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A Mixed-Methods Analysis of ICT's Role in Enhancing Secondary School Efficiency in Sylhet, Bangladesh

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ABSTRACT
This study employed a mixed-methods approach to examine inefficiencies in secondary schools across rural and urban areas of Sylhet division, Bangladesh. Using stochastic frontier analysis, researchers identified key factors impeding school effectiveness, such as student and teacher numbers and instructional skills, revealing positive interactions—for example, more teachers and classrooms correlated with improved teaching quality and student engagement. Tobit regression assessed the role of Information and Communication Technology (ICT), showing that frequent use of tools like computer labs and multimedia projectors could reduce inefficiencies, though inconsistent application limited their effectiveness. Qualitative insights from Key Informant Interviews (KII) and Focus Group Discussions (FGD) in Habiganj and Sylhet highlighted barriers including poor student attendance, outdated technologies, resource shortages, and insufficient ICT training. Participants pointed to challenges like low student motivation, discipline issues, and limited parental involvement, all negatively affecting school efficiency. Alarming issues such as a teacher-student ratio of 1:80, scarcity of qualified teachers, and inadequate facilities—including libraries and laboratories—were prevalent, with transportation problems further hindering attendance among low-income students. The findings underscore the urgent need for government investment in teacher training, reduction of class sizes, enhancement of ICT infrastructure, and socio-economic interventions to improve attendance and resource availability, especially in rural areas. Addressing these issues is crucial for fostering better educational outcomes and overall school effectiveness in Sylhet.

KEYWORDS
Efficiency; Secondary Schools; ICT, Teachers' Preference and Perceptions; Sylhet Division of Bangladesh.

INTRODUCTION

In recent years, Bangladesh has experienced rapid progress in integrating Information and Communication Technology (ICT) within its educational sector. Despite these advancements, the Sylhet Division continues to display concerning disparities in educational performance when compared to other regions of the country. Notably, Sylhet exhibits lower literacy rates and suboptimal educational outcomes, raising questions about the underlying factors contributing to these challenges.

This study seeks to explore the root causes behind the sluggish development of school education in the Sylhet division. Particular emphasis is placed on critical elements such as the performance and instructional methodologies of teachers and students—components vital for fostering effective teaching and meaningful learning experiences.

A comprehensive understanding of the current state of ICT utilization in the educational landscape can offer valuable insights for educators and policymakers striving to overcome barriers to technology integration. Although the importance of ICT in cultivating collaborative and innovative learning environments is widely acknowledged, there remains a paucity of research evaluating its direct impact on the performance of secondary schools across Bangladesh.

Furthermore, the readiness and competency of teachers in employing ICT tools play a pivotal role in shaping educational outcomes. Inadequate ICT integration can potentially intensify existing socio-economic and geographic disparities, especially in rural areas where access to technology and reliable internet remains critically limited.

The development of educational institutions is intrinsically linked to the assessment of student learning outcomes and the effective application of ICT in classrooms (Hanushek & Wößmann, 2010; Shava, 2022; Solas & Sutton, 2018). As the educational landscape continues to evolve, understanding the dynamic relationship between ICT integration and student performance becomes essential for devising strategies that enhance learning experiences (Ajani, 2024; Manzi & Moreeng, 2024; Taole, 2024). Despite widespread recognition of ICT's potential to improve educational effectiveness, current research reveals a significant gap in comprehensive analyses of its impact on creating synergistic and equitable educational environments.

Previous research has utilized a diverse array of methodologies to assess school efficiency, prominently featuring approaches such as the frontier efficiency measurement method and stochastic frontier analysis (Sengupta & Sfeir, 1986). These techniques have been instrumental in evaluating both effective and ineffective educational practices. For example, while the positive impact of Information and Communication Technologies (ICT) on improving educational outcomes has been acknowledged, there remains a notable gap in the systematic application of advanced analytical techniques—such as Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA)—specifically within the context of secondary education and

its integration with ICT. This underscores the need for more comprehensive and sophisticated analytical approaches to better understand and enhance school efficiency in this domain.

Noteworthy contributions from scholars such as Mahmudi et al. (2014), Grosskopf, Hayes, and Taylor (2009), and Skolverket (2005) have effectively employed Data Envelopment Analysis (DEA) to evaluate school efficiency across diverse contexts. Despite these advances, the adaptation of DEA methodologies specifically to examine the role of Information and Communication Technology (ICT) remains limited and underexplored. This gap underscores the need for dedicated research focused on how educators leverage ICT advancements to enhance pedagogical effectiveness and overall school performance.

Moreover, as Chakraborty (2009) emphasized, controlling for socio-economic and environmental factors is critical for an accurate assessment of educational outcomes. Incorporating methodologies such as Tobit regression analysis—successfully utilized by Scippacercola and D'Ambra (2014)—enables a more nuanced understanding of the determinants influencing school efficiency.

In this context, the present study aims to evaluate the efficiency of secondary schools within the Sylhet division by examining the role of ICT integration. The primary objective is to assess how ICT contributes to school effectiveness through the application of stochastic frontier analysis. Additionally, the study will investigate the impact of teachers' preferences on teaching and learning processes, employing Tobit regression analysis. Through this comprehensive approach, we aspire to generate valuable insights that can inform and enhance educational practices and policy development in the Sylhet division of Bangladesh.

LITERATURE REVIEW

The educational landscape worldwide has undergone significant transformation owing to the integration of technology. This section critically examines existing scholarly work to identify gaps and inform the development of a stochastic frontier model aimed at assessing the efficiency of secondary schools in Bangladesh's Sylhet division, with a particular focus on the role of Information and Communication Technology (ICT).

Integration of ICT in Global Education

The incorporation of ICT into educational systems has become a strategic priority across the globe, with the European Economic Area exemplifying substantial investments in educational technology (Balanskat et al., 2006; Demir et al., 2026). Despite these efforts, a persistent challenge remains: many educators underutilize the potential of ICT within classroom settings. This underutilization limits the technology's capacity to positively influence student learning outcomes (Park, 2009; Teo, 2009; Khan, Hassan & Clement, 2012; Jamieson-Procter et al., 2013). The importance of ICT as an essential component of literacy instruction is widely recognized, reinforcing its necessity across diverse educational contexts (Soby & Egeberg, 2010). The advent of computers in schools during the early 1980s marked a pivotal point, with scholars predicting that ICT would play a transformative role in education (Bransford, Brown & Cocking, 2000;

Yelland, 2001). Researchers have since identified various strategies to leverage technology for enhancing literacy and broader educational practices, including innovative pedagogical approaches and resource integration (Dawes, 2001; Lefebvre, Deaudelin & Loiselle, 2006; Ghavifekr et al., 2014; Marti-nezI & Tadeu, 2018).

