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The Mobile Phone Technology, Gender Inclusive Education and Public Accountability in Sub-Saharan Africa

Forthcoming: Telecommunications Policy

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Abstract

This study assesses the relevance of mobile phone technology in complementing gender-inclusive education (i.e. primary, secondary and tertiary) to promote public accountability (i.e. involving horizontal, vertical and diagonal accountability dynamics). The study utilizes the generalized method of moments (GMM) technique to establish the empirical evidence based on 48 Sub-Saharan African countries for the period 2005-2018. The following findings are documented from the linkages between mobile phone technology, inclusive education and public accountability. First, the interactions between mobile phone technology and inclusive education promote public accountability. Second, with regard to net effects, while unexpected negative signs are established, the corresponding positive interactive effects indicate that enhancing the penetration of mobile phone technology beyond some critical thresholds ensures positive net effects. Hence, policymakers should ensure that mobile phone technology penetration exceeds the established thresholds in order for gender-inclusive education to positively affect public accountability.

Keywords: Mobile phone technology, educational quality, public accountability, Africa

1. Introduction

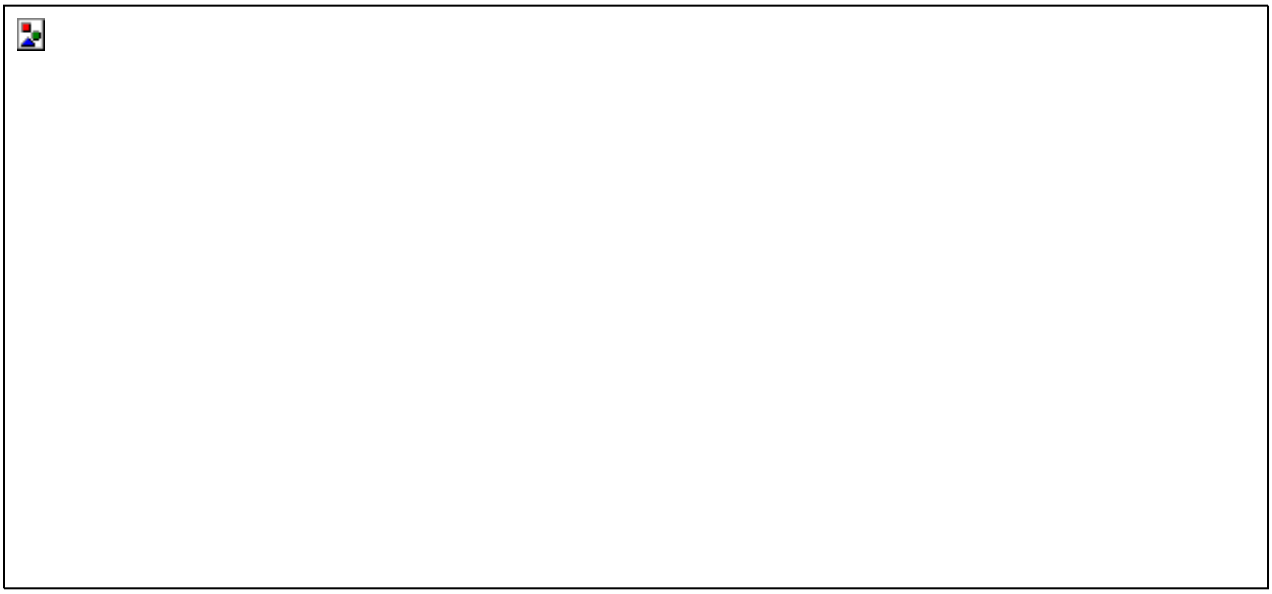
Public accountability is attributed to be the hallmark of modern democratic governance that acts as a check on the tyranny of leaders who tend to privatize executive power (Bovens, 2007; Schmitter, 2004; Mulford & Moreno, 2006). Northern Ireland Open Government Network (2015) clarified the definition of the concept that public accountability is concerned with the obligation of public servants to provide actual performance information, explain decision-making and justify behaviour that raises public questions, enabling public debates to ensure transparency in governance and permits the imposition of sanctions on the government over inefficient performance cases as well as misuse of executive power. Public accountability is important as it serves as a check not just for evaluative purposes but also for preventive purposes, hence, enhancing the learning capacity of public administration through information sharing for public scrutiny.

Information has been established to be a key building block to a wide range of strategies that attempt to tackle weaknesses in public service and public accountability (Lindsay & Tamar, 2017). A strategy as posited by Northern Ireland Open Government Factsheet (2015) entails the use of information to trace connections between the past, present and future for better decision making. Lindsay and Tamar (2017) further mentioned that for an improved public accountability system, three crucial factors must be taken into consideration, namely: the availability of transparent and reliable data/information, the digital technological dividends and the tension among the various stakeholders in the economy. This stresses the important role of information technology has to play in public accountability, as the dissemination tools are equally as important as the information.

Regarding Sub-Saharan Africa's (SSA) performance in educational quality (or gender-inclusive education), and public accountability, Asongu and Odhiambo (2019) noted the poor education policy syndrome in the region. Some of the issues faced by the SSA's education system include relatively poor infrastructure

(Ejemeyovwi, Osabuohien & Osabohien, 2018) and education facilities (Antoninis, 2009; Ejemeyovwi, Osabuohien, Johnson & Bowale, 2019)[1]. Information technology on another note, is not approaching saturation levels in the region because of the high potential for more technology adoption (Asongu & Boateng, 2018; Ejemeyovwi & Osabuohien, 2020). This claim is evident in Figure 1. In addition, governance and institutions in Africa have been relatively poor (Asongu and Nwachukwu, 2016; Asongu & Nwachukwu, 2019), and this indicates the relatively low level of public accountability trend in the region.

