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The Effect of Digital Technology on Educational Inequality in Ghana: Evidence from Three Rounds of the Ghana Living Standards Survey

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Abstract

Between 2005/06 and 2016/17, mobile phone ownership among Ghanaian households rose from 18% to 89% and internet access rose from 17% to over half of households, yet mean household-level educational inequality did not fall: the education Gini rose from 0.250 to 0.272 and the Theil-T index from 0.326 to 0.343. This paper investigates that tension using microdata from the fifth, sixth, and seventh rounds of the Ghana Living Standards Survey (GLSS). Educational inequality is measured with a household-level education Gini coefficient and Theil-T index computed from years of schooling of household members aged 15 and above; digital technology is captured through mobile phone ownership, internet access, their interaction, and a composite principal-component index. Pooled OLS and quantile regression, together with fractional logit and variance-inflation-factor diagnostics, are estimated for each round and for the three rounds pooled with round fixed effects. Internet access and mobile ownership are associated with

significantly lower household educational inequality in most specifications, and this equalising association strengthens markedly over time; by 2016/17, the effect operates primarily through joint holding of both technologies rather than either alone. Rising digital access, on its own, has not been sufficient to reduce aggregate educational inequality in Ghana, even as its equalising role has intensified, and digital-inclusion policy must be paired with investment in schooling infrastructure and rural connectivity.

Keywords: Educational Inequality; Digital Technology; Digital Divide; Education Gini Coefficient; Theil Index; Ghana.

1. Introduction

Ghana's digital transformation over the past decade has been rapid by any standard. Among households surveyed in the Ghana Living Standards Survey (GLSS), mobile phone ownership rose from just 18% in 2005/06 to 86% by 2012/13 and 89% by 2016/17; household internet access rose over the same window from 17% to 89%, before a stricter, individually verified measure of internet use recorded 35% in 2016/17. If digital technology functions as the equalising force that a large policy and academic literature expect it to be, this decade of expansion should show up as a decline in educational inequality. It does not. Using a household-level education Gini coefficient computed from the years of schooling of household members aged 15 and above, mean educational inequality in this study's own estimation sample is 0.250 in 2005/06, 0.256 in 2012/13, and 0.272 in 2016/17 - essentially flat, then rising, rather than falling. The Theil-T index tells the same story (0.326, 0.314, 0.343). This paper is built around explaining that apparent contradiction: digital technology access expanded dramatically in Ghana over 2005/06-2016/17, its estimated equalising effect on educational inequality strengthened over the same period, and yet aggregate educational inequality did not decline. Understanding how all three of these facts can be true simultaneously is the central empirical and policy problem this paper addresses.

Education is widely acknowledged as a central driver of socio-economic development because it enhances human capital, productivity, and individual well-being (Sen, 1988; Acemoglu & Angrist, 2001). International frameworks such as the Universal Declaration of Human Rights recognise education as a fundamental right and encourage countries to embed educational access within their constitutions and development policies (United Nations, 1948). Empirical evidence demonstrates that education supports long-term economic growth (Becker et al., 1990; Rebelo, 1991), reduces poverty, and promotes gender equality by improving the capabilities of disadvantaged groups (Antoninis et al., 2016). These insights justify global and national commitments to expanding equitable access, yet despite sustained commitments, significant inequalities in educational access and learning outcomes persist across many countries (UNESCO, 2020). Such disparities undermine human capital formation and weaken pathways for social mobility, reinforcing intergenerational disparities in welfare and perpetuating long-term social and economic disadvantage (Hanushek & Woessmann, 2008; Black & Devereux, 2011).

Over the past four decades, Ghana has experienced substantial expansion in its education sector, marked by increased enrolment at the primary, secondary, and tertiary levels. Policy reforms and public investments have contributed to near-universal primary enrolment and rising participation in secondary education. However, improvements in average educational attainment have not translated into equitable outcomes across population groups: significant disparities persist in educational access and attainment when measured by years of schooling and completion rates (Afoakwa et al., 2022; Buabeng & Amo-Darko,

2024), and these inequalities are particularly pronounced across regions, with northern Ghana consistently lagging behind southern regions. Recent census data show adult literacy rates below 42% in the Northern, Northeast, and Savannah regions compared to over 75% in Ashanti and Eastern (Ghana Statistical Service, 2021), and this study's own descriptive results (Section 5.2) confirm the pattern persists: population-level educational inequality in northern Ghana remains roughly twice that of southern Ghana in every survey round examined here.

The Government of Ghana has implemented several education policies aimed at reducing inequality, including the Free Compulsory Universal Basic Education programme, the Capitation Grant, and the School Feeding Programme, with public expenditure on education accounting for approximately 3.9% of GDP in 2018 (World Bank, 2018). Despite these interventions, educational inequality persists across regions and socio-economic groups (Afoakwah et al., 2022), indicating that policy efforts have not fully addressed structural disparities. Digital technology has emerged over the same period as a potential complementary lever: digital learning tools are increasingly integrated into national education systems to promote inclusive and future-ready learning, and international organisations argue that Information and Communication Technologies (ICTs) can improve education quality by expanding access to information and enabling innovative pedagogy (UNESCO, 2015a; UNESCO, 2015b). Empirical studies in Africa suggest digital technology can support human development outcomes when access is widespread and complemented by adequate institutional support (Asongu & le Roux, 2017), but unequal access to digital infrastructure raises the concern that its benefits accrue disproportionately to those already better positioned, particularly in low-income and rural settings where limited connectivity and poor broadband access hinder equitable engagement with digital learning resources.

Existing empirical studies on educational inequality in Ghana focus primarily on gender and regional disparities and rely predominantly on a single inequality measure, the education Gini coefficient, computed at the population level (Senadza, 2012; Adu-Danso, 2018; Afoakwah et al., 2022). This literature has not examined the role of digital technology as a determinant of educational inequality, nor has it distinguished within-household disparities in schooling among co-resident adults from between-group disparities across the population. This paper addresses both omissions directly, and Section 2.3 sets out precisely how.

The remainder of this paper proceeds as follows. Section 2 reviews the relevant literature and identifies the specific gaps this study addresses. Section 3 sets out the theoretical framework. Section 4 describes the data and estimation methodology, including the household-level construction of the inequality indices. Section 5 reports and discusses the results for each survey round and for the three rounds pooled, including a direct test of whether the technology-inequality relationship has strengthened over time. Section 6 discusses policy implications, Section 7 discusses limitations, and Section 8 concludes.

2. Literature Review

2.1 Digital Technology, the Digital Divide, and Educational Inequality

The integration of digital technology into education systems has become a central feature of contemporary education policy worldwide (UNESCO, 2015a; World Bank, 2018). Digital technologies - mobile phones, computers, and internet connectivity - are increasingly used to support instructional delivery, assessment, and access to educational resources (UNESCO, 2015b), and from a human capital perspective, technology-enhanced education is expected to improve skill acquisition and learning efficiency (Hanushek & Woessmann, 2008). However, diffusion has not been uniform, giving rise to the digital divide (Norris, 2001): inequalities first conceptualised as disparities in physical access to ICT infrastructure, then extended to encompass disparities in digital skills, patterns of use, and the capacity to translate access into meaningful outcomes (Warschauer, 2006; Van Dijk, 2020).

