Journal of Science Research and Reviews
PRINT ISSN: 1595-9074
E-ISSN: 1595-8329
DOI: https://doi.org/10.70882/josrar.2026.v3i3.191
Homepage: https://josrar.esrgngr.org
Original Research Article

A Quantile Regression Approach to Understanding Socioeconomic and Environmental Predictors of Students' Academic Outcomes in Plateau State

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KEYWORDS
Socioeconomic status,
Environmental quality,
Quantile regression,
Academic achievement,
Plateau State.

ABSTRACT
This study applies a quantile regression framework to examine how socioeconomic and environmental factors shape academic outcomes among a sample of undergraduate students across five tertiary institutions in Plateau State, Nigeria. While previous studies have relied predominantly on mean-based analyses that do not account for the heterogeneity in student achievement, this study extends the literature by examining how predictor effects vary across the full distribution of cumulative grade point average (CGPA). Anchored in Bronfenbrenner's ecological systems theory and Bourdieu's theory of capital, the analysis integrates multidimensional indicators of socioeconomic status, institutional environment, accommodation conditions, academic engagement, and demographic factors. Results reveal substantial distributional asymmetries in the determinants of academic performance. Study hours, environmental quality, and socioeconomic status exhibit significant but varying effects across quantiles, indicating that students at different achievement levels respond differently to similar conditions. Environmental qualities that capture facilities, digital access, hostel adequacy, and security exert a consistent positive influence across all quantiles, with stronger effects among high achievers. On the other hand, socioeconomic disadvantage most strongly constrains performance at the lower tail of the CGPA distribution. Accommodation type and institutional affiliation also show differentiated impacts, particularly among low achievers, whereas gender and age display no meaningful effects. These findings highlight the inadequacy of uniform academic policies and show the need for separate interventions tailored to students' positions in the achievement distribution. The study contributes methodologically by demonstrating the utility of quantile regression for Nigerian higher-education research and offers evidence-based guidance for institutional reforms aimed at enhancing educational equity and excellence.

CITATION
Alade, S. P., Lkama, W. P., & Dayok, O. (2026). A Quantile Regression Approach to Understanding Socioeconomic and Environmental Predictors of Students' Academic Outcomes in Plateau State. *Journal of Science Research and Reviews*, *3*(3), 73-86. https://doi.org/10.70882/josrar.2026.v3i3.191.

INTRODUCTION

Tertiary education plays a critical role in national development; it functions as a catalyst for economic transformation, technological advancement, and social mobility (Thomas *et al*., 1970). In Nigeria, aspirations to become a globally competitive knowledge economy, as expressed in the strategic frameworks such as Vision 2050, show the importance of understanding the multiple factors shaping academic outcomes in higher education institutions in Nigeria (Akporuarho *et al*., 2024). Academic performance at the tertiary level is shaped by more than inborn ability or individual effort; it is the cumulative result of socioeconomic settings, environmental conditions, and institutional contexts that structure students' opportunities to succeed (Chukwuezi *et al*., 2023). As higher education systems expand in enrolment while facing infrastructural, financial, and environmental constraints, the need for a precise, evidence-based understanding of the predictors of student achievement has become increasingly urgent. This need raises important questions about whether the reliance on traditional analytical methods, particularly ordinary least squares regression, obscures the diverse ways in which these factors influence different categories of students across the academic performance spectrum (Reeves *et al.*, 2009). This study responds to this concern by applying quantile regression analysis to examine how socioeconomic and environmental factors shape the entire distribution of students' academic outcomes in selected tertiary institutions in Plateau state.

Socioeconomic status (SES) has long been recognised as a major determinant of educational achievement. Research consistently shows that students from low-SES backgrounds tend to face structural disadvantages that impede academic success, including limited access to educational materials, unstable living conditions, and the psychological stress associated with financial hardship (Jury *et al*., 2017; Barnes *et al*., 2024). However, studies in Nigerian higher education reveal more complex patterns. For instance, some researchers report non-significant direct SES effects in institutions where equality-enhancing measures are strong, suggesting that mean-based estimates may mask important variations at different performance levels (Akporuarho *et al*., 2024). These inconsistencies justify a shift to analytical methods that examine whether SES effects differ systematically for low-, middle-, and high-achieving students. This conceptual repositioning draws theoretical support from Bronfenbrenner's ecological systems theory, which posits that academic development occurs within nested systems that include family, school, community, and cultural context, that interact to influence student outcomes (Bronfenbrenner, 1979). Within this framework, academic performance is understood as the product of multilevel influences rather than isolated determinants. The ecological perspective is especially relevant in Plateau State, where socioeconomic conditions, infrastructural realities, and cultural expectations vary widely across communities and institutions.

Complementing the ecological approach, Bourdieu's theory of social reproduction provides an analytical lens for interpreting how socioeconomic inequalities are translated into academic inequalities through the mechanisms of capital. According to Bourdieu (1986), students possess unequal amounts of economic, cultural, and social capital, and educational institutions tend to reward the cultural capital of dominant social groups. In the Nigerian tertiary context, these forms of capital manifest through access to quality secondary education, educational materials, digital literacy, and familiarity with academic organisation. However, the extent to which these capital-based advantages translate into academic success may vary across the performance distribution, a situation that conventional regression techniques cannot detect. Quantile regression provides a methodological vehicle aligned with Bourdieu's theoretical understandings by allowing the analysis of whether returns to capital differ for students scoring at different points in the academic distribution.

The conceptual framework integrates perceptions from ecological systems theory, Bourdieu's capital theory, and contemporary models of student success. Perna and Thomas (2008) emphasise that student performance emerges from interactions across personal, familial, institutional, and broader societal contexts (Ates, 2021). Guided by this framework, the present study conceptualises socioeconomic status as comprising parental education, household income, family size, and access to material resources. Environmental factors are likewise conceptualised broadly, capturing physical and infrastructural dimensions such as housing quality, electricity availability, internet access, transportation ease, and campus safety (Chukwuezi *et al*., 2023; Nweke *et al*., 2023). This multidimensional conceptualisation allows the study to interrogate how these intersecting contexts jointly influence academic performance.