Figure 1: Mobile phone penetration in different regions



Information technology is important for public accountability, and in the same vein, educational quality is important not only for public accountability but also for information technology (Bovens 2007). This is so because some level of educational quality is required for adequate technology utilization, and at the same time, educational quality ensures the demand for public accountability. Some education is required for handling some of the complex processes offered by technological innovations (Cloete, 2017). Educational quality also informs

[1]The terms "education quality", "school enrollment", "inclusive education" and "gender-inclusive education" are used interchangeably throughout the paper.

the public servants about the need for public accountability and the technological medium to disseminate information to the public.

Notably, extant contemporary public accountability literature has fundamentally concentrated on *inter alia:* emphasis on public accountability and public policy changes through voters' reaction to changes in tax policy (Mörk & Nordin, 2019); design framework for public accountability in the educational reform (Hutt & Polikoff, 2020); relationship between transparency and ethical accountability (Herrera & Mahecha, 2018); empirical perception of forms of public accountability (Reddick, Demir, & Perlman, 2020); the relevance of anti-corruption measures for accountability performance (Heinrich & Brown, 2017); establishing citizen political knowledge for accountability (Opalo, 2020); an assessment of public accountability, public expenditure and financial accountability (Loozekoot & Dijkstra, 2017); investigating the nexuses of political trust and armed conflict underpinning accountability (Gates & Justesen, 2020); the determinants of information disclosure to foster accountability for sustainable transnational governance (Schleifer, Fiorini & Auld, 2019); and the importance of digital transparency in the convergence of public accountability (Ramírez & Tejada, 2019).

The examination of the "educational quality" – "technology threshold" – "public accountability" hypothesis in SSA is motivated by the relatively poor performance of the variables as discussed above and extant gap apparent in literature. The present study departs from studies such as Abugre (2018) who emphasized the importance of governance in promoting the quality of higher education; Asongu and Odhiambo (2019) who focused on enhancing the role of technology on quality education in SSA; Tchamyou, Asongu and Odhiambo (2019) who examined the role of information technology in modulating the effect of education and lifelong learning on income inequality and economic growth in Africa by a couple of ways; Ekong, Adiat, Ejemeyovwi and Alalade (2019); and Alalade, Ejemeyovwi, Ekong and Adeyemo (2019). The study differs

by examining public accountability as against the use of other common governance and institution variables. The study considers the mobile technology threshold while examining the role of educational quality on public accountability and focus on the SSA region is due to the relatively poor performance of public accountability in the sub-region.

Building on the conceptual issues above and extending the work of Asongu and Odhiambo (2019), this study's objectives are: (i) to establish the net effect of mobile phone technology in modulating the effect of educational quality on public accountability and (ii) provide policy makers with minimum thresholds of mobile phone penetration needed to harness educational quality to promote public accountability. The corresponding research questions are the following: (i) what is the net effect on public accountability from the role of mobile phone technology in moderating the incidence of educational equality on public accountability? (ii) What levels of mobile phone technology penetration should be attained for educational quality to promote public accountability?

To achieve the stated objective, the study is structured as follows: section two presents the data, technique of estimation and other methodological issues associated with the study. Regarding the analysis, the study utilizes the generalized method of moments (GMM) technique of estimation to analyse the data with a view of handling possible endogeneity issues in the empirical model. Section three deals with presentation and discussion of results whereas section four concludes the paper with implications and future research directions.

2. Data and Methodology

2.1 Data

Following the motivation of this study, the research assesses the panel dataset of forty-eight (48) countries in Sub-Saharan Africa for the period 2005-2018. The

choice of the selected countries and periodicity is limited by data availability. This study sources data from two reputable databases, namely, (a) Varieties of Democracy database (V-Dem), and (b) World Development Indicators (WDI) of the World Bank.

First, accountability indicators are obtained from the Varieties of Democracy (V-Dem) database. The database is created to produce better democracy indicators. V-Dem contains over 350 indicators on democracy and political system, which dates from 1789 till recent times. It is acclaimed that the procedures underpinning the construction process of the dataset are more transparent compared to other social science databases (Dom, 2018). From the database, four accountability indicators are sourced. These include: the vertical accountability index, diagonal accountability index, horizontal accountability index and accountability index. Details on the construction of the accountability indicators can be found in Lührmann *et al.* (2017), however a summary is outlined in Appendix 1 for definitions and sources of variables.

Second, the mobile phone penetration, educational quality and control variables are sourced from the World Development Indicators of the World Bank. In accordance with Tchamyou (2017) from knowledge economy literature, the mobile phone penetration is measured by the mobile cellular subscriptions (per 100 people).

The educational quality indicator used in the study is the "primary school enrollment, secondary school enrollment and tertiary school enrollment" gender parity indexes. The reasons underpinning the employment of these educational indicators include the lifelong learning motives and the necessity of educational quality in socio-economic development (Asongu, 2020; Asongu, Orim, & Nting, 2019). Moreover, these educational quality variables also double as gender inclusive variables given the relevant feature of gender inclusion in sustainable development goals (SDGs).

Three control variables (i.e. gross domestic product growth, population growth and foreign direct investment) are adopted for this study in which their influence remains debatable. Economic growth and population have been used by Asongu and Nwachukwu (2018) to predict the negative signals of Arab Spring governance. However, a positive nexus could be expected from these indicators because countries with higher income levels are associated with higher democratic standards, while a growing population requires more devoted government resources in managing the population (Asongu & Nwachukwu, 2016) as well as demands for public accountability. Likewise, financial globalization (i.e. foreign investment) is said to weaken domestic governments and citizens' emancipation because it encourages self-interest by prioritizing the dominance of markets over the interests of domestic governments, thereby influencing the standards of governance (Asongu, Nting, & Nnanna, 2020; Farazmand, 1999; Lalountas, Manolas & Vavouras, 2011). It is important to emphasize that the adoption of limited control variables is consistent with scholarly literature because in the GMM approach, there is a choice between avoiding variable omission bias and having robust estimates. This procedure is consistent with GMM-centric empirical studies that select less than three control variables to eliminate issues surrounding instrument proliferation (Asongu & Odhiambo, 2020b; Kavya & Shijin, 2020). Appendix 1 provides the definitions and sources of variables; Appendix 2 captures descriptive statistics while Appendix 3 discloses the correlation matrix.