Within education specifically, digital technology plays a dual role documented across a large literature. It can function as an equalising mechanism by expanding access to learning materials and broadening participation among disadvantaged students (UNESCO, 2015b; Vosloo, 2011), or, where access to devices and connectivity is uneven, it can reinforce existing educational inequalities (Warschauer, 2010; Van Dijk, 2020). Evidence from both developed and developing contexts suggests students from higher-income households and urban areas are more likely to benefit from digital learning innovations than disadvantaged counterparts (OECD, 2018; World Bank, 2021). In Sub-Saharan Africa specifically, mobile phone adoption has expanded rapidly while broadband internet and advanced digital learning tools remain highly uneven across regions and socio-economic groups (World Bank, 2021), and rural, low-income households face persistent barriers to digital access that limit their ability to benefit from technology-enabled education (UNESCO, 2020).

Ghana is a particularly instructive case because mobile phone penetration and internet usage have increased sharply over the past two decades while access remains uneven across regions and socio-economic groups (World Bank, 2021; Afoakwah et al., 2022), giving the country's own household survey data enough within-country variation in digital access, over enough time, to test whether the equalising or the divisive reading of digital-divide theory better describes what actually happened to educational inequality as technology diffused.

2.2 Empirical Evidence on Technology, Learning, and Inequality

The economics-of-education literature on digital technology and educational inequality remains inconclusive (Falek et al., 2018; Centeno et al., 2010; Cranmer, 2013; Checchi et al., 2019). One strand

argues that geographic and accessibility barriers facing rural and low-income students can be mitigated by the growing availability of digital technologies: Kayaduman et al. (2022) show novice teachers receiving mentorship from experts through long-distance professional development, and Darling-Hammond et al. (2014) find that one-to-one technology access benefits underserved students, particularly technologies promoting high interactivity and discovery-based learning. A second strand argues the opposite: Warschauer and Matuchniak (2010) contend technology acts as an intellectual and social amplifier that widens the gap between high- and low-performing schools, and Falck et al. (2018) argue that computer use may require cognitive and self-regulatory skills that are less developed among disadvantaged students, so that the same technology produces divergent returns depending on who is using it. Checchi et al. (2015), evaluating an Italian ICT-funding intervention, found real but modest literacy gains concentrated among low-income children - evidence that the equalising and divisive readings are not mutually exclusive but can coexist depending on implementation.

A separate, smaller literature has used the education Gini coefficient specifically, following its popularisation by Thomas et al. (2001), to measure educational inequality directly. Senadza (2012) used the education Gini to examine gender and spatial inequality in Ghana, finding that the three northern regions had both lower attainment and higher inequality; using Mongolian LSMS/HSES data, Otgontugs et al. (2019) found the adult education Gini declined from 0.274 in 2002 to 0.178 in 2012, with the exception of higher education, which remained essentially unchanged near 0.491, illustrating that inequality trends can move in different directions across attainment levels and time periods within the same country. Adu-Danso (2018) demonstrated a non-linear relationship between average years of schooling and educational inequality in Ghana, with a threshold near nine years of schooling, and Anlimachie (2019) and Gaddah et al. (2015) linked the rural-urban achievement gap in Ghana specifically to remoteness and geographic distance. None of this Gini-based literature incorporates digital technology as an explanatory variable.

A third, ICT-economics literature has examined digital technology's aggregate relationship with education quality without using inequality indices as the outcome: Asongu and Odhiambo (2019) find mobile phones and internet penetration improve education quality in Sub-Saharan Africa on average, though with more complex effects at higher penetration; Rodrigues and Biagi (2017) find ICT use outside school is positively associated with PISA 2015 achievement among low-SES students specifically. This literature establishes that digital technology matters for education outcomes in aggregate, but - because it does not use inequality indices - it cannot speak to whether those aggregate gains are distributed evenly or are concentrated among already-advantaged households.

2.3 Research Gap and Contribution

Read together, these three literatures leave a specific and addressable gap. The Ghana-focused education-inequality literature (Senadza, 2012; Adu-Danso, 2018; Afoakwah et al., 2022) has established that regional, gender, and rural-urban disparities in educational attainment are large and persistent, but has not asked whether digital technology access explains any part of the variation in inequality across households, nor has it tracked a single, consistently constructed inequality measure across more than one survey round to test whether the technology-inequality relationship itself is stable over time. The ICT-and-education literature (Asongu & Odhiambo, 2019; Rodrigues & Biagi, 2017) has established that digital technology correlates with education outcomes on average but has not applied that finding to an explicit measure of within-country educational inequality and has generally treated mobile ownership and internet access as substitutable rather than testing whether they are complements. And the broader digital-divide literature (Warschauer, 2006; Van Dijk, 2020) offers two competing theoretical predictions - equalising versus divisive - without country-specific, multi-round evidence to adjudicate between them as digital penetration itself changes.

This paper closes these gaps in four specific ways. First, it constructs a household-level education Gini coefficient and Theil-T index - rather than the population-level index used throughout the existing Ghana literature - computed from the years of schooling of household members aged 15 and above, which captures within-household disparities among co-resident adults that a population-average index cannot see, while also reporting the conventional population-level index by demographic subgroup for direct comparability with prior studies (Senadza, 2012). Second, it measures digital technology three ways in every specification - internet access and mobile ownership as separate main effects, their interaction, and a composite index constructed via principal component analysis - allowing the analysis to test directly whether mobile and internet access are substitutes or complements in their relationship with educational inequality, a distinction the existing literature has not tested. Third, it uses three separate, nationally representative rounds of the GLSS spanning 2005/06 to 2016/17 - a period of the fastest digital expansion in Ghana's history - and pools them with round fixed effects and round-by-technology interaction terms to test explicitly whether the technology-inequality relationship has strengthened, weakened, or stayed constant as digital penetration rose, a temporal question no existing single-round study can answer. Fourth, it triangulates the main OLS results against quantile regression across the conditional distribution of inequality and fractional logit robustness checks, and reports variance-inflation-factor diagnostics that reveal - and correct for - a severe multicollinearity problem specific to the most recent survey round, a methodological check absent from the prior literature that, if omitted, would have led to over-confident conclusions about the 2016/17 cross-section considered in isolation.

The result, previewed in Section 1 and detailed in Section 5, is a more complete and more honest picture than either the technology-optimist or technology-pessimist reading of digital-divide theory alone would produce: digital technology's estimated equalising relationship with educational inequality has strengthened substantially over the study period, but this has not been sufficient, on its own, to reduce aggregate educational inequality in Ghana, which instead appears flat to rising over the same period.

3. Theoretical Framework

3.1 Digital Divide Theory

This study is grounded in Digital Divide Theory, which provides a conceptual lens for understanding how inequalities in access to, use of, and benefit from digital technology shape social and educational outcomes. The digital divide was initially conceptualised as disparities in physical access to information and communication technologies across individuals and groups (Norris, 2001); subsequent theoretical developments extend this concept to include differences in digital skills, quality of use, and the capacity to translate digital access into meaningful educational and social advantages (Warschauer, 2006; Van Dijk, 2020).

Within education, the theory posits that unequal access to digital tools and connectivity can reinforce pre-existing educational inequalities along socio-economic, geographic, and demographic lines (Warschauer, 2010), while equitable distribution and effective integration of digital technologies into education systems may instead reduce educational disparities by expanding learning opportunities for disadvantaged groups (UNESCO, 2015). Because these two predictions are opposite and both theoretically grounded, the theory on its own does not determine which pattern should be observed in Ghana; the empirical analysis in Section 5, and specifically the round-by-round and pooled interaction results, is designed to adjudicate between them using thirteen years of national survey data spanning the country's period of fastest digital expansion.

4. Data and Methodology

4.1 Study Design

This study adopts a quantitative, repeated cross-sectional research design using secondary household survey data from Ghana. Secondary data are appropriate here because the research objective requires nationally representative information on education outcomes and digital technology access over time; large-scale household surveys enable examination of structural inequalities that small-scale primary data collection cannot reliably capture (Wooldridge, 2010).