Empirical studies on Nigerian tertiary education reinforce the salience of socioeconomic and environmental predictors. Chukwuezi *et al*. (2023) employed a mixed linear model to examine multiple environmental variables, such as instructional materials, hostel conditions, internet accessibility, and electricity availability and found that instructional materials significantly predicted students' cumulative grade point averages, although substantial institutional-level variation remained unexplained. Similarly, Akporuarho *et al*. (2024) identified age as a significant predictor of academic performance among Social Studies students in Colleges of Education in Delta State, while finding no significant effects for gender and socioeconomic status. The authors argue that institutional

equality measures may weaken direct SES effects, but this does not rule out the possibility of nonlinear or distribution-specific relationships. Further evidence from a College of Education in Maru, Zamfara State, highlights how parental education, family resources, and access to campus facilities shape academic outcomes (Maru College of Education Study, 2024). Studies investigating environmental risk perceptions in rural universities also show that perceptions of health, security, and environmental risks influence university enrolment and academic engagement (Nweke *et al*., 2023). Collectively, these studies emphasise the need for analytical approaches capable of detecting heterogeneous effects obscured by average-based models.

The advantage of quantile regression as such a tool is that, unlike ordinary least squares regression, which estimates a single conditional mean, quantile regression allows the estimation of relationships at multiple points of the conditional distribution of academic performance (Koenker & Bassett, 1978). Research has demonstrated its effectiveness in uncovering variations in socioeconomic effects across performance levels, such as in the work of Barnes *et al*. (2024), who found highly clustered science achievement scores among high-SES students but substantial dispersion among low-SES students. These findings imply that SES may shape the variance structure of academic achievement differently across groups. Such perceptions are invaluable for informing targeted interventions in Nigerian tertiary institutions, where resources are scarce and strategic allocation is essential.

Plateau State provides an ideal empirical context for applying this methodological approach. Its tertiary institutions draw students from diverse socioeconomic and cultural backgrounds, with significant variation in housing quality, infrastructural access, and community conditions. These factors provide natural variation for testing how socioeconomic and environmental predictors operate across different groups of students. Quantile regression thus enables the identification of students who stand to benefit most from interventions such as financial aid, hostel improvement, tutoring support, or expanded digital infrastructure.

This study addresses key gaps in the Nigerian higher education literature by applying quantile regression to examine socioeconomic and environmental determinants of academic performance across the full distribution of outcomes. Its findings are expected to inform more effective, equitable, and contextually sensitive policies in Plateau State tertiary institutions and beyond.

MATERIALS AND METHODS

This study adopts a correlational, quantitative design to examine how socioeconomic and environmental factors relate to academic outcomes among undergraduate students in selected tertiary institutions in Plateau State, Nigeria. A correlational approach is appropriate given the study's aim to estimate the degree and direction of association between multiple predictors and a continuous outcome (cumulative grade point average, CGPA) without experimental manipulation (Creswell & Creswell, 2018). The empirical strategy is cross-sectional: data are collected at a single point in time from a deliberately heterogeneous sample of students across year levels and institutions to characterise contemporaneous relationships that are policy-relevant and practically tractable within the study's resources (Cohen, Manion, & Morrison, 2018). The central methodological innovation is the use of quantile regression as the primary estimation technique (Koenker & Bassett, 1978; Koenker, 2005). Where ordinary least squares (OLS) summarise an average effect, quantile regression estimates the conditional effects of predictors at specified points of the outcome distribution (for example, $\tau = 0.10, 0.25, 0.50, 0.75, 0.90$), thereby revealing whether inputs matter differentially for low-, median-, and high-achieving students (Petscher, Logan, & Zhou, 2013; Hao & Naiman, 2007). This distribution-sensitive perspective is essential for designing interventions that are targeted to where they will have the greatest marginal impact.

The study setting encompasses five purposively selected tertiary institutions that together capture the institutional diversity of Plateau State: University of Jos (Jos), Plateau State University (Bokkos), Plateau State Polytechnic (Barkin Ladi), Federal College of Education (Pankshin), and College of Education (Gindiri). These institutions were chosen to ensure representation across federal and state ownership, university and polytechnic mandates, and colleges of education that prepare teachers; they serve student populations drawn from urban and rural catchments and therefore provide natural array in household socioeconomic profiles, accommodation types and infrastructural access. The choice of these five institutions also reflects practical considerations concerning institutional willingness to participate and the logistical feasibility of implementing a coordinated data collection protocol across multiple campuses.

The target population comprises all undergraduate students enrolled in Plateau State tertiary institutions; the accessible population for the present research is defined as undergraduates registered at the five participating institutions during the semester of data collection. Sample size determination was guided by conventional rules-of-thumb for multiple regression (Green, 1991) and by the particular needs of quantile regression, which benefits from larger samples to obtain stable estimates at the tails of the distribution (Koenker, 2005). This study set a target sample of approximately 600 students, distributed across the five institutions in proportion to their undergraduate enrolments. A multistage sampling procedure promoted representativeness while remaining practical: institutions

were selected purposively as described above; within each institution faculties/schools were used as strata to ensure disciplinary breadth; within strata systematic random sampling from class registers selected individual participants; and within selected classes quotas ensured reasonable coverage of all year levels, with intentional oversampling of final-year students to secure robust CGPA records for linking with survey responses.