2.2 Methodology

2.2.1 GMM specification

In the light of the attendant literature, data behaviour usually determines the choice of the estimation strategy adopted in a study. The choice of GMM approach builds on five justifications in accordance with contemporary

literature (Asongu, 2020) which are discussed in no order of importance. First, the number of the cross sections (i.e. N) should exceed the corresponding number of periods (i.e. T). Given that there are forty-eight sampled Sub-Saharan African countries for fourteen years (i.e. 2005-2018), the N>T criterion for the adoption of the GMM estimation is fulfilled. Second, a degree of persistence should be maintained in the data behaviour. This procedure is met because the four accountability indicators adopted in this study remain persistent and this is evident as the correlation between their respective level and first lag values is higher than the rule of thumb of 0.800 (Tchamyou, 2019, 2020b). Third, pertaining to the data structure and nature of the panel dataset, it is obvious that the empirical analysis accounts for cross-country differences in the estimation strategy. Fourth, the system GMM estimator considers the inherent biases in the difference GMM approach. Fifth, the study deals with the endogeneity issue through (a) the application of internal instrumentation to control for simultaneity and (b) utilization of time-invariant omitted indicators to account for the unobserved heterogeneity

Among the extant GMM approaches, this study follows the Roodman (2009a, 2009b) approach, an improvement of Arellano and Bover (1995) technique, which has been documented in recent literature to limit instrument proliferation (Asongu & Odhiambo, 2019).

This study adopts the two-step approach that addresses the heteroscedasticity issues instead of the one-step procedure that only controls for homoscedasticity. Below equations in level (1) and first difference (2) recapitulate the standard system GMM estimation technique.

$$A_{i,t} = \sigma_0 + \sigma_1 A_{i,t-\tau} + \sigma_2 M_{i,t} + \sigma_3 E_{i,t} + \sigma_4 ME_{i,t} + \sum_{h=1}^{3} \delta_h W_{h,i,t-\tau} + \eta_i + \xi_t + \varepsilon_{i,t} \quad (1)$$

$$A_{i,t} - A_{i,t-\tau} = \sigma_1(A_{i,t-\tau} - A_{i,t-2\tau}) + \sigma_2(M_{i,t} - M_{i,t-\tau}) + \sigma_3(E_{i,t} - E_{i,t-\tau}) + \sigma_4(ME_{i,t} - ME_{i,t-\tau}) + \sum_{h=1}^{3} \delta_h(W_{h,i,t-\tau} - W_{h,i,t-2\tau}) + (\xi_t - \xi_{t-\tau}) + (\varepsilon_{i,t} - \varepsilon_{i,t-\tau}) \quad (2)$$

where $A_{i,t}$ is the accountability indicator (i.e. accountability index, horizontal accountability index, vertical accountability index, diagonal accountability index) of country i in period t, σ_0 is a constant, M represents the mobile phone penetration (i.e. mobile cellular subscriptions (per 100 people)), E reflects the educational quality measures (gender parity "primary school enrollment, secondary school enrollment and tertiary school enrollment"), ME denotes the interactions between the mobile phone penetration and educational quality ("mobile phone penetration x primary school enrollment", "mobile phone penetration x secondary school enrollment", and "mobile phone penetration x tertiary school enrollment"), *W* is the vector of control variables (GDP growth, population growth and foreign direct investment), τ denotes the coefficient of autoregression that is one within the framework of this study because a year lag is capable of capturing past information, ξ_t is the time-specific constant, η_t is the country-specific effect and $\varepsilon_{i,t}$ is the error term.

2.2.2 Identification and exclusion restrictions

The identification and exclusion restrictions are indispensable for a robust GMM estimation. This is consistent with contemporary literature (Asongu et al., 2020b; Asongu & Nwachukwu, 2016; Tchamyou, 2020b) that validates "years" to be strictly exogenous whereas all explanatory variables (i.e. the educational quality indicators, mobile phone penetration proxy and the control variables) are acknowledged as predetermined and suspected endogenous. This identification approach is consistent with Roodman (2009b) and Meniago and

Asongu (2018) who argue that it is unlikely for "years" to turn out to be endogenous after a first difference.[2]

In accordance with the above stance, years affect the accountability dynamics exclusively through the predetermined and endogenous variables. Specifically, the Difference in Hansen Test (DHT) is employed to establish the statistical validity of exclusion restrictions procedure. Thus, the underlying exclusion assumption only holds when the null hypothesis of the DHT is not rejected. This means that the assumption of exclusion restrictions is validated, provided the alternative hypothesis of the DHT relating to instrumental variables (IV) (year, eq(diff)) is rejected. Moreover, the identification procedure and the exclusion restrictions validity criterion are in line with the standard instrumental variable Sargan Overidentifying Restrictions (OIR) test. This indicates that the strictly exogenous variables influence accountability dynamics exclusively through the exogenous components of the endogenous explaining variables (Asongu & Nwachukwu, 2016; Tchamyou & Asongu, 2017).

3. Results

3.1 Results presentation

Tables 1-4 present the empirical findings. In Table 1, the linkages pertain to the relationship between the mobile phone, education quality and the accountability index, whereas Table 2 discloses the nexuses between the mobile phone, education quality and the horizontal accountability index. Table 3 is concerned with the associations between the mobile phone, education quality and the vertical accountability index, Table 4 captures the connections between the mobile phone, education quality and the diagonal accountability index. Each table has three main specifications in line with the three main

[2]Hence, the procedure for treating ivstyle (years) is "iv (years, eq [diff])" whereas the gmmstyle is employed for predetermined variables.

independent variables of interest (i.e. primary school enrollment, secondary school enrollment and tertiary school enrollment). In addition, all specifications have two sub-specifications (i.e. one without control variables and the other with the set of control variables). To establish the validity of the estimated models, four information procedures are duly employed.[3] In this light of the established information procedures, the estimated models are overwhelmingly valid without any exemption.

