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RESEARCH ARTICLE

Determinants of Primary School Efficiency in Morocco: Application of Data Envelopment Analysis to TIMSS database

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ABSTRACT

This article aims to analyse the efficiency of primary education schools in Morocco using the database "Trends in International Mathematics and Science Study" (TIMSS) in the fourth year of primary education compiled in 2019 by the International Association for the Evaluation of Educational Achievement (IEA). We used the methodology of Data Envelopment Analysis 'DEA' to determine the efficiency scores for each school. Also, the analysis of external factors that impact the efficiency scores is carried out using the Tobit econometric model. Particular attention is paid to the characteristics of the student and parents. The results of the DEA show that the average score efficiency is 60%, and the number of efficient schools is 17 schools which represent 6,44% of the total of schools. Moreover, the model Tobit confirms the hypothesis that the socioeconomic environment of the student has a significant impact on the efficiency of primary schools in Morocco.

1. INTRODUCTION

No one denies that education plays a significant role in creating responsible, productive, and creative human capital. Also, education is fundamental to social justice (**El Alaoui, 2022**) and is the linchpin of economic and social development (**El Bouhali & El Alaoui, 2022**). Today debates about the efficiency of educational systems give rise to conflicts and uneasy interactions between proponents and opponents of educational reform in industrialized societies and developing countries, emerging or transitioning.

Indeed, many research works related to educational economics agree on the important role of schools as a locomotive for the socio-economic development of any country. School is the first contact with the outside world, enabling children to acquire and develop knowledge, skills, and attitudes, whatever their social background. to this end, empirical studies have analyzed the link between school performance and the socioeconomic conditions of pupils.

In the 1950s, initial evaluations of the school's efficiency-focused solely on quantitative measures. Education officials place great importance on access to education and are always looking to improve enrolment rates and prevent school dropouts. Until the 1990s, the authorities began to give importance to qualitative indicators.

The following article has two objectives in this respect: firstly, it attempts to measure the efficiency of Moroccan primary schools using the Data Envelopment Analysis (DEA) method; secondly, it tries to investigate how school, teacher and student factors affect the efficiency scores using the Tobit model.

The efficiency concept and the numerous contributions will be examined first in order to appropriately conduct our research. Next, the methodology for analysis and the database used will be discussed. Then, the results and discussion will be presented, and the final section concludes.

2. THEORETICAL AND EMPIRICAL REVIEW

The DEA method was originally developed by (Charnes et al., 1978), building on the contributions of (Farrell, 1957). Its first applications to the school context were aimed at determining the optimal combination of school time and programs. The application of DEA in education is quiet difficult because it is challenging to identify stable parameters for the school production function (Bessent et al., 1983).

(Bessent et al., 1983) assert that DEA can help educational decision-makers make informed decisions about which program proposals to fund or implement by providing a quantitative method for evaluating the efficiency and effectiveness of different proposals.

(Sengupta & Sfeir, 1988) used DEA to evaluate the efficiency of 25 Californian districts. They used variables such as average teacher remuneration, the ratio of Anglo-American students, average classroom occupancy, a socioeconomic indicator of parents' background, and test results / scores. They found that DEA is robust in situations where combinations of outputs and inputs are concentrated around the mean with normal error distributions.

In order to implement this idea in the education system, schools must be viewed as businesses / companies focusing on education output (Schultz, 1963). These companies are therefore seen as components of a productive process (education) that converts inputs (resources) into outputs (human capital). Schools produce graduates and teachers who motivate students to make a positive impact on the world as identified (Saultz & Saultz, 2017).

2.1 Fundamental ideas of efficiency

The company's production is linked to the efficiency strategy. A production system must be able to minimise inputs for a given quantity of outputs, and maximise outputs from a given quantity of inputs to be considered efficient. Many authors such as **(Debreu & Gérard, 1951; Farrell, 1957; Koopmans, 1951)** introduced the concept of efficiency in their analysis.