4.2 Sources of Data and Sample Construction

This study employs the fifth (2005/06), sixth (2012/13), and seventh (2016/17) rounds of the Ghana Living Standards Survey (GLSS) from the Ghana Statistical Service. Round five covered 49,005 households in 3,267 enumeration areas (62.6% rural, 37.4% urban). Round six used a two-stage stratified design with 1,200 enumeration areas as primary sampling units allocated across Ghana's ten administrative regions by probability-proportional-to-size sampling, with 15 households per unit (18,000 households nationwide). Round seven used a similar two-stage design with 1,000 primary sampling units drawn from the 2010 Population and Housing Census frame and 15 households per unit (15,000 households nationwide).

Each round's raw microdata arrives as separate file - a household roster, an education module, an ICT section, and a poverty/welfare aggregate file - which were merged into a single working file per round. Round 5 merged the roster (sec1.dta), education (sec2a.dta), asset ownership (sec12b.dta, providing mobile-phone ownership), household ICT (sec7.dta), and welfare/quintile file (pov_gh5.dta), yielding 37,128 individual records (90.71% matched to the education section). Round 6 merged the equivalent SEC1/SEC2a/SEC7/POV_GHA_2013_GLSS6 files, yielding 72,372 records (91.51% education match). Round 7 required locating the ICT in Section 5C of the questionnaire ("ICT for age 12 years+", file g7sec5c.dta); merging g7sec1.dta, g7sec2.dta, g7sec5c.dta, and 18_GHA_POV_2017_GLSS7.dta yielded 59,864 records (91.07% education match).

Because the inequality measures used here are only meaningful for individuals who have completed, or had the realistic opportunity to complete, a stable level of schooling, all analysis restricts the sample to household members aged 15 and above: 22,143 individuals in Round 5, 43,261-43,267 in Round 6, and 36,079-36,225 in Round 7, for a pooled analytic sample of 101,483. Digital technology is measured with mobile phone ownership and internet access indicators built separately for each round to reflect that round's questionnaire structure: Round 5 draws mobile ownership from the household asset module and internet access from the household ICT section; Round 6 draws both from Section 7, with internet access coded 1 if the household reports either owning or having access to it; Round 7 draws both from Section 5C, collapsed from the individual to the household level by taking the household maximum across members aged 12 and above.

Table 1. Definition and Measurement of Variables

Variable	Measurement
Dependent Variables	
Education Gini index (edu_gini)	Household-level Gini coefficient of years of schooling (yos9), computed across household members aged 15+

Variable	Measurement
Theil-T index (edu_theil)	Household-level Theil-T index of years of schooling (yos9), computed across household members aged 15+
Independent Variables	
Internet	= 1 if household has internet access/use, 0 otherwise (definition varies slightly by round; see Section 4.2)
Mobile Phone	= 1 if household owns/has access to a mobile phone, 0 otherwise
Mobile x Internet	Interaction of Mobile Phone and Internet, capturing the joint effect of holding both
Digital technology index (digitech)	Composite index from principal component analysis of Mobile Phone and Internet (household level)
Age	Age of the individual, in years
Age squared (ln_agesq)	Natural log of age squared
Household size (ln_hhsize)	Natural log of number of people in the household
Gender (male)	= 1 if individual is male, 0 if female
Income quintile	National welfare quintile, 1 (poorest) to 5 (richest)
Residence (urban)	= 1 if household is in an urban area, 0 if rural
Religion (religion4)	4-category: Christianity, Muslim, Traditionalist, No religion
North	= 1 if household is in the Northern, Upper East, or Upper West region
Round (pooled sample only)	= 5, 6, or 7 (GLSS 2005/06, 2012/13, 2016/17)

Source: Authors' construct.

4.3 Justification for the Choice of Survey Periods

GLSS5, GLSS6, and GLSS7 span the period of Ghana's fastest digital expansion and employ broadly similar sampling designs, allowing consistent measurement of educational outcomes and digital access across time. GLSS5 represents the early phase of digital diffusion (household mobile ownership around 18% and internet access around 17% in the 15+ analytic sample); GLSS6 and GLSS7 capture accelerated adoption (mobile ownership 86% by 2012/13 and 89% by 2016/17). This coverage allows the study to test not only the average association between digital access and inequality but whether that association has itself changed as penetration rose - the subject of the pooled interaction model in Section 5.6.

4.4 Measurement of Educational Inequality

Educational inequality is measured at the household level using the education Gini coefficient and the Theil-T index, computed from years of schooling (yos9) of household members aged 15 and above. Following Barro and Lee (1997) and Thomas et al. (2001), years of schooling is coded on a nine-level, grade-based scale (Table 2). For each household, members aged 15+ are ranked by years of schooling and the Gini

coefficient is computed using equation (1); the Theil-T index is computed in parallel using equation (2). Both indices are computed once per household.

Household-level computation was chosen, rather than a single population-wide index, because it captures within-household disparities in schooling among co-resident adults - for example between a household head and other adult members - which a population-level index averaged across all individuals in a subgroup cannot see. Restricting computation to members aged 15+ avoids conflating still-in-progress schooling among children and adolescents with completed or near-complete attainment among adults, which would otherwise mechanically inflate measured inequality in households with young children. A complementary population-level ("between-group") Gini and Theil-T index is also reported by demographic subgroup - gender, religion, urban/rural residence, and north/south location - in Tables 4 through 6, computed by ranking all individuals aged 15+ within each subgroup and applying the same formula across the whole subgroup population; these subgroup indices are numerically distinct from, and larger in magnitude than, the household-level indices used as regression dependent variables, and serve a descriptive rather than an explanatory purpose.

$$EGC = (1/\mu) \times \sum_i \sum_j p_i |y_i - y_j| p_j \quad (1)$$

where EGC is the education Gini coefficient, μ is mean years of schooling, p_i and p_j are population shares at each attainment level, and y_i and y_j are years of schooling at those levels.

$$T = \sum_i (y_i / Y) \ln[(y_i / Y) / (1/N)] \quad (2)$$

Employing the Theil-T index alongside the Gini coefficient is appropriate because Theil's index is more sensitive to changes at the lower end of the distribution, including the substantial share of individuals with zero years of schooling, helping avoid bias toward changes concentrated among the already-schooled majority.

Table 2. Educational Attainment Levels and Years of Schooling

Level of attainment	Description	Years
No education	Never attended school, or up to pre-school	0
School but no grade	Primary school, year 1-5, not completed	3
Completed Primary	Completed six years of primary education	6
Partial Junior Secondary	Junior secondary/middle school without completion (BECE/MSLC)	7.5
Completed Basic Education	BECE or Middle School Leavers Certificate	9
Partial Secondary	Partial secondary/vocational, S1-S5, or partial teacher training	10.5
Completed Secondary	Vocational/Commercial, SSCE, O-Level, Teachers' Cert A/B	12

Level of attainment	Description	Years
Partial Tertiary	Upper/Lower 6 (A-Level), partial technical/professional qualification	14
Completed Tertiary	Polytechnic or University qualification	16

Source: Adapted from Thomas et al. (2001) and Senadza (2012).