In accordance with the recent literature based on the interactive regressions (Asongu & Nwachukwu, 2018; Asongu & Odhiambo, 2019a), the study computes the net effects to assess the incidence of mobile phone penetration in modulating the effect of educational quality on public accountability. For example, in Column 1 of Table 1, the net effect of mobile phone in modulating the effect of primary school enrollment on accountability index is -0.136 ([57.206 x 0.00244] + [-0.276]). In this computation, 57.206 is the mean value of mobile phone penetration, 0.00244 is the conditional effect from the interaction between mobile phone penetration and primary school enrollment while -0.276 is the unconditional effect of the primary school enrollment.

The study establishes the following findings from Table 1-4. There are negative net effects from the role of mobile phone in modulating the effect of education quality (i.e. primary school enrollment, secondary school enrollment and tertiary school enrollment) on accountability index. There is a negative net effect from the relevance of mobile phone in modulating the effect of primary school enrollment on horizontal accountability index. In addition, there are negative

[3]"First, the null hypothesis of the second-order Arellano and Bond autocorrelation test (AR (2)) in difference for the absence of autocorrelation in the residuals should not be rejected. Second the Sargan and Hansen over-identification restrictions (OIR) tests should not be significant because their null hypotheses are the positions that instruments are valid or not correlated with the error terms. In essence, while the Sargan OIR test is not robust but not weakened by instruments, the Hansen OIR is robust but weakened by instruments. In order to restrict identification or limit the proliferation of instruments, we have ensured that instruments are lower than the number of cross-sections in most specifications. Third, the Difference in Hansen Test (DHT) for exogeneity of instruments is also employed to assess the validity of results from the Hansen OIR test. Fourth, a Fisher test for the joint validity of estimated coefficients is also provided" (Asongu et al., 2020) p.177)

net effects from the importance of mobile phone in modulating the effect of education quality (i.e. primary school enrollment, secondary school enrollment and tertiary school enrollment) on diagonal accountability index. However, it is important to emphasize the absence of some net effects from the modulating incidence of mobile phone on educational quality for public accountability. This occurrence signals the incapability of non-state actors to watch over and reprimand the activities of the politicians and the civil servants. Most of the control variables with significance have the expected signs.

3.2 Discussion and policy implications through established thresholds

The established negative net effects are unexpected because mobile phone penetration was anticipated to modulate educational quality for the promotion of public accountability. The unexpected negative effects can be traceable to the prevalent gender exclusion in school enrollment and low levels of public accountability. Although the marginal effects between the mobile phone and educational quality are consistently positive from the findings, the unconditional effects of the mobile phone and educational quality remain negative. However, these independent negative effects are not interpreted independently in interactive regressions because interactive regressions are not interpreted as linear additive models (Tchamyou, 2019). It follows that the stand-alone indicators (i.e. mobile phones and educational quality measures) must be understood concurrently with the corresponding conditional effects in order to assess the overall incidence on public accountability: this is the main justification for computing net effects and thresholds in interactive regressions. Having established the net effects, this study also proceeds with the computation of minimum thresholds at which mobile phone could enhance education quality (i.e. gender inclusive education) for public accountability. These thresholds have policy implications because below the critical masses, mobile phone penetration is not high enough to modulate education quality for public accountability.

Table 1: Mobile phone, educational quality and accountability index

	Dependent Variable: Accountability Index					
Variables	Primary	Secondary	Tertiary	Primary	Secondary	Tertiary
	Without Control Variables			With Control Variables		
Acc. Index (-1)	**1.121*** (0.0631)**	**1.043*** (0.0424)**	**1.014*** (0.0342)**	**1.069*** (0.0279)**	**1.033*** (0.0267)**	**0.947*** (0.0225)**
Mobile	**-0.00236** (0.00113)**	-0.000508 (0.000394)	-0.000132 (0.000177)	**-0.00127* (0.000738)**	**-0.000523** (0.000220)**	0.000200 (0.000139)
PSE	**-0.276*** (0.0733)**			**-0.210*** (0.0537)**		
SSE		-0.0238 (0.0251)			**-0.0353** (0.0160)**	
TSE			**-0.0363*** (0.0121)**			-0.00481 (0.00765)
Mobile x PSE	**0.00244** (0.00120)**			**0.00133* (0.000718)**		
Mobile x SSE		0.000402 (0.000407)			**0.000608*** (0.000169)**	
Mobile x TSE			**0.000255** (0.0000957)**			0.0000696 (0.0000571)
GDP				**0.000558** (0.000269)**	**0.000852*** (0.000282)**	**0.00107*** (0.000317)**
Population				0.00231 (0.00384)	0.00460 (0.00306)	-0.000517 (0.00243)
FDI				**-0.000532*** (0.000127)**	**-0.000465*** (0.000111)**	**-0.000138* (0.0000811)**
Time Effects	Yes	Yes	Yes	Yes	Yes	Yes
Net Effects	-0.136	na	-0.022	-0.134	-0.001	na
Positive Mobile Threshold(s)	113	na	142	158	58	na
AR(1)_P-value	[0.015]	[0.045]	[0.016]	[0.017]	[0.040]	[0.018]
AR(2)_P-value	**[0.209]**	**[0.290]**	**[0.116]**	**[0.299]**	**[0.321]**	**[0.133]**
Sargan Prob	**[0.788]**	[0.009]	**[0.880]**	**[0.604]**	]0.005]	[0.041]
Hansen Prob	**[0.567]**	**[0.174]**	**[0.256]**	**[0.548]**	**[0.316]**	**[0.320]**
DHT for instruments						
(a)Instruments in levels						
H excluding group	**[0.114]**	[0.008]	**[0.768]**	**[0.491]**	[0.062]	**[0.260]**
Dif (null, H=exogenous)	**[0.754]**	**[0.724]**	**[0.186]**	**[0.508]**	**[0.672]**	**[0.384]**
(b) IV (years, eq(diff))						
H excluding group				**[0.368]**	[0.037]	**[0.245]**
Dif (null, H=exogenous)				**[0.594]**	**[0.833]**	**[0.410]**
Fisher	**136.2***	**2145***	**587.4***	**1002***	**2686***	**258482***
Number of Instruments	27	27	27	39	39	39
Number of Countries	48	44	42	47	43	42
Observations	471	348	311	465	342	308