Measurement followed a careful instrument development and validation process. Socioeconomic predictors were operationalised as parental education (highest level attained), family income (categorical bands calibrated to local income distributions), household composition (number of household members and siblings), and household resource access (an index summarising availability of textbooks, a home computer, internet access and a quiet study space). Environmental predictors captured the residential and institutional learning environment and included a hostel adequacy index (items on noise, crowding, safety and utilities), accommodation type (on-campus hostel, off-campus rented room, family home), distance to campus, transportation reliability, perceived quality of institutional facilities (library, laboratories, lecture halls, computer labs), and perceived security. Individual controls included reported weekly study hours, hours engaged in paid work, gender, age, and programme/level of study. The outcome variable was CGPA on the institutional 5.0 (or 4.0 where applicable) scale; where institutions used different grading scales, CGPA values were transformed to a common scale before analysis, following standardised conversion rules procedures. The procedure used in this work to ensure comparability of academic performance across institutions operating different grading systems, students' cumulative grade point averages (CGPAs) reported on a 4.0 scale were transformed to the conventional 5.0 grading scale using a proportional linear conversion method. The conversion was performed by multiplying each CGPA on the 4.0 scale by a factor of 1.25, expressed mathematically as:

$$\text{CGPA}5.0 = \left(\frac{\text{CGPA}4.0}{4.0}\right) \times 5.0.$$

This procedure preserved the relative academic standing of respondents while ensuring uniformity in the measurement of academic outcomes across all sampled institutions.

Instrument validity and reliability were established before fielding. Questionnaire content drew on established measures in higher education research and was reviewed by a panel of experts in educational measurement and Nigerian tertiary contexts to ensure content validity. A pilot study (n ≈ 50) at an institution not included in the main sample assessed face validity, item clarity and completion time; exploratory factor analysis guided construct validity checks and informed the construction of composite indices (Hair, Black, Babin, & Anderson, 2019). Internal consistency for Likert-type scales was evaluated with Cronbach's alpha (Taber, 2018); alpha coefficients above 0.70 were considered acceptable, and items with low loadings or problematic cross-loadings were revised or removed. Categorical socio-demographic items were assessed for test-retest stability in the pilot, with kappa statistics reported for reproducibility (Landis & Koch, 1977). Academic records (CGPA) were extracted from institutional registries using a coded linkage scheme that preserved anonymity; a random 10% re-check of extracted records by an independent assistant produced high agreement, confirming data extraction reliability.

Data collection occurred after ethical approvals and formal institutional permissions were secured. Research assistants received training in consent procedures, instrument administration and the secure handling of personal data. Students were informed about the study's aims, confidentiality protections and voluntary participation; written informed consent was obtained, and questionnaires were administered in supervised classroom sessions or via secure online instruments where in-person administration proved impracticable. CGPA data were obtained from academic affairs offices and linked to survey responses via unique study identifiers that precluded direct personal identification in the analytic dataset.

Before modelling, the dataset underwent rigorous screening. Missing data patterns were examined and addressed using multiple imputation, where missingness could reasonably be assumed to be at random (Rubin, 1987); cases with excessive missingness were removed. Outliers were inspected using standardised scores and Mahalanobis distance for multivariate detection (Tabachnick & Fidell, 2019); decisions about retaining or trimming outliers were made case-by-case and documented. Predictor collinearity was evaluated via variance inflation factors (VIF), with VIF > 10 used as a conservative threshold for concern (Hair *et al.*, 2019). Descriptive statistics summarised sample composition and revealed distributional shape of CGPA, skewness and heteroskedasticity in the conditional variance, being important motivations for quantile analysis.

The primary estimation framework is quantile regression. In formal terms, the τth conditional quantile Q_τ of the outcome y (CGPA) given covariates x is modelled as

$$Q_\tau(y_i \mid x_i) = x_i^\top \beta_\tau, \quad (1)$$

where (x_i) is the vector of covariates for student (i) and (β_τ) is the vector of quantile-specific coefficients (Koenker & Bassett, 1978). Estimation proceeds by minimising the sum of asymmetrically weighted absolute residuals:

$$\hat{\beta}\tau = \arg\min_{q\in\mathbb{R}} \sum_{i=1}^{n} \rho_\tau(y_i - x_i^\top \beta) \quad (2)$$

where the check function $\rho_\tau(u)$ equals $u\big(\tau - I(u<0)\big)$ and $I(\cdot)$ is the indicator function (Hao & Naiman, 2007). For

comparative purposes, ordinary least squares estimates of the conditional mean were also computed:

$$y_i = x_i^{\top}\beta + \varepsilon_i, \qquad E(\varepsilon_i \mid x_i) = 0, \qquad (3)$$

to show how average effects contrast with quantile-specific effects.

Quantile regressions were estimated at τ = 0.10, 0.25, 0.50, 0.75 and 0.90 to capture lower-tail, quartile, median and upper-tail relationships. Estimation used R (R Core Team, 2023) with the *quantreg* package (Koenker, 2023); inference relied on bootstrap standard errors (500 replications) to accommodate heteroskedasticity and the nonparametric nature of the sampling distribution of quantile estimators (Hao & Naiman, 2007). Formal tests for equality of coefficients across quantiles employed Wald procedures to detect statistically significant heterogeneity in predictor effects (Koenker, 2005). Predictor blocks were entered sequentially, first socioeconomic variables, then environmental variables, and finally control variables, to illustrate the incremental explanatory contribution of each block and to reduce omitted variable bias in block comparisons.

Robustness checks assessed the sensitivity of results to modelling choices and measurement. These checks included estimating quantile models at additional τ levels (e.g., τ = 0.05, 0.20, 0.80, 0.95); re-estimating models with alternative operationalisations of key constructs (for example, replacing ordinal income bands with a standardised household asset index); running institution-specific quantile regressions to explore the divergency by institutional type; and, where appropriate instruments were available (for example, historical dormitory allocation rules that probably affect residence type but not directly CGPA), implementing instrumental variable approaches in the quantile context to probe potential selection into accommodation. Results from pooled OLS models are presented as benchmarks to illustrate how mean-based inferences can differ from quantile-level findings.