4.5 Empirical Model

The effect of digital technology on educational inequality is estimated with:

$$Gini_edu = d0 + c1(Internet) + c2(Mobile) + c3(Mobile \times Internet) + c4(Digitech) + c5(Gender) + c6(Quintile) + c7(Age) + c8(\ln AgeSq) + c9(Urban) + c10(\ln HHsize) + Region\ FE + [Round\ FE] + e \quad (3)$$

$$Theil_edu = d0 + c1(Internet) + c2(Mobile) + c3(Mobile \times Internet) + c4(Digitech) + c5(Gender) + c6(Quintile) + c7(Age) + c8(\ln AgeSq) + c9(Urban) + c10(\ln HHsize) + Region\ FE + [Round\ FE] + e \quad (4)$$

Three nested specifications of the technology block are estimated for both dependent variables in every round and in the pooled sample: Model A includes internet access and mobile ownership as separate main effects; Model B adds their interaction; Model C replaces internet, mobile, and their interaction with a single composite digitech index constructed via principal component analysis (PCA) of household mobile ownership and internet access. The Kaiser-Meyer-Olkin (KMO) measure and first-component eigenvalue are reported for each round's PCA to justify the index.

Two estimation techniques are used. Pooled ordinary least squares (OLS), with standard errors clustered on the primary sampling unit, is the benchmark. Quantile regression traces the effect of digital technology across the conditional distribution of educational inequality at quantiles 0.40, 0.50, 0.60, 0.75, and 0.90, rather than the conventional 0.10/0.25/0.50/0.75/0.90 set, because approximately 30% of households have an education Gini of exactly zero, which makes the 0.10 and 0.25 quantiles degenerate. For a response y and predictors $X = (x_1, \dots, x_p)$, the quantile regression model for quantile $\tau(\tau)$ is $Q(\tau|X) = b_0(\tau) + b_1(\tau)x_1 + \dots + b_p(\tau)x_p$.

As a robustness check, given that the education Gini is bounded on $[0,1]$, a fractional logit model is estimated for edu_gini , with average marginal effects reported; the Theil-T index can exceed 1 and is therefore not modelled this way. Post-estimation diagnostics include the variance inflation factor to check multicollinearity and Pregibon's linktest to check functional-form misspecification. Finally, the pooled sample is estimated with round fixed effects and round-by-technology interaction terms (round $\times$ internet, round $\times$ mobile) to test directly whether the strength of the technology-inequality relationship changed between 2005/06 and 2016/17.

5. Results and Discussion

5.1 Descriptive Statistics

Table 3 reports descriptive statistics for the pooled analytic sample (household members aged 15+, N = 101,483). Mean household-level educational inequality across the pooled sample is moderate (mean education Gini 0.260, mean Theil-T 0.327), with substantial variation. Mean age is 36.3 years and mean household size is 5.63. Mobile phone ownership is high on average (72.4%), while internet access is close to an even split (54.4%), reflecting the pooling of an early-diffusion round with two later, higher-penetration rounds.

Table 3. Descriptive Statistics of Continuous Variables (Pooled Sample, Age 15+)

Variable	Obs.	Mean	Std. Dev.	Min	Max
Education Gini (edu_gini)	101,479	0.2604	0.2512	0	0.9167
Theil-T index (edu_theil)	101,479	0.3272	0.4328	0	2.4849
Mobile phone ownership	101,483	0.7235	0.4473	0	1
Internet access/use	101,483	0.5438	0.4981	0	1
Mobile x Internet	101,483	0.4727	0.4993	0	1
Digital technology index (PCA)	101,483	0.0516	1.0633	-3.677	3.005
Male	101,483	0.4669	0.4989	0	1
Urban	101,483	0.3954	0.4889	0	1
Age (years)	101,483	36.30	17.51	15	99
Household size	101,483	5.63	3.40	1	29

Source: Authors' computation using GLSS 5, 6, 7 (pooled, age 15+).

Table 4 reports the distribution of the income quintile variable by round. The share of the analytic sample in the poorest quintile rises from 23.9% in 2005/06 to 26.3% in 2012/13 and 29.2% in 2016/17, a shift that reflects each round's own national quintile construction rather than a direct claim about real income trends. Table 5 reports the distribution of religious affiliation, which is comparatively stable across rounds, with Christian households consistently the majority.

Table 4. Income Quintile Distribution by Round (Age 15+)

Quintile	2005/06	2012/13	2016/17	Total
1 (poorest)	5,293	11,368	10,538	27,199
2	4,064	8,357	7,507	19,928
3	3,907	7,794	6,221	17,922
4	4,066	7,864	5,810	17,740

Quintile	2005/06	2012/13	2016/17	Total
5 (richest)	4,813	7,878	6,003	18,694
Total	22,143	43,261	36,079	101,483

Table 5. Religious Affiliation Distribution by Round (Age 15+)

Religious affiliation	2005/06	2012/13	2016/17	Total
Christianity	14,721	29,519	24,544	68,784
Muslim	4,095	8,722	7,596	20,413
Traditionalist	2,121	2,721	2,350	7,192
No religion	1,182	2,252	1,534	4,968
Total	22,119	43,214	36,024	101,357

Source: Authors' computation using GLSS 5, 6, 7. Religion totals fall slightly below the full analytic N due to a small number of missing responses in each round.

5.2 Educational Inequality by Demographic Group

Tables 6 through 8 report the population-level (between-group) education Gini and Theil-T index by gender, religious affiliation, and location, computed separately for each survey round following the method described in Section 4.4. Round 5 additionally reports the breakdown by ecological zone (Table 8a).

Table 6. Educational Inequality by Gender (Population-Level Gini/Theil-T)

Gender	2005/06 Gini	2005/06 Theil	2012/13 Gini	2012/13 Theil	2016/17 Gini	2016/17 Theil
Female	0.5634	0.6723	0.5068	0.5517	0.5143	0.5613
Male	0.4305	0.4117	0.3859	0.3375	0.3989	0.3565
Total	0.5009	0.5497	0.4505	0.4519	0.4606	0.4659

Source: Authors' computation, GLSS 5, 6, 7. "Total" is the population-level index across all individuals aged 15+ in that round.

Table 7. Educational Inequality by Religious Affiliation (Population-Level Gini/Theil-T)

Religion	2005/06 Gini	2005/06 Theil	2012/13 Gini	2012/13 Theil	2016/17 Gini	2016/17 Theil
Christianity	0.3920	0.3514	0.3592	0.2993	0.3786	0.3266
Muslim	0.6750	0.9439	0.6113	0.7758	0.6008	0.7447
Traditionalist	0.8842	1.9698	0.7992	1.4107	0.7807	1.3261
No religion	0.5459	0.6262	0.5801	0.6994	0.5507	0.6308
Total	0.4997	0.6308	0.4493	0.4863	0.4590	0.4929

Source: Authors' computation, GLSS 5, 6, 7.

Table 8. Educational Inequality by Location (Population-Level Gini/Theil-T)

Location	2005/06 Gini	2005/06 Theil	2012/13 Gini	2012/13 Theil	2016/17 Gini	2016/17 Theil
Rural	0.6013	0.7580	0.5347	0.6031	0.5414	0.6162
Urban	0.3270	0.2601	0.3174	0.2460	0.3249	0.2503
South	0.3838	0.3380	0.3483	0.2844	0.3463	0.2785
North	0.7910	1.3671	0.6640	0.9066	0.6609	0.8950
Total	0.5006	0.6331	0.4504	0.4855	0.4603	0.5019

Source: Authors' computation, GLSS 5, 6, 7.

Table 8a. Ecological Zone Breakdown, round 5 Only (Population-Level Gini/Theil-T)

Ecological Zone	Gini (2005/06)	Theil-T (2005/06)
Coastal	0.3386	0.2665
Forest	0.3754	0.3312
Savannah	0.7435	1.1720
Total	0.4992	0.6190

Source: Authors' computation, GLSS 5. Zone breakdown for Rounds 6 and 7 not estimated in the current analysis.