Koopman defined efficiency in technical terms. Technical production efficiency is defined as the ability to increase or decrease the output and/or input of one unit without affecting the other unit's output or input levels.

Conversely, the first technical efficiency metric, the "coefficient of resource utilisation," was introduced by **(Debreu & Gérard, 1951)**, who defined efficiency as the difference between the total amount of realised inputs and outputs and the highest possible level. However, it was **(Farrell, 1957)** who dissociated dissociating the technical efficiency from the allocative efficiency. Technical efficiency results from the ability to avoid wasteful production, as defined by **(Coleman & al, 1966; Koopmans, 1951)**. The manufacturing unit's capacity to use its inputs in the best possible ratios given their pricing, is called *allocative efficiency*. Total economic efficiency is thus determined by the combination of these two efficiency levels.

2.2 Review of literature on the efficiency of schools

(Coleman & al, 1966) are among the first studies to use the input-output theory and a function of education production. He was the first to establish a connection between the contributions made by the school and the student performances. This study's key contribution is its illustration of how social factors in the realm of education affect students' academic achievement.

Many studies now use the function of educational output to assess the effectiveness of elementary schools, including those conducted by **(Cordero et al., 2017; Liouaeddine et al., 2018; El Bouhali & El Alaoui, 2023)**. This approach is also used to evaluate the effectiveness of academic institutions, as demonstrated by the research **(Abbott & Doucouliagos, 2003)**.

Empirical studies show that a student's traits affect his academic achievement based on variables related to students and their parents. Indeed, several studies lean on the gender effect, some researchers have concluded that boys succeed better than girls.

The socioeconomic status (SES) level of students is a vital factor that positively and significantly impacts academic success and, consequently, school efficiency. The parent's attributes, such as their educational attainment and socioeconomic standing, may be inferred from the indicators. According to **(Hoff, 2003),** children with high socioeconomic level mothers perform better on tests than other kids their age. According to (**Memon et al., 2016**), parents' educational levels have a significant impact on their children's likelihood of passing pre-medical entrance tests.

When it comes to primary school, the SES level of the students is the greatest explanatory variable about the scores that the kids receive on standard tests **(Deller & Rudnicki, 1993)**. This variable is related to school efficiency, as demonstrated by **(Meunier, 2007)** using PISA 2000 data from 156 Swiss schools.

Preschool education has benefits for the rest of a student's academic career, according to research from **(Benbiga et al., 2012; Liouaeddine et al., 2017, 2018; Mostafa & Green, 2013)** who found that students who had at least one year of preschool education performed better on performance tests than students who had not received any preschool instruction. This outcome may be explained by the way early education gets kids ready for academic learning in schools. The advantages for pupils increase with the length of the preschool program.

The effect of preschool education can be seen in the repetition of grades. On the impact of this variable on students' learning and motivation in the classroom, several studies have shown consistency. According to **(Benbiga et al., 2012; Holmes & Matthews, 1984)**, repeating grade results in significantly worse performance for kids than not repeating it. Grade repetition has a positive impact on students' academic achievement in Florida, according to **(Greene & Winters, 2007)**. One year after these kids repeated their grades, their performance is compared to that of less proficient kids who progressed a grade rather than repeating.

Unrelated factors have been looked at, particularly family backgrounds, which are crucial for comprehending the variations in school performance levels. In general, children do better on standardized tests when their parents have higher levels of education, regardless of the methodology used by the researchers to measure this relationship. There is broad agreement on this aspect. Among this research, **(Coleman & al, 1966)** demonstrate that regardless of a student's social background, the level of education of the instructor is a key source of variation in the student's performance on standardised examinations. Numerous other research studies, especially the work of **(Benbiga et al., 2012)**, further support this truth.

