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Managerial practices and school efficiency: a data envelopment analysis across OECD and MENA countries using TIMSS 2019 data

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Abstract

School-level inefficiencies and mismanagement can have serious repercussions for human resource development and labor market outcomes. This paper investigates the extent and consequences of existing technical inefficiency of schools with respect to their resource- and people-management aspects at a cross-country level across Organisation for Economic Cooperation and Development (OECD) and the Middle East and North Africa (MENA) regions. It employs a non-radial Data Envelopment Analysis (DEA) alongside a second stage Tobit regression model using datasets in the latest Trends in International Mathematics and Science Study (TIMSS) 2019. The analysis covers 5164 schools across 26 countries. In the first stage of DEA analysis, it is evident that technical inefficiencies exist similarly across schools of both OECD and MENA nations, irrespective of the method used for efficiency calculation. While availability of educational resources is a necessary condition for improving learning outcomes, it is surely not sufficient. In the second stage of the Tobit regression, the model confirms that improved utilization of the existing resources through better educational management systems can yield higher cognitive achievement at the school-level. The empirical findings also reveal that discipline maintained within the student body at school is one of the most important and significant factors associated with higher school level input- and output-efficiency across both MENA and OECD regions. Moreover, different aspects of people management, particularly target setting, student as well as teacher motivation, and parental involvement in school management are found to be positively associated with school-level technical efficiency across the two regions, albeit in varying degrees. Overall, educational management policies should shift focus from solely providing higher quantity of resources to improving the technical efficiency of schools through enhanced school-level management, by encouraging disciplinary action, as well as by supporting stakeholder incentives that foster motivation and participation.

Keywords: School management, Data envelopment analysis, Tobit regression, OECD, MENA, TIMSS 2019

Introduction

The efficiency of a nation's education system impacts its human resource development and labor market outcomes. Efficient educational institutions are those that are able to use their inputs optimally to achieve maximum possible outputs. If the output is fixed, efficiency refers to minimizing the use of inputs to achieve the output. While improvements in the level of school inputs over time (such as school's physical infrastructure, budget, or number of teaching staff) have significantly increased enrollment rates at different levels of education, these investments have not necessarily translated into a proportionate increase in outputs such as student learning outcomes (World Development Report, 2018). As a result, in recent years, focus has shifted from the amount of inputs to 'how' the inputs are actually utilized and managed by institutions. In this context, the managerial capability of schools should play a critical role. The objective of this paper is to explore the existing state of school-level efficiencies across countries and to analyze the extent to which school management practices have an impact on these efficiencies.

School-level technical efficiency

Over the years, the literature on efficiency within the education sector has grown. Witte and Lopez-Torres (2015) reviewed 223 papers in the context of education to examine the technical efficiency of educational provision. They laid out an overview of input and output variables that contribute to school-level efficiency. The authors found that improvements in inputs such as student attendance rate, expenditures, student–teacher ratio, parental visit index, teacher experience and management skills contribute to the efficient functioning of schools, when that is measured using output variables like number of school pass-outs and test-scores of students. The study also reported that most of the research on school-level technical efficiency has used primary datasets that are restricted to particular contexts. Overall, cross-country comparisons of school-level efficiency has remained limited with a handful of studies analyzing efficiency using large-scale international datasets such as Program for International Student Assessment (PISA). Of these, Afonso and Aubyn (2006) examined the efficiency of educational expenditure across 25 countries and showed that the per-capita Gross Domestic Product (GDP) and adult educational attainment contribute significantly towards the efficiency of educational systems. Agasisti (2014) observed that teachers' salaries and internet-use positively contribute towards improving efficiency in schools. It is to be noted that "efficiency" here reflects the efficacy of school-level inputs in terms of improving learning outcomes—making it a school-level variable, setting it apart from learning efficiency which is an individual-level variable that lacks standardization. Thieme et al., (2012) examined the physical resources employed in the production of educational services while comparing the efficiency of national educational systems of 54 participating countries in the PISA (2006) study. This study found that both endowment and efficient usage of educational resources have a significant impact on learning outcomes across countries. To reinforce this conclusion, the study considered multidimensional characteristics of the education system and found that while unavoidable natural factors can result in an average deterioration of 2.9 percent of learning outcomes, endowment of educational resources and an efficient management system have much higher average repercussions of 7.1 and 7.8 percent respectively. Giminez et al., (2007) examined the efficiency of educational systems in 31 countries and observed the tendency of countries with a communist past to have a more efficient system. Here also, technical efficiency of a specific system was defined as the maximum academic performance derived from limited amount of available educational resources. Aparicio et al., (2018) utilized PISA 2012 data from OECD countries to determine the existence of trade-offs between outputs such as reading and mathematics test scores. This paper found that, in general, global trends indicate a higher level of efficiency in schools to achieve reading competency rather than mathematics. Delprato and Antequera (2021) showed that the efficiency of schools within low- and middle-income countries (LMIC) could be increased by reducing the within-country disparity of students' disadvantages.

The afore-mentioned body of literature only bolsters the argument that an education system is vastly multidimensional and versatile in nature which cannot be restricted within generalized definitions. While these papers have compared various inputs and outcomes at country-level in order to understand what increases educational efficiency, they have often overlooked and not factored for school-level heterogeneities. Unobserved heterogeneities across different schools could significantly affect school-level achievement and ignoring these heterogeneities could lead to biased estimates.

School management

Economics of education research uses a traditional Education Production Function (EPF) to analyze school-level heterogeneities and to define the relationship between inputs and outputs of a school. It is important to elucidate here that generalized definitions of inputs and outputs used in an EPF will not be able to give contextual support to the wide range of research questions catering to different components of the education system. Nevertheless, for the purpose of this study, the education system is viewed in a perspective where the definition of output, albeit the 'learning output' of schools, is contextually straitjacketed in the regime of learning outcomes which in turn contribute towards economic growth e.g., average achievement of students in school measured by test scores; rest of the variables (most specifically availability of resources and efficiency of their usage) are to be considered as inputs. Typically, with international large scale assessment data, student achievement measured through math, science, or reading scores is considered as the output while other factors at country-, school-, student-levels are considered as inputs. Specifically, school-level policy-levers and inputs that are used in the production of education include school infrastructure, class size, teacher–pupil ratio, teacher qualifications, type of school ownership, per-pupil expenditure incurred by schools, amongst others (Hanushek, 2003). Here, the level of inputs and resources employed at schools are influenced by supply-side policy decisions and parental demand and expectations from the school.

On the supply-side, the literature on school-level efficiency has found that only improving the levels of physical resources available to schools has limited impact on student performance (Angrist et al., 2013; Dobbie & Fryer, 2013; Hanushek & Woessmann, 2011). In a world struggling with limited resources, focus on the "quantity of school resources" being employed often fails to explain the variation in the "quality of the inputs" or the efficiency of their use (Hanushek, 2003). Here, proper school-level management can help optimize the use of resources, promote accountability, and improve school-level learning outcomes, while accommodating for different institutional contexts and requirements (Angrist et al., 2013; Bloom et al., 2015; Dobbie & Fryer, 2013).

