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"Digital interoperability platforms, mobile phones, governance quality and financial inclusion in sub-Saharan Africa: Evidence of synergies"

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FIT IN Initiative

Digital interoperability platforms, mobile phones, governance quality and financial inclusion in sub-Saharan Africa: Evidence of synergies

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Abstract
This study complements the extant literature by assessing how mobile phone usage and governance quality moderate the incidence of digital interoperability platforms on financial inclusion in sub-Saharan Africa. A multidimensional measure of financial inclusion and five digital interoperability dynamics (any, diversified, third-party, bilateral, and multilateral digital interoperability platforms) are used to provide empirical evidence based on multilevel model (MLM) regressions. The findings show that mobile phone usage, governance quality and all types of digital interoperability platforms, unconditionally promote financial inclusion. These findings are consistent across different methods and alternative weighting schemes used in generating the financial inclusion index. We also find that complementing three digital interoperability platforms (i.e., any, diversified and third-party) with the two moderating variables (i.e., mobile phone and governance quality) engenders positive synergy effects on financial inclusion. Policy implications are discussed.

***Keywords*:** Digital platforms; interoperability; financial inclusion; sub-Saharan Africa
***JEL Classifications*:** D10; D14; D31; D60; O30

1. Introduction

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This study assesses the relevance of digital interoperability dynamics in promoting financial inclusion, especially when moderated with mobile phones and governance quality (GQ) in sub-Saharan Africa. The focus of the study is motivated by three main strands in the policy and scholarly literature, notably: (i) the importance of financial inclusion in sub-Saharan Africa; (ii) the relevance of leveraging policy frameworks on mobile phones and GQ and (iii) gaps in the extant digital interoperability literature. The three strands are put in perspective in the same order of chronology.

First, consistent with contemporary inclusive finance and development literature (Tchamyou et al., 2019; Bukari & Koomson, 2020; Chima et al., 2021; Koomson et al., 2020a; Peprah et al., 2020), financial inclusion is important, especially in poor regions such as sub-Saharan Africa because, financial services are fundamental in driving economic growth, enhancing healthcare utilization, and fostering the creation of wealth. According to the narrative, inclusive finance reflects the scale to which small businesses and individuals can receive finance-oriented services such as indemnification, transfers, advances and savings. Moreover, Koomson et al. (2020a) articulate that financial inclusion is more relevant in sub-Saharan Africa because compared to developed countries, the sub-region is characterized by less accessibility to formal monetary markets and by extension, people in this sub-region have less access to opportunities of saving and borrowing from formal financial institutions. Low information technology penetration and poor GQ have been documented as some of the factors associated with financial inclusion in poor countries (Asongu & Odhiambo, 2021).

Second, in order to promote financial inclusion in sub-Saharan Africa, policy makers can leverage the potential of improving mobile phone penetration and GQ. Consistent with contemporary literature based on interactive regressions (Tchamyou, 2019; I. Ofori et al., 2021; P. Ofori et al., 2021), policy variables such as macroeconomic and institutional indicators are likely to be improved by policymakers to influence other macroeconomic outcomes in the targeted directions. As it stands, mobile phone penetration (Tchamyou, 2017) and GQ (Tchamyou, 2021) levels are low in sub-Saharan Africa and thus can be improved in order to provide enabling conditions through which digital interoperability platforms can promote financial inclusion. This notwithstanding, the extant literature, to the best of our knowledge, is sparse on how digital interoperability platforms can be moderated by policy variables to promote financial inclusion in sub-Saharan Africa.

Third, in the light of the above, as substantiated in Section 2, the positioning of this study departs from the extant literature on digital interoperability platforms which, consistent with Chiu and Wong (2021) have largely focused on three main areas of research. The first is concerned with the pricing of digital currencies (Schilling & Uhlig, 2019; Biais et al., 2020). The second is centered on the robustness and functioning of digital platforms (Biais et al., 2019; Wajid & Bhullar, 2019). The third area focuses on mining digital currencies and determining the corresponding fees (Huberman et al., 2021; Easley et al., 2019).

The closest paper in the literature to this study is Wajid and Bhullar (2019) in the second strand. The authors have introduced an interoperability framework with the purpose of promoting transparency across a plethora of platforms. Such a framework enhances the creation of an ecosystem that is relevant for the deployment of services and applications across multiple platforms. The data obtained from the research put emphasis on the potential of interoperability among various levels of digital platforms. Moreover, the framework is useful in that, it does not only enable transparency to be promoted across the suggested platforms, but also permits the identification of opportunities for potential collaboration as well as avenues of new ecosystems. The present study departs from Wajid and Bhullar (2019) by leveraging multiple suggested digital interoperability platforms (any, diversified, third-party, bilateral and multilateral digital interoperability platforms), in order to assess how such platforms interact with mobile phones and aspects of transparency (e.g. GQ) in order to influence financial inclusion.

