given the available resources.

Schultz (1963) points that while primary education might suffice for basic production of goods and services, workers with secondary education can use technology in the workplace, and tertiary education is certainly important in the process to invent and to innovate technology. In other words, the level of economic advancement needs to be backed up with a proportionally qualified workforce. As a middle-income country, secondary education remains as a crucial stage for Malaysia to develop its human capital development before it can establish itself as a knowledge-based economy. For that matter, an evaluation of whether the investment made in Malaysia's secondary education is efficient merits further scrutiny.

For the study, secondary students' achievements in mathematics and science in the Trends in International Mathematics and Science Study (TIMSS) are employed. High achievements in both subjects are considered as an important ingredient for a nation to progress. Low performance in the subjects may hamper the level of competitiveness of Malaysia. Again, according to the UN 2010 MDG, the gap in mathematics and science achievements between Malaysian students and their counterparts in Asian countries like Korea, Singapore and Taiwan could slow its pace of growth to catch up with those first-tier economies.

The Concept Of Efficiency In Education

According to Worthington (2001), technical efficiency in education deals with the best use of educational inputs, such as school resources, in order to improve students' academic achievement. Worthington further states that allocative efficiency 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.

Productivity in education, according to Rolle (2004) is related to the issues of how to achieve the efficient production of educational outcomes. Rolle states that in the context of public education institutions, educational productivity debates cover the issues of how to: minimise costs; maximise the utilisation of available resources; meet increased and diversified educational objectives and how to become accountable to the public for the expenditure of resources. The issue on how to maximise the utilisation of the available resources is the main focus of this study.

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 the 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 technical efficiency, allocative efficiency and cost efficiency of schools. The study here will only evaluate the level of technical efficiency of 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.

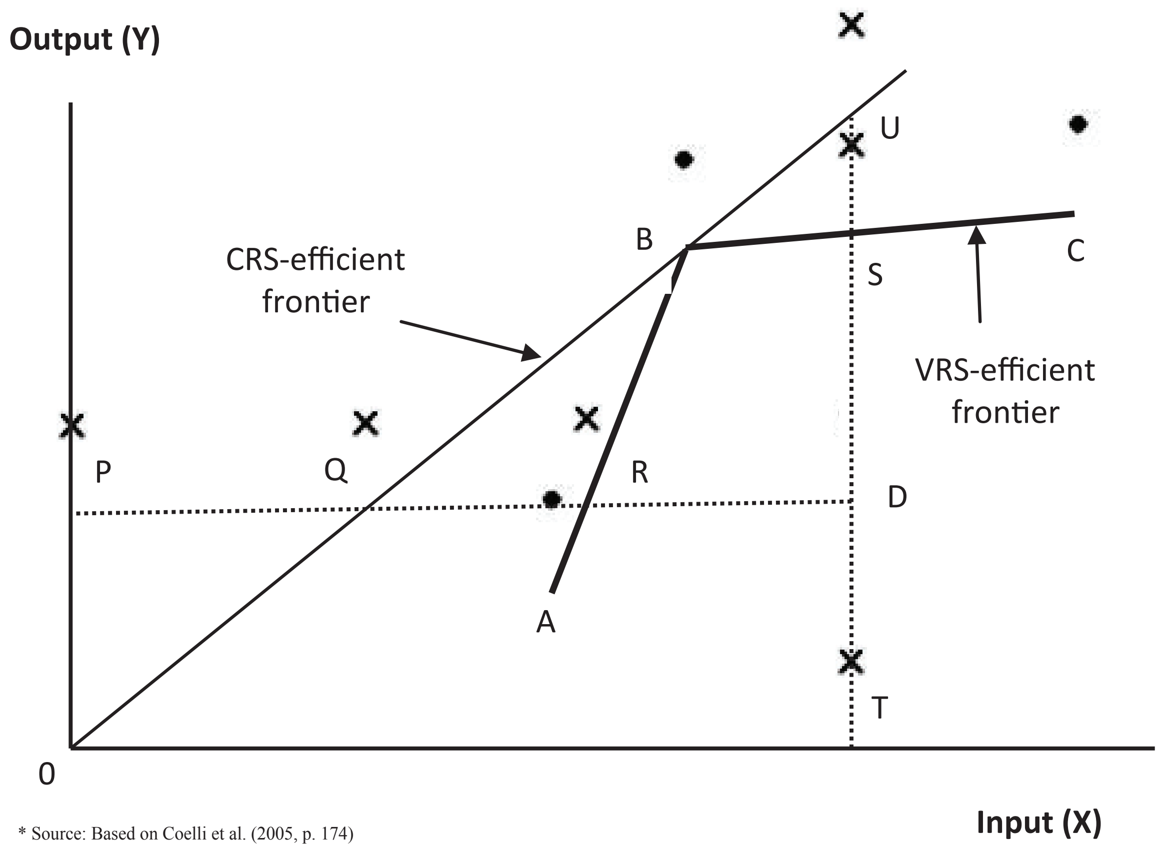
DATA ENVELOPMENT ANALYSIS (DEA)

THEORETICAL FRAMEWORK OF DEA

Two basic DEA models have been widely applied: (1) the constant returns to scale (CRS) model of Charnes, Cooper and Rhodes (1978), and (2) the variable returns to scale (VRS) model of Banker, Charnes and Cooper (1984). In Figure 1, 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 1, points *A*, *B*, *C* and *D* represent the observed performance of four DMUs (such as countries), given their level of input and output and production technology. The CRS model is represented by the thin line extending from the origin of Figure 1 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.

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*) (Figure 1). The frontier is piecewise linear and concave. The VRS-frontier assumes variable returns to scale where: (1) increasing returns to scale occurs in the first solid line (*AB*) segment, and (2) decreasing returns to scale 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).