School management can be defined as the process of running a school by optimally using available resources and facilitating proper coordination between them in order to promote effective learning of the students at school. School management literature originally derives from the research on managerial practices in firms and manufacturing units and their association with productivity (Bloom et al., 2012). However, compared to the research literature related to the management of firms and business organizations, the discussion on school management in the education sector is limited. So far, school management has been measured in varied ways across different academic papers and disciplines. For instance, Bloom et al. (2015) developed an international management index for schools in four areas: monitoring, operations, people and target-setting. Leaver et al., (2019) also developed a school management index using OECD's PISA dataset. PISA-based people management scores of a school included aspects related to teacher employment alongside the intrinsic motivation and effort exerted by them. Involvement of parents is also considered to be an indicator contributing to good school management.

International Association for the Evaluation of Educational Achievement (IEA)—TIMSS dataset is an international large-scale student assessment that includes school-, teacher-, and student-level data that can be collectively used for understanding the extent of resource and people management in schools. A study behind creating the TIMSS background indices by Martin and Preuschoff (2007) discussed how the availability and efficiency of use of resources in the teaching of specific subjects, like math and science could be considered as an indicator of good school-level operations. In this, TIMSS uses two indices to measure the extent of availability of resources for math and science teaching: (i) Availability of school resources for mathematics instruction (ASRMI); (ii) Availability of school resources for science instruction (ASRSI). Availability of calculators, relevant library materials, computers, computer software, audio-visual resources for mathematics and science instructions, budget for supplies, instructional spaces, and materials, alongside school buildings were the main variables that were considered while calculating the aforementioned indices. Further, the TIMSS dataset includes aspects like years of experience of a school principal and target-setting by educational stakeholders, which can also be considered as important indicators of school-management (Bouchamma et al., 2014; Coelli and Green, 2012). For instance, Coelli and Green (2012) point out that it may take a number of years for a school leader or principal to have a measurable effect on the educational productivity and school-level efficiency. Furthermore, the TIMSS study also includes an index of the principal's perception of the school climate, which includes aspects like teachers' motivation, discipline, ability to implement their goals and instructions. Such aspects also contribute to understanding the extent of people management in schools.

School management and technical efficiency

Management policies and practices have been found to have significant consequences on school-level outcomes like student achievement. Bloom et al., (2015) reported that management quality is positively correlated with student achievement across all countries. Woessmann (2016) compared student achievement scores across multiple countries to present evidence that differences in the organization and governance of the school systems causes a considerable difference in student achievements. In the US, charter schools (public schools with more flexible school management) alongside schools with 'no excuses' policy emerged and have been researched for their emphasis on better school management practices. Alterations to management practices have been found to optimize instructional time, multi-stakeholder involvement, school discipline, and eventual math and reading achievement, improving school-level efficiency (Thernstrom & Thernstrom, 2004; Whitman, 2008). Some other studies find that schools which include robust managerial practices such as taking teacher feedback, monitoring student performance, encouraging inclusive classroom cultures, and focusing on strong administrative leadership and discipline are likely to be more efficient in achieving learning outcomes (Madden et al., 1976; Purkey & Smith, 1983; Thernstrom & Thernstrom, 2004). Such schools can employ the inclusivity of the stakeholders and use it as a feedback loop to further optimize their resource allocation and function with higher efficiency. Managerial practices may not only affect student learning outcomes directly but also indirectly, where poor processes such as lack of effective use of school resources, lack of motivation among teachers and staff, and indiscipline among teachers and students may lead to non-conducive learning environments (World Development Report, 2018). Overall, management of resources and people form an integral component of transforming inputs into optimal learning outcomes in schools and achieving technical efficiency.

It is important to note that overlapping areas of interest come forth when school management is talked about. This stems from the fact that education systems usually operate in many layers, including multiple dimensions of learning and instruction contributing to educational outcomes. In fact, keeping aside the obvious educational resources already named earlier, the effects of several geographical, cultural, socio-economic, and political attributes are woven into the very fabric of any such systems as well. Involvement of so many factors call for localization of any aforesaid optimization exercise to accommodate distinctive requirements of any individual group of learners and instructors as globalized solutions are bereft of the ability to accommodate such diversity. This is where the question of school autonomy also comes in. Beside pinpointing the unique management issues, autonomy also espouses accountability among school management bodies through decentralization, which pushes for higher efficiency.

This paper compares the 5164 schools within and across OECD and MENA countries to ascertain and analyze whether school management practices contribute towards school efficiency. To address this question, the paper first analyzes the technical efficiencies of schools in OECD and MENA countries. Next, it analyzes the association between different school management variables and the efficiency of schools, while controlling for other school-level factors. This enables us to understand whether different school management practices contribute towards differences in school efficiency and how these associations differ across OECD and MENA countries. The findings highlight the managerial aspects that limit schools from achieving higher learning outcomes.

Therefore, unlike examining the efficiency of the overall education systems of the countries, data clustered at the school- and national-level to examine the efficiency of schools situated in different countries has been used. Within this, we also identify variables within the TIMSS 2019 dataset that can be used to measure resource- and people-management across schools. Finally, the geographical scope of this paper is also unique as it compares the schools in OECD and MENA countries. Previous research on cross-country analysis using frontier methods has primarily focused on OECD or the European countries. However, the Human Capital Index 2018 has revealed large cognitive gaps in MENA countries. Even though the region's average spending on education is higher than the world average, its learning outcomes remain among the lowest (El-Kogali & Krafft, 2019). The MENA region also has the lowest share of human capital in total wealth globally (Lange et al., 2018) with implications for the labor market and economic outcomes in these countries. Thus far, only a few studies have analyzed the prevailing efficiencies in schools within the MENA group. Naturally, the question arises: in what ways do schools in MENA countries lag in comparison to their OECD counterparts? In particular, do school management practices contribute to this gap in the learning output of schools across OECD and MENA nations? If so, then which aspects of school management contribute more towards their school inefficiency? This paper addresses these questions by applying frontier methods in educational research while combining it with the literature on management practices in schools.

The current paper applies a two-stage methodology as outlined below:

> *Stage 1:* It measures the technical efficiencies of schools using a non-radial Data Envelopment Analysis (DEA) method.
> *Stage 2:* It regresses the technical efficiency of schools on school management variables using a Tobit regression.

In the following parts of this paper, the "Methods" Section details the methodology followed for this study, the "Results" Section describes the data and variables as well as reports the results, and the "Discussion and Conclusion" section outlines and summarizes the findings.