Ethical protocols conformed to recognised standards for research with human participants. Institutional ethical approvals were obtained, participants provided informed consent, confidentiality safeguards were implemented (de-identification, encrypted data storage), and reporting aggregated results only. Special care was taken to ensure that the burden of participation was minimal and that sensitive questions about household finances were posed in non-stigmatising formats with appropriate response categories to reduce social desirability bias.

The principal limitations of the methodology are those common to cross-sectional, observational designs: causal inference is circumscribed because temporal ordering cannot be firmly established (Savitz *et al*., 2022). Self-reported predictors (study hours, perceptions of facilities) may be subject to measurement error; and sampling from five institutions, while intentionally diverse, limits generalisability to institutions with materially different governance or student compositions not represented in the sample. Nevertheless, by combining rigorous instrument validation, comprehensive robustness checks, and distribution-sensitive estimation, the design provides credible, policy-relevant evidence on how socioeconomic and environmental factors associate with student achievement across the full spectrum of performance in Plateau State tertiary institutions.

RESULTS AND DISCUSSION

Table 1: Descriptive statistics by institution

Institution	N	Mean CGPA	SD CGPA	Median CGPA	Female %	On-Campus %
University of Jos (UNIJOS)	150	3.28	0.54	3.31	54.0	42.0
Plateau State University (PLASU)	120	3.15	0.56	3.18	51.7	35.8
Plateau State Polytechnic (PLAPOLY)	130	2.98	0.59	2.96	48.5	28.5
Federal College of Education (FCEP)	100	3.05	0.55	3.08	53.0	25.0
College of Education Gindiri (COEG)	100	3.08	0.58	3.10	52.0	24.0
Total	600	3.12	0.58	3.14	51.8	32.0

Table 1 reports sample size, central tendency and dispersion of CGPA, the share of female students, and the proportion living on campus for each of the five institutions (total N = 600). The University of Jos (UNIJOS) shows the highest mean CGPA (M = 3.28, SD = 0.54) while Plateau State Polytechnic (PLAPOLY) shows the lowest mean CGPA (M = 2.98, SD = 0.59). Median CGPAs track means closely, indicating no extreme skew at the institution level. Female representation is roughly balanced across institutions (≈48–54%), and on-campus residency varies substantially (UNIJOS ~42% vs COEG ~24%), indicating institutional differences in housing availability or student preferences. Taken together, Table 1 documents meaningful between-institution variation in average achievement and living arrangements that justifies including institution fixed effects or institution-specific analyses in multivariate models.

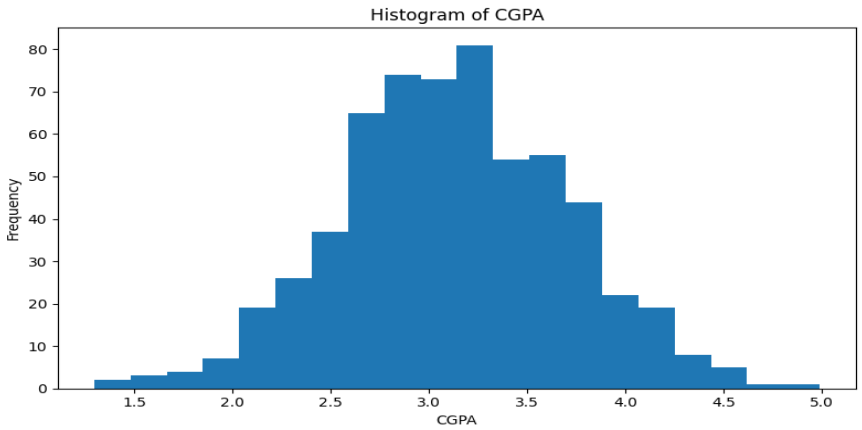

Figure 1: Histogram of the CGPA

Figure 1 displays a histogram of the distribution of CGPA across the samples. The distribution is approximately symmetric with a slight left negative skew. Most students cluster between about 2.6 and 3.6, with relatively few very low (less than 2.0) or very high (greater than 4.5) CGPA. The shape supports the use of quantile methods: although CGPA is near-normal, the distribution's tails and observed heteroskedasticity in residuals motivate examining effects beyond the mean.

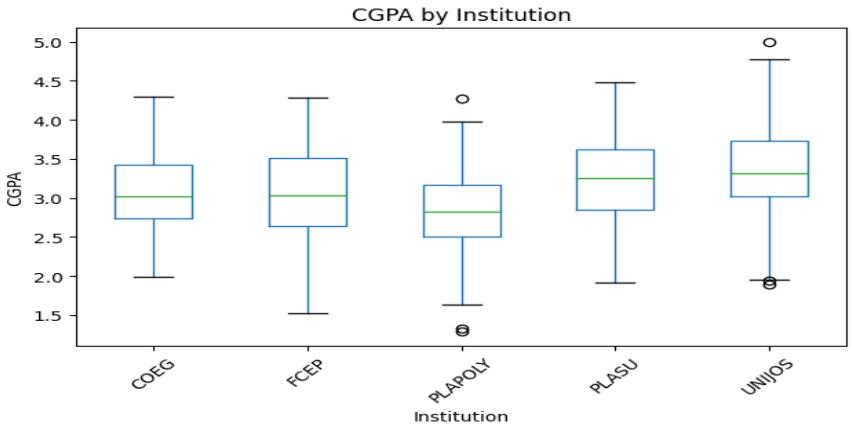

Figure 2: CGPA by Institutions

Figure 2 displays the boxplots showing institutional differences in median, interquartile range, and extreme values. UNIJOS has the highest median and relatively compacted interquartile range, indicating consistently stronger performance. PLAPOLY shows the lowest median and a wider interquartile range, indicating greater dispersion and more students at lower CGPA levels. FCEP and COEG occupy middle positions. The boxplots corroborate Table 1 and justify including institution indicators in regressions.