Across all three rounds, women, Muslim and Traditionalist households, rural households, and northern households consistently exhibit substantially higher population-level educational inequality than men, Christian households, urban households, and southern households respectively. The magnitude of these gaps narrows only modestly between 2005/06 and 2016/17, and in several cases - Traditionalist households, the rural/urban gap - remains very wide throughout, underscoring that these structural and locational disparities have proven considerably more persistent than the growth in digital access documented below.

5.3 Round 5 (2005/06): Regression Results

Table 9 reports OLS estimates for edu_gini and edu_theil in Round 5 (N = 22,127-22,143, age 15+; standard errors clustered on the primary sampling unit). Model A enters internet and mobile as separate main effects; Model B adds their interaction; Model C replaces them with the composite digitech index. The PCA underlying digitech in Round 5 has a first-component eigenvalue of 1.317 (KMO = 0.500).

Table 9. OLS Regression Results — Round 5 (2005/06)

Variable	Gini A	Gini B	Gini C	Theil A	Theil B	Theil C
Internet	0.0079 (0.66)	0.0156 (1.06)	-	0.0052 (n.s.)	0.0127 (n.s.)	-
Mobile	-0.0590*** (-7.41)	-0.0519*** (-5.18)	-	-0.1054*** (-7.48)	-0.0986*** (-)	-
Mobile x Internet	-	-0.0201 (-1.36)	-	-	-0.0193 (n.s.)	-
Digitech (PCA)	-	-	-0.0165*** (-4.68)	-	-	-0.0315*** (-5.18)
Male	-0.0009	-0.0009	-0.0014	-0.0025	-0.0025	-0.0032
Quintile 4 (vs. 1)	-0.0302**	-0.0309**	-0.0321**	-0.0907***	-	-
Urban	-0.0269***	-0.0285***	-0.0214**	-0.0559***	-	-0.0469***
Age	0.0068***	0.0068***	0.0069***	0.0103***	-	-
ln(Age-squared)	-0.1230***	-0.1229***	-0.1241***	-0.1763***	-	-
ln(HH size)	0.1288***	0.1287***	0.1264***	0.1715***	-	-
Constant	0.6815***	0.6808***	0.6769***	0.9567***	0.9561***	0.9463***
F-statistic	66.72	63.50	67.46	50.40	48.12	51.72
R-squared	0.2013	0.2014	0.1985	0.2006	0.2007	0.1982
N	22,127	22,127	22,127	22,127	22,127	22,127

Notes: *t*-statistics in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$, n.s. = not significant. Region fixed effects and full quintile dummies included in all models. "-" denotes a coefficient not separately reported in this table for brevity.

Multicollinearity diagnostics (Model B) show a mean VIF of 3.62, well within conventional thresholds. Pregibon's linktest is significant on both the linear and squared linear predictor for both dependent variables, motivating the quantile and fractional logit specifications below.

Table 9a. Quantile Regression — Round 5 (2005/06)

Quantile	Gini: Internet	Gini: Mobile	Gini: Mobint	Theil: Internet	Theil: Mobile	Theil: Mobint
0.40	0.0081	-0.0306***	-0.0097*	0.0022	-0.0186***	-0.0035
0.50	0.0096**	-0.0549***	-0.0103**	0.0007	-0.0489***	0.0006
0.60	0.0090	-0.0648***	-0.0072	-0.0019	-0.0794***	0.0123
0.75	-0.0015	-0.0732***	0.0112	-0.0035	-0.1399***	0.0285**
0.90	0.0277**	-0.0968***	-0.0999***	-0.0135	-0.2516***	0.0081

Notes: $N = 22,127$ at each quantile

Mobile ownership reduces household educational inequality at every quantile in Round 5, and the effect grows moving up the distribution of both indices. Internet access alone is not a significant equaliser except at the extreme 90th percentile, and the mobile x internet interaction becomes significantly negative only at the 90th percentile of the Gini distribution - mobile phone ownership, not yet internet access, was the dominant equalising channel this early in the diffusion process.

Table 9b. Fractional Logit Robustness — Round 5 (edu_gini)

Variable	Coefficient	Average Marginal Effect
Internet	0.1136 (1.24)	0.0197 (1.24)
Mobile	-0.3503*** (-5.34)	-0.0608*** (-5.35)
Mobile x Internet	-0.1459 (-1.44)	-0.0253 (-1.43)
Male	-0.0343** (-2.24)	-

Notes: t -statistics in parentheses; *** $p < 0.01$, ** $p < 0.05$. $N = 22,127$.

Taken together, round 5 shows mobile phone ownership as the dominant equalising digital-technology channel in the earliest phase of diffusion, with effects strongest among the most unequal households.

5.4 Round 6 (2012/13): Regression Results

By 2012/13, mobile ownership had risen to 86% and internet access to 89% of the analytic sample. Table 10 reports OLS estimates ($N = 43,261$). The digitech PCA eigenvalue is 1.063 (KMO = 0.500).

Table 10. OLS Regression Results — Round 6 (2012/13)

Variable	Gini A	Gini B	Gini C	Theil A	Theil B	Theil C
Internet	-0.0215*** (-2.73)	-0.0223 (-1.19)	-	-0.0514*** (-3.05)	-0.0614 (-1.63)	-
Mobile	0.0227*** (2.79)	0.0219 (1.15)	-	-0.0039 (n.s.)	-0.0142 (n.s.)	-
Mobile x Internet	-	0.0010	-	-	0.0121	-

Variable	Gini A	Gini B	Gini C	Theil A	Theil B	Theil C
		(0.05)			(n.s.)	
Digitech (PCA)	-	-	0.0003	-	-	-0.0131**
			(0.11, n.s.)			(-2.57)
Male	-0.0041***	-	-0.0036**	-0.0095***	-	-0.0090***
F-statistic	186.24	177.89	192.11	93.12	89.26	97.89
R-squared	0.2647	0.2647	0.2632	0.2338	0.2339	0.2334
N	43,261	43,261	43,261	43,261	43,261	43,261

Notes: *t*-statistics in parentheses; *** $p < 0.01$, ** $p < 0.05$. Income quintile, age, $\ln$ -age-squared, $\ln$ -household-size, urban, and region fixed effects included in all models.

Unlike Round 5, internet access in Round 6 is associated with significantly lower inequality (Model A), while mobile ownership is associated with significantly higher inequality on the Gini measure - a reversal from Round 5. Once the interaction is added (Model B), neither internet, mobile, nor their interaction remains individually significant: mean VIF rises to 4.29 (mobile 7.19, mobint 12.22), reflecting that mobile and internet ownership were both already near 85-90% and hence highly correlated by 2012/13.

Table 10a. Quantile Regression — Round 6 (2012/13)

Quantile	Gini: Internet	Gini: Mobile	Gini: Mobint	Theil: Internet	Theil: Mobile	Theil: Mobint
0.40	-0.0046	0.0639***	-0.0103	-0.0514**	-0.0039	-
0.50	-0.0069	0.0465**	-0.0200	-0.0614	-0.0142	0.0121
0.60	-0.0069	0.0401**	-0.0299*	0.0024	0.0520**	-0.0207
0.75	-0.0314*	-0.0321**	-0.0053	-0.0029	0.0465**	-0.0234
0.90	-0.0319***	-0.0317***	-0.0043	-0.0163	0.0428**	-0.0315

Notes: $N = 43,261$ at each quantile.

The Round 6 quantile results show a crossover: mobile ownership is associated with significantly higher inequality at lower and middle quantiles but significantly lower inequality at upper quantiles, while internet only becomes a significant equaliser at the top of the distribution - technology access was not yet uniformly equalising at this intermediate stage of diffusion.