* Source: Based on Coelli et al. (2005, p. 174)

FIGURE 1. The best-practice reference frontier

Given the CRS-efficient and VRS-efficient frontiers, an inefficient DMU has two major projection paths to improve its performance, namely, (1) an input-oriented path, and (2) 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 the study, an output-oriented path is adopted because in the context of public education, the allocations to schools are made with expectations of full utilisation of the allocations provided, together with high students' academic achievement. Conservation of inputs is not the objective of public education and as such an analysis based on the input-oriented path is not appropriate.

Referring to Figure 1, 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. 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*). Based on a simple productivity measure (productivity = output/input), the ratio form of DEA can be expressed as $\sum_{m=1}^{M} u_m y_{mj} \Big/ \sum_{n=1}^{N} v_n x_{nj}$, where u_m are the output weights and v_n are the input weights. The weights for outputs and inputs are estimated as the best advantage for each DMU to maximise its relative efficiency. The mathematical programming problem to solve for the optimal value of the weights is set out as:

$$\text{For each } j;\ \max_{u,v} \frac{\sum_{m=1}^{M} u_m y_{mj}}{\sum_{n=1}^{N} v_n x_{nj}} \qquad (2)$$

subject to:

$$\frac{\sum_{m=1}^{M} u_m y_{mj}}{\sum_{n=1}^{N} v_n x_{nj}} \le 1, \text{ for each } j = 1, \ldots, J$$

$$u_m, v_n \ge 0,\ m = 1, \ldots, M;\ n = 1, \ldots, N$$

where in finding the values of u and v, the first constraint sets the maximum efficiency value of the j^{th} DMU to be less than or equal to one, and 1 signifies the most efficient score. The second constraint is to indicate that the input and output weights are non-negative. The problem with equation (2) is that it has an infinite number of solutions. If (u^*, v^*) is one solution, then $(\alpha\mu^*, \alpha v^*)$ is another solution, and so on (Coelli, 1996b, p. 11). The problem can be solved by adding another constraint, $\sum_{n=1}^{N} v_n x_{nj} = 1$, which yields:

$$\text{For each } j,\ \max_{\mu,\upsilon} \sum_{m=1}^{M} \mu_m y_{mj} \qquad (3)$$

subject to:

$$\sum_{n=1}^{N} \upsilon_n x_{nj} = 1$$

$$\sum_{m=1}^{M} \mu_m y_{mj} - \sum_{n=1}^{N} \upsilon_n x_{nj} \le 0, \text{ for } j = 1, \ldots, J$$

$$\mu_m, \upsilon_n \ge 0$$

where the change in notation from u and v to μ and v is designed to reflect the transformation of the linear programming from the ratio form to the so-called multiplier form (Coelli, 1996, p. 11). The objective of equation (3) is to maximise the weighted output of the j^{th} DMU subject to the constraint that the sum of input weights of the j^{th} DMU must equal one. At the same time, the objective function maintains the condition that the output weights must not exceed the input weights. Note also that the linear programming in equation (3) must be solved J times, once for each DMU in the sample. Equation (3) is an output-oriented linear programming problem under constant returns to scale (CRS) assumption.

A duality in the linear programming of DEA means that the maximised value of the objective function in the multiplier form [as given by equation (3)] can also be written as the minimised value of the objective function in the so-called an envelopment form, as given below:

$$\text{For each } j,\ \min_{\theta_j,\boldsymbol{\lambda}}\ \theta_j \qquad (4)$$

subject to:

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

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

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

where θ_j is the technical efficiency of the j^{th} DMU and λ is the vector of weights assigned to each DMU (λ also is known as peer weights). Note that the linear programming in equation (4) must be solved J times, once for each DMU in the sample. As such, a different set of λ is obtained for each j^{th} solution of the linear programming. The un-bold 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 second constraint puts the condition that the inputs used by the observed DMU j minus the sum of inputs weights of all the DMUs must be more than or equal to zero. The last constraint is to ensure that the value of λ is non-negative. Equation (4) is an input-oriented linear programming of DEA under constant returns to scale (CRS) assumption.

By adding a convexity constraint, $\sum_{j=1}^{J}\lambda_j = 1$, to equation (4), the CRS linear programming is now modified to a variable returns to scale (VRS) linear programming as set out below:

$$\text{For each } j,\ \sum_{j=1}^{J}\lambda_j y_{mj} \geq y_{mj},\ \text{for } m = 1, ..., M \quad (5)$$

subject to:

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

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

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

where the purpose of the convexity constraint, according to Coelli et al (2005), 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 weights 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.

The envelopment form of an output-oriented VRS DEA, on the other hand, is given by:

$$\text{For each } j, -\phi_j y_{mj} + \sum_{j=1}^{J}\lambda_j y_{mj} \geq 0,\ \text{for } m = 1, ..., M \ (6)$$

subject to:

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

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

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

where ϕ_j is the output weight of the j^{th} DMU to be maximised and λ (bold) and λ's (un-bold) are as defined above. The value of ϕ_j is $1 \le \phi_j < \infty$. The measure of technical efficiency for the j^{th} DMU is given by $1/\phi_j$ [Coelli (1996b, p. 23)]. To maximise ϕ_j, the first constraint puts the condition that the weighted outputs of the observed DMU *j* must be less than or equal to the sum of output weights of all the DMUs. 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. The third constraint implies that the sum of all the peer weights must equal one and the last constraint is to ensure that the value of λ is non-negative.

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

$$m^{th} \text{ output target: } \quad \lambda_1 y_{m1} + \ldots + \lambda_J y_{mJ}, \text{ for } m = 1, \ldots, M,$$
$$n^{th} \text{ input target: } \quad \lambda_1 x_{n1} + \ldots + \lambda_J x_{nJ}, \text{ for } n = 1, \ldots, N. \quad (7)$$

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.