Methods

In the first stage of our methodology, we estimate the efficiency scores of schools using a non-radial Data Envelopment Analysis (DEA). DEA was developed by Charnes et al., (1978) as a non-parametric linear programming approach for measuring technical efficiency of schools. DEA is a methodology used to assess or quantify the technical efficiency of a DMU (Decision Making Unit i.e., school in the case of this paper). In this context, a school as a DMU is efficient if by using the given inputs, it can achieve the maximum possible output or if for a given level of output, it uses the minimum possible inputs.

A DEA study involves a matrix composed of the inputs, outputs and complementary elements of the sample of schools considered in this study. This matrix is formulated in the DEA model to calculate the relative efficiency scores of each school, using the observed data and a basic optimization model. A set of target values, called benchmarks or an efficiency frontier is calculated for the schools, and benchmarking each school against this efficiency frontier is expected to help identify inefficient schools and transform them to efficient entities. In other words, the efficiency frontier here is considered akin to a production possibility set (Cooper et al., 2007) that envelops all units. The DEA methodology simply works by projecting each DMU or school on the efficiency frontier to calculate the maximum improvements that is achievable on the inputs and outputs of the school.

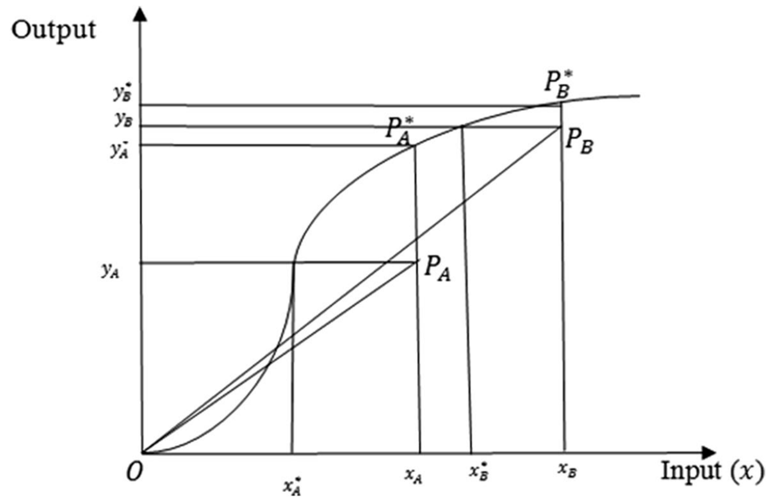

Fig. 1 Output-oriented and input-oriented technical efficiency

The purpose of this exercise is to measure the existing efficiency of schools in converting its physical resources into school-level learning outputs. However, the ability to convert inputs into outputs depends on managerial practices of schools too. So, we examine the association between the efficiency scores estimated in the first stage with school-level management variables in the second stage Tobit regression in our analysis.

First stage analysis: non-radial DEA model for measuring efficiency

There exists a variety of Data Envelopment Analysis (DEA) models, which are chosen depending on the needs behind a study. Three variants of DEA models exist based on orientation, i.e., output-oriented, input-oriented, and non-oriented (Cooper et al., 2007). In an input-oriented model, an inefficient entity becomes efficient by minimizing inputs and keeping the output level constant and an output-oriented model works correspondingly. A non-oriented model pursues both input minimization and output maximization and can include models that can manage multiple inputs as well as outputs (Cooper et al., 2007). Two variants of the non-oriented model exist based on metrics, namely radial and non-radial models. The radial models are represented by the CCR model (Charnes et al., 1978) based on proportional changes in the levels of inputs and outputs. The non-radial models (e.g., SBM or Slacks-based measure of efficiency models) on the other hand do not consider proportional changes in inputs and outputs in the quest of achieving unit efficiency.

Across all DEA models, performance measurement of each DMU involves determining the relative efficiency of a productive unit by considering its proximity to an efficiency frontier.

In Fig. 1, y_A^* and y_B^* are the maximum feasible and achievable outputs for inputs x_A and x_B, respectively. The observed outputs are y_A and y_B, respectively. To evaluate the efficiency of A, we need the point P_A^* showing the maximum output y_A^* producible from A's input. The points P_A^* and P_B^* are vertical projections of the points P_A and P_B onto the frontier of the axis. Here, the input bundle is kept unchanged, and the output level is expanded until the frontier is reached. For the t-th school, producing output y_t, the maximum output y^* producible from the same input bundle x_t is determined.

If ϕ^* be the maximum value of ϕ such that $(x_t, \phi y_t)$ lies within the production possibility frontier, then $y^* = \phi^* y_t$

Here, we assume that a DMU can reach the efficient production frontier by reducing inputs or increasing outputs in equal proportions. Radial DEA models such as CCR and BCC optimize the inputs or outputs of a DMU in fixed proportions. However, in reality that may not always be feasible. For example, as in our case, schools may decide to disproportionately expand a particular input to improve their efficiency. Hence, we use a non-radial DEA measure to estimate the efficiency of schools, which allows non-proportional reductions in positive inputs or augmentations in positive outputs. Among the various non-radial DEA measures, we employ Russell input and output measures of technical efficiency (Färe & Lovell, 1978).

Trostel (2004) examined empirical evidence across different countries and found that human capital production showed significantly increasing returns at low levels of educational attainment and decreasing returns at high levels of educational attainment. Therefore, we use variable returns to scale (VRS) technology. Hence, we can obtain the output-oriented measure of technical efficiency under variable returns to scale (VRS) by solving the following linear programming problem:

$$\text{Max}(\frac{1}{s}\sum_{r=1}^{s}\phi_r + \varepsilon\sum_{r=1}^{s}s_r^+)$$

$$\text{Subject to, } \sum_{j=1}^{n}\lambda_j x_{ij} + s_i^- = x_{i0} \qquad i = 1, 2, \ldots, m$$

$$\sum_{j=1}^{n}\lambda_j y_{rj} \geq \phi_r y_{r0} r = 1, 2, \ldots s, s$$

$$\phi_r \geq 1$$

$$\lambda_j \geq 0, (j = 1, 2, \ldots, n)$$

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

$$Max\sum_{i=1}^{m}s_i^-$$

$$\text{Subject to, } \sum_{j=1}^{n}\lambda_j x_{ij} + s_i^- = x_{i0}$$

$$\sum_{j=1}^{n}\lambda_j y_{rj} = \phi_r^* y_{r0} r = 1, 2, \ldots., s$$

$$\lambda_j \geq 0, j = 1, 2, \ldots, n$$

where, ϕ^* indicates the efficiency coefficient and $1/\phi^*$ is the output-oriented efficiency score; the m inputs are $x_{ij} = (x_{1j}, x_{2j}, \ldots, x_{mj})$ and s outputs are $y_{ij} = (y_{1j}, y_{2j}, \ldots, y_{sj}).s_i^-$ and s_r^+ represent the input and output slacks respectively.