Table 10b. Fractional Logit Robustness — Round 6 (edu_gini)

Variable	Coefficient	Average Marginal Effect
Internet	-0.1232 (-1.31)	-0.0214 (-1.31)
Mobile	0.0741 (0.80)	0.0129 (0.80)
Mobile x Internet	0.0264 (0.26)	0.0046 (0.26)

Notes: $N = 43,261$. None of the three AMEs is significant, consistent with the elevated VIF diagnosed above. A robustness check using internet_use (active use) instead of internet access yields similar fit (Gini: $F(20,1199)=190.25$, $R^2=0.2680$; Theil: $F(20,1199)=96.34$, $R^2=0.2375$).

Round 6 is the round in which the technology-inequality relationship is least clear-cut on its own: internet's equalising role appears only in the simplest specification, mobile's association changes sign across the distribution, and the interaction term is undermined by rising multicollinearity as mobile and internet penetration converge.

5.5 Round 7 (2016/17): Regression Results

By 2016/17, mobile ownership had reached 89% of the analytic sample, while the individually verified internet-use measure records 35%. Table 11 reports OLS estimates (N = 36,079). The digitech PCA eigenvalue is 1.257 (KMO = 0.500).

Table 11. OLS Regression Results — Round 7 (2016/17)

Variable	Gini A	Gini B	Gini C	Theil A	Theil B	Theil C
Internet	-0.0411*** (-8.72)	0.0603 (1.68)	-	-0.1015*** (-11.92)	0.0529 (0.82)	-
Mobile	0.0451*** (4.89)	0.0479*** (5.15)	-	0.0403** (2.48)	0.0447*** (2.72)	-
Mobile x Internet	-	-0.1026*** (-2.86)	-	-	-0.1564** (-2.43)	-
Digitech (PCA)	-	-	-0.0037 (n.s.)	-	-	-0.0256*** (-5.76)
Male	-0.0012	-	-0.0017	-0.0029	-	-0.0039
F-statistic	207.73	-	-	-	-	-
R-squared	0.3028	-	-	-	-	-
N	36,079	36,079	36,079	36,079	36,079	36,079

Notes: *t*-statistics in parentheses; *** $p < 0.01$, ** $p < 0.05$. Income quintile, age, $\ln$ -age-squared, $\ln$ -household-size, urban, and region fixed effects included in all models.

Round 7's diagnostics carry the most important specification caveat in this study. The variance inflation factor for Model B is severe (mean VIF 11.98), driven almost entirely by the mobile x internet interaction (VIF 91.95), because by 2016/17 mobile ownership (89%) and internet use (35%, concentrated among mobile owners) had become closely associated. Model B's coefficients for Round 7 alone should be interpreted with caution; Model A and the pooled specification, where the equivalent VIF falls to 6.86, are more reliable guides.

Table 11a. Quantile Regression — Round 7 (2016/17, edu_gini)

Quantile	Internet	Mobile	Mobile x Internet
0.40	0.1075***	0.0747***	-0.1346***
0.50	0.0625***	0.0563***	-0.1060***
0.60	0.0563 (n.s.)	0.0431***	-0.1090***
0.75	0.0460***	0.0285***	-0.1269***
0.90	-0.0230**	-0.0169***	-0.0676***

Notes: *** $p < 0.01$, ** $p < 0.05$. $N = 36,079$.

The mobile x internet interaction is consistently, strongly negative (equalising) across all five quantiles, in contrast to the main effects, which are positive at lower and middle quantiles and only turn negative at the 90th percentile. This is the clearest single-round evidence that holding both mobile and internet access jointly - a genuine complementarity, not simply an averaging of two main effects - is what drives digital technology's equalising effect by 2016/17.

Table 11b. Fractional Logit Robustness — Round 7 (edu_gini)

Variable	Coefficient	Average Marginal Effect
Internet	0.3483* (1.71)	0.0621* (1.71)
Mobile	0.2319*** (4.53)	0.0413*** (4.55)
Mobile x Internet	-0.5895*** (-2.90)	-0.1050*** (-2.90)

Notes: *** $p < 0.01$, * $p < 0.10$. $N = 36,079$.

By 2016/17, digital technology's equalising effect operates overwhelmingly through the joint holding of mobile and internet access rather than through either technology alone, robust across OLS (net of the collinearity caveat), quantile regression, and fractional logit.

5.6 Pooled Results (GLSS 5, 6, 7 Combined)

Appending the three rounds' harmonised extracts yields a pooled sample of 116,468 round-level observations; after the age-15+ restriction, the pooled regression sample is 101,467-101,483. All pooled models include survey-round fixed effects and cluster standard errors on a combined round-cluster identifier.

Table 12. OLS Regression Results — Pooled Sample (with Round Fixed Effects)

Variable	Gini A	Gini B	Gini C	Theil A	Theil B	Theil C
Internet	-0.0271*** (-6.84)	-0.0052 (-0.61)	-	-0.0667*** (-8.84)	-0.0293* (-1.91)	-
Mobile	0.0128** (2.52)	0.0254*** (4.10)	-	-0.0110 (n.s.)	0.0107 (n.s.)	-
Mobile x Internet	-	-0.0279*** (-3.16)	-	-	-0.0476*** (-2.98)	-
Digitech (PCA)	-	-	-0.0042*** (-2.63)	-	-	-0.0205*** (-7.00)
Male	-0.0024**	-0.0023**	-0.0023**	-0.0059***	-0.0057***	-0.0059***
F-statistic	368.68	356.21	380.13	204.37	196.27	212.71
N	101,467	101,467	101,467	101,467	101,467	101,467

Notes: *t*-statistics in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. Income quintile, age, $\ln$ -age-squared, $\ln$ -household-size, urban, region, and round fixed effects included in all models.

Pooling resolves the Round-7-specific multicollinearity problem: mean VIF for Model B falls to 3.87. In the pooled Model B, internet's main effect becomes statistically indistinguishable from zero once the interaction is included, while mobile and the interaction remain significant and work in opposite directions - mobile ownership alone is associated with slightly higher inequality, but holding both mobile and internet together is associated with significantly lower inequality, echoing the Round-7 finding that digital technology's equalising effect in Ghana runs primarily through combined access.

5.6.1 Has the Technology-Inequality Relationship Changed Over Time?

To test directly whether the association between digital technology and educational inequality has strengthened or weakened between 2005/06 and 2016/17, internet and mobile are each interacted with survey round (base category: 2005/06).

Table 13. Pooled OLS with Round x Technology Interactions

Variable	edu_gini	edu_theil
Internet (2005/06 baseline)	0.0138 (n.s.)	0.0034 (n.s.)
Mobile (2005/06 baseline)	-0.0402*** (-5.45)	-0.0899*** (-6.81)
Round 2012/13 x Internet	-0.0397*** (-3.26)	-0.0582** (-2.43)
Round 2016/17 x Internet	-0.0566*** (-5.49)	-0.1032*** (-5.42)
Round 2012/13 x Mobile	0.0562*** (5.21)	0.0777*** (4.01)
Round 2016/17 x Mobile	0.0893*** (7.68)	0.1410*** (6.87)
Male	-0.0023** (-2.09)	-0.0055*** (-2.85)
F-statistic	320.57	176.77
R-squared	0.2592	0.2391
N	101,467	101,467

Notes: *t*-statistics in parentheses; *** $p < 0.01$, ** $p < 0.05$. Base round is 2005/06.