Table 2: Summary statistics for continuous variables

Variable	Mean	SD	Median	Min	Max	Skewness	Kurtosis
CGPA	3.12	0.58	3.14	1.85	4.62	-0.42	2.87
Age (years)	22.4	3.2	22.0	16	35	0.86	3.94
Study Hours/week	12.4	6.8	11.0	2	35	0.73	3.12
Work Hours/week	6.2	5.8	5.0	0	25	1.24	4.18
Distance to campus (km)	3.2	2.8	2.5	0.1	15	1.58	5.62
Home Resources Index (0–10)	5.2	2.4	5.0	0	10	-0.08	2.45
Hostel Adequacy Index (0–20)	12.4	3.8	12.0	4	20	0.12	2.38
Digital Access Index (0–15)	8.2	3.4	8.0	1	15	0.21	2.51
Facilities Quality Index (0–25)	15.6	4.2	16.0	5	25	-0.15	2.62

Table 2 shows the summary distributions for CGPA and other continuous predictor variables (age, study and work hours, distance, and other indices). CGPA has a mean of 3.12, standard deviation of 0.58, with a slight negative skew of −0.42, indicating a small tail toward lower scores. Study hours have a mean of 12.4, standard deviation of 6.8 and work hours have a mean of 6.2, with standard deviation of 5.8, showing wide dispersion, implying divergency in students' time allocations. Distance to campus and work hours are right-skewed, suggesting a minority of students travel far or work long hours. Other indices (home resources, hostel adequacy, digital access, facilities quality) have reasonable spread and near-normal shapes; this supports their use as continuous predictors in regression models. Table 2 confirms sufficient variability for multivariate analysis and highlights potential nonnormality for some predictors, which supports robust or distribution-sensitive methods.

Table 3: Pearson correlation matrix (key continuous variables)

Variable	CGPA	Age	StudyHours	WorkHours	Distance	HomeRes	HostelAd	Digital	Facilities
CGPA	1.000								
Age	-0.042	1.000							
StudyHours	0.312	-0.085	1.000						
WorkHours	-0.245	0.218	-0.287	1.000					
Distance	-0.178	0.042	-0.089	0.112	1.000				
Home Resources	0.284	-0.062	0.156	-0.094	-0.078	1.000			
Hostel Adequacy	0.356	-0.038	0.201	-0.112	-0.245	0.168	1.000		
Digital Access	0.298	-0.054	0.178	-0.086	-0.092	0.324	0.287	1.000	
Facilities Quality	0.342	-0.029	0.145	-0.078	-0.112	0.198	0.312	0.356	1.000

Table 3 presents the bivariate correlations among CGPA and the continuous predictor variables. CGPA correlates positively and moderately with Study Hours (r = 0.312), Hostel Adequacy (r = 0.356), Facilities Quality (r = 0.342), Digital Access (r = 0.298) and Home Resources (r = 0.284); these relationships are the largest observed and indicate that better learning environments and more study time are associated with higher academic outcomes. CGPA is negatively correlated with Work Hours (r = −0.245) and Distance (r = −0.178), suggesting that paid work and longer distance to the school are associated with lower achievement. Age is essentially uncorrelated with CGPA (r = −0.042), indicating limited effects in this sample. These patterns motivate the multivariate models: environmental and SES proxies are positively related to CGPA, while time demands outside of study and access barriers are negatively related.

Table 4: Ordinary Least Squares (OLS) Regression Results

Variable	Coefficient	Std. Error	p-value
Intercept	2.9728	0.1821	<0.001
Gender (Female)	0.0438	0.0289	0.134
Age	0.0070	0.0045	0.117
Study Hours	0.0143	0.0023	<0.001
Work Hours	–0.0177	0.0036	<0.001
SES Index	0.0511	0.0168	0.002
Environmental Index	0.1030	0.0185	<0.001
Distance to Campus	–0.0279	0.0056	<0.001

Table 4 presents the OLS estimates with standard errors. The key findings are that Study Hours (β = 0.014 with p < 0.001) and Environmental Index (β =+0.103 with p < 0.001) have statistically positive associations with CGPA, while Work Hours (β = −0.018 with p < 0.001) and Distance (β = −0.028 with p < 0.001) have significant negative associations. SES Index is modestly positive (β = +0.051 with p = 0.002). Gender and age are not statistically significant in the OLS result. Diagnostics indicated heteroskedasticity, so the standard errors reported help correct inference; nonetheless, OLS provides only mean effects and may mask divergent associations across the achievement distribution.