***, **, *: significance levels at 1%, 5% and 10% respectively. Acc: Accountability. Mobile: mobile phone technology. PSE: primary school enrollment. SSE: secondary school enrollment. TSE: tertiary school enrollment. GDP: GDP growth. Population: population growth. FDI: foreign direct investment: Difference in Hansen Test for Exogeneity of Instruments Subsets. Dif: Difference. OIR: Over-identifying Restrictions Test. The significance of bold values is twofold. 1) The significance of estimated coefficients and the Wald statistics. 2) The failure to reject the null hypotheses of: a) no autocorrelation in the AR(1) & AR(2) tests and; b) the validity of the instruments in the Sargan and Hansen tests. Constants are included in all regressions. ( ) for standard errors of estimated coefficients and [ ] for p-values of all other tests with the exception of the Fisher test. na: not applicable because at least one estimated coefficient needed for the computation of net effects or thresholds is not significant. The mean value of mobile phone penetration is 57.206.

In the light of the aforementioned clarifications, in Column 1 of Table 1, a threshold of 113 (0.276/0.00244) represents the minimum mobile phone penetration threshold for gender inclusive primary education to have a net positive effect on public accountability. In the computation, 0.276 is the absolute value of unconditional effect for gender inclusive primary education on the accountability index while 0.00244 represents the conditional effect between mobile phone penetration and gender inclusive primary education on the accountability index.

Table 2: Mobile phone, educational quality and horizontal accountability index

	Dependent Variable: Horizontal Accountability Index					
Variables	Primary	Secondary	Tertiary	Primary	Secondary	Tertiary
	Without Control Variables			With Control Variables		
Horizontal Acc. Index (-1)	**1.057*** **	**0.960*** **	**0.934*** **	**1.036*** **	**0.992*** **	**0.938*** **
	(0.0436)	**(0.0473)**	**(0.0442)**	**(0.0175)**	**(0.0228)**	**(0.0295)**
Mobile	**-0.00311** **	-0.000665	0.000332	**-0.00157** **	**-0.000702** **	0.000171
	(0.00134)	(0.000563)	(0.000245)	**(0.000759)**	**(0.000336)**	(0.000153)
PSE	**-0.257** **			**-0.191*** **		
	(0.109)			**(0.0395)**		
SSE		0.0109			-0.00837	
		(0.0379)			(0.0229)	
TSE			0.00515			0.0116
			(0.0165)			(0.0160)
Mobile x PSE	**0.00332** **			**0.00172** **		
	(0.00145)			**(0.000736)**		
Mobile x SSE		0.000649			**0.000680** **	
		(0.000632)			**(0.000287)**	
Mobile x TSE			-0.000101			-0.0000949
			(0.000141)			(0.000103)
GDP				**0.00153*** **	**0.00155*** **	**0.00245*** **
				(0.000472)	**(0.000434)**	**(0.000617)**
Population				0.00294	0.00132	-0.00347
				(0.00308)	(0.00417)	(0.00490)
FDI				**-0.000584** **	**-0.000440***	0.000109
				(0.000222)	**(0.000255)**	(0.000118)
Time Effects	Yes	Yes	Yes	Yes	Yes	Yes
Net Effects	-0.067	na	na	-0.093	na	na
Positive Mobile Threshold(s)	77	na	na	111	na	na
AR(1)_P-value	[0.018]	[0.026]	[0.044]	[0.016]	[0.021]	[0.043]
AR(2)_P-value	**[0.164]**	**[0.420]**	**[0.249]**	**[0.186]**	**[0.389]**	**[0.256]**
Sargan Prob	**[0.704]**	[0.016]	**[0.852]**	**[0.777]**	**[0.057]**	**[0.429]**
Hansen Prob	**[0.659]**	**[0.432]**	**[0.237]**	**[0.839]**	**[0.427]**	**[0.274]**
DHT for instruments						
(a)Instruments in levels						
H excluding group	**[0.264]**	[0.028]	[0.078]	**[0.202]**	**[0.137]**	[0.042]
Dif (null, H=exogenous)	**[0.703]**	**[0.868]**	**[0.398]**	**[0.966]**	**[0.658]**	**[0.687]**
(b) IV (years, eq(diff))						
H excluding group				**[0.736]**	[0.089]	**[0.324]**
Dif (null, H=exogenous)				**[0.740]**	**[0.796]**	**[0.289]**
Fisher	**457.6*** **	**1152*** **	**9372*** **	**78505*** **	**5863*** **	**1352*** **
Number of Instruments	27	27	27	39	39	39

Number of Countries	48	44	42	47	43	42
Observations	471	348	311	465	342	308

***, **, *: significance levels at 1%, 5% and 10% respectively. Acc: Accountability. Mobile: mobile phone technology. PSE: primary school enrollment. SSE: secondary school enrollment. TSE: tertiary school enrollment. GDP: GDP growth. Population: population growth. FDI: foreign direct investment: Difference in Hansen Test for Exogeneity of Instruments Subsets. Dif: Difference. OIR: Over-identifying Restrictions Test. The significance of bold values is twofold. 1) The significance of estimated coefficients and the Wald statistics. 2) The failure to reject the null hypotheses of: a) no autocorrelation in the AR(1) & AR(2) tests and; b) the validity of the instruments in the Sargan and Hansen tests. Constants are included in all regressions. ( ) for standard errors of estimated coefficients and [ ] for p-values of all other tests with the exception of the Fisher test. na: not applicable because at least one estimated coefficient needed for the computation of net effects or thresholds is not significant. The mean value of mobile phone penetration is 57.206.