Teachers' Attitudes Toward Technology-Based Teaching and Learning

The successful integration of ICT in education heavily depends on teachers' acceptance and attitudes toward technology use (Dudeney, 2010; Zhang, 2013; Waters & Hensley, 2020). Empirical studies have demonstrated a significant correlation between teachers' beliefs about the utility and ease of use of ICT and their actual adoption of technological tools in instruction (Cassim & Obono, 2011; Chien, Wu & Hsu, 2014; Dagdilelis, 2018). These findings underscore the critical need to foster positive perceptions and attitudes toward technology among educators to promote effective implementation and maximize the benefits of ICT in educational environments.

Measuring School Efficiency with ICT

Methodologically, the evaluation of school efficiency has been grounded in frontier performance measurement techniques, notably the stochastic frontier analysis (SFA) and data envelopment analysis (DEA). Seminal work by Sengupta and Sfeir (1986) laid the foundation for applying frontier methods to educational assessment. Sengupta (1987) further established that frontier approaches yield more accurate efficiency estimates compared to traditional non-frontier methods. Subsequent research has employed these econometric techniques to evaluate technical efficiency across various educational institutions, including primary and secondary schools (Deller & Rudnicki, 1993; Chalos & Cherian, 1995), universities (Athanassopoulos & Shale, 1997), and colleges (Grosskopf et al., 1991; Wyckoff & Lavinge, 1991; Johnes & Johnes, 1995; Beasley, 1995; Madden et al., 1997; Färe, Grosskopf & Weber, 1989; Grosskopf et al., 1999). For instance, Skolverket (2005) conducted a comparative analysis of Swedish secondary schools, while Grosskopf et al. (2001) investigated determinants of technical and allocative efficiency among schools in Texas. Moreover, Bettinger (2005) examined the impact of charter schools on student achievement relative to traditional public schools in Michigan. In a more recent context, Scippacerola and D'Ambra (2014) utilized SFA with Tobit regression models to evaluate school performance in Campania, Italy, addressing the unique challenges of limited data on technical efficiency.

METHODOLOGY

Conceptual Framework

Effective utilization of Information and Communication Technology (ICT) hinges significantly on the attitudes and perceptions of the stakeholders involved. Assessing teachers' perceptions of various ICT tools and their potential to enhance instruction is crucial for multiple reasons.

Firstly, such assessments provide valuable insights that support policymakers and educators in the development and implementation of ICT integration strategies within secondary schools.

Understanding teachers' viewpoints enables the formulation of targeted policies that address actual needs and concerns, fostering a more conducive environment for technological adoption.

Secondly, evaluating perceptions offers a comparative perspective among teachers, students, and policymakers regarding ICT use in secondary education. This holistic understanding helps identify gaps, align expectations, and promote collaborative efforts towards effective ICT integration.

Lastly, insights gained from these assessments assist educational administrators and policymakers in devising appropriate strategies to manage the inevitable changes associated with ICT adoption. In the context of the Sylhet division in Bangladesh, such informed decision-making is essential for ensuring that ICT implementation is both effective and sustainable, ultimately advancing the quality of secondary education in the region.

Figure 1.

Conceptual Framework of the Study

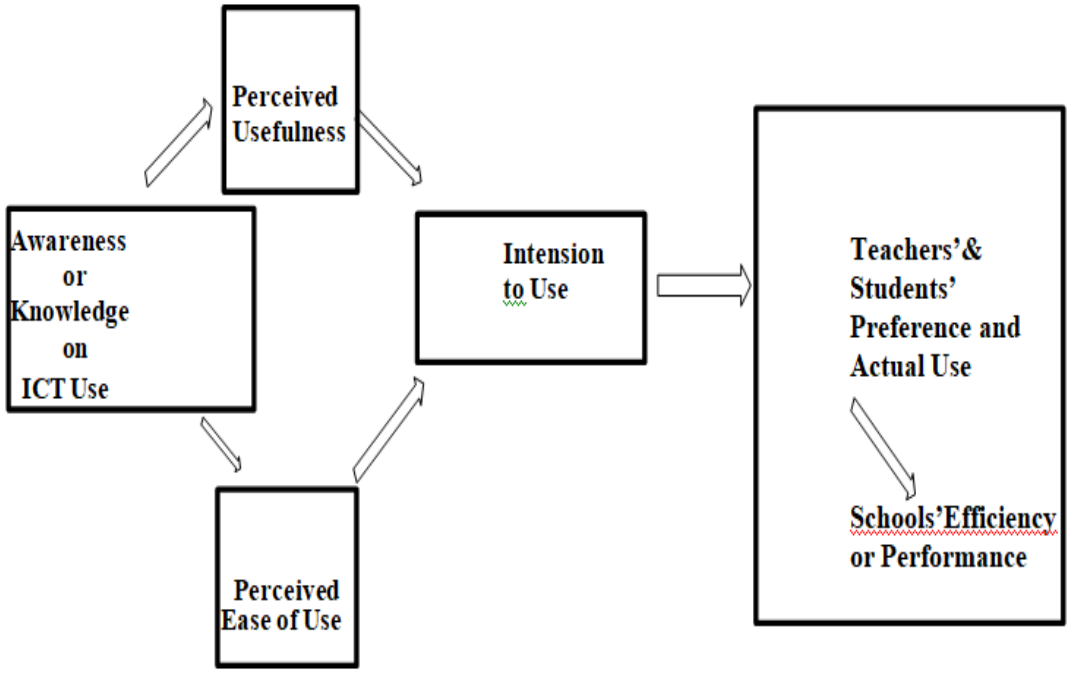


Figure 1 presents the conceptual framework guiding this research. It delineates the key components relevant to the study, illustrating how knowledge, preferences, and perceptions influence perceptions of the usefulness and ease of use of Information and Communication Technologies (ICT). These elements are thoughtfully interconnected, enabling a comprehensive examination of their interrelationships. This integration facilitates the assessment of ICT effectiveness and provides insight into the critical factors contributing to inefficiencies within schools.