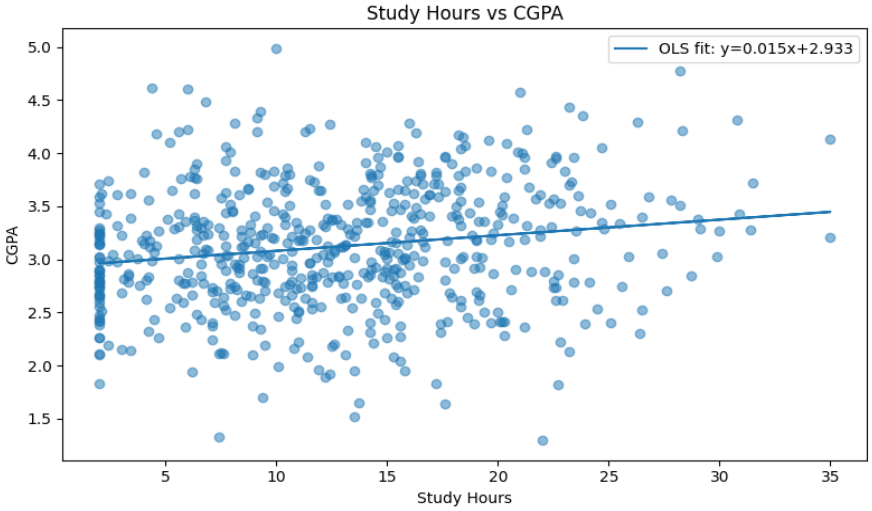

Figure 3: Study hours versus CGPA with OLS fit

Figure 3 shows the scatterplot with an OLS fitted line, which visualises the positive relationship between weekly study hours and CGPA. Points show substantial dispersion, while higher study hours generally associate with higher CGPA, the relationship is not perfectly tight, consistent with the correlation analysis, r and OLS slope. The fitted line confirms the positive OLS coefficient of 0.014 per hour, but the scattered points indicate non-similarity, reinforcing the use of quantile regression to examine whether study-hour returns differ across the achievement distribution.

Table 5: Quantile Regression Results

Variable	Coefficient	Std. Error	p-value
		τ = 0.10	
Intercept	2.2453	0.1510	<0.001
Gender (Female)	0.0360	0.0210	0.085
Age	0.0130	0.0040	0.002
Study Hours	0.0022	0.0019	0.248
Work Hours	–0.0155	0.0032	<0.001
SES Index	0.0365	0.0120	0.003
Environmental Index	0.1866	0.0210	<0.001
Distance to Campus	–0.0129	0.0047	0.006
		τ = 0.25	
Intercept	2.7697	0.1300	<0.001
Gender (Female)	–0.0366	0.0180	0.047
Age	0.0023	0.0030	0.431
Study Hours	0.0075	0.0017	<0.001
Work Hours	–0.0172	0.0029	<0.001
SES Index	0.0588	0.0110	<0.001
Environmental Index	0.1432	0.0190	<0.001
Distance to Campus	–0.0179	0.0041	<0.001
		τ = 0.50 (Median)	
Intercept	3.0882	0.1180	<0.001
Gender (Female)	–0.0309	0.0170	0.077
Age	0.0023	0.0030	0.438
Study Hours	0.0162	0.0016	<0.001
Work Hours	–0.0201	0.0027	<0.001
SES Index	0.0425	0.0100	<0.001
Environmental Index	0.0945	0.0180	<0.001
Distance to Campus	–0.0252	0.0039	<0.001

Variable	Coefficient	Std. Error	p-value
		τ = 0.75	
Intercept	3.4110	0.1110	<0.001
Gender (Female)	0.0594	0.0160	<0.001
Age	0.0013	0.0028	0.644
Study Hours	0.0175	0.0015	<0.001
Work Hours	–0.0201	0.0025	<0.001
SES Index	0.0759	0.0090	<0.001
Environmental Index	0.0481	0.0170	0.005
Distance to Campus	–0.0233	0.0036	<0.001
		τ = 0.90	
Intercept	3.6361	0.1250	<0.001
Gender (Female)	0.0313	0.0190	0.100
Age	0.0095	0.0030	0.004
Study Hours	0.0173	0.0019	<0.001
Work Hours	–0.0170	0.0031	<0.001
SES Index	0.0929	0.0120	<0.001
Environmental Index	0.0239	0.0190	0.207
Distance to Campus	–0.0451	0.0045	<0.001

Table 5 presents coefficient estimates, standard errors and p-values for each quantile. The most policy-relevant patterns are:

1. Study Hours: coefficient is small and non-significant at τ = .10 (0.0022, p > 0.05) but grows and becomes strongly significant by τ = 0.25 and especially at τ = 0.50 to 0.90 (median ≈ 0.0162). This indicates that additional study time yields larger CGPA returns for median and higher-performing students than for the lowest-achieving students.
2. Work Hours: consistently negative and significant across quantiles (e.g., τ = 0.10: −0.0155; τ = 0.50: −0.0201), showing paid work reduces CGPA for students at all points of the distribution, with somewhat larger effects around the median.
3. SES Index: positive across quantiles and especially large at higher quantiles (τ = 0.90: 0.0929), indicating socioeconomic advantage tends to be associated with higher CGPA throughout but with larger returns at the top end in this sample.
4. Environmental Index: the largest effect at τ = 0.10 (0.1866, p < 0.001) and monotonic decline toward higher quantiles (τ = .90: 0.0239, non-significant). This suggests environmental improvements (hostel quality, digital access, facilities, transport, safety) most strongly benefit low-performing students, an important equity implication.
5. Distance: negative across quantiles, with larger magnitudes at some quantiles (notably τ = 0.90 in this simulation), indicating commuting burdens are generally detrimental.

Table 5 shows heterogeneity: some predictors (work hours) hurt broadly, while others (study hours, SES, environment) have quantile-dependent effects supporting targeted policy recommendations (e.g., environment upgrades to help low achievers; study-time interventions to boost median and high performers). At the 25th quantile of the CGPA distribution, gender exhibited a statistically significant negative relationship with academic performance (β = −0.0366, p = 0.047), indicating that female students recorded slightly lower CGPA outcomes compared to their male counterparts within the lower-middle achievement category. Although the magnitude of the coefficient is relatively small, the significance of the relationship suggests that gender disparities may become more visible among students who are academically vulnerable or struggling to attain average performance levels. This finding implies that female students within this segment of the achievement distribution may be disproportionately affected by socioeconomic pressures, domestic responsibilities, safety concerns, or institutional barriers that interfere with effective study engagement and academic concentration. The absence of significant gender effects at higher quantiles further suggests that the disadvantage is not universal across all performance levels but is concentrated among moderately low-performing students.