It holds from the computed thresholds that a mobile phone penetration level of below 113 is not favourable for gender inclusive primary education to induce a positive effect on public accountability. Furthermore, under the specification without control variables in Table 1, the corresponding threshold of mobile phone is 142 for gender inclusive tertiary education to induce a positive effect on the accountability index. Specifications with control variables in Table 1 establish that minimum thresholds of mobile phone are 158 and 58 (per 100 people) for gender inclusive primary education and gender inclusive secondary education respectively, to promote accountability index.

Table 3: Mobile phone, educational quality and vertical accountability index

	Dependent Variable: Vertical Accountability Index					
Variables	Primary	Secondary	Tertiary	Primary	Secondary	Tertiary
	Without Control Variables			With Control Variables		
Vertical Acc. Index (-1)	**0.737*** **	**0.735*** **	**0.609*** **	**0.866*** **	**0.791*** **	**0.655*** **
	(0.118)	**(0.109)**	**(0.0950)**	**(0.0587)**	**(0.0374)**	**(0.0518)**
Mobile	-0.000606	0.00122	**0.00123** **	0.00262	0.000753	**0.00125*** **
	(0.00187)	(0.00102)	**(0.000550)**	(0.00170)	(0.000479)	**(0.000427)**
PSE	-0.254			**0.186***		
	(0.165)			**(0.107)**		
SSE		0.0872			**0.120*** **	
		(0.0601)			**(0.0220)**	
TSE			0.00825			0.0180
			(0.0408)			(0.0433)
Mobile x PSE	0.00138			-0.00219		
	(0.00189)			(0.00179)		
Mobile x SSE		-0.000595			-0.000278	
		(0.00111)			(0.000436)	
Mobile x TSE			0.0000105			-0.000401
			(0.000331)			(0.000302)
GDP				0.000639	0.000737	0.000599
				(0.000619)	(0.000482)	(0.000789)
Population				**0.00805***	**0.0105*** **	**-0.0140** **
				(0.00445)	**(0.00216)**	**(0.00584)**
FDI				**-0.000353***	**-0.000414** **	0.000269
				(0.000192)	**(0.000154)**	(0.000414)
Time Effects	Yes	Yes	Yes	Yes	Yes	Yes

Net Effects	na	na	na	na	na	na
Positive Mobile Threshold(s)	na	na	na	na	na	na
AR(1)_P-value	[0.016]	[0.097]	[0.028]	[0.035]	**[0.126]**	[0.042]
AR(2)_P-value	**[0.015]**	**[0.233]**	**[0.111]**	**[0.026]**	**[0.287]**	**[0.081]**
Sargan Prob	**[0.344]**	[0.006]	**[0.386]**	[0.013]	[0.0001]	[0.089]
Hansen Prob	**[0.611]**	**[0.500]**	**[0.273]**	**[0.611]**	**[0.624]**	**[0.201]**
DHT for instruments						
(a)Instruments in levels						
H excluding group	**[0.176]**	[0.068]	**[0.533]**	**[0.184]**	**[0.119]**	**[0.148]**
Dif (null, H=exogenous)	**[0.722]**	**[0.778]**	**[0.218]**	**[0.804]**	**[0.888]**	**[0.320]**
(b) IV (years, eq(diff))						
H excluding group				**[0.086]**	**[0.643]**	**[0.303]**
Dif (null, H=exogenous)				**[0.953]**	**[0.509]**	**[0.213]**
Fisher	**12.72*** **	**1221*** **	**32.78*** **	**4950*** **	**400.6*** **	**436.4*** **
Number of Instruments	27	27	27	39	39	39
Number of Countries	48	44	42	47	43	42
Observations	471	348	311	465	342	308

***, **, *: significance levels at 1%, 5% and 10% respectively. Acc: Accountability. Mobile: mobile phone technology. PSE: primary school enrollment. SSE: secondary school enrollment. TSE: tertiary school enrollment. GDP: GDP growth. Population: population growth. FDI: foreign direct investment: Difference in Hansen Test for Exogeneity of Instruments Subsets. Dif: Difference. OIR: Over-identifying Restrictions Test. The significance of bold values is twofold. 1) The significance of estimated coefficients and the Wald statistics. 2) The failure to reject the null hypotheses of: a) no autocorrelation in the AR(1) & AR(2) tests and; b) the validity of the instruments in the Sargan and Hansen tests. Constants are included in all regressions. ( ) for standard errors of estimated coefficients and [ ] for p-values of all other tests with the exception of the Fisher test. na: not applicable because at least one estimated coefficient needed for the computation of net effects or thresholds is not significant. The mean value of mobile phone penetration is 57.206.

In addition, the corresponding thresholds in Table 2 for mobile phone penetration are between 77 and 111 (per 100 people) for gender inclusive primary education to positively promote the horizontal accountability index. It follows that above the established thresholds, mobile phone penetration will moderate gender inclusive primary education for an overall positive effect on the horizontal accountability index.

As apparent in Table 3, neither net effects nor thresholds are computed for the nexuses between mobile phone technology, gender inclusive education and vertical accountability. This is essentially because, as clarified in the footnote of the attendant table, both estimated coefficients relevant for the computation of net effects and/or thresholds should be significant before the computations of net effects and corresponding thresholds.

The following thresholds for mobile phone (per 100 people) can be established from Table 4. Between 77 and 80 "gender inclusive primary education"; 64 and 122 "gender inclusive secondary education" and 150 "gender inclusive tertiary

education" for the diagonal accountability index. It can be concluded that such thresholds have economic significance and make economic sense because the computed thresholds fall within the minimum and maximum values in the summary statistics. In addition, the concept of threshold is consistent with the recent literature on the importance of critical masses in complementary and substitution effects for economic development (Asongu & Asongu, 2019; Asongu et al., 2020; Hammoudeh & McAleer, 2015). Moreover, it is relevant to note that, in the real world, inclusive education and mobile phone technology do not interact in isolation to influence public accountability. Hence, while the modeling exercise is tailored to engage specifications with and without a conditioning information set (i.e. control variables), our best estimators are from estimations with a conditioning information set.