Calculation Of Scale Efficiency

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 1 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 1 is given by:

$$SE = PQ/PR. \quad (8)$$

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

$$\text{Scale inefficiency} = 1 - SE = QR/PR \quad (9)$$

Another way to calculate scale efficiency is given by.

$$TE_{CRS} = TE_{VRS} \text{ x } SE, \quad (10)$$

because

$$\frac{PQ}{PD} = \left(\frac{PR}{PD}\right)\left(\frac{PQ}{PR}\right) \quad (11)$$

From equation (11), the CRS technical efficiency can be decomposed into two parts: (1) the VRS technical efficiency (which is also known as 'pure' technical efficiency), and (2) the scale efficiency (Coelli et al, 2005).

Adjusting FOR The Environmental Factors

The solutions of the mathematical linear programming of DEA, as discussed in the previous section, will involve two strategies: (1) no control is made on the effects of the environmental factors, and (2) 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 the environmental factors create a cross-sectional heterogeneity across countries, where some countries may perform better than the other countries due to their 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 the socio-economic heterogeneity in the production environment, therefore, need to be considered when comparing the efficiency scores; hence, the relevance of the second strategy.

To control for the environmental factors, the sample that comprises of 44 countries are divided into high and middle income countries. The divisions are based on the World Bank's classification. Separate estimations for high (J = 21) and middle (J = 23) income countries therefore are undertaken. 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 group.

Data And Sample

Source Of Data

A cross-sectional dataset of 44 countries is employed for the DEA estimations. The source of the data is from the World Bank's database on Education Statistics. Only 44 countries are considered in the analysis because the data on these countries are complete. Furthermore, since there were only 48 countries participated in the 2007 TIMSS for the 8th grade, the output data is therefore limited by the number of the participating countries.

Countries with missing outputs or inputs data are dropped from the dataset. Data for year 2007 is considered because the latest TIMSS results are available for the year. A panel data analysis is not employed because a construction of panel dataset results in a fewer number of observation (DMU) since a country may participate in one year but not in the other years in TIMSS.

Output Data

In order to measure the level of technical efficiency of Malaysian investment in secondary education (relative to other countries), an international assessment such as the Trends in International Mathematics and Science Study (TIMSS) is employed for the DEA analysis. The outputs employed are a country's 8th grade mean scores in science and mathematics in TIMSS (Martin et al 2008). An international assessment offers a unique opportunity to benchmark Malaysia's performance to the performance of other countries. With such data, a comparison can be made to know how efficient Malaysia has been in an internationally competitive environment.

The scale of TIMSS achievement levels are as follows: (1) advanced – score above 625; (2) high – score between 550 and 625; (3) intermediate – score between 475 and 550; and low – score between 400 and 475. The summary statistics of the selected countries performance in TIMSS 2007 are shown in Table 1. The countries' performance in science (463 points) is on average better than in mathematics (447 points). The deviation however, is larger in mathematics with the standard deviation of 72. The standard deviation for science is 60. Although the Malaysian secondary students' score in mathematics (474 points) is higher than the average selected countries' average (447 points), there is a huge gap between Malaysia and the highest scoring country, South Korea (597 points). The countries with higher scores in mathematics as compared to Malaysia (as shown in Figure 2) could be the exemplars for Malaysia to learn from in order to improve its mathematics performance.

TABLE 1. Summary Statistics of the Outputs (Year 2007)

Statistics	Mathematics	Science
Average	447	463
Std dev	72	60
Minimum	307	303
Maximum	597	567
Observations	44	44

For science, the performance of Malaysian students (471 points) is above the average marks of the selected countries' scores (463 points). The gap between Malaysia and the higher performing countries however, remains significantly large. As shown in Figure 3, there are 20 countries in the leading positions in science. Singapore leads the pack with the highest score of 567 points.