We can obtain the input-oriented measure of technical efficiency by using the linear programming (LP) problem as illustrated below:

$$\text{Min}\left(\frac{1}{m}\sum_{i=1}^{m}\theta_i - \varepsilon\sum_{r=1}^{s}s_r^+\right)$$

Subject to, $\sum_{j=1}^{n}\lambda_j x_{ij} \leq \theta_i x_{i0} i = 1, 2, \ldots, m$

$$\sum_{j=1}^{n}\lambda_j y_j - s_r^+ \geq y_{r0} r = 1, 2, \ldots, s$$

$$\theta_i \leq 1 i = 1, 2, \ldots, m$$

$$\lambda_j \geq 0 j = 1, 2, \ldots, n$$

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

$$\lambda_j \geq 0, j = 1, 2, \ldots, n$$

$$Max\sum_{r=1}^{s}s_r^+$$

Subject to, $\sum_{j=1}^{n}\lambda_j x_{ij} = \theta_i^* x_{i0} i = 1, 2, \ldots, m$

$$\sum_{j=1}^{n}\lambda_j y_j - s_r^+ \geq y_{r0} r = 1, 2, \ldots, s$$

$$\lambda_j \geq 0 j = 1, 2, \ldots, n$$

Here θ^* is the technical efficiency.

Figure 1 shows that to achieve the output y_A, the efficient input required is x_A^*. However, say the school management employs resources at level x_A, which is greater than the efficiency level of input. This highlights the inefficiency in the production function.

Second-stage tobit regression: association between technical efficiency and school-level management

The technical efficiency scores tell us the extent to which schools are efficient in converting their inputs to learning outputs. In this part, we explore the role of different school management practices that may contribute towards any inefficiencies and the extent to which management practices affect school efficiencies. School management practices include resource management and people management factors. Even though these factors are not inputs in the conventional sense, that is, they do not align with physical inputs, they are critical in the overall functioning of a school. Specifically, these factors are critical in transforming the school inputs into the desired outputs. Hence, a two-stage approach is adopted wherein the efficiency scores derived from the first stage are used to estimate Eq. (1) using the Tobit regression method:

$$e_{ij} = \alpha_0 + \beta M_{ij} + C_j + \varepsilon_{ij} \quad (1)$$

where, e_{ij} is the technical efficiency score of school i in the country j; M_{ij} is the vector of management variables of school i in the country j.

Since country-level factors may impact the learning outcomes, country fixed effects represented by the term C_j are considered. The technical efficiency measures are truncated between zero and one. Therefore, Eq. (1) is used to measure estimate the association between efficiency scores and management variables using the Tobit method.

Data

The TIMSS 2019 database contains information on student achievements, student backgrounds, and school-level inputs and provides useful data on the assessment of students on mathematics and science at Grade 4 and Grade 8 levels. It also presents data collected from the students' parents or caregivers, teachers, and school principals. At a higher grade, school management factors particularly people management, including managing and motivating adolescent children become increasingly significant. Therefore, we focus on school-level efficiencies at Grade 8 level. We carry out our analysis using data from 5164 schools from 26 countries (15 OECD[1]; 11 MENA[2]). All the OECD and MENA countries that participated in TIMSS 2019 and had carried out assessments for Grade 8 students were included in this study.

Table 1 lists the number of schools included in the TIMSS 2019 sample for Organisation of Economic Cooperation and Development (OECD) and Middle East and North Africa (MENA) regions. Among the OECD countries, Australia has highest number of schools covered in the TIMSS 2019 sample followed by USA and Lithuania. In MENA countries, UAE has 623 schools whereas the dataset for Bahrain includes 112 schools.

Student achievement

TIMSS 2019 provides data for a representative sample of students in a country and uses item response theory (IRT) scaling methods (Lord & Novick, 2008) to design an overall description of the achievement of a nation's entire student population. Hence, it constructs plausible values[3] of students' achievement scores in mathematics and science. These values are drawn from a distribution, given the individual ability, background, and difficulty of the question. We consider one plausible value chosen at random (pv1 in this

[1] OECD countries: Australia, Chile, England, Hungary, Finland, France Ireland, Israel, Italy, Japan, Korea, Lithuania, Norway, Sweden, and USA.

[2] MENA countries: Bahrain, Egypt, Iran, Jordan, Kuwait, Lebanon, Morocco, Oman, Qatar, Saudi Arabia, UAE.

[3] Plausible values are intermediary computations that incorporate the students' responses to the test items and background information. Plausible values are considered as a better alternative to account for the students' unobserved proficiency values. Plausible values represent what the performance of an individual on the entire assessment might have been, had it been observed.

Table 1 Data composition: number of schools across OECD and MENA countries covered in TIMSS 2019

Country name	Number of schools
OECD countries	
Australia	284
Chile	164
England	136
Finland	154
France	150
Hungary	154
Ireland	149
Israel	157
Italy	158
Japan	142
Korea	168
Lithuania	194
Norway	157
Sweden	150
USA	273
MENA countries	
Bahrain	112
Egypt	169
Iran	220
Jordan	235
Kuwait	171
Lebanon	204
Morocco	251
Oman	228
Qatar	152
Saudi Arabia	209
UAE	623
Grand total	5164

case) for mathematics and science respectively for each student (Rutkowski et al., 2010)[4]. As this study has been undertaken with a school as the unit of analysis, we have followed standard TIMSS user manuals and have calculated the within-school sampling weights in order to compute the weighted average of the students' scores at the school-level for each subject. It is to be noted here that within-school weights are not publicly available and require additional calculation. It is determined by multiplying the within-classroom weight by the inverse of the probability of sampling a classroom within a school. The detailed calculation used in this paper has been provided in the Appendix. Table 2 depicts the ranking of OECD and MENA countries based on their national averages of math and science scores. The table shows that while some countries have relatively

[4] Given we have used only the first plausible value, ignoring the imputation variance, the borderline results that are statistically significant should be interpreted with caution.

Table 2 Ranking of OECD and MENA countries according to score in math and science

Country name	Maths score	Rank	Science score	Rank
OECD countries				
Korea	602.59	1	558.93	2
Japan	590.99	2	567.73	1
Ireland	521.84	3	521.83	7
USA	514.73	4	522.80	6
Hungary	514.47	5	527.67	4
Israel	510.78	6	506.87	11
England	509.21	7	511.99	10
Australia	508.57	8	524.19	5
Finland	508.33	9	542.86	3
Norway	505.11	10	495.66	13
Sweden	502.07	11	520.48	8
Lithuania	501.71	12	512.35	9
Italy	497.88	13	502.14	12
France	482.90	14	489.17	14
Chile	445.26	15	465.89	15
MENA countries				
Bahrain	482.70	1	487.45	1
UAE	467.68	2	464.01	3
Qatar	450.85	3	477.28	2
Iran	444.24	4	448.10	6
Lebanon	423.38	5	366.27	11
Jordan	417.76	6	448.35	5
Egypt	414.55	7	390.14	10
Oman	411.43	8	457.04	4
Saudi Arabia	409.38	9	445.59	7
Kuwait	399.87	10	440.77	8
Morocco	387.55	11	390.75	9

Scores are weighted average of students corresponding to actual sample size of country. International point of reference for comparison is 500

better results in math (Ireland, USA, Bahrain, UAE, Qatar) others do better in science (Hungary, Finland, Australia, Iran, Jordan, Saudi Arabia).