Table 4: Mobile phone, educational quality and diagonal accountability index

	Dependent Variable: Diagonal Accountability Index					
Variables	Primary	Secondary	Tertiary	Primary	Secondary	Tertiary
	Without Control Variables			With Control Variables		
Diagonal Acc. Index (-1)	**1.052*** **	**1.059*** **	**1.082*** **	**1.072*** **	**1.074*** **	**1.002*** **
	(0.0280)	**(0.0356)**	**(0.0417)**	**(0.0134)**	**(0.0153)**	**(0.0187)**
Mobile	**-0.00276** **	**-0.00123** **	-0.000366	**-0.00242*** **	**-0.000675** **	-0.000167
	(0.00122)	**(0.000558)**	(0.000244)	**(0.000803)**	**(0.000327)**	(0.000109)
PSE	**-0.225*** **			**-0.197*** **		
	(0.0743)			**(0.0409)**		
SSE		**-0.0739*** **			**-0.0723*** **	
		(0.0185)			**(0.0143)**	
TSE			**-0.0656*** **			-0.00690
			(0.0182)			(0.00949)
Mobile x PSE	**0.00293** **			**0.00246*** **		
	(0.00130)			**(0.000810)**		
Mobile x SSE		**0.00116** **			**0.000594** **	
		(0.000503)			**(0.000287)**	
Mobile x TSE			**0.000436*** **			**0.000176*** **
			(0.000128)			**(5.91e-05)**
GDP				**0.000664** **	0.000224	**0.00134*** **
				(0.000248)	(0.000345)	**(0.000358)**
Population				**-0.00693*** **	**-0.00604***	0.00151
				(0.00238)	**(0.00314)**	(0.00165)
FDI				**-0.000324*** **	**-0.000280** **	0.000125
				(9.43e-05)	**(0.000109)**	(0.000119)
Time Effects	Yes	Yes	Yes	Yes	Yes	Yes
Net Effects	-0.057	-0.008	-0.041	-0.056	-0.038	na
Positive Mobile Threshold(s)	77	64	150	80	122	na
AR(1)_P-value	[0.083]	[0.031]	[0.007]	[0.082]	[0.029]	[0.017]

AR(2)_P-value	**[0.189]**	**[0.618]**	**[0.129]**	**[0.244]**	**[0.851]**	[0.083]
Sargan Prob	**[0.148]**	**[0.122]**	**[0.496]**	**[0.278]**	**[0.226]**	[0.025]
Hansen Prob	**[0.162]**	**[0.234]**	**[0.479]**	**[0.189]**	**[0.264]**	**[0.108]**
DHT for instruments						
(a)Instruments in levels						
H excluding group	[0.017]	[0.061]	**[0.312]**	**[0.019]**	**[0.070]**	**[0.391]**
Dif (null, H=exogenous)	**[0.534]**	**[0.435]**	**[0.480]**	**[0.684]**	**[0.566]**	**[0.087]**
(b) IV (years, eq(diff))						
H excluding group				**[0.064]**	**[0.220]**	**[0.081]**
Dif (null, H=exogenous)				**[0.490]**	**[0.356]**	**[0.261]**
Fisher	**705.9*** **	**18213*** **	**389*** **	**1231*** **	**1989*** **	**161478*** **
Number of Instruments	27	27	27	39	39	39
Number of Countries	48	44	42	47	43	42
Observations	471	348	311	465	342	308

***, **, *: significance levels at 1%, 5% and 10% respectively. Acc: Accountability. Mobile: mobile phone technology. PSE: primary school enrollment. SSE: secondary school enrollment. TSE: tertiary school enrollment. GDP: GDP growth. Population: population growth. FDI: foreign direct investment. DHT: Difference in Hansen Test for Exogeneity of Instruments Subsets. Dif: Difference. OIR: Over-identifying Restrictions Test. The significance of bold values is twofold. 1) The significance of estimated coefficients and the Wald statistics. 2) The failure to reject the null hypotheses of: a) no autocorrelation in the AR(1) & AR(2) tests and; b) the validity of the instruments in the Sargan and Hansen tests. Constants are included in all regressions. ( ) for standard errors of estimated coefficients and [ ] for p-values of all other tests with the exception of the Fisher test. na: not applicable because at least one estimated coefficient needed for the computation of net effects or thresholds is not significant. The mean value of mobile phone penetration is 57.206.

4. Concluding implications and future research directions

This study assesses the linkages between the mobile phone penetration, educational quality (i.e. in terms of gender inclusive education) and public accountability to establish the minimum threshold of mobile phone penetration for education quality to promote public accountability in 48 Sub-Saharan African countries for the period 2005-2018. Four accountability measures are used, namely, accountability index, horizontal accountability index, vertical accountability index and diagonal accountability index. The mobile phone penetration is proxied by the mobile cellular subscriptions (per 100 people). Three educational quality measurements are employed: gender inclusive primary education, gender inclusive secondary education and gender inclusive tertiary education. The study establishes the following main findings. There are negative net effects from the role of mobile phone in modulating the effect of education quality on public accountability.

Although the negative net effects are unexpected, the unexpected negative effects can be traceable to the prevalent low levels of gender inclusive education and public accountability. Accordingly, from the findings, the

marginal effects between mobile phone and educational quality are consistently positive, which motivates the computation of mobile phone technology thresholds needed for net positive effects on dynamics of public accountability.

Given that our best estimators are specifications with a conditioning information (i.e. control variables), the minimum mobile phone penetration thresholds are: (a) 158 (per 100 people) for gender inclusive primary education; and 58 (per 100 people) for gender inclusive secondary education to positively influence accountability index; (b) 111 (per 100 people) for gender inclusive primary education to positively promote the horizontal accountability index and (c) 80 (per 100 people) for gender inclusive primary education and 122 (per 100 people) for gender inclusive secondary education to positively promote diagonal accountability index. It can be concluded that such thresholds have economic significance and make economic sense because the computed thresholds fall within the minimum and maximum values in the summary statistics.