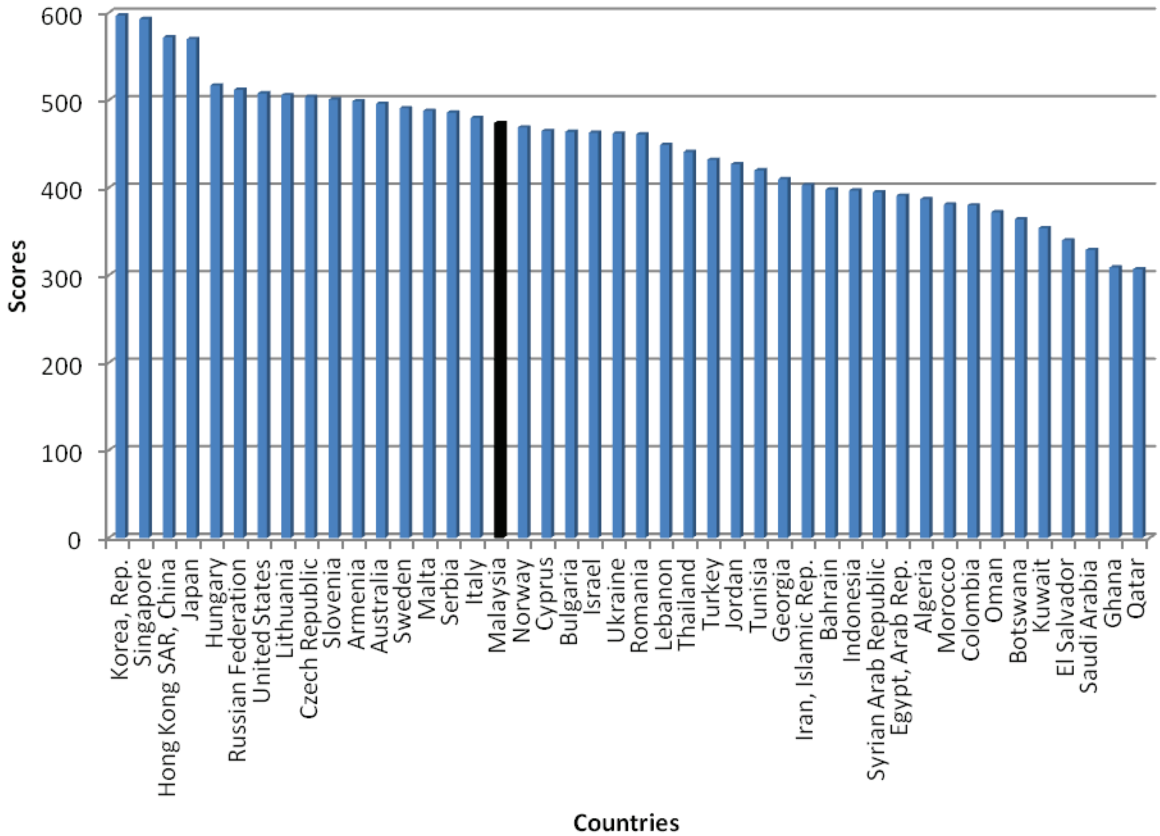


FIGURE 2. TIMSS 2007 Math Performance (mean scores of the selected countries)

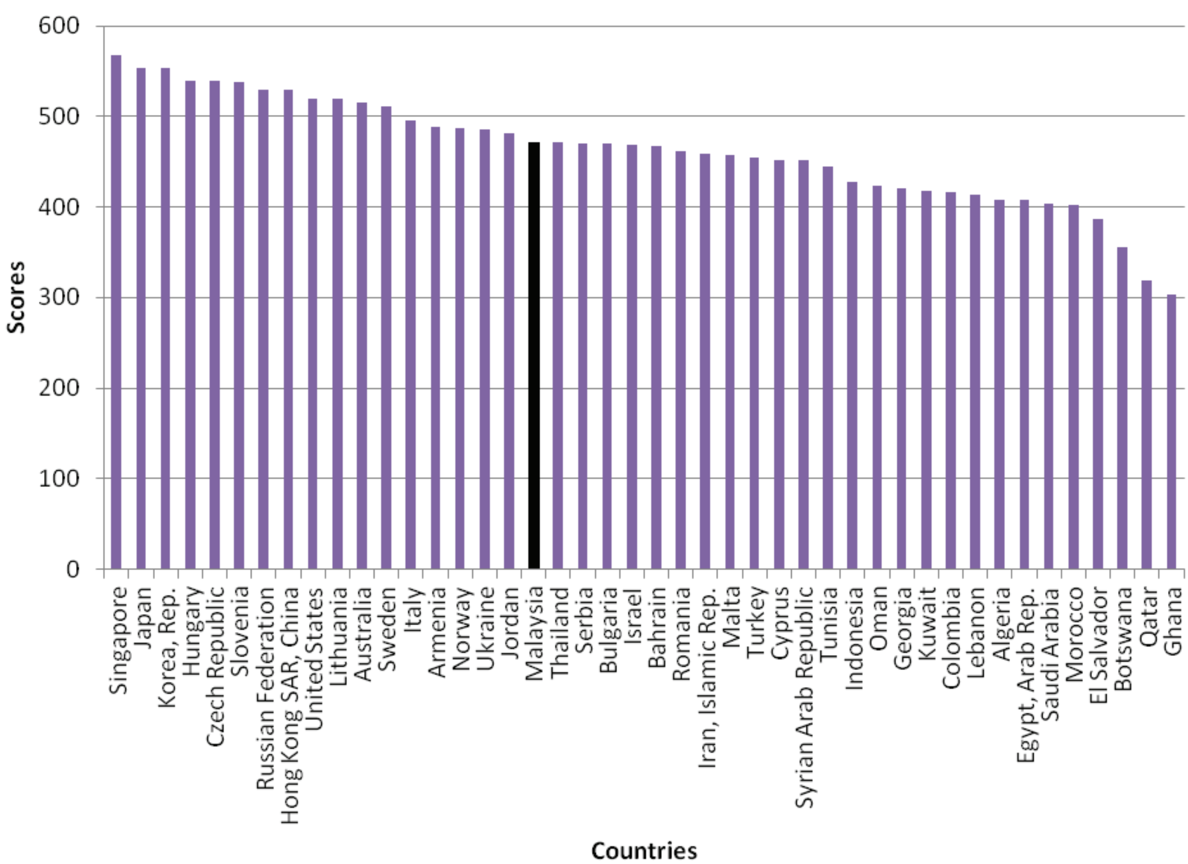


FIGURE 3. TIMSS 2007 Science Performance (mean scores of the selected countries)

To summarise, the performance of Malaysian students in TIMSS can be considered as averaged. An analysis of the amount of educational inputs that had been allocated to secondary education may provide insights into the observations thus far. The discussion now turns to analyse the allocated inputs of education by each country. The hypothesis is that if the allocation of educational inputs by Malaysian government is relatively proportional as those high achieving countries, then the issue of inefficiency in inputs utilisation could be one reason for the failure to translate the allocated inputs into higher students' achievements.

INPUT DATA

For the analysis, two educational inputs have been employed, namely, secondary educational expenditure as a percentage of GDP and student-teacher ratio. These inputs are discretionary inputs of education because they are under the direct control of the Ministry of Education. In the study of educational production function, these two inputs have been found to have impacts on students' academic performance. Educational expenditure has a positive effect on students' achievement (Hedges et al 1994) while student-teacher ratio has a negative relationship with students' achievement (Finn et al 2003).