It exists an abundance of literature that discusses the effects of educators' attributes, such as their degree of education and experience, on the academic achievement of their pupils and the effectiveness of their schools. Despite this, there remains disagreement regarding them. According to **(Coleman & al, 1966)**, there isn't enough solid data to support the idea that a teacher's education or experience level improves a school's effectiveness. Recent studies, such as those by **(Hanushek & Woessmann, 2017)**, have discovered, however, that effective instructors have an impact on student's academic attainment and, consequently, on the school system's effectiveness. Numerous research supports the idea that instructors' training and experience have an impact. **(Diagne, 2006; Liouaeddine et al., 2018; Meunier, 2007)** have noted a favourable correlation between teacher qualities and academic success in schools.

Regarding the impact of the school’s variables, there is disagreement over the relationship between the size of the class and the effectiveness of the school when it comes to the influence of the school's variables. According to certain research, smaller classes benefit some kids, particularly those in primary school and those from socioeconomically challenged backgrounds **(Altinok & Kingdon, 2009; El Bouhali & El Alaoui, 2022)**.

Indeed, **(Kirjavainen & Loikkanent, 1998)** compared the effectiveness of 291 high schools from which students had graduated and found that, on average, inefficiency increased with class size; at 11 students per class, the school's inefficiency decreased, and at 27 students per class, the inefficiency increased again. Similarly, **(Fredriksson et al., 2013)** proved that smaller class sizes quickly improve students' noncognitive and cognitive abilities. Furthermore, **(Hanushek & Woessmann, 2017)** suggest that it is only in schools with low teacher quality that class size has a

significant impact. However, **(Hanushek, 1997, 2003)** continue to distinguish between any recurring pattern and a strong correlation between average class size and academic achievement.

Using the Moroccan TIMSS and PIRLS database (2011), some Moroccan researchers have found that a large student population affects the academic performance of Moroccan students, particularly in scientific disciplines, and consequently on the effectiveness of the school system **(Liouaeddine et al., 2017, 2018**). However, the standard linear regression modelling has limitations because it does not resolve the endogeneity of the variable "Class Size". The study of **(El Bouhali & El Alaoui, 2022**) suggests using the instrumental variable to represent this interaction. The primary results indicate that the second strategy has greater advantages compared to the first.

In addition, Research on the impact of the location of the school on this issue is mixed. According to many authors **(Bradley et al.,2001; Benbiga et al., 2012; Liouaeddine et al., 2017, 2018; Meunier, 2007**), urban schools are more effective than rural schools. Nonetheless, (**Kirjavainen & Loikkanent, 1998**) demonstrated that schools in rural areas are more effective than those in metropolitan areas.

3. METHODOLOGY AND DATA

3.1 The DEA model

The contributions of (Farrell, 1957) have influenced much research on the frontier of efficient production. Initially, the DEA was used to assess the technological efficiency of organisations whose production technology was not well established, particularly in educational institutions. The economic assumptions of the DEA method include the convexity of the combination and the free disposal of inputs and outputs.

DEA is a non-parametric method of the comparative analysis, the aim of which is to compare production units (decision units) according to the resources (inputs) they use to produce products (outputs). Decision units that use fewer inputs to produce more outputs form the benchmark (the efficiency frontier). The decision unit whose bridge is on the frontier has an efficiency score of one and is therefore considered efficient. The decision unit with a bridge above the frontier will have a score below 1 and will be inefficient. This non-parametric method is suitable when there are many inputs and outputs.

There are two models: According to the first, companies develop in an environment of continuous returns to scale (CRS). When all organisations have grown to their ideal size, it is right. According to the second model, organisations develop in an environment where there are Varying Returns to Scale (VRS). If an organisation is not operating at its ideal size, it makes sense.

Note that the DEA model can be either input or output oriented. In an input-oriented model, inputs are minimised for a given level of outputs, whereas in an output-oriented model, outputs are maximised for a given level of inputs.