It is also worthwhile to articulate that the negative unconditional effects of inclusive education in the accountability dynamics is an indication that inclusive education is a necessary but not a sufficient condition for the promotion of public accountability in the sampled countries. Hence, it is relevant for the underlying inclusive education channels to be complemented with other policy variables in order to engender the anticipated effects on public accountability. Moreover, given that the mean value of mobile phone penetration is 57.206, relative to the computed thresholds; it implies that sampled countries have to promote policies favoring mobile phone penetration in order for the potentials effects on public accountability to be realized. Such policies can be tailored towards addressing constraints in affordability as well as the lack of the relevant infrastructure which are considerable barriers to information and communication technology access. The attendant policies to be implemented

should be centered around, *inter alia*: facilitating low pricing schemes from mobile operators.

The findings of this study have shown that when mobile phone penetration have reached certain critical masses, policy designed to promote inclusive education can lead to public accountability, most probably because the mobile phone can be used to emphasize the level at which citizens of a country can participate in holding their elected and government officials to account. It is important to also emphasize that the findings cannot be extended to all countries because counter arguments exists in countries such as China where the mobile cannot be substantially used to facilitate voting and universal suffrage.

The main caveat of the study is that country-specific effects are not taken into account in an effort to avoid endogeneity originating from the nexus between the lagged dependent variable and the error term. Hence, it would be worthwhile for future research to engage country-specific empirical techniques with the relevant data in order to provide findings with more country-specific implications. Future studies can also focus on assessing how the established findings withstand empirical relevance within the framework of other developing regions such as Latin America and Asia. Moreover, taking on board other variables that can be leveraged to modulate gender-inclusive education in the light of promoting public accountability is worthwhile. By extension, other governance variables could also be considered.

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Appendices

Appendix 1: Definitions and Sources of Variables

Variables	Acronyms	Definitions	Sources
Accountability index	Accountability	"Government accountability is understood as constraints on the government's use of political power through requirements for justification for its actions and potential sanctions."	V-Dem
Vertical accountability index	Vertical	"Vertical accountability captures the extent to which citizens have the power to hold the government accountable."	V-Dem
Horizontal accountability index	Horizontal	"Horizontal accountability concerns the power of state institutions to oversee the government by demanding information, questioning officials and punishing improper behavior."	V-Dem
Diagonal accountability index	Diagonal	"Diagonal accountability covers the range of actions and mechanisms that citizens, civil society organizations CSOs, and an independent media can use to hold the government accountable."	V-Dem
Mobile phone	Mobile	Mobile cellular subscriptions (per 100 people)	WDI
Primary school enrollment	PSE	School enrollment, primary (gross), gender parity index (GPI)	WDI
Secondary school enrollment	SSE	School enrollment, secondary (gross), gender parity index (GPI)	WDI
Tertiary school enrollment	TSE	School enrollment, tertiary (gross), gender parity index (GPI)	WDI
GDP growth	GDP	GDP growth (annual %)	WDI
Population growth	Population	Population growth (annual %)	WDI
Foreign Direct Investment	FDI	Foreign direct investment, net inflows (% of GDP)	WDI

Note: V-Dem = Varieties of Democracy Database; WDI = World Bank Development Indicators. Abbreviation: Accountability, accountability index; vertical, vertical accountability index; horizontal; horizontal accountability index; diagonal, diagonal accountability index; mobile, mobile phone technology; PSE, primary school enrollment; SSE, secondary school enrollment; TSE, tertiary school enrollment; GDP, GDP growth; Population, population growth; FDI, foreign direct investment.

Appendix 2: Descriptive Statistics

Variables	Observations	Mean	SD	Minimum	Maximum
Accountability	666	.659	.223	.026	.946
Vertical	666	.664	.195	.069	.938
Diagonal	666	.694	.237	.038	.957
Horizontal	666	.568	.275	.013	.966
Mobile	657	57.206	39.829	.538	184.298
PSE	512	.939	.089	.553	1.158
SSE	381	.885	.198	.347	1.388
TSE	336	.759	.449	.064	3.46
GDP	644	4.438	4.807	-46.082	20.716
Population	665	2.499	.923	-2.629	5.028
FDI	641	5.067	9.09	-6.37	103.337

Abbreviation: Accountability, accountability index; vertical, vertical accountability index; horizontal; horizontal accountability index; diagonal, diagonal accountability index; mobile, mobile phone technology; PSE, primary school enrollment; SSE, secondary school enrollment; TSE, tertiary school enrollment; GDP, GDP growth; Population, population growth; FDI, foreign direct investment.

Appendix 3: Correlation matrix

	Accountability	Vertical	Diagonal	Horizontal	Mobile	PSE	SSE	TSE	GDP	Popul	FDI
Accountability	1										
Vertical	0.907***	1									
Diagonal	0.948***	0.786***	1								
Horizontal	0.898***	0.835***	0.755***	1							
Mobile	0.373***	0.431***	0.263***	0.389***	1						
PSE	0.283***	0.307***	0.185**	0.293***	0.465***	1					
SSE	0.311***	0.363***	0.155*	0.420***	0.471***	0.659***	1				
TSE	0.219***	0.268***	0.0838	0.345***	0.553***	0.343***	0.674***	1			
GDP	-0.0848	-0.0595	-0.0840	-0.0563	-0.223***	-0.130*	-0.203**	-0.207**	1		
Population	-0.229***	-0.296***	-0.0910	-0.369***	-0.440***	-0.301***	-0.621***	-0.716***	0.159*	1	
FDI	0.105	0.0558	0.117	0.0779	0.116	0.117	0.132*	0.297***	0.0172	-0.0710	1

*p< 0.05, **p< 0.01, ***p< 0.001. Abbreviation: Accountability, accountability index; vertical, vertical accountability index; horizontal; horizontal accountability index; diagonal, diagonal accountability index; mobile, mobile phone technology; PSE, primary school enrollment; SSE, secondary school enrollment; TSE, tertiary school enrollment; GDP, GDP growth; Population, population growth; FDI, foreign direct investment.