Study Area

The study took into account forty secondary schools that were chosen at random from four districts, Moulvibazar, Habiganj, Sylhet and Sunamganj under Sylhet division, Bangladesh covering both urban and rural areas. Sylhet division is situated in the northeastern region of

Bangladesh, occupying a strategically significant position. It is bordered by the Indian states of Meghalaya to the north and east, Assam to the northeast, and the Chittagong Division of Bangladesh to the south and southwest. To the west, it shares boundaries with the Indian states of Tripura and Mizoram.

Research Design

This study employed a mixed-method approach, utilizing structured questionnaires and interviews to gather comprehensive data on teachers' perceptions regarding ICT interventions during the 2022–2023 academic year within the Sylhet division of Bangladesh. The participants included secondary school head teachers, assistant head teachers, non-trained teachers, and trained teachers. Data collection was conducted through direct administration of questionnaires and interviews, ensuring the acquisition of both quantitative and qualitative insights.

Sampling Design for the Quantitative Component

A stratified random sampling technique was employed to select a representative sample of secondary schools. A total of twelve schools were chosen—five urban and five rural schools were randomly selected from four districts within the Sylhet division. From these schools, a total of 40 secondary schools (10 per school) were sampled, resulting in a total of 400 respondents. The sampling distribution was as follows:

Urban schools: 5 schools × 10 respondents each = 50 respondents

Rural schools: 5 schools × 10 respondents each = 50 respondents

However, due to the inherent differences in urban and rural settings, there was an uneven distribution of survey participants, with urban teachers constituting a larger proportion of the overall sample. This distribution reflects the demographic realities of the region and ensures the inclusion of diverse perspectives.

Sample Size Determination

Participants were randomly selected to ensure the sample's representativeness, encompassing head teachers, trained teachers, and non-trained teachers from secondary schools across four districts: Sylhet, Moulvibazar, Habiganj, and Sunamganj. Each district contributed approximately 100 respondents, culminating in a total sample size of 400.

The sample size calculation was based on the following formula:

$$n = z^2[P(1-P)/d^2] * D_{eff}$$

where:

n = required sample size

Z = 1.96 (standard normal variate at 95% confidence level)

P = estimated proportion of the attribute (set at 50% or 0.50 due to lack of prior data)

d = desired precision or margin of error (5%, or 0.05)

D_{eff} = design effect (1.041 to account for sampling design)

Substituting the values:

$n = \frac{(1.96)^2 \times 0.50 \times (1-0.50) \times 1.041}{(0.05)^2} \approx 400.$

This calculation indicates that a sample size of 400 respondents across four clusters is sufficient to achieve the desired statistical confidence and precision.

Data Sources and Variables Construction

Data collection were conducted among the teachers of secondary schools using a structured questionnaire in the financial year 2022-2023 in Sylhet division of Bangladesh. A comprehensive and systematic questionnaire was employed as the primary data collection instrument to effectively gather relevant information aligned with the study's objectives. The questionnaire was meticulously structured into five distinct sections, each targeting specific facets of teachers' experiences and perceptions regarding ICT integration in secondary education.

Section (i): Background Traits of Secondary School Teachers

This section collected demographic and professional information to contextualize the data. It included items such as age, gender, years of teaching experience, level of educational qualification, and type of school (public or private).

Section (ii): Teachers' Preferred ICT Use

Here, teachers were asked about their preferences and attitudes toward using various ICT in their teaching practices. Questions explored which ICT tools and technologies they favored, the purposes for which they preferred to use ICT (e.g., instructional delivery, assessment, student engagement), and their comfort level or enthusiasm for adopting new technologies.

Section (iii): ICT Tools Used in the Classroom

This section focused on identifying specific ICT tools and resources that teachers incorporate into their classroom activities. Items included usage of computers, multimedia projectors, interactive whiteboards, and online resources.

Section (iv): ICT Challenges Met by Teachers

The final section delved deeper into specific challenges faced during ICT integration. Teachers reported on issues such as insufficient access to devices, unreliable internet connectivity, lack of technical support, limited digital literacy among staff and students, and resistance to change.

Overall, the systematic questionnaire served as a comprehensive tool to gather both quantitative and qualitative data, enabling a detailed analysis of secondary school teachers' backgrounds, ICT preferences, usage patterns, perceptions of effectiveness, and the challenges they face in integrating ICT into their teaching.

The data description and the variables related to the secondary schools were described in Table 1 (see appendix).

Sampling Design for the Qualitative Component

The qualitative component of this study comprised one Key Informant Interview (KII) and one Focus Group Discussion (FGD), conducted across two distinct districts within the Sylhet division. These qualitative methods were employed to validate and enrich the findings derived from the quantitative survey. Each FGD and KII involved a total of ten participants, selected to explore

perceptions, preferences, and experiences related to the impact of teachers' perceptions, ICT utilization, and integration within the educational context.

Participant selection for both the FGD and KII was guided by insights gathered from a preliminary review of local communities, teachers, students, and subject matter experts at the national level. The perceptions and preferences regarding the effectiveness of ICT integration were identified and shortlisted based on these consultations, ensuring relevance and depth in the qualitative inquiry. This approach facilitated a comprehensive understanding of contextual factors influencing ICT adoption and attitudes toward its use in teaching and learning environments.

Sampling Design for Qualitative Component

The study conducted 1 Key Informant Interview (KII) and 1 Focus group Discussion (FGD) into two different districts under Sylhet division to validate the findings of quantitative survey. Each FGD and KII conducts with 10 participants on the impact of teachers' perceptions, preference and ICT use. The perceptions and preferences on the effectiveness of ICT integration were shortlisted based on local communities, teachers, students and experts' opinion in a national level.