First stage summary statistics

Overall, the cognitive achievement of students at a school depends on several school-level inputs, home resources, and environmental factors. These constitute the input variables for our school-level DEA model. Specifically, we include general resource availability with a school, number of instructional hours in a school, and the number of computers available in a school to account for school-level inputs.[5] Since the socioeconomic status (SES) of students may also affect learning outcomes and students may self-select into schools depending on their SES, we adjust for the home resource availability of students. TIMSS 2019 collected this data from the surveyed students and for the purposes of our school-level analysis, this variable was averaged at the

[5] Another input which is considered in literature is the student–teacher ratio for each school. TIMSS dataset does not provide this information and hence that has not been included in our paper.

Table 3 First stage summary statistics

	Mean	Standard deviation	Minimum	Maximum
Output variables				
Mathematics achievement score	472.93	75.48	215.96	746.79
Science achievement score	479.08	77.84	191.75	690.79
School-level input variables				
General resource availability *(TIMSS index varies from 0–1)*	0.72	0.20	0.25	1.00
Number of computers	72.86	96.10	0.00	1612.00
Annual instructional hours	1034.30	194.27	435.00	2430.00
Home educational resources (Scale provided by TIMSS)	10.28	1.03	5.61	13.20
Share of students speaking the language of test *(25% or less = 1, 26 to 50% = 2, 51 to 75% = 3, 76 to 90% = 4 and 90% or above = 5)*	1.96	1.46	1	5

school-level. To capture heterogeneities across the school population, that may not be captured by aforementioned variables, we also adjust for the share of students speaking the language of the test within a school. Table 3 shows a variation in both the school-level output and input variables aggregated for all the schools across OECD and MENA countries.

Second stage summary statistics

In the second stage, variables capturing various aspects of school management are regressed on the estimated values of school-level technical efficiency (both input and output-oriented efficiencies). Taking reference from the earlier reviewed management literature and working within the constructs of the TIMSS 2019 data for cross-country comparisons, two broad categories of school management (i.e., resource and people management) are considered. These are the explanatory variables considered in the second stage.

a. Resource Management: Availability of special resources for specific subjects for teaching and learning within the school:

(i) The extent of resource availability for math teaching, an index provided by TIMSS
(ii) The extent of resource availability for science teaching, an index provided by TIMSS

b. People Management: These variables include the roles, incentives, responsibilities, and interaction between students, teachers, and parents. They broadly include:

(i) Strategic Leadership: principal's experience in years as a principal. This variable was included to capture the overall managerial capacity and experience of the school leader.
(ii) Target-setting and Motivation for Learning: These inputs include the motivation of students and teachers.

c. Student targets and motivation to meet goals: We calculated student's motivation levels by averaging the variables: students' desire to do well and students' ability to reach goals. The Cronbach's alpha score for these variables is 0.89.
d. Teachers' targets and motivation to meet goals: On teachers' understanding of school's curricular goals, degree of teachers' success in implementing school's curriculum, teachers' expectations of students' achievement, and teacher's ability to inspire and combined them to construct an index of teachers' motivation. The data such that a higher degree of motivation gets a higher value were decoded. These variables to construct our index of teachers' motivation were averaged out. The Cronbach's alpha score was 0.91.

(iii) Control and Discipline within the school:

e. Teachers' presenteeism: We used data on teacher presenteeism, that is related to whether teacher absenteeism or irregular attendance is a problem in a school or not. This variable has been considered as teacher absenteeism might lead to disciplinary problems among teachers.
f. Parental involvement in school processes: To create the index on parental involvement, the average of the extent of parental involvement, the extent of parental commitment, the extent of parental expectations, and parental support were calculated. Here too, Cronbach's alpha was high at 0.93.
g. Student discipline: The index on student discipline is calculated based on problems of lateness, absenteeism, classroom disturbance, cheating, profanity, vandalism, theft, intimidation of students and teachers, and physical injury to teachers. TIMSS data provided the combined index on students' discipline.

Table 4 describes these variables and shows that the MENA countries significantly lag behind the OECD countries in different aspects of school management, except in respect of school principals' experience, student targets and motivation to meet goals, and teachers' targets and motivation to meet goals.

Results

Results from the DEA and Tobit regression from the TIMSS 2019 database for the 26 OECD and MENA countries are presented below.

DEA results

The average output-oriented and input-oriented technical efficiencies of different schools across the 26 selected countries are presented in Table 5. The estimated input-oriented and output-oriented technical efficiencies may differ given the assumption of VRS technology. As per the DEA model, the countries with a technical efficiency score of 1.00 will be treated as efficient and less than 1 will be treated as inefficient. Results show that in both OECD and MENA countries, for a given level of output, schools tend to under-utilize their inputs and function inefficiently. In other words, schools across both regions have scope for improving their technical efficiencies.

The schools in MENA countries, on average, have input-oriented technical efficiency of 0.58. This suggests that the average achievement scores in MENA schools

Table 4 Second stage summary statistics

	All countries		**MENA countries**		**OECD countries**		**Difference between MENA and OECD countries**
	Mean	***Standard deviation***	***Mean***	***Standard deviation***	***Mean***	***Standard deviation***	
Math resource availability *(a scale provided by TIMSS)*	10.15	1.92	9.58	2.11	10.70	1.51	− 1.12***
Science resource availability *(a scale provided by TIMSS)*	10.23	2.06	9.64	2.28	10.82	1.62	− 1.18***
Experience of school principal *(in years)*	9.44	7.78	9.57	7.84	9.31	7.72	0.27
Student targets and motivation to meet goals *(index varies from 0 to 1)*	0.72	0.13	0.73	0.14	0.72	0.13	0.01***
Teachers' targets and motivation to meet goals *(index varies from 0 to 1)*	0.64	0.10	0.64	0.10	0.63	0.09	0.01***
Teacher presenteeism *(index varies from 1 to 4)*	0.83	0.20	0.79	0.23	0.87	0.15	− 0.08***
Parental involvement *(index varies from 0 to 1)*	0.66	0.16	0.65	0.17	0.67	0.14	− 0.01***
Student discipline *(a scale provided by TIMSS)*	10.31	2.10	10.22	2.50	10.40	1.61	− 0.18***

*p < 0.1

** p < 0.05

*** p < 0.01

could have been achieved using forty-two percent fewer inputs than what is being presently used. Amongst the MENA countries, schools in Lebanon show the lowest efficiency while schools in Saudi Arabia demonstrate an above average efficiency value of 0.62. In comparison to MENA countries, the average input-oriented technical efficiency of OECD countries is marginally higher at 0.59. Among the 15 OECD nations, South Korean schools report the highest input-oriented technical efficiency while schools in Norway have the lowest efficiency scores. Overall, across both regions, policies that recommend higher levels of inputs may not be sufficient to ensure higher technical efficiency of schools. This result is corroborated by the output-oriented technical efficiency scores, that have also been presented in Table 5.