Since our database contains inputs and outputs formulated in the form of reports, it is necessary to use a model with Variable Returns to Scale (VRS). The equation of this model is as follows:

$$min\theta_k - \varepsilon\left[\sum_{r=1}^{s} S_{ik}^{+} + S_{ik}^{-}\right]$$

under the restrictions:

$$\begin{cases} 1 - \sum_{j=1}^{n} X_{ij}\lambda_j + S_{ik}^{-} = \theta_k X_{ik} \\ 2 - \sum_{j=1}^{n} y_{ij}\lambda_j - S_{ik}^{+} = y_{rk} \\ 3 - \lambda_j (j = 1, \dots\dots\dots, n), S_{ik}^{+} (r = 1, \dots\dots., s), S_{ik}^{-} (i = 1, \dots\dots., m) \geq 0 \end{cases}$$

With:

- y_j and x_j are the r-vectors and the s-vectors of outputs and inputs for the school k;
- Each school's s × n matrix of outputs and m × n matrix of inputs is represented by the matrices y and x;
- The parameter θk shows the percentage amount that we may subtract from the inputs of school k proportionately. Therefore, for this school to do the finest activity, it must be minimized on their part. The school is considered efficient and situated on the frontier when θk = 1;
- All of the efficient schools that serve as a reference for the school k have their weights determined by the n-vector λj;
- The nonnegative slack variables Sr+ and Si− represent an excess of input and a deficiency of output, respectively.

This study attempts to examine the efficiency of primary schools using the 2019 TIMSS (Trends in International Mathematics and Science Study) database applied to the Morocco context.

3.2 Data and DEA model

This study uses the TIMSS 2019 database of Moroccan fourth graders. This database is linked to an international study conducted by the International Association for the Evaluation of Educational Achievement (IEA). The main aim of this study is to evaluate different education systems around the world using a standardised test based on an assessment of students' learning in mathematics and science. In addition, the TIMSS survey is based on contextual questionnaires (about students, teachers, homes/parents and schools), subject tests and academic progress as measured by test scores. Parents and pupils answer questions about their family situation, demographics and school environment. Teachers also answer questions about their teaching methods, training, class size, etc. Questions about school resources and teacher absenteeism are also answered by the headteachers. They also answer questions about the school's environment, including the socio-economic status of the pupils and the characteristics of the surrounding community. A wide range of factors are therefore covered by this research.

Our study included 7723 Moroccan fourth graders from 264 different primary schools, taught by 528 different teachers. According to IEA requirements, this sample is representative of fourth grade students.

On the basis of this database, our analysis selected the most important and most frequently occurring variables from the current literature. The table 1 provides a summary of the selected inputs and outputs of the study.

Table 1: Combinations of inputs and outputs of the DEA model

	Inputs	**Outputs**
DEA model	• Absenteeism • School-parent relationship • Library • Teachers' experience • Proportion of teachers has master or doctorate • Class size	• Scores in mathematics • Scores in science

Source: Prepared by authors.

4. RESULTS

4.1 Results of the efficiency of the DEA

Based on the DEA model's output, the average score efficiency is 60%. The difference between this average and the max score (100%) calculates the proportionate drop in inputs that doesn't affect output levels. Schools may also retain the same level of output while reducing their inputs by 40%. Also, 17 schools are efficient, which represent 6.44% of the total of schools.

Table 2: Synthesis of results for the DEA model

DEA	
Average	0.60
Minimum	0.20
Number of efficient schools	17
Percentage of efficient schools	6.44%

Source: Prepared by authors.

According to the school efficiency analysis, urban schools typically have an efficiency score of 60%. However, the average in a rural area is 61%. We found that rural schools have higher average efficiency scores than urban schools; this is because more teachers in rural schools have master's degrees or licenses than in urban schools.

Table 3: Efficiency scores according to the location

Efficiency scores according to the location	**Urban**	**Rural**
Average	0.59	0.61
Minimum	0.23	0.20
Number of schools	164	100
Number of efficient schools	9	8
Percentage of efficient schools	5.49%	8%

Source: Prepared by authors.