Summary statistics of the inputs are presented in Table 2. The average allocation of educational expenditure for secondary schools for the 44 countries is approximately 4.7% with a relatively small standard deviation of 1.4%. Botswana is the country with the highest allocation of secondary educational expenditure as a percentage of GDP at 8.1% and Lebanon is the country with the lowest allocation. Malaysia, on the other hand, has an allocation of 4.5% of secondary educational expenditure as a percentage of GDP.

TABLE 2. Summary Statistics of the Secondary Education Input Variables in 2007 for the Selected Countries

Statistics	Education Expenditure as a Percentage of GDP	Student-teacher Ratio
Average	4.65	14.30
Std dev	1.36	5.61
Minimum	2.6	7.46
Maximum	8.1	30.7
Observations	44	44

Caution however needs to be exercised when comparing countries using this percentage data. High income countries (with high GDP), for example, may have a small percentage allocation but in terms of absolute value, the figures can be higher than a low income country with high percentage allocation. By using the percentage figure for the analysis, countries' educational allocations are normalised and more comparable. In Figure 4 present each country's secondary educational expenditure as a percentage of GDP in a bar chart. Malaysia's allocation is once again at the mid-point of the distribution. This observation may justify the average performance of Malaysia in TIMSS 2007.

For student-teacher ratio, the average ratio is 14 students per teacher in secondary schools. The range of minimum and maximum student-teacher ratio is between 7 to 31 students per teacher. The level of student-teacher ratio for Malaysia is 15 students per teacher. As shown in Figure 5, Iran has the highest student-teacher ratio (31) and Georgia has the lowest ratio (7).

The heterogeneity in the cross-section of the data is accounted for by dividing the 44 countries into 21 high-income and 23 middle-income countries. The division captures a significant difference in the socio-economic characteristics of the countries, where countries with relatively homogenous socio-economic characteristics are grouped together. Based on the division, summary statistics of the output 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, there is also a significant difference, where high-income countries have higher inputs than the middle-income countries.

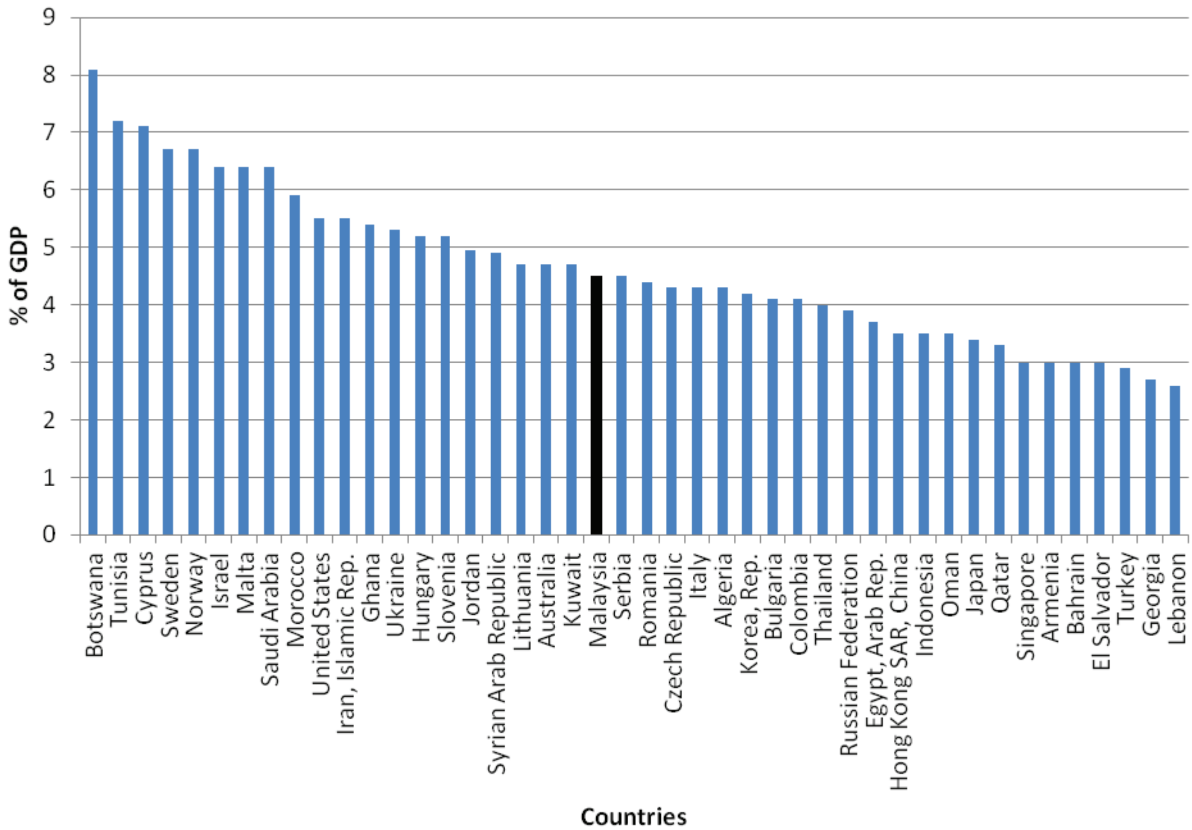


FIGURE 4. Secondary Education Expenditure as a Percentage of GDP (2007)