The average output-oriented technical efficiency across all countries in the current study is 0.75. This shows that given the inputs, there is a potential for the school-level output to increase by about 25 percent to be on the efficiency frontier. Schools in OECD countries also have higher output-oriented efficiency than those in MENA countries. Chile reports the lowest output-oriented technical efficiency and South Korea is found to have the highest output-oriented technical efficiency. The output-oriented technical efficiency of schools in the MENA region is not only lower but it also reports greater variation across and within member countries. Table 5 shows that within-country inequalities in terms of school-level technical efficiency are also greater within MENA countries. Among the MENA countries, Lebanon has the lowest output-oriented technical efficiency of 0.65, implying that schools in Lebanon

Table 5 Country-wise summary of school efficiencies

	Input oriented efficiency		Output oriented efficiency	
	Mean	**SD**	**Mean**	**SD**
OECD countries				
Australia	0.54	0.07	0.76	0.07
Chile	0.58	0.05	0.71	0.07
England	0.55	0.08	0.76	0.09
Finland	0.62	0.07	0.80	0.05
France	0.54	0.06	0.73	0.05
Hungary	0.64	0.08	0.81	0.07
Ireland	0.59	0.07	0.78	0.05
Israel	0.60	0.10	0.78	0.10
Italy	0.57	0.07	0.76	0.05
Japan	0.70	0.06	0.87	0.04
Korea	0.72	0.08	0.88	0.05
Lithuania	0.62	0.07	0.79	0.07
Norway	0.53	0.06	0.74	0.05
Sweden	0.54	0.09	0.77	0.06
USA	0.55	0.08	0.77	0.09
Average: OECD Countries	0.59	0.07	0.78	0.06
MENA Countries				
Bahrain	0.57	0.11	0.75	0.08
Egypt	0.61	0.08	0.66	0.11
Iran	0.64	0.12	0.85	0.08
Jordan	0.64	0.07	0.72	0.10
Kuwait	0.61	0.09	0.69	0.10
Lebanon	0.48	0.07	0.65	0.09
Morocco	0.57	0.10	0.72	0.12
Oman	0.60	0.09	0.70	0.09
Qatar	0.55	0.13	0.72	0.09
Saudi Arabia	0.62	0.08	0.71	0.09
UAE	0.52	0.10	0.71	0.12
Average: MENA countries	0.58	0.10	0.72	0.10
Average all countries	0.59	0.08	0.75	0.08

could improve their student achievement by 35 percent using the same amount of inputs.

In the next section we use the estimated input-and output-inefficiency scores at the school-level to explore its association with the schools' management of resources and people.

Tobit regression analysis results

Does school management have implications on school-level technical efficiencies, if so, in what ways? We use the Tobit model to regress school-level management variables on the technical efficiency scores obtained in the first stage, alongside other explanatory variables, to answer this question. Table 6 illustrates the results from this second stage regression.

Table 6 Tobit regression results on input-oriented technical efficiency

	(1) All countries Coefficients (Std. Error)	(2) OECD Coefficients (Std. Error)	(3) MENA Coefficients (Std. Error)
Constant	0.693 *** (0.011)	0.6058 *** (0.014)	0.785 *** (0.014)
Resource management			
Math resource availability	− 0.007 * (0.003)	− 0.004 (0.004)	− 0.010 * (0.004)
Science resource availability	− 0.014 *** (0.002)	− 0.011 *** (0.004)	− 0.014 *** (0.004)
People management			
Experience of school principal	− 0.000 * (0.000)	− 0.000 (0.000)	− 0.000 ** (0.000)
Student targets and motivation to meet goals	0.0459 *** (0.012)	0.020 (0.017)	0.055 ** (0.0172)
Student discipline	0.004 *** (0.000)	0.005 *** (0.001)	0.003 *** (0.001)
Teachers' targets and motivation to meet goals	0.045 ** (0.015)	− 0.015 (0.021)	0.065 ** (0.023)
Teacher presenteeism	− 0.029 *** (0.007)	0.006 (0.011)	− 0.040 *** (0.010)
Parental involvement	0.058 *** (0.010)	0.131 *** (0.015)	0.001 (0.014)
Country fixed effects	Yes	Yes	Yes
Observations	5164	2574	2590
Log-likelihood	6804.764	3129.765	3788.314
	10293 df	5128 df	5156 df

The table reports the estimates of Tobit regression for the entire sample of schools in MENA and OECD countries in TIMSS 2019 with input-oriented technical efficiency taken as the dependent variable

* $p < 0.1$

** $p < 0.05$

*** $p < 0.01$

Column (1) reports the results for the entire sample, Columns (2) and (3) report the results for schools across OECD and MENA countries, respectively. Taken together, the results show that the aspects of school management associated with the input-oriented technical efficiencies of different schools include resource management, target setting, motivation, control, and discipline. Our results show that the coefficients for math and science resource availability, which are measures of resource management, are both negative and significant for the full sample. A unit increase in math and science resource availability reduces the input-oriented technical efficiency score by 0.007 and 0.014 units for our full sample, respectively. This implies that the existing resources for math and science subjects available to schools remain under-utilized across all countries. In particular, a further increase in math resource availability leads to a significant loss of school-level efficiency in MENA countries, whereas an increase in resource availability for teaching science significantly lowers the learning output of both MENA and OECD schools. In other words, as the input-oriented technical efficiency evaluates the efficiency in the use of the inputs given a certain level of output, the results show that, in general, the observed outputs can be achieved using fewer resources. Underutilization and sub-optimal management of resources contributes to overall school-level inefficiency.

Several aspects of people management are also included in the Tobit regression. The results show that an increase in target-setting and motivation amongst students and teachers improve input-oriented technical efficiency in the full sample. A unit increase in student motivation index increases the overall input-oriented

Table 7 Tobit Regression results on Output-oriented technical efficiency

	(1) All countries Coefficients (Std. error)	(2) OECD Coefficients (Std. error)	(3) MENA Coefficients (Std. error)
Constant	0.588 *** (0.012)	0.5958 *** (0.012)	0.709 *** (0.018)
Resource management			
Math resource availability	− 0.000 (0.003)	− 0.004 (0.003)	0.002 (0.005)
Science resource availability	− 0.006 *(0.003)	− 0.002 (0.003)	− 0.009 (0.005)
People management			
Experience of school principal	− 0.000 (0.000)	− 0.000 (0.000)	− 0.0001 (0.000)
Student targets and motivation to meet goals	0.100 *** (0.013)	0.0605 *** (0.0152)	0.122 *** (0.021)
Student discipline	0.004 *** (0.000)	0.006*** (0.000)	0.003 ** (0.001)
Teachers' targets and motivation to meet goals	0.0535 ** (0.017)	− 0.004 (0.019)	0.097 *** (0.029)
Teacher presenteeism	− 0.015.(0.008)	− 0.003 (0.0102)	− 0.015 (0.013)
Parental involvement	0.093 *** (0.011)	0.133 *** (0.01)	0.062 *** (0.018)
Country fixed effects	Yes	Yes	Yes
Observations	5164	2590	2574
Log-likelihood	6804.764	3788.314	3129.765
	10,293 df	5156 df	5128 df