4.2 Results of the econometric modelling

Based on the efficiency scores obtained using the DEA model, the variables that determine primary school efficiency are examined in the following.

4.2.1 The model Tobit

The aim of this econometric modelling is to explain the efficiency scores of schools. Due to the censoring of this variable, the Tobit model is used (Tobin, 1958). Tobit fits a linear regression model to a continuous outcome that has been censored. Below is the equation for the generic Tobit regression model:

$$\begin{cases} Y_t = X_t\beta + \mu_t \; If \; X_t\beta + \mu_t > 0 \\ 0 \; If \; X_t\beta + \mu_t \leq 0 \\ t = 1, 2, 3, \dots \dots, N, \end{cases}$$

where the independent distribution error μ_t is assumed to be a normal distribution with an average of zero, the dependent variable Y_t, the independent variable vector X_t, and the unknown coefficients β.

The following definitions apply to this study's efficiency score:

$$DEA = \alpha + \beta_i X_t + \mu_t$$

where DEA is the efficiency, $X_i$is the matrix of the independent variables, $\beta_i$is the coefficients to estimate, and μ_t is the independent distribution error assumed to be a normal distribution with an average of zero.

4.2.2 Results

The result of this estimation shows that the value of R2 is 0.1165. Thus, the model is able to explain 12% of the variability of the efficiency scores, the dependent variable. Given the nature of the individual data, this is satisfactory, even if it is low.

The calculated coefficients are generally non-zero according to the Chi-square statistic (938.12) and the probability (P = 0.000).

Table 4: Tobit model summary

Log likelihood	-41.08
LR chi2(6)	56.78
Prob > chi2	0.00*
Pseudo R2	0.12

* the significance level is 5%.

Source: Prepared by authors

To examine the impact of each exogenous variable on the performance of Moroccan primary schools. On the basis of these results, we will examine in the following sections the weight of the exogenous variables, as well as the consequences of increasing a single unit of a particular variable independently on the efficiency ratings of Moroccan primary schools.

5. DISCUSSION

This section discusses the main findings in relation to the characteristics of pupils and their parents, and the characteristics of schools and teachers.

5.1 The characteristics of pupils and their parents

The gender factor does not seem to affect the efficiency of schools. According to Table 5, efficiency scores are not significantly affected by the number of girls in the class (Sig=0.306). This result is consistent with that of (**Liouaeddine et al., 2018**).

The estimator shows that the educational level of the parents has a significant impact on the dependent variable. The model shows that the efficiency scores increase as the level of the parents increases. In fact, parents with primary education outperform parents who did not attend school by 0.6%. In addition, in schools where the parents' educational level is secondary or higher, the scores also increase by almost 4%. This suggests that more educated parents may be able to help their children with their schoolwork and provide an environment conducive to learning. Educated parents are also more likely to recognise the importance of education for their children.

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Table *5:* Results of the estimates

Variables	**Coefficient**	**t**	**Signification**
Education level of the parents			
• **Primary**	0.006	1.19	0.234

education	0.043	6.06	0.000
• **Secondary**	0.040	5.28	0.000
• **higher**	Ref		
• **Did not go to school**			
Preschool			
• **Yes**	0.023	4.49	0.000
• **No**	Ref		
Percentage of students Come from economically disadvantaged homes			
• **Less than 10%**	Ref		
• **Between 11% and 25%**	-0.088	-9.93	0.000
• **Between 26% and 50%**	-0.132	-15.82	0.000
• **More than 50%**	-0.165	-21.21	0.000
Percentage of students Come from economically affluent homes			
• **Less than 10%**	Ref		
• **Between 11% and 25%**	0.061	7.01	0.000
• **Between 26% and 50%**	0.019	2.18	0.029
• **More than 50%**	-0.040	-5.74	0.000
Teachers' experience			
• **Less than 5 years**	Ref		
• **Between 5 and 10 years**	0,008	0.93	0.355
• **Between 10 and 20 years**	0,038	5.45	0.000
• **More than 20 years**	0,018	2.84	0.004
School's location			
Urban	Reference		
Rural	-0.033	-5.94	0.000
Proportions of girls in the class	0.026	1.02	0.306
Class size	0.00005	4.73	0.000
the constant	0.655	40.48	0.000
Number of observations	264		