This is the central novel finding of the study. Internet access has no significant relationship with household educational inequality at baseline (2005/06), but its equalising association becomes significantly negative and progressively larger in 2012/13 and again in 2016/17 - the internet-inequality relationship has strengthened considerably as internet access itself has diffused. Mobile ownership shows the opposite pattern: its negative baseline effect is progressively offset by positive round interactions, consistent with mobile's marginal equalising power diminishing once penetration approaches saturation and the remaining variation in inequality is increasingly explained by who has internet access rather than who has a phone.

Table 14. Fractional Logit Robustness — Pooled Sample (edu_gini)

Variable	Coefficient	Average Marginal Effect
Internet	-0.0322 (-0.64, n.s.)	-0.0057 (-0.64, n.s.)
Mobile	0.1170*** (3.38)	0.0205*** (3.39)
Mobile x Internet	-0.1500*** (-2.93)	-0.0263*** (-2.93)
Male	-0.0357*** (-5.90)	-

Notes: *** $p < 0.01$. $N = 101,467$; round fixed effects included. Confirms the pooled OLS pattern: the mobile x internet interaction is a robust, significant equaliser, while internet's unconditional main effect is not significant once mobile and the interaction are both in the model.

5.7 Has Educational Inequality Actually Declined? A Trend Check

A natural reading of Sections 5.3-5.6 - internet and mobile access mostly reducing inequality, and their joint effect growing stronger over time - might suggest measured educational inequality in Ghana has been falling as digital access expanded. The household-level descriptive means do not support that reading: mean education Gini among individuals aged 15+ is 0.2503 in 2005/06, 0.2555 in 2012/13, and 0.2722 in

2016/17; mean Theil-T is 0.3261, 0.3142, and 0.3432. Both indices are essentially flat between 2005/06 and 2012/13 and then rise between 2012/13 and 2016/17, rather than declining monotonically.

This does not contradict the regression findings, which describe partial, *ceteris paribus* associations, but it does mean rising digital access has coincided with, not prevented, a rise in aggregate household-level educational inequality. Several explanations are consistent with both facts holding simultaneously. First, the composition of who gains digital access changed across rounds: by 2016/17 mobile ownership was near saturation, so remaining cross-household variation in technology access concentrated in internet use, which the pooled interaction model (Table 13) shows became a stronger equaliser precisely as it diffused - implying its equalising effect operated on a shrinking pool of unconnected households while other, non-technology drivers of inequality (Tables 6-8) continued to widen or held steady. Second, income quintile and household-size effects, large and consistently significant across all rounds, may have moved in an inequality-increasing direction for reasons unrelated to digital technology, more than offsetting technology's own equalising contribution in the aggregate. Third, the change in the internet measure between Round 6 (household-reported access, 89% prevalence) and Round 7 (individually verified use aged 12+, 35% prevalence) means part of the level shift in mean inequality between those rounds could reflect measurement change rather than a real deterioration; the Round 5-to-6 trend, measured on more comparable definitions, is itself close to flat (0.2503 to 0.2555), which is the more conservative basis for the non-declining-trend claim.

The honest conclusion is that digital technology access, and internet access in particular, has become a progressively stronger predictor of lower educational inequality among households that have it, but this has not yet been sufficient to reduce aggregate educational inequality in Ghana over 2005/06-2016/17, which instead appears flat to rising. This qualifies any policy narrative that treats expanding digital access alone as sufficient to close Ghana's educational inequality gap.

5.8 Lorenz Curve and Empirical Distribution

The Lorenz curve and empirical cumulative distribution function of years of schooling for the pooled sample of household members aged 15+ are reported in the Appendix (Figures A1 and A2).

6. Policy and Practical Implications

These findings carry more qualified policy implications than a simple "digital technology reduces inequality" narrative would suggest. Because the equalising role of internet access, and especially the joint holding of mobile and internet access, has strengthened considerably between 2005/06 and 2016/17, expanding affordable internet connectivity remains a credible lever for reducing household-level educational inequality going forward, particularly as internet penetration remains well below mobile penetration and therefore has more room to close remaining gaps.

First, because the internet-inequality relationship strengthened over time rather than being strong from the outset, policy should not assume early-stage digital rollout automatically delivers equalising benefits; benefits appear to accrue as access matures and as households increasingly hold both mobile and internet access jointly rather than either alone. Second, because mobile ownership is already near-saturated (86-89%) by 2012/13-2016/17, further mobile-specific interventions likely have limited additional equalising potential; policy should instead prioritise closing the remaining internet-access gap, where this study finds the strongest and still-growing equalising effect. Third, the persistence of very large gaps in population-level educational inequality by religion, rural/urban residence, and north/south location (Tables 6-8), essentially unmoved by rising digital access, points to a structural set of disparities that digital policy alone cannot close; complementary investment in rural school infrastructure and teacher deployment to northern and Savannah-zone districts is necessary alongside, not instead of, digital-access expansion. Fourth, given that mean aggregate educational inequality did not decline over 2005/06-2016/17 despite rising digital access (Section 5.7), policymakers should treat digital inclusion as one input among several, pairing connectivity investment with affordability measures and digital-literacy programmes, and monitoring whether new access reaches the specific groups shown here to carry the highest burden of educational inequality. Finally, because this study's measures capture ownership and access rather than intensity or quality of use, future policy evaluation should track these dimensions directly, since the complementary effect of joint mobile and internet access identified here suggests that policies bundling connectivity with device access are likely to be more effective than either in isolation.

7. Limitations

This study has several limitations. First, digital technology is measured using binary indicators for mobile phone ownership and internet access/use together with a composite PCA index; these capture access but not intensity, quality, affordability, or purpose of use. Second, the internet-access measure is not perfectly comparable across rounds: Rounds 5 and 6 rely on household-reported access, while Round 7's measure is individually verified and restricted to members aged 12+, contributing to the sharp apparent drop in

prevalence between Round 6 (89%) and Round 7 (35%); the round-interaction results in Table 13 should be read with this caveat, and the Round 5-to-6 comparison is the more conservative basis for any trend claim. Third, severe multicollinearity between mobile and internet access in the Round 7 cross-section (mean VIF 11.98) means the Round 7 standalone Model B coefficients should not be over-interpreted individually; the quantile, fractional logit, and pooled specifications are more reliable guides. Fourth, this study documents an association, not a causal effect: digital technology access is not randomly assigned, and unobserved household characteristics likely influence both technology adoption and educational inequality simultaneously; a panel or instrumental-variables design would be needed to support a causal interpretation. Fifth, the study focuses on Ghana, and caution is warranted when generalising the results, including the finding that aggregate inequality has not declined despite rising digital access, to other countries with different educational systems and policy environments.

For future research, panel data following the same households over time would allow a more credible causal test of whether digital access reduces educational inequality. Research should also examine internet-use quality and intensity and whether the strengthening internet-inequality relationship identified here continues in survey rounds after 2016/17.

8. Conclusion

This study provides new evidence, built from household-level educational inequality measures across three rounds of the GLSS, that digital technology's relationship with educational inequality in Ghana is real but more conditional and time-varying than a simple equalising story would suggest. Mobile phone ownership was the dominant equalising channel in 2005/06, when digital penetration was low; by 2012/13, as mobile and internet access both approached near-universal levels, the technology-inequality relationship became ambiguous and afflicted by multicollinearity; and by 2016/17, the equalising effect of digital technology operated overwhelmingly through the joint holding of mobile and internet access rather than either alone, a complementary relationship confirmed by quantile regression, fractional logit, and pooled estimation alike. A direct test of whether this relationship changed over time shows internet access's equalising association strengthened significantly and monotonically between 2005/06 and 2016/17.