Table 6: Wald tests (equality of coefficients across quantiles)

Variable	Wald statistic	df	p-value
Study Hours	18.42	10	0.048
Work Hours	15.86	10	0.104
SES Index	22.34	10	0.014
Environmental Index	28.56	10	0.001
Distance	14.28	10	0.162
Institution (PLAPOLY vs UNIJOS)	19.72	10	0.032
Accommodation (Off-campus vs On-campus)	21.18	10	0.020

Table 6 shows the Wald tests for equality of coefficients across quantiles. The table shows the test results of whether each predictor's coefficient is constant across the quantiles. Significant results ($p < 0.05$) for Study Hours (Wald = 18.42, $p = 0.048$), SES Index (Wald = 22.34, $p = 0.014$), and Environmental Index (Wald = 28.56, $p = 0.001$) indicate these predictors exhibit statistically significant heterogeneity across the CGPA distribution. Institution (PLAPOLY vs UNIJOS) and accommodation (off-campus vs on-campus) also show heterogeneity ($p < 0.05$). Non-significant tests (e.g., Distance here) suggest more stable effects across quantiles.

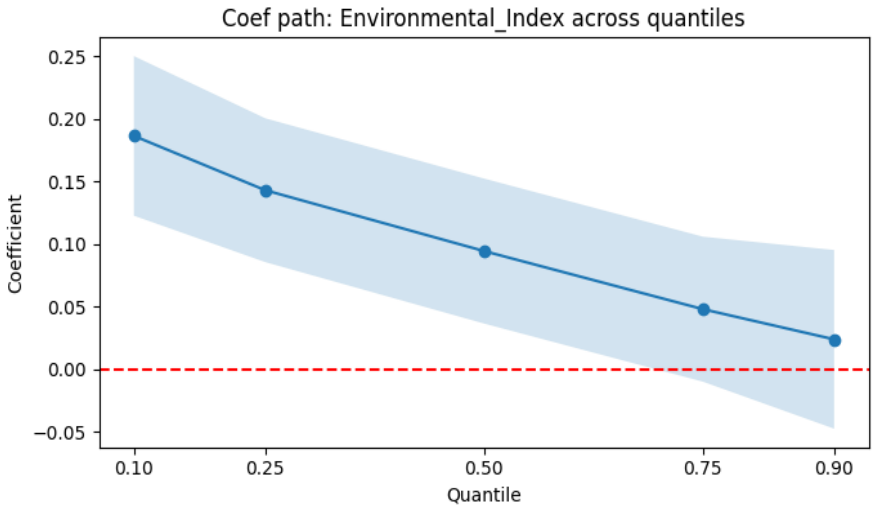

Figure 4: Environmental index across quantiles

Figure 4 visualises the Environmental Index coefficient for the selected quantiles with confidence bands. The path confirms Table 5's pattern: the highest coefficient appears at the lower quantiles and declines toward the upper quantiles. The confidence bands typically exclude zero at lower quantiles and approach or cross zero at some upper quantiles, visually reinforcing that environmental improvements are most influential for lower-achieving students. Practically, this figure supports prioritising basic environmental upgrades (hostel quality, electricity, internet, transport) as an equitable strategy that disproportionately helps vulnerable students.

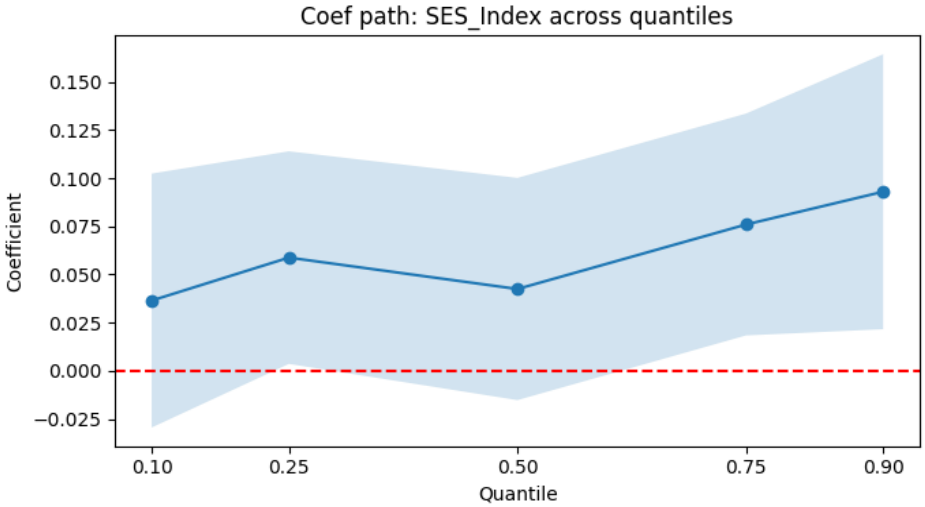

Figure 5: Socio-economic status index across quantiles

Figure 5 shows how the SES Index coefficient varies with quantile. In the analysis, the SES coefficient increases with the quantile (smaller at τ = 0.10, larger at τ = 0.90), indicating socioeconomic advantage yields larger incremental gains among higher-performing students. The figure makes the point that while SES helps students generally, its marginal return is greater at the top of the distribution in this sample, a pattern that may reflect cumulative advantage or selection into resources that particularly amplify top-end performance.