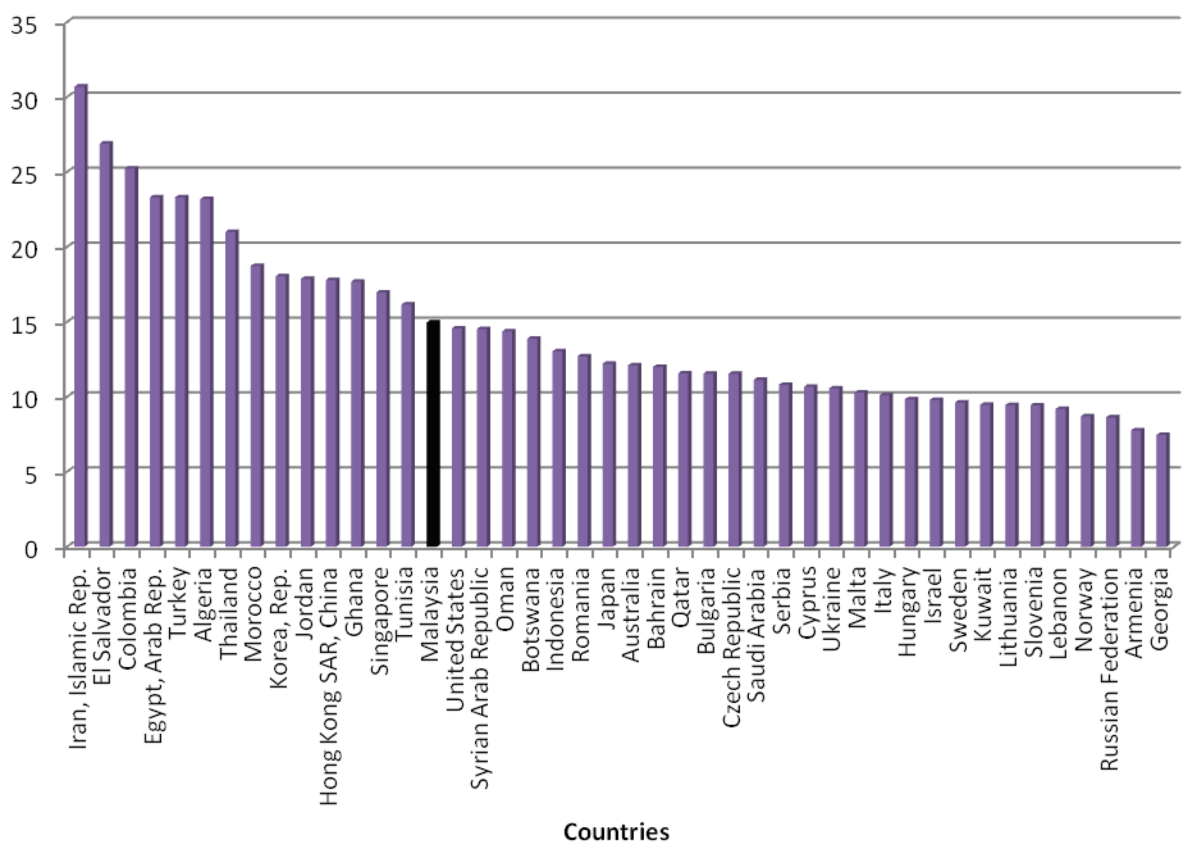


FIGURE 5. Student-Teacher Ratio (Secondary School, 2007)

TABLE 3. Summary Statistics of the Outputs and Inputs according to High-Income and Middle-Income Countries Divisions

	High-income Countries				Middle-income Countries			
		Std dev	Min	max	Mean	Std dev	Min	Max
Outputs								
Math	475.52	82.12	307	597	420.78	50.54	309	506
Science	489.76	61.78	319	567	437.83	48.24	303	519
Inputs								
Secondary Edu. Exp. As % of GDP	4.83	1.36	3	7.1	4.49	1.37	2.6	8.1
Secondary student-teacher ratio	11.85	2.88	8.63	18.06	16.53	6.55	7.46	30.7

RESULTS

The efficiency scores based on output-oriented DEA were obtained using a software package called DEAP 2.1.[5] The solution of the DEA linear programming involving all the 44 countries are first discussed. Then, the discussion proceeds with the results obtained after controlling for the environmental variables. The results for the CRS-DEA are obtained after solving the linear programming problem as given by equation (3). For the VRS-DEA, the results are obtained after solving the linear programming problem as given by equation (6).

Summary statistics of the DEA results for the 44 countries are presented in Table 4. As shown in the table, on average, the CRS-technical efficiency is 71%. The average technical efficiency under the VRS assumption, on the other hand, is 86% with a standard deviation of 0.12. The minimum technical efficiency score under the CRS assumption is 33% while under the VRS assumption, it is 55%.

TABLE 4. Summary Statistics of DEA Efficiency Involving 44 Countries

Statistics	CRS Technical Efficiency	VRS Technical Efficiency	Scale Efficiency
Average	0.71	0.86	0.82
Std dev	0.18	0.12	0.13
Min	0.33	0.53	0.55
Max	1.00	1.00	1.00

In Table 5, details of each country's score and ranking are shown. Ghana is the country with the lowest technical efficiency scores under both the CRS and VRS assumptions. In other words, due to technical inefficiency, Ghana has failed to realise its potential output more than the other countries. Armenia and Singapore are the countries that have recorded a CRS-technical efficiency score of 100%. Nine countries however, have the maximum score of 100% under the VRS assumption, namely, Armenia, Georgia, Hungary, Japan, South Korea, Lebanon, Russia, Singapore and Slovenia (Table 5). These countries form the VRS frontier against which the performance of the other countries is evaluated.

Table 5 analysed Malaysia's technical efficiency. As shown in the table, Malaysia is only 62% technically efficient under the CRS assumption and 84% efficient under the VRS assumption. One point to emphasise here is that for both the CRS and VRS technical efficiencies, Malaysia's scores are below the average score of the sample (refer to Table 4). The findings suggest that due to technical inefficiency, the secondary educational resources in Malaysia were not being utilised fully to the realisation of higher TIMSS scores. The study however, does not investigate into the factors that may explain the inefficiency to shed light on the issue. It can be a possible topic for future research.