The table reports the estimates of Tobit regression for the entire sample of schools in MENA and OECD countries in TIMSS 2019 with output-oriented technical efficiency taken as the dependent variable

* $p < 0.1$

** $p < 0.05$

*** $p < 0.01$

technical efficiency score by 0.046 units overall, with a significant increase of 0.055 units in MENA countries, whereas the relationship remains statistically insignificant in OECD countries. Other aspects of people management are more region dependent. For instance, improvement in teachers' target setting and motivation (i.e., greater alignment of teachers' understanding with curriculum goals and school objectives) is found to increase input-oriented technical efficiency by 0.065 units or 6.5 percent in the MENA region however, for OECD countries, the association between technical efficiency and teachers' motivation is not statistically significant. The school principal's experience shows no significant correlation with the input-oriented technical efficiency of schools across both regions, which corroborates earlier literature (Coelli & Green, 2012).

Further, in MENA countries, increasing the presence of teachers may not translate into better output necessarily, especially, indicating under-utilization and need for capacity development of the existing teaching force. Student discipline is significantly and positively correlated with input-oriented technical efficiency across schools in both groups of countries. A unit increase in parental involvement in school processes also shows a significant and positive association with an increase of 0.131 units in the input-oriented technical efficiency score in OECD countries. This association is much weaker and statistically insignificant in MENA countries.

Table 7 shows the results of the Tobit regression with output-oriented technical efficiency as the dependent variable. Column (1) reports the results for the entire sample, Column (2) reports the results for schools in OECD countries, and Column (3) reports the results for schools in MENA countries.

As output-oriented technical efficiency implies the efficiency in the achievement of output for each unit of input, the results show that high level of output efficiency can be achieved by ensuring better people management in schools. From Table 7, it is clearly seen that the availability of resources for mathematics and science alone show no significant association with output-oriented technical efficiency specifically in MENA or OECD regions. So, a school which wants to increase its output-oriented technical efficiency should not solely focus on resource management, rather factors related to people management such as student's discipline and parental involvement are crucial. Moreover, these factors are more important for schools in OECD countries.

An improvement in parental involvement is found to increase output-oriented technical efficiency by 6.2 per cent in MENA countries and by 13.3 per cent in OECD countries. Teachers' targets and motivation to meet goals is found to significantly increase technical efficiency by 9.7 per cent in MENA region. Further, an improvement in target setting and motivation for students is significantly associated with an improvement in technical efficiency of schools across the full sample. This is found to increase technical efficiency by 12.2 per cent in MENA regions and by 6.05 per cent in OECD countries. Similar to the findings for the input-oriented technical efficiency, experience of the school principal shows no significant correlation with output-oriented technical efficiency. Thus, it appears that the experience of school principal is not a determining factor for both input- and output-oriented technical efficiency.

Discussion and Conclusion

Management of both resources and people forms an integral component of the transformation of available resources and inputs into better student learning. Poor management of resources in schools and educational institutions can adversely contribute to poor delivery of education and low-quality outcomes. Thus, managerial efficiency implies that both physical and human resources are optimally utilized to achieve maximum possible outputs. This paper used school-level data from 5164 schools across 26 OECD and MENA countries participating in TIMSS 2019 and examined the technical efficiency of schools and its association with their managerial practices, using a two-stage methodology. We calculated both output-oriented and input-oriented technical efficiency using a non-radial Data Envelopment Analysis method. We regressed the technical efficiency of schools on school management variables using a Tobit model. Our findings on global school-level efficiency and its relationship with school management validate earlier studies and also present some novel perspectives.

Firstly, the analysis has revealed an existence of technically inefficient schools in all the countries analyzed. The presence of inefficiencies across countries shows that inputs by themselves or increasing physical resources may not be sufficient for improving learning outcomes. In terms of both input- and output-oriented technical efficiency calculations, there is scope for better utilization of the resources employed by the schools across OECD and MENA countries. In fact, it is possible to improve the learning outcomes of both mathematics and science by improving resource management. As shown in Table 4, the available resources for mathematics and science teaching in MENA countries are fewer than those available in OECD countries. MENA countries had mathematics resource availability scale with a 9.58 mean against 10.70 mean value for the OECD countries (p-value < 0.01). A similar trend was found for the resource availability for science teaching where MENA countries showed a mean value of 9.64 against a higher mean of 10.82 for the OECD countries (p-value < 0.01). In conjunction, the second-stage Tobit regression analysis has revealed that resource utilization and management can improve the input-oriented technical efficiencies of schools, especially in MENA countries. These results demonstrate that the source of inefficiency in MENA schools is possibly a combination of both the shortage of resources specific to mathematics and science teaching as well as the lack of optimal utilization and management of the same resources.

The results also reveal that different aspects of people management, particularly target setting, motivation, and discipline assume more significance in improving the technical efficiencies of schools across both OECD and MENA countries. Compared to the OECD countries, schools in MENA countries have a slightly higher index of target setting and motivation for both the teachers and students. The index value for students' target setting and motivation is 0.73 and 0.72 in MENA and OECD countries, respectively as shown in Table 4. For teachers' target and motivation to meet goals, the index value is 0.64 for MENA countries against 0.63 in OECD countries (p-value < 0.01). Despite schools in MENA countries having comparatively greater indices for these variables, the results show that the extent of motivation and target setting is not sufficiently high to achieve significantly better outputs. A positive and significant association between school efficiency and the target setting and motivation for students and teachers particularly in the MENA countries, as shown in Tables 6, 7, indicates that there is an untapped potential for improving student and teacher motivation further to significantly improve school-level learning outcomes across this region.

Student discipline is worse in MENA schools than in the OECD ones. A positive association between student discipline and school efficiency is evident from the results. Given the findings of schools in the US, where 'No Excuse Schools' have better learning outcomes (Thernstrom & Thernstrom, 2004; Whitman, 2008) as discussed earlier in this paper, the schools in both MENA and OECD countries can improve their efficiency by strengthening the disciplinary actions and incentives in their people management policies and practices. With this, schools are expected to be better positioned to utilize instructional time and physical resources more effectively and efficiently.

Another aspect of 'No Excuse' schools is teacher accountability, which includes disciplined and motivated teachers. Our results support the fact that greater extent of motivated teachers does improve school efficiencies. Moreover, while improving student and teacher motivation and ensuring discipline among both teachers and students, policy makers and school authorities should be mindful that students' belongingness should be ensured, and their competencies should be nurtured and not curbed (Golann, 2015).