Cobb-Douglas Stochastic Frontier Model Specification (Battese & Coelli, 1992)

Followed by (Battese & Coelli, 1992), the specification of Cobb-Douglas frontier model for secondary school is as follows:

$lnY_i = \beta_0 + \beta_1 \ln(X_1) + \beta_2 \ln(X_2) + \beta_3 \ln(X_3) + \beta_4 \ln(X_4) + V_i - U_i$ (1)

where, ln= natural logarithm; Y_i= percentage of students passed in SSC; X_1 = quantity of teachers; X_2= quantity of students; X_3= quantity of class rooms; X_4= teacher's teaching ability; β_i = unknown parameters (i=1, 2…4). The systematic error component V_i, thought to be distributed independently and identically as $V_i \sim NID(0, \sigma_v^2)$, independent of U_i which measure the technical efficiency. U_i is considered to be non-negative truncations of independent, identically N (μ ,σ_v^2). The technical efficiency of the i-th secondary school is expressed as: $TE_i = exp(-U_i)$ (2). The total deviation of output from the frontier output attributable to efficiency is well-defined as $\gamma = \sigma_u^2 / (\sigma_u^2 + \sigma_v^2)$ by the composite error term.

Specification of Cobb-Douglas Stochastic Frontier Model with Technical Inefficiency (Battese & Coelli, 1995)

The specification form of Cobb-Douglas technical inefficiency effects model (Battese & Coelli, 1995) has two parts, first part is the same as the line of equation (1) and second part is followed by the technical inefficiency $U_i's$ which are independently distributed as truncations at zero of $N(\mu, \sigma_u{}^2)$. Specifically, U_i is defined as $Z_i\ \delta$, where Z_i is a vector of explanatory variables that affect the inefficiency of the outcome, and δ is a vector of parameters. Additionally,

$$U_i = Z_i\ \delta + W_i \quad (3),$$

where the random variable W_i adheres to a truncated normal distribution $N(\mu, \sigma^2)$, with the truncation point being $-Z_i\ \delta$. The technical efficiency of the i-th secondary school is:

$TE_i = EXP(-U_i) = EXP(-Z_i\,\delta - W_i)$ (4).

The $U_i's$ are defined as

$$U_i = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + \delta_3 Z_{3i} + \delta_4 Z_{4i} + +\delta_5 Z_{5i} + \delta_6 Z_{6i} + +\delta_7 Z_{7i} + W_i \quad (5)$$

where U_i's are deemed to be independently distributed, non-negative random variables for the ith secondary school, U_i, were obtained by truncating a $N(0, \sigma_i^2)$ so that $Z_{1i} =$ i-th secondary school's ICT lab, $Z_{2i} =$ online class, $Z_{3i} =$ multimedia project used always in i-th secondary school, $Z_{4i} =$ multimedia project used frequently, $Z_{5i} =$ multimedia project used sometimes, $Z_{6i} =$ multimedia project used occasionally, $Z_{7i} =$ multimedia project used never, $\delta_0, \delta_1, \delta_{2,}\delta_3, \delta_4, \delta_5, \delta_6, and\ \delta_7$ are the parameters that require estimation include W_i, which represent disturbance terms. The coefficients β, and δ are unknown parameters, alongside the variance parameters, which is defined as $\sigma^2 = \sigma_v^2 + \sigma_u^2$. The parameter γ, defined as $\gamma = \frac{\sigma_u^2}{\sigma^2}$, represents the ratio of the variance of secondary school technical efficiency to the total variance of output.

Translog Stochastic Frontier Model Specification: Insights from Battese & Coelli (1992)

Followed by (Battese & Coelli, 1992), the specification of Translog frontier model for secondary school is as follows:

$lnY_i = \beta_0 + \sum_{i=1}^{4} \beta_i \ln(X_i) + \sum_{i=1}^{4} \beta_i^2\, ln\left(X_i^2\right)) + \sum_{i<j}^{4} \beta_i\, \beta_j ln\left(X_i\, X_j\right))+V_i\ -\ U_i$ (6)

where, ln= natural logarithm; Y_i= percentage of students passed in SSC; X_i ; i=1, 2, 3, 4 are the same as the equation (1), X_i^2 ; $i = 1, 2, 3, 4$ are the square quantity of teachers, students, class rooms, and teaching ability of the teachers; $X_i\, X_j$ are the interaction effects of the input variables, $\beta_i\beta_j$ are the unknown parameters ($i < j = 1, 2, 3, 4$). $U_i\ and\ V_i$ are the same as the equation (1). The technical efficiency here is the same as the equation (2).

Translog Stochastic Frontier Model Specs: Battese & Coelli (1995) with Technical Inefficiency

The specification form of Translog inefficiency effects model (Battese & Coelli, 1995) has two parts, first part is the same as the line of equation (6) and second part is followed by the technical inefficiency $U_i's$ which follows $N\left(\mu, \sigma_u^{\,2}\right)$ as well as it is the same as the equation (4) and (5). The MLE was used to estimate the parameters of the inefficiency effects model using FRONTIER version 4.1 based on (Coelli, 1996).

Likelihood Ratio Tests

The likelihood ratio test statistic that assists in deciding which secondary school output is preferable, the Cobb-Douglas or the Translog nodel. It is evaluated by:

$$\lambda = -2[ln\{L(H_0)/L(H_1)\}] = -2[ln\{L(H_0)\} - ln\{L(H_1)\}] \quad (7)$$

where $L\left(H_0\right)$ and $L(H_1)$ are the likelihood values under the null and alternative hypotheses. The null hypothesis is disproved when $\lambda_{LR} > \chi_c^{\,2}$.

Tobit Regression Model Specification

Followed by (Kumbhakar & Lovell, 2003), the specification of the Tobit regression can be formulated to examine the role of ICT in secondary school inefficiency:

$$E_i = \phi_0 + \phi_1 TSR_i + \phi_2 TE(2-5yrs)_i + \phi_3 TE(5-10yrs)_i + \phi_4 TE(10+yrs)_i + \phi_5 ST(NG)_i + \phi_6 ST(MPO)_i + \phi_7 SL(R)_i + \phi_8 PTM(C)_i + \phi_9 ICT{-}TA(M)_i + \phi_9 ICT{-}TA(H)_i + \xi i \quad (8)$$

where E_{it} is defined the efficiencies of the i-th secondary schools based on Cobb-douglas, and Translog with (Battese & Coelli, 1992; 1995); TSR_{it} = teacher-student ratio of the ith secondary school; TE_{it} = teaching experience (0-2 years, 2-5 years, 5-10 years, and 10 years above); ST_{it} = school type (government, non-government, MPO); SL_{it} = school location; PTM_{it} = preference of teaching methods (modern, conventional); ICT-TA_{it} = ICT teaching ability (low, medium, high). ξ_{it} is the error term.