In Table 5, the 44 countries are also sorted according to their CRS and VRS technical efficiency scores, from the highest to the lowest in order to rank them. The Pearson correlation of the CRS and VRS rankings is 0.86, suggesting a

TABLE 5. Efficiency Scores and Rankings of All the 44 Countries

DMU	CRS	VRS	Scale	RTS	CRS Ranking	VRS Ranking
Algeria	0.51	0.72	0.71	drs	39	39
Armenia	1.00	1.00	1.00	-	1	1
Australia	0.68	0.93	0.73	drs	28	14
Bahrain	0.89	0.89	1.00	-	8	19
Botswana	0.41	0.64	0.64	drs	42	42
Bulgaria	0.70	0.85	0.82	drs	24	24
Colombia	0.54	0.74	0.73	drs	38	37
Cyprus	0.68	0.85	0.80	drs	27	25
Czech Republic	0.77	0.98	0.78	drs	17	10
Egypt, Arab Rep.	0.58	0.72	0.81	drs	32	38
El Salvador	0.68	0.68	1.00	-	26	41
Georgia	0.95	1.00	0.95	irs	6	6
Ghana	0.33	0.53	0.62	drs	44	44
Hong Kong SAR, China	0.85	0.96	0.89	drs	12	12
Hungary	0.87	1.00	0.87	drs	11	9
Indonesia	0.71	0.77	0.92	drs	21	34
Iran, Islamic Rep.	0.44	0.81	0.55	drs	40	30
Israel	0.76	0.87	0.87	drs	18	22
Italy	0.78	0.92	0.85	drs	15	17
Japan	0.95	1.00	0.95	drs	5	5
Jordan	0.57	0.85	0.67	drs	35	26
Korea, Rep.	0.77	1.00	0.77	drs	16	8
Kuwait	0.70	0.78	0.90	drs	22	33
Lebanon	0.98	1.00	0.98	irs	3	3
Lithuania	0.87	0.97	0.90	drs	10	11
Malaysia	0.62	0.84	0.74	drs	31	27
Malta	0.74	0.91	0.82	drs	19	18
Morocco	0.41	0.71	0.57	drs	43	40
Norway	0.89	0.92	0.97	drs	9	16
Oman	0.69	0.76	0.91	drs	25	35
Qatar	0.57	0.59	0.96	drs	36	43
Romania	0.64	0.83	0.76	drs	29	28
Russian Federation	0.98	1.00	0.98	drs	4	4
Saudi Arabia	0.58	0.74	0.78	drs	34	36
Serbia	0.70	0.89	0.79	drs	23	21
Singapore	1.00	1.00	1.00	-	2	2
Slovenia	0.91	1.00	0.91	drs	7	7
Sweden	0.85	0.95	0.89	drs	13	13
Syrian Arab Republic	0.56	0.81	0.69	drs	37	31
Thailand	0.64	0.83	0.76	drs	30	29
Tunisia	0.44	0.79	0.56	drs	41	32
Turkey	0.83	0.86	0.97	irs	14	23
Ukraine	0.73	0.89	0.82	drs	20	20
United States	0.58	0.93	0.62	drs	33	15

high correlation between the rankings. As shown in Table 5, Malaysia is placed 31st based on the CRS technical efficiency, and is positioned 27th based on the VRS technical efficiency.

Based on the VRS frontier, Japan and Singapore are found to be the role-model countries (peers) for Malaysia to imitate in order to improve its technical efficiency. 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 level of inputs available. As shown in Table 6, in the case of Malaysia, the projected outputs are 583 for mathematics and 562 for science—the calculation is based on equation (7). The projected outputs are obtained from the piecewise linear frontier constructed by joining the identified efficient countries (Figure 1). 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.

TABLE 6. Projected Outputs for Malaysia

Outputs	Original value	Projected value	% Difference
Mathematics	474	583	23%
Science	471	562	19%

So far in the analysis, I have not controlled for the effects of environmental factors on technical efficiency. To control for the environmental factors, the 44 countries are divided into high and middle income countries. Due to the division, two separate DEA models are estimated.

Table 7, I provide summary statistics of the efficiency scores obtained under each division. After controlling for the environmental factors, the high-income countries achieve higher average efficiency scores as compared to the middle-income countries. The average VRS technical efficiency of the high-income countries, for example, is 91% as compared to 88% for the middle-income countries. The high-income countries are also more scale efficient with a score of 90%, while the middle-income countries' score is 76%. Among the high-income countries, United States is the least technically efficient country based on the VRS assumption (Table 8).

Table 8, there are seven countries with the VRS efficiency score of one, namely, Australia, Bahrain, Cyprus, Czech Republic, Hong Kong, Hungary and Israel (Table 8). These countries form the VRS frontier against which the performance of other countries is evaluated.

In Table 9, the efficiency scores of the middle-income countries together with their rankings are shown. Ghana has the lowest CRS and VRS efficiency scores and thus ranked 23rd. Four countries are technically efficient under the VRS assumption, namely, Armenia, Lebanon, Georgia and Lithuania. Among the four efficient countries, the number of times each of them acts as a peer (exemplar) is also identified.[6] The objective of the exercise is to discriminate between superior and inferior peers among the identified efficient countries. Lithuania, for example, appears 17 times as a peer to the other countries (including Malaysia) with relatively the same level of inputs. Armenia, on the other hand, appears 11 times as a peer to the other countries. Although Lebanon and Georgia have VRS efficiency scores of one, the number of peer count for these countries is zero. They form part of the VRS frontier but do not stand as a peer to the other countries. The reason for the situation is because the positions of

TABLE 7. Summary Statistics of DEA Efficiency based on the Division of the DMUs into the High and Middle Income Countries