At the same time, this study surfaces an important tension: mean household-level educational inequality in Ghana did not decline over this period - essentially flat between 2005/06 and 2012/13, then rising by 2016/17 - even as digital access expanded dramatically and its estimated equalising effect strengthened. Digital inclusion therefore appears to be a necessary complement to, but not a substitute for, the broader structural interventions needed to reduce Ghana's educational inequality: closing large and persistent gaps

by gender, religion, rural-urban residence, and north-south location that narrowed only modestly, and in several cases barely at all, over more than a decade.

These findings reposition the relationship between the digital divide and educational inequality as a genuinely evolving, and still incompletely closed, policy challenge in Ghana's education system. Addressing educational inequality requires integrated digital-education strategies that prioritise affordability and internet connectivity specifically, while sustaining parallel investment in rural and northern school infrastructure and targeted support for the population groups shown here to carry the most persistent inequality burden. Future research extending this analysis with panel data, richer measures of digital-technology intensity, and survey rounds beyond 2016/17 will be essential for confirming whether the strengthening equalising relationship identified here continues.

Declarations

Data Availability: The datasets analysed in this study (GLSS Rounds 5, 6, and 7) are available from the Ghana Statistical Service via formal data request at <https://microdata.statsghana.gov.gh/index.php/home>. In addition, the used data for the analysis has been attached to the system during the submission of the material.

Code Availability: The complete Stata do-file package used to construct all variables and produce every table in this manuscript is available upon reasonable request and has been attached to aid the review of the paper if needed.

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Ethics Approval: Not required. This study relied exclusively on secondary, de-identified household survey data obtained from a public statistical agency, with no direct involvement of human participants by the authors.

Consent to Participate: Not applicable. The study used secondary data; no primary data were collected from human participants by the authors.

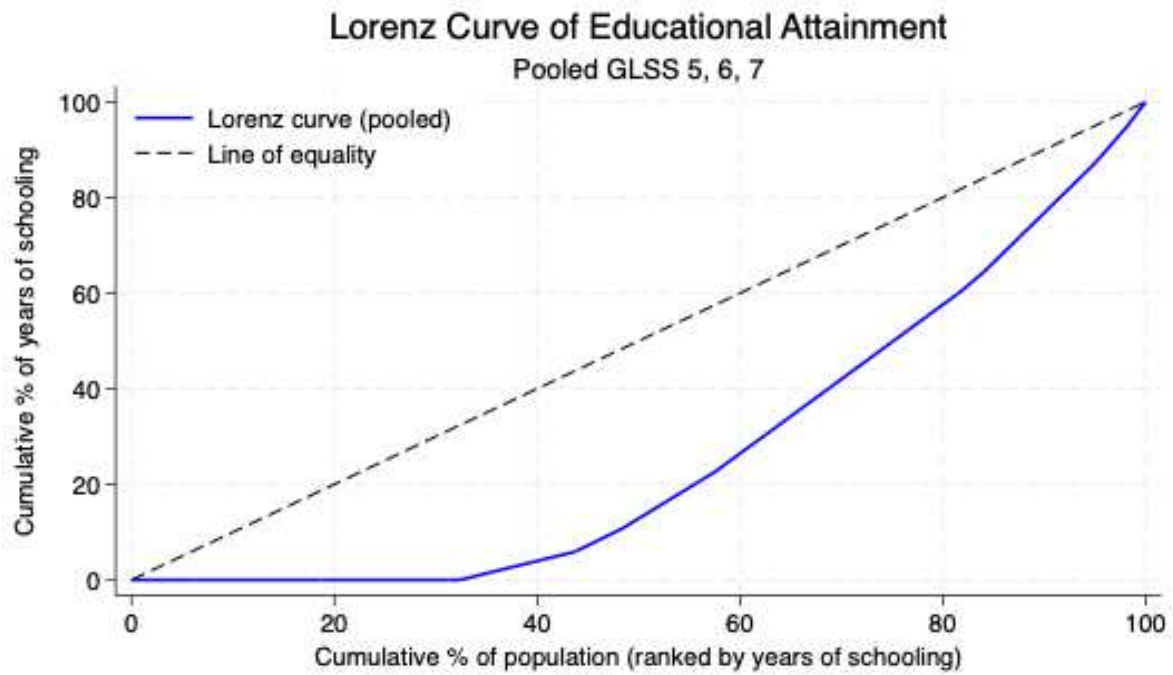
Consent to Publish: Not applicable. The study is based on anonymised secondary data obtained from a publicly available data request procedure.

Authors' Contributions: N.P.P. & A.A., conceived the study, constructed the datasets, conducted the empirical analysis, and drafted the manuscript. I.K.A., and K.A.O.-M. contributed to the theoretical framing, reviewed and revised the manuscript critically, and approved the final version.

Appendix

Appendix A. Lorenz Curve and Empirical CDF (Pooled Sample)

Figure A1: Lorenz Curve of Educational Attainment, Pooled GLSS 5, 6, 7



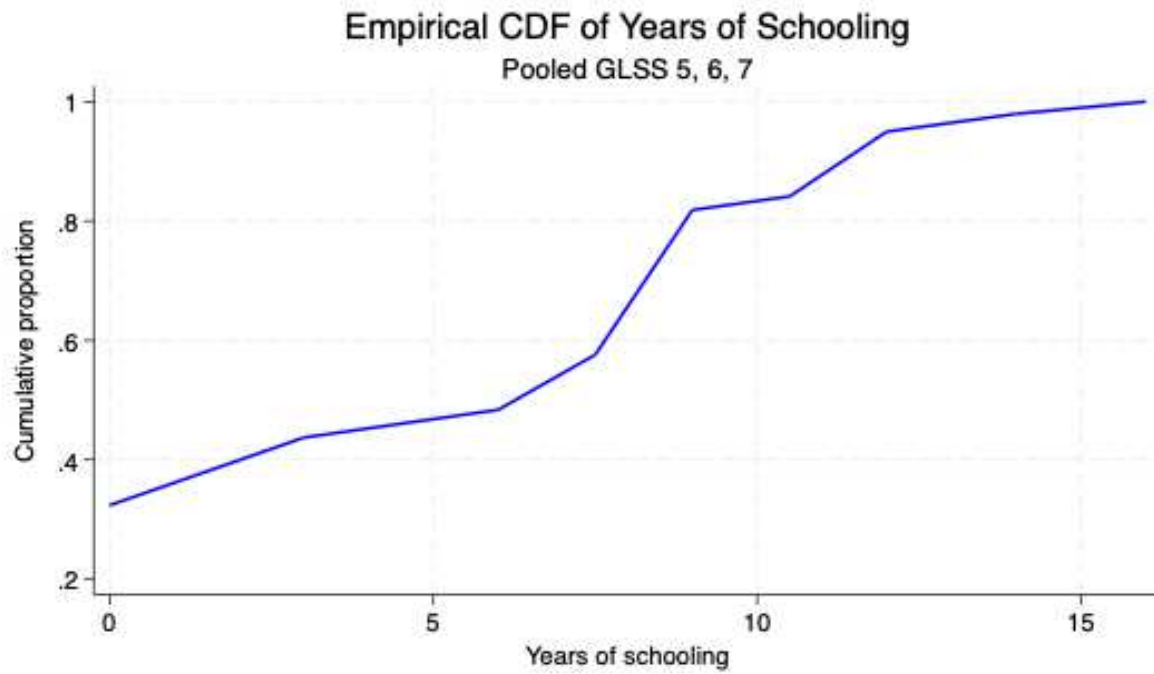


Figure A2: Empirical CDF of Years of Schooling, Pooled GLSS 5, 6, 7

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