Validity of the Study

Content Validity:

The study employs a mixed-methods approach, combining quantitative surveys and qualitative interviews or observations, which enhances the comprehensiveness of data collection related to ICT's impact on school efficiency. The use of multiple data sources and methods helps ensure that the findings accurately reflect the complex role of ICT in the educational context of Sylhet.

Construct Validity:

Proper operationalization of key constructs such as "ICT integration" and "school efficiency" is crucial. If the study clearly defines these constructs and uses validated measurement instruments or frameworks, it enhances construct validity.

Internal Validity:

The study's design should account for potential confounding variables (e.g., socioeconomic factors, school infrastructure differences) to establish a causal or associative relationship between ICT use and efficiency improvements.

External Validity:

The extent to which findings can be generalized beyond the sample depends on the sampling strategy. If the sample of secondary schools in Sylhet is representative of the wider population, the results may be applicable to similar contexts within Bangladesh or comparable regions.

Reliability of the Study

Data Collection Instruments:

If standardized questionnaires, interview protocols, or observation checklists are used and tested for consistency, this enhances reliability.

Consistency of Data Gathering:

Training researchers and ensuring standardized procedures during data collection reduce variability and increase reliability.

Data Analysis Procedures:

Using systematic and replicable analysis methods (e.g., statistical tests for quantitative data, coding schemes for qualitative data) ensures that the study's findings are consistent and can be verified or replicated.

Triangulation:

The mixed-methods approach itself acts as a reliability check, where qualitative findings can corroborate quantitative results, providing a more reliable overall picture.

QUANTITATIVE RESULTS AND DISCUSSION

Descriptive Statistics of the Secondary Schools in Sylhet Division

Table 2 presented the descriptive statistics of secondary schools in the Sylhet division.

Table 2.

Percentage Distribution of the Secondary Schools in Sylhet Division

Variables		Frequency	Percentage
Teaching Experience	<1 Year	9	17.31
	1-5 Years	9	17.31
	6-10 Years	10	19.23
	>10 Years	24	46.15
School Type	Government	11	21.15
	Non-government	26	50.00
	MPO	11	21.15
School location	Urban	30	57.69
	Rural	22	42.31
Preference of teaching style	Modern	45	86.54
	Conventional	7	13.46
Education	SSC	10	19.23
	HSC	13	25.00
	Graduation	25	48.08
	Post-graduation	4	7.69
ICT in teaching ability	Low	4	7.69
	Medium	31	59.62
	High	17	32.69
ICT lab	Yes	38	73.08
	No	14	26.92

The teachers with over 10 years of experience are the most prevalent. The number of teachers with less than 1 year and those with 1 to 5 years of experience are nearly identical. The number of non-government type schools is noticed highest compared to both Government and MPO type schools and, both Government and MPO type schools are found to be almost the same. The dataset included to 57.69% urban schools and 42.31% rural schools. The 86.54% of teachers preferred a modern teaching style, while the remaining teachers favored conventional methods. The most of teacher's education level is 'graduation' and noticed highest 48.08% while the post-graduation is lowest 7.69% and the teacher's teaching ability in ICT is noticed medium 59.62%, high 32.69% in both SSC and HSC level education and low 7.69% respectively. The presence of ICT labs was found to be quite satisfactory, with 73.08% of schools having an ICT lab, while 26.92% did not have one.

Results of Cobb-Douglas Stochastic Frontier Model for Secondary Schools: Inefficiency Effects Analysis (Battese & Coelli, 1992; 1995)

The estimated parameters of the Cobb-Douglas model (Battese & Coelli, 1992) were offered in Table 3. The analysis shows that technical efficiency (TE) is positively influenced by the coefficients for teachers, students, and teaching competence, although these results are not statistically significant. Conversely, the coefficient for the number of classrooms is negative and insignificant, suggesting that increasing classrooms may decrease efficiency. The parameter γ is positive but insignificant, indicating that 98.96% of the outcome variation remains unexplained. The σ-square value is 0.0610, indicating a reasonable model fit.

Table 3.

Maximum Likelihood Estimates of the Cobb-Douglas Stochastic Frontier Model for Secondary Schools: With and Without Inefficiency Effects

Variables	Parameters	Estimate	Pr(>|z|)	Estimate	Pr(>|z|)
		Battese and Coelli, 1992		Battese and Coelli, 1995	
Intercept	β_0	4.1399	2.888e-05 ***	4.1373	2.906e-05 ***
X_1	β_1	0.0047	0.9958	0.0043	0.9962
X_2	β_2	0.0750	0.8247	0.0734	0.8380
X_3	β_3	-0.0627	0.8840	-0.0586	0.9057
X_4	β_4	0.1929	0.8444	0.1922	0.8460
Estimation of Inefficiency Effects Model					
Z_1	δ_1			-0.0203	0.9833
Z_2	δ_2			0.0096	0.9922
Z_3	δ_3			0.0180	0.9856
Z_4	δ_4			-0.0215	0.9827
Z_5	δ_5			-0.0036	0.9971
Z_6	δ_6			-0.0058	0.9953
Z_7	δ_7			0.0032	0.9974
Variance Parameters					
sigmaSq	σ^2	0.0613	0.7466	0.0625	0.8520
gamma	Π	0.9896	0.2959	0.9872	0.2839
Log likelihood value		25.9889		26.2700	
Mean efficiency		0.83557		0.83798	

*, **, *** Significance level at 1, 5, and 10%, respectively.

In the TE model parameters presented in Table 3 (Battese & Coelli, 1995), it was found that higher teacher competency, student engagement, and teaching ability positively affect efficiency. The negative coefficient for classrooms reveals that more classrooms may reduce TE. The σ-square value of 0.0625 indicates a good model fit, while γ is 0.9872, showing that 98.72% of outcome variations stem from inefficiency. In the inefficiency effects model, a positive coefficient indicates reduced TE. The negative coefficient for ICT labs suggests they may lower secondary school inefficiency, whereas online classes tend to increase it. Additionally, both

frequent and rare use of multimedia projectors negatively impacts school inefficiency, contributing to improvements in TE.