Statistics	High-income Countries (J = 21)			Middle-income Countries (J = 23)		
	CRS	VRS	Scale	CRS	VRS	Scale
Average	0.82	0.91	0.90	0.68	0.88	0.76
Std dev	0.12	0.10	0.07	0.19	0.10	0.16
Min	0.59	0.63	0.71	0.35	0.61	0.51
Max	1.00	1.00	1.00	1.00	1.00	1.00

TABLE 8. Efficiency Scores and Rankings of the High-income Countries

DMUs	CRS	VRS	Scale	RTS	CRS Ranking	VRS Ranking
Australia	1.00	1.00	1.00	-	1	1
Bahrain	1.00	1.00	1.00	-	2	2
Cyprus	1.00	1.00	1.00	-	3	3
Czech Republic	0.93	1.00	0.93	drs	4	4
Hong Kong SAR, China	0.93	1.00	0.93	irs	5	5
Hungary	0.80	1.00	0.80	drs	12	6
Israel	0.89	1.00	0.89	drs	7	7
Italy	0.86	0.98	0.88	drs	9	8
Japan	0.86	0.96	0.90	drs	10	9
Korea, Rep.	0.87	0.95	0.91	drs	8	10
Kuwait	0.77	0.93	0.82	drs	15	11
Malta	0.66	0.93	0.71	drs	19	12
Norway	0.91	0.92	0.99	drs	6	13
Oman	0.83	0.92	0.91	drs	11	14
Qatar	0.80	0.91	0.88	drs	13	15
Russian Federation	0.80	0.87	0.91	drs	14	16
Saudi Arabia	0.73	0.85	0.86	drs	16	17
Singapore	0.72	0.78	0.92	drs	17	18
Slovenia	0.71	0.76	0.94	drs	18	19
Sweden	0.59	0.74	0.80	drs	21	20
United States	0.60	0.63	0.95	irs	20	21

TABLE 9. Efficiency Scores and Rankings of the Middle-income Countries

DMUs	Status	CRS	VRS	Scale	RTS	CRS Ranking	VRS Ranking
Algeria	UM	0.58	0.80	0.732	drs	17	19
Armenia	LM	1.00	1.00	1	-	1	1
Botswana	UM	0.41	0.72	0.568	drs	22	22
Bulgaria	UM	0.71	0.93	0.762	drs	10	11
Colombia	UM	0.63	0.82	0.762	drs	15	17
Egypt, Arab Rep.	LM	0.68	0.82	0.832	drs	12	18
El Salvador	LM	0.79	0.79	1	-	6	20
Georgia	LM	0.96	1.00	0.959	irs	4	3
Ghana	LM	0.35	0.61	0.565	drs	23	23
Indonesia	LM	0.75	0.86	0.873	drs	7	15
Iran	UM	0.51	0.88	0.58	drs	19	13
Jordan	UM	0.60	0.93	0.646	drs	16	10
Lebanon	UM	1.00	1.00	1	-	2	2
Lithuania	UM	0.87	1.00	0.874	drs	5	4
Malaysia	UM	0.64	0.94	0.686	drs	14	7
Morocco	LM	0.42	0.78	0.541	drs	21	21
Romania	UM	0.65	0.91	0.707	drs	13	12
Serbia	UM	0.70	0.96	0.727	drs	11	6
Syria	LM	0.57	0.87	0.651	drs	18	14
Thailand	UM	0.72	0.93	0.778	drs	9	9
Tunisia	UM	0.44	0.86	0.511	drs	20	16
Turkey	UM	0.96	0.97	0.995	irs	3	5
Ukraine	UM	0.73	0.93	0.781	drs	8	8

Note: UM denotes upper-middle income and LM denotes lower-middle income these countries are at the lower end (Figure 1) of the frontier) and no other countries are relatively comparable to them in terms of inputs. Although they form parts of the frontier, an exclusion of them from the sample will not affect the efficiency scores of the other countries.

In order to evaluate the performance of Malaysia, Table 9 is now referred. In the table, efficiency scores of each of the middle-income countries are presented. As shown in the table, Malaysia is ranked 14th (CRS efficiency of 64%) based on the CRS technical efficiency and 7th (VRS efficiency of 94%) based on the VRS efficiency. From the estimated VRS-DEA frontier, Malaysia is found to be in the state of decreasing returns to scale (DRS). In other words, for the case of Malaysia, a proportional change in the inputs of education results in less than a proportional change in the outputs of education.

Malaysia needs to improve its efficiency. For that matter, Malaysia may learn from its peers, namely, Lithuania (peer weight = 0.88) and Armenia (peer weight = 0.11). Since Lithuania's peer weight is larger than Armenia's, Malaysia should learn more from Lithuania. Had Malaysia been technically efficient, given its level of educational inputs (secondary educational expenditure as a percentage of GDP of 4.5% and student-teacher ratio of 15 for the secondary schools), the country should have scored 505 in mathematics and 515 in science. Those are the projected outputs for Malaysia in order to improve its technical efficiency (refer to Table 10).

TABLE 10. Projected Outputs for Malaysia (DMUs = 23 middle-income countries)

Outputs	Original value	Projected value	% Difference
Mathematics	474	505	6.5%
Science	471	515	9.3%

CONCLUSION

From the analysis conducted based on DEA, Malaysia was technically inefficient in terms of utilising its educational resources to achieve better TIMSS results in comparison with other countries. The CRS efficiency for Malaysia was 62% and the VRS efficiency was 84%. Even after controlling for the environmental variable, Malaysia's secondary education remains technically inefficient, where the CRS efficiency was 64% and the VRS efficiency was 94%. The findings suggest that had Malaysia been technically efficient, it should have achieved better TIMSS results. To improve its level of technical efficiency, Malaysia may learn from the peer countries, namely Japan, Singapore and Lithuania.

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