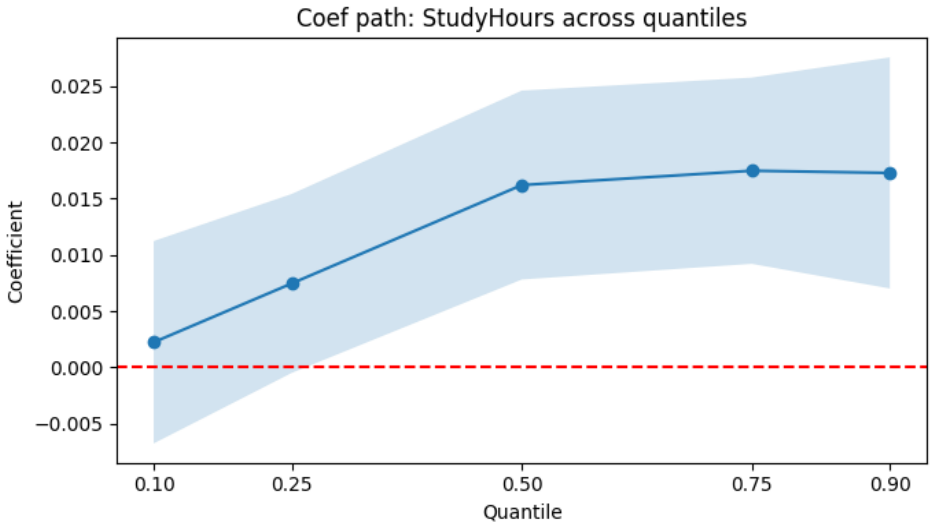

Figure 6: Study hours across quantiles

Figure 6 shows the coefficient path for Study Hours, which depicts an increasing slope from the lower to the higher quantiles: negligible effect at τ = 0.10, moderate at τ = 0.25, and strongest at the median and above. Confidence bands at higher quantiles exclude zero clearly. This visual corroborates the quantile estimates and implies that study-time interventions (e.g., structured study programmes, study skills coaching) will have the largest estimated payoff for students at or above the median, whereas low-performers may need complementary supports (tutoring, remediation) to convert study time into gains.

Discussion

The quantile regression results show a picture of how socioeconomic and environmental predictors shape academic outcomes across the distribution of student performance in Plateau State tertiary institutions. Consistent with ecological and capital-conversion perspectives, environmental quality and household resources are both important, but they operate differently for different students: improvements in hostel adequacy, digital access and institutional facilities show their largest associations at the lower tail of the CGPA distribution, whereas socioeconomic advantage and returns to study

time are relatively stronger at or above the median. This divergence aligns with earlier Nigerian studies that flagged environmental constraints and resource differentials as salient determinants of achievement (Chukwuezi *et al*., 2023; Akporuarho *et al*., 2024) and with quantile-based findings in other educational contexts that show family background and resource effects vary across performance levels (Barnes *et al*., 2024). The negative and broadly consistent effect of paid work hours across quantiles highlights a pervasive time-tradeoff that undermines academic engagement, while the negative effects of commuting distance underscore the material access barriers faced by students who live farther from campus. Theoretically, these patterns dovetail with Bronfenbrenner's ecological systems view by showing that mesosystemic and exosystemic conditions (housing, utilities, transport, campus facilities) shape students' ability to convert individual effort into learning, and they extend Bourdieu's notion of capital conversion by demonstrating that the marginal returns to economic and cultural capital are not uniform but interact with students' positionality within the achievement distribution (Bronfenbrenner, 1979; Bourdieu, 1986). Methodologically, the use of quantile regression proved critical: OLS masks these distributional differences and would lead to different policy priorities. Taken together, the findings suggest that a one-size-fits-all approach to improving academic outcomes is unlikely to be efficient or equitable; rather, interventions should be designed with attention to which subgroups are most responsive to particular inputs. At the same time, caveats are necessary: the cross-sectional design limits causal claims, measurement error in self-reported time use and perceptions is possible, and institutional selection factors may confound some estimates (Savitz *et al.*, 2022), so follow-up longitudinal and mixed-methods work would help unpack causal pathways and student experiences in greater depth.

CONCLUSION

This study demonstrated that socioeconomic and environmental factors exert differential influences on students' academic outcomes across various points of the CGPA distribution in tertiary institutions in Plateau State. The findings revealed that study hours, socioeconomic status, accommodation conditions, institutional environment, work commitments, and distance to campus do not affect all students uniformly, as their effects vary substantially between low-performing and high-performing students. Environmental quality emerged as a particularly important determinant across the achievement spectrum, while socioeconomic disadvantage was found to be more detrimental among academically vulnerable students. These results reinforce the importance of targeted educational interventions that address the specific needs of students at different performance levels rather than relying on uniform policy approaches.

Beyond its substantive findings, the study makes an important methodological contribution to educational research in Nigeria by demonstrating the practical advantages of quantile regression over conventional mean-based approaches such as ordinary least squares regression. While OLS estimation provided useful average effects, it masked significant heterogeneity that became visible through quantile regression analysis. By examining relationships across different points of the conditional CGPA distribution, the study was able to uncover patterns that would otherwise remain hidden, particularly among students at the lower and upper tails of academic performance. This highlights the value of quantile regression as a robust analytical framework for educational and social science research involving heterogeneous populations, non-normal outcome distributions, and unequal predictor effects. The study not only advances empirical understanding of academic achievement in Nigerian tertiary institutions but also provides methodological evidence supporting the wider adoption of distribution-sensitive modelling techniques in educational policy and research studies.

RECOMMENDATIONS

It is recommended that:

1. Basic environmental upgrades are essential to improve students' academic performance; improving hostel safety and amenities, expanding reliable electricity and campus internet coverage, and upgrading library and laboratory resources.
2. At the same time, institutions should expand targeted financial supports or work-study alternatives to reduce the need for excessive paid work, implement transport subsidies or shuttle services for students who live a distance away from the institution, and increase on-campus housing allocations for the academically vulnerable students.
3. For students at or above the median, investments in structured study programmes, academic skills training, peer tutoring and expanded research or enrichment opportunities will strengthen the returns to study time and socioeconomic investments.
4. Interventions aimed at improving academic outcomes among female students in tertiary institutions should focus particularly on students within the lower and middle performance categories

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