Translog Stochastic Frontier Model for Secondary Schools: Evaluating Inefficiency Effects (Battese & Coelli, 1992; 1995)

The maximum likelihood estimates (MLE) of the Translog model parameters are detailed in Table 4. The analysis revealed a positive correlation between the number of teachers and significant teaching ability, although the squared effects of teaching ability negatively impacted the efficiency of secondary schools. Notably, positive interaction effects were found between the number of teachers and classrooms, students and classrooms, students and teaching ability, and classrooms and teaching ability, indicating these factors collectively enhance school efficiency in the Sylhet division. The model demonstrates a good fit with a σ-square value of 0.0532 and a γ value of 0.9928, reflecting that 99.28% of outcome variation can be explained.

Furthermore, based on the work of Battese & Coelli (1995), it was noted that while the number of teachers and teaching ability are positively significant, the squared effects of teaching ability are negatively significant, suggesting a decline in efficiency. Interaction effects among key factors were also found to promote efficiency. Interestingly, the presence of an ICT lab reduces inefficiency, while online classes tend to increase it. Notably, the use of multimedia projectors showed a negative effect on inefficiency, meaning their frequent use contributes positively. The γ value of 0.9949 and σ-square value of 0.0528 further indicate a strong model fit, with 99.49% of random variation linked to inefficiency.

Findings on Optimal Model Selection (Battese & Coelli, 1992; 1995)

Table 5 presents the results of the likelihood ratio test for model selection in the Sylhet division. The Translog model exhibited a likelihood value of 33.229, while the Cobb-Douglas model had a value of 25.989. The chi-square value of 14.481 was insignificant, indicating that the Translog model is preferable according to Battese & Coelli (1992). Additionally, for the subsequent analysis, the Translog and Cobb-Douglas models had likelihood values of 33.661 and 26.270, respectively, with an insignificant chi-square value of 14.781. Thus, based on these findings, the Translog model remains the more suitable choice as per Battese & Coelli (1995).

Table 5.

Likelihood Ratio Test Results for Optimal Model (Battese & Coelli, 1992; 1995)

Model	Log Likelihood Value	Degrees of freedom	Chisq	Pr(>Chisq)
Trans_Sylhet Div_92	33.229	17		
CD_Sylhet Div_92	25.989	7	14.481	0.1522
Trans_Sylhet Div_95	33.661	24		
CD_Sylhet Div_95	26.270	14	14.781	0.1402

Efficiency Outcomes for Sylhet Division's Secondary Schools: Rural vs. Urban

Table 6 presents the efficiency of secondary urban and rural schools district by district in the Sylhet division. The analysis employed both the Translog stochastic frontier model (Battese &

Coelli, 1992) and the Cobb-Douglas stochastic frontier model (Battese & Coelli, 1995), both of which proved superior in evaluating the effectiveness of urban and rural schools, respectively. For urban schools, the Translog model (Battese & Coelli, 1992) revealed a higher average efficiency of 84.67%, compared to 84.66% with the later model. The Cobb-Douglas model (Battese & Coelli, 1995) indicated an average efficiency of 83.63% for urban schools against 83.44% for the earlier version. In rural areas, the mean efficiency was 81.11% per the Translog model (Battese & Coelli, 1992) versus 80.98% (Battese & Coelli, 1995), while the Cobb-Douglas model indicated 81.24% for the latter against 80.71% for the former. This data demonstrates that urban secondary schools generally outperformed their rural counterparts. Sylhet district achieved the highest urban efficiency scores, recording 90.61% and 90.41% under the Cobb-Douglas models (Battese & Coelli, 1995; 1992, respectively). The Translog model reflected even higher efficiency at 90.87% (Battese & Coelli, 1995) and 90.79% (Battese & Coelli, 1992), indicating that urban secondary schools in Sylhet excel compared to those in other districts. Additionally, Sylhet's rural schools attained average efficiencies of 89.54% and 86.42% via the Cobb-Douglas and Translog models, respectively, signifying their superiority over neighboring districts as well.

Table 6.

Average Secondary School Efficiency by District (Rural & Urban)

Districts	**Urban**				**Rural**			
	TL 92	**TL 95**	**CD 92**	**CD 95**	**TL 92**	**TL 95**	**CD 92**	**CD 95**
Habiganj	0.8163	0.8157	0.7384	0.7414	0.8288	0.8277	0.8192	0.8222
Moulvibazar	0.8067	0.8063	0.8317	0.8339	0.7027	0.7007	0.6749	0.6793
Sumanganj	0.8559	0.8558	0.8627	0.8640	0.8490	0.8473	0.8496	0.8528
Sylhet	0.9079	0.9087	0.9049	0.9061	0.8642	0.8636	0.8848	0.8954
Overall Mean	**0.8467**	**0.8466**	**0.8344**	**0.8363**	**0.8111**	**0.8098**	**0.8071**	**0.8124**

Findings from the Tobit Regression Model on the Efficiency of Secondary Schools in Sylhet Division

Table 7 (see appendix) details the factors affecting secondary school efficiency in the Sylhet division, analyzed using the Translog frontier and stochastic Cobb-Douglas models. Tobit regression indicates that the student-to-teacher ratio has a significant negative effect on efficiency in the Cobb-Douglas model (Battese & Coelli, 1992; 1995). Additionally, both models show that teaching experience of 1-5 years and over 10 years, MPO school status, and conventional teaching methods also negatively impact secondary school efficiency. Other variables were found to be non-significant.

QUALITATIVE RESULTS AND DISCUSSION

Assessment of the Impact of ICT on Secondary School Efficiency in Habiganj and Sylhet through Key Informant Interviews and Focus Group Discussions

Key Informant Interviews

Respondents identified the five most influential factors affecting secondary school efficiency as:
Number of teachers
Number of students
Classroom availability
Teaching experience
School location
When discussing inefficiencies, nearly 25% of respondents highlighted poor student attendance and challenging economic conditions as primary barriers to optimal school performance. Concerning ICT education, approximately 25% reported facing significant obstacles, including:
Insufficient number of computers
Lack of modern teaching materials
Limited pedagogical support for ICT teachers
Financial constraints hindering development

Furthermore, about one-third of respondents pointed out that outdated or malfunctioning computers and the absence of effective pedagogical models for ICT integration are major hurdles. Additionally, 20% emphasized that the scarcity of internet-connected computers and the limited ICT skills among teachers are critical issues impacting effective ICT implementation.