One way to ensure greater accountability of schools and teachers is to increase the extent of parental engagement with school authorities. As Muralidharan and Singh

(2020) shows that in absence of monitoring, the schools may not have incentives to improve their managerial practices. Our results support this finding. There exists significant positive association between parental engagement and input- and output-oriented technical efficiency, respectively across both MENA and OECD countries.

In sum, the paper finds that in order to achieve greater efficiency in transforming school inputs into higher learning outcomes, they need to be complemented by efficient management of physical resources as well as human resources. Given the colossal intricacy of any education system, the choice of variables made in this paper are limited and by no means encompass the entirety of the input–output framework underlying the educational operation. Therefore, a generalization is to be considered debatable and a matter of further research. Additionally, the obvious limitation of DEA being sensitive to the choice of inputs and output is to be mentioned here. Moreover, the possibility of measurement error due to unobserved inputs and outputs cannot be entirely ruled out. However, as DEA is a nonparametric technique, sensitivity to changes in the "functional form" of the production frontier is a less relevant concern than it is in econometric estimation (Stolp, C. 1990). Further it should be noted that the research focus of this study is related to the association between managerial practices and efficient functioning of schools and consequently the DEA technique uses a school as the Decision-Making Unit (DMU). This restricts the scope of conducting any heterogeneous analysis at the student level or addressing the possibilities of change in technical efficiency arising due to that. Another limitation our study is that we have incorporated student achievement scores of only two subjects i.e., mathematics and science to signify our decision-making unit, whereas school-level performance can be holistically judged in terms of producing outputs only when all critical cognitive and non-cognitive aspects taught in school are measured and evaluated. The literature has shown that the outputs of schools are not limited to just test results or student promotion but can be a multi-dimensional construct. Several non-academic outcomes could also be considered important outputs of schools (e.g., student well-being, socioemotional skills, life skills, civic participation, etc.), and might be unrelated with academic achievement. Given data limitations this study only focuses on cognitive achievement. Despite such limitations, the findings in this paper throw up interesting observations, especially for policy purposes. They indicate that a higher level of inputs is not sufficient to ensure higher technical efficiency of schools. While governments across the globe have focused on increasing inputs and resources for schools, efficient management of those resources becomes critical in achieving better learning outcomes. Further, different aspects of human resource management such as target setting and motivation of students and teachers, students' discipline, and parental involvement in school activities contribute towards achieving greater efficiency of the schools compared to availability and utilization of physical resources. A balanced approach in improving school management involves taking all the stakeholders in the school education, namely, students, parents and teachers into confidence. School management practices that focus on optimal use of physical resources and more so human resources can potentially create an environment conducive towards learning and holistic growth of students, thereby, improving the learning outcomes of students.

Appendix 1

Construction of within-school sampling weights

Within-school sampling weight is obtained by multiplying the within-classroom weight by the inverse of the probability of sampling a classroom within a school[6]:

$$w_{(s)ijk} = \prod_{ijk} p_{ij}^{-1}(p_{ijk}^{-1} * r_{ijk}^{-1})$$

where: p is the probability of selection. r is the probability of response or participation, given selection. i is schools. j is classrooms. k is students.

In TIMSS database, p_{ij}^{-1} is given by WGTFAC2, p_{ijk}^{-1} is given by WGTFAC3 and r_{ijk}^{-1} is given by WGTADJ3. By, multiplying **WGTFAC2*WGTFAC3*WGTADJ3** we will get within-school sampling weight.

Appendix 2

Details of the variables from the TIMSS 2019 dataset used in this study

Variable	Question	Questionnaire
General resource availability	How much is your school's capacity to provide instruction affected by a shortage or inadequacy of the general school resources: instructional materials, supplies, school buildings and grounds, heating/cooling, lighting systems, instructional space, technologically competent staff, audiovisual resources for delivering instruction, computer technology, and resources for students with disability	TIMSS 2019 School Questionnaire
Number of computers	How many computers (including tablets) does your school have for use by (fourth and eighth grade) students?	TIMSS 2019 School Questionnaire
Annual instructional hours	How many days per year is your school open for instruction?	TIMSS 2019 School Questionnaire
Students speaking the language of test	Approximately what percentage of students in your school have <language of test> as their native language?	TIMSS 2019 School Questionnaire
Home educational resources	About how many books are there in your home? (Do not count magazines, newspapers, or your schoolbooks)	TIMSS 2019 Student Questionnaire

[6] https://nces.ed.gov/pubs2001/200105.pdf

Variable	Question	Questionnaire
Math resource availability	How much is your school's capacity to provide instruction affected by a shortage or inadequacy of resources for mathematics instruction: teachers with specialization, computer applications, library resources, calculators, concrete objects or materials to help students understand quantities or procedures *(TIMSS provides an index by using these questions where a higher value reflects greater resource availability)*	TIMSS 2019 School Questionnaire
Science resource availability	How much is your school's capacity to provide instruction affected by a shortage or inadequacy of resources for science instruction: teachers with specialization, computer applications, library resources, science equipment and materials for experiments *(TIMSS provides an index by using these questions where a higher value reflects greater resource availability)*	TIMSS 2019 School Questionnaire
Experience of school principal	By the end of this school year, how many years will you have been a principal altogether?	TIMSS 2019 School Questionnaire
Student targets and motivation to meet goals	How much do you agree with these statements: I usually do well in mathematics/science, I am good at working out difficult mathematics/science problems	TIMSS 2019 Student Questionnaire
Teachers' targets and motivation to meet goals	How would you characterize each of the following within your school: teachers' understanding of school's curricular goals, degree of teachers' success in implementing school's curriculum, teachers' expectations of students' achievement, and teacher's ability to inspire	TIMSS 2019 School Questionnaire
Teacher presenteeism	To what degree is each of the following a problem among teachers in your school: arriving late or leaving early; absenteeism *(This variable has been recoded to reflect presenteeism, hence a higher value reflects higher teacher attendance in schools)*	TIMSS 2019 School Questionnaire
Parental involvement	How would you characterize each of the following within your school: the extent of parental involvement, the extent of parental commitment, the extent of parental expectations, and parental support	TIMSS 2019 School Questionnaire

Variable	Question	Questionnaire
Student discipline	To what degree is each of the following a problem among (fourth/eighth grade) students in your school: lateness, absenteeism, classroom disturbance, cheating, profanity, vandalism, theft, intimidation of students and teachers, and physical injury to teachers *(TIMSS provides an index of student discipline using this question where a higher value reflects greater discipline)*	TIMSS 2019 School Questionnaire

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Author contributions

AB Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Resources; Software; Supervision; Validation; Visualization; Writing—original draft; review & editing. NA Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Supervision; Validation; Writing—original draft; review & editing. All authors read and approved the final manuscript.

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