Source: Prepared by authors

5.2 The characteristics of schools and teachers

The model predicts that the socio-economic status of pupils increases the effectiveness of schools. The higher the proportion of economically disadvantaged pupils, the lower the efficiency score. Conversely, the greater the proportion of pupils from economically affluent parents, the more effective the schools are as measured by test scores. For example, students from affluent households are forced to attend the same school because of their parents' location and social status, which has a positive peer effect. Conversely, in Morocco, couples from disadvantaged backgrounds typically send their children to public schools, adhere to school maps, and locate them in underprivileged regions with other children from similar backgrounds, which could lead to a negative peer effect. As a result, the level of efficiency is influenced by the composition of the student body.

This result is consistent with empirical studies, mainly by **(Coleman & al, 1966; Deller & Rudnicki, 1993; Hanushek, 2003; Hoxby, 2000; Liouaeddine et al., 2017, 2018; Masci et al., 2018; Meunier, 2007; Tsakiridou & Stergiou, 2015**), who confirms the beneficial effects of schools' social structure on students' academic performance and, consequently, on efficiency.

We observe that the variable of teacher experience has an impact on the effectiveness of schools. According to Table 5, schools employing teachers with more than ten years' experience are more

likely to be effective than those employing teachers with less than ten years' experience. In fact, scores improve by 3.8% and 1.8%, respectively, depending on the level of teacher experience (between 10 and 20 years and over 20 years). This finding is consistent with the research of **(Chakraborty & Harper, 2017)**, who found that teaching experience improves the efficiency of primary schools in Australia. On the other hand, the findings are inconsistent with those of **(Coleman & al, 1966; Liouaeddine et al., 2018)** who found little evidence to support the impact of teacher experience. Furthermore, **(Summers & Wolfe, 1977)** demonstrate that the impact of teaching effectiveness on students outcomes is not uniform and depends on educational attainment. However, **(Murnane & Phillips, 1981)** find no relationship between these two factors.

Additionally, the level of efficiency appears to be influenced by the location of the school. This finding is consistent with a study conducted in Greek primary schools by **(Tsakiridou & Stergiou, 2015),** which found that urban educational institutions appear to be more efficient than semiurban and rural educational institutions. Also, the findings of this study differ from those of **(Liouaeddine et al., 2018)**, who hypothesised that there is no relationship between urban and rural schools.

6. CONCLUSION

The main objective of this paper was to assess the technical efficiency of Moroccan primary schools using the non-parametric DEA model and to examine the impact of student, teacher and school characteristics on the efficiency scores.

The empirical results show that the operation of these academic institutions is characterised by a significant level of technological efficiency. The average efficiency score is 60%. In other words, the schools studied were able to save 40% of the resources used while maintaining the same level of performance. In addition, there are 17 efficient schools, or 6.44% of all schools, which is a high number. According to the research by location, rural schools had better average efficiency scores than urban schools. In addition, the socio-economic background of the pupils, the educational level of the parents and the experience of the teachers seem to have a significant impact on the variation in efficiency scores.

However, these results should be interpreted with caution. The study has a number of limitations, some of which are related to the data used. An example of a limitation in this study is the use of qualitative elements in calculating the efficiency scores. More financial data, especially the budget allocated to each school or district, would have been preferable, but we do not have access to such data. In addition, exploring these boundaries may lead to entirely new contributions to scholarship. They offer opportunities for future studies.

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