Regarding school environment factors such as discipline, student motivation, teacher satisfaction, and parental support, nearly 50% of respondents considered these aspects as having an average level of barrier impact, indicating room for improvement in these areas.

Focus Group Discussions

In a focus group conducted in Habiganj, participants highlighted several key factors influencing secondary school efficiency:

Teacher-Student Ratio and Human Resources:

The average teacher-student ratio stands at approximately 1:80, with many schools unable to provide adequate classroom space. A notable shortage of qualified teachers exists, particularly as newly hired staff often lack proper training. This situation underscores the need for targeted government intervention to establish comprehensive training programs. High teacher workloads and a deficit of subject-specific educators further impede effective instruction.

Infrastructure Challenges:

Many schools lack essential facilities such as playgrounds, laboratories, and libraries. Existing laboratories tend to be undersized and underutilized due to a shortage of trained teachers. While some schools possess decent infrastructure, laboratory equipment requires upgrading to meet current educational standards.

Geographical and Accessibility Issues:

School location significantly influences efficiency. Many institutions are situated in rural areas with poor road conditions, making access difficult for students from low-income families who

often travel long distances on foot. The limited availability of transportation exacerbates attendance issues.

Technological Resources and ICT Integration:

The majority of schools lack online classes and sufficient teaching technology. Few institutions have functional projectors or reliable internet connectivity. Some schools, such as those equipped with Sheikh Russel Digital Labs, show promise; however, slow internet speeds hinder the delivery of quality instruction.

ICT Human Resources and Training:

There is a considerable shortage of skilled ICT teachers, and existing staff seldom receive ongoing professional development. This results in a gap between ICT potential and practical application, as teachers lack the necessary resources and training to integrate ICT effectively into their pedagogy.

Parental and Community Engagement:

Parental awareness about the importance of education remains limited, especially in rural contexts. Financial constraints and a lack of awareness negatively influence student motivation and school attendance, further affecting overall school efficiency.

CONCLUSION AND RECOMMENDATIONS

This study presents a comprehensive model for assessing the efficiency of secondary schools within the Sylhet division of Bangladesh, utilizing Stochastic Frontier Analysis (SFA) complemented by a Tobit regression framework to examine the impact of various contextual variables on efficiency scores. Notably, the research advances beyond prior investigations by demonstrating that the Translog stochastic frontier model offers superior accuracy over the traditional Cobb-Douglas specification in evaluating school performance in this region.

The analysis identifies the number of qualified teachers and their pedagogical capabilities as key positive determinants of school efficiency, indicating a direct correlation with enhanced educational outcomes. Conversely, findings reveal that the presence of ICT laboratories and the extent of teachers' engagement with ICT tools—such as multimedia projectors used frequently, occasionally, or rarely—are associated with detrimental effects on efficiency, underscoring existing challenges in integrating ICT into secondary education.

A comparative evaluation highlights that urban secondary schools consistently outperform their rural counterparts within the Sylhet division. Interestingly, rural schools in the Sylhet district exhibit comparatively higher performance levels than those in other districts, suggesting district-specific factors influencing outcomes.

The Tobit regression results, based on the Cobb-Douglas model by Battese & Coelli (1992, 1995), indicate that a higher teacher-student ratio negatively influences school efficiency. Additionally, both the Cobb-Douglas and Translog models identify certain variables—namely, teaching experience (particularly 1–5 years and over 10 years), the presence of MPO (Monthly

Pay Order) schools, and traditional teaching methods—as significant negative contributors to efficiency.

Qualitative insights obtained through Key Informant Interviews (KII) and Focus Group Discussions (FGD) further illuminate the challenges faced by secondary schools. Prominent among these are low student attendance, economic hardships affecting students, inadequate access to computers, insufficient pedagogical support for ICT teachers, financial constraints such as internet expenses, lack of modern instructional materials, and limited availability of internet-connected devices. The study also notes that many schools lack adequately trained ICT teachers and that while some schools have multimedia classrooms, internet connectivity remains absent in numerous institutions.

Additional infrastructural and resource-related factors influencing educational efficiency include the teacher-student ratio (averaging 1:80), teaching competencies, experience levels, quality of school infrastructure, laboratory facilities for science education, library resources, prayer spaces, canteens, playgrounds, and residential facilities for teachers and students.

Based on these findings, several strategic recommendations are proposed to bolster secondary school efficiency in Sylhet. Paramount among these is increasing the recruitment of qualified teachers and enhancing their pedagogical skills. Addressing the barriers to effective ICT integration—such as investing in modern teaching resources, improving internet connectivity, and providing targeted support to ICT educators—is essential. Additionally, bolstering financial support for schools to acquire necessary resources and infrastructure will be critical. Implementing targeted interventions tailored to the unique needs of rural schools can help bridge performance gaps. Finally, maintaining optimal teacher-student ratios will foster more personalized instruction and improve learning outcomes.

In conclusion, concerted efforts across these domains have the potential to significantly improve the efficiency and quality of secondary education in the Sylhet division, ultimately contributing to better educational achievements and socio-economic development in the region.

Limitations of the Study

Sampling Limitations:

The study may have limited generalizability if the sample of schools or participants (students, teachers, administrators) is not representative of all secondary schools in Sylhet or Bangladesh.

Data Collection Constraints:

Reliance on self-reported data (questionnaires, interviews) might introduce bias due to social desirability or inaccurate recall. Technical issues or language barriers could affect the quality and completeness of data collected.

Methodological Limitations:

The integration of qualitative and quantitative data might pose challenges in analysis and interpretation, potentially leading to inconsistencies.

Resource and Time Constraints:

Limited resources and time may restrict the scope of the study, such as the depth of qualitative analysis or the number of schools surveyed. Financial constraints might limit the deployment of extensive ICT interventions or longitudinal follow-up.

Generalizability:

Findings specific to Sylhet may not be directly applicable to other regions with different socio-economic or technological contexts within Bangladesh or beyond.

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Ethical Compliance & Privacy and Informed Consent

This study adhered to rigorous ethical research principles, prioritizing voluntary participation, informed consent, and data confidentiality. Recognizing the absence of a formal institutional review board, we grounded our ethical framework in the principles of the Helsinki Declaration of 1975, as revised in 2008. Prior to participation, all respondents received comprehensive information regarding the research objectives, the voluntary nature of their contribution, data privacy protocols, and their unconditional right to withdraw at any point. Informed consent was obtained digitally via Google Forms before participants commenced the survey. The collection of personally identifiable information was strictly limited to instances where explicit consent was granted. While formal institutional ethical approval was deemed unnecessary due to the non-medical and non-interventional nature of the study, all obligatory ethical considerations, including the protection of privacy, the assurance of confidentiality, and the facilitation of voluntary participation, were meticulously observed throughout the research process.

Data availability: Data will be made available on request.

Declaration of interest statement: The author declares that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this study.

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APPENDIX

Table 1.

Names of the Variables and Descriptions

Variable Names	**Symbol and Variable Description**
The percentage of students who achieved SSC	Y
Teacher's quantity	X_1
Student's quantity	X_2
Class rooms	X_3
Teacher's ability	X_4
ICT lab in schools	Z_1
Online courses in schools	Z_2
Secondary schools always employ multimedia projects	Z_3
Multimedia project are frequently utilized in secondary education	Z_4

Intermittent usage of multimedia projects in secondary schools	Z_5
Seldom are multimedia projects employed in secondary schools	Z_6
No multimedia project is ever employed in secondary schools	Z_7
Ratio of Teacher-student	ϕ_1
Teaching experience	0-2 years (Ref.), 2-5 years (ϕ_2), 5-10 years (ϕ_3), and 10 years above (ϕ_4)
School type	Government (Ref.), Non-government (ϕ_5), and MPO (ϕ_6)
School location	Semi-urban (Ref.) and rural (ϕ_7)
Preference of teaching methods	Modern (Ref.) and conventional (ϕ_8)
ICT teaching ability	Low (Ref.), medium (ϕ_9), and high (ϕ_{10})

Table 4.

Maximum Likelihood Estimates of Translog Stochastic Frontier Model for Secondary Schools (Including and Excluding Inefficiency Effects)

Variables	**Parameters**	**Estimate**	**Pr(>|z|)**	**Estimate**	**Pr(>|z|)**
		Battese and Coelli, 1992		**Battese and Coelli, 1995**	
Intercept	β_0	6.1501	6.414e-10 ***	6.1503	5.846e-10 ***
X_1	β_1	1.0883	0.2538	1.0886	0.2322
X_2	β_2	-1.0911	0.2329	-1.0901	0.2147
X_3	β_3	-0.1257	0.8959	-0.1254	0.8913
X_4	β_4	1.9638	0.0486 *	1.9640	0.0484 *
X_1^2	β_1^2	-0.4690	0.6028	-0.4688	0.5840
X_2^2	β_2^2	0.1163	0.7603	0.1163	0.6828
X_3^2	β_3^2	-0.6566	0.4773	-0.6564	0.4765
X_4^2	β_4^2	-3.1609	0.0015 **	-3.1609	0.0015 **
$X_1 X_2$	$\beta_1\beta_2$	-0.0662	0.8850	-0.0667	0.8769
$X_1 X_3$	$\beta_1\beta_3$	0.5928	0.4768	0.5928	0.4521
$X_1 X_4$	$\beta_1\beta_4$	-1.0976	0.2546	-1.0971	0.2564
$X_2 X_3$	$\beta_2\beta_3$	0.0079	0.9873	0.0077	0.9870
$X_2 X_4$	$\beta_2\beta_4$	0.4941	0.5728	0.4946	0.5832
$X_3 X_4$	$\beta_3\beta_4$	0.3121	0.7485	0.3123	0.7490
Estimation of Inefficiency Effects Model					
Z_1	δ_1			-0.0048	0.9961

Z_2	δ_2			0.0095	0.9922
Z_3	δ_3			0.0087	0.9930
Z_4	δ_4			-0.0097	0.9921
Z_5	δ_5			-0.0051	0.9958
Z_6	δ_6			-0.0024	0.9980
Z_7	δ_7			0.0036	0.9970
Variance Parameters					
sigmaSq	σ^2	0.0532	0.9172	0.0528	0.9243
gamma	Π	0.9928	0.1486	0.9949	0.3018
Log likelihood value		33.2293		33.6606	
Mean efficiency		0.8450		0.8425	

*, **, *** Significance level at 1, 5, and 10%, respectively.

Table 7.

Factors Influencing Efficiency in Secondary Schools - Tobit Regression Model

Variables		**Parameters**	**Tobit Regression Model**			
			TL_1992	**TL_1995**	**CD_1992**	**CD_1995**
Intercept		ϕ_0	0.915***	0.913***	1.048***	1.044***
Teacher Student Ratio		ϕ_1	-0.0003	-0.0002	-0.001**	-0.001**
Teaching Experience	< 1 Year					
	1-5 Years	ϕ_2	-0.151***	-0.153***	-0.164***	-0.160***
	6-10 Years	ϕ_3	0.005	0.005	-0.016	-0.014
	> 10 Years	ϕ_4	-0.054	-0.055	-0.086*	-0.082*
School Type	Government					
	Non-government	ϕ_5	-0.001	-0.001	0.002	0.002
	MPO	ϕ_6	-0.091	-0.091*	-0.108**	-0.107**
School Location	Urban					
	Rural	ϕ_7	-0.029	-0.030	-0.034	-0.034
Preference of Teaching Methods	Modern					
	Conventional	ϕ_8	-0.084	-0.084*	-0.095**	-0.095**
ICT Teaching Ability	Low					
	Medium	ϕ_9	0.062	0.063	0.018	0.018
	High	ϕ_{10}	0.044	0.044	-0.047	-0.045
Log likelihood	44.439					
Sigma	0.075					

*, **, *** indicates significant at 10%, 5% and 1% level respectively