In the light of the above, this study complements the extant literature by assessing how digital interoperability platforms influence financial inclusion, especially when moderated by mobile phones usage and GQ. Hence, this study aims to address the research question: how do mobile phones usage and GQ moderate the effect of digital interoperability platforms on financial inclusion in sub-Saharan Africa? The policy relevance of the study is premised on the importance of financial inclusion in achieving most sustainable development goals (SDGs). As argued by Klapper (2016), financial inclusion is vital in achieving a plethora of SDGs, *inter alia*, job creation, poverty elimination, gender equality and health wellbeing.

The rest of the study is organized as follows. The theoretical underpinnings and extant literature are covered in Section 2 while the data and methodology are provided in Section 3 and Section 4, respectively. The empirical results are discussed in Section 5. Section 6 concludes with implications and future research directions.

2. Theoretical underpinnings and literature review

The literature review is arranged in two parts. Section 2.1 presents the theoretical underpinnings regarding digital platforms and financial inclusion. Section 2.2 focuses on the link between digital interoperability platforms, mobile phones, and financial inclusion.

2.1 Theoretical underpinnings

Consistent with contemporary literature (Mhella, 2019), the theoretical underpinning of the nexus between digital platforms and financial inclusion can be articulated by relevance of complementing digital platforms with mobile phones and GQ. The first theoretical strand is the underpinning that regulatory and legal frameworks are worthwhile in the development of mobile phone related services needed for financial inclusion purposes (Di Castri & Gidvani, 2014; Asongu, 2015; Ondiege, 2015; Mhella, 2019; Maina, 2018; Asongu et al., 2021a). It follows that both mobile phones and GQ are necessary for digital interoperability platforms to affect financial inclusion. Mhella (2019) illustrates this assumption with an example in Tanzania whereby a regulatory framework is clearly apparent with the goal to oversee, investigate and supervise mobile money services.

In the second strand, it is also worthwhile to note that the theoretical connections between digital platforms, GQ, mobile phone usage and financial inclusion are also entrenched in technology acceptance models (TAM), such as the theory of reasoned action (TRA), the theory of planned behavior (TPB) and the technology acceptance model (Yousafzai et al., 2010; Nikiforova, 2013; Cusick, 2014; Asongu et al., 2018). In summary, the models are broadly consistent with the perspective that the mobile phone user, prior to adopting and using a given mobile technology, has some prior knowledge of the institutional environment governing the use of mobile phones, the digital platforms on which mobile phones are used, as well as the corresponding benefits in terms of financial inclusion.

According to the TRA, customers adopting the mobile phone have rational characteristics (Fishbein & Ajzen, 1975; Ajzen & Fishbein, 1980; Bagozzi, 1982). Narrowing the perspective to this study, the underlying rational characteristics motivate new ideas as to how mobile phone users leverage digital platforms to improve their opportunities of financial inclusion, contingent on GQ. The TPB improves the TRA with the perspective that differences are apparent between mobile

phone users who are conscious of the positive externalities from the usage of mobile phones with digital platforms, compared to customers who are unaware of the usefulness of such mobile phones in financial inclusion by way of digital platforms (Ajzen, 1991). Hence, mobile phone users are both aware and unaware of potential financial inclusion benefits linked to specific digital platforms within a certain institutional environment. Looking at the TAM, a decision by a user to adopt a given technology is contingent on the user's motivation to be friendly with the given technology as well as on the user's preferences in adopting the channel of transaction (David, 1989). Within the specific remit of this study, users are aware of various dynamics in terms of digital interoperability platforms (e.g., any, diversified, third-party, bilateral and multilateral digital interoperability platforms). Hence, five main digital interoperability dynamics are used in the present study.

2.2 Digital interoperability and financial inclusion

Digital interoperability has been identified as one of the key pillars needed to leverage the benefits of financial technology in creating improved financial inclusion (Arner et al., 2020). In recent years, Interoperability is said to no longer be limited by national borders, and non-bank payment service providers have thus emerged and made available, new and innovative types of payment such as mobile money (Lammer et al., 2016). The availability of interoperability has broken down barriers and made it possible for one to easily transfer money to different types of accounts (Lammer et al., 2016).

Bourreau and Valleti (2015) argue that timing is of essence when a country decides to implement digital interoperability systems as the institution of interoperability technology too early could dampen innovation while instituting it too late might result in the development of monopoly powers. In markets, where interoperability has not been institutionalized there is a high tendency for the development of such monopoly powers. When one or two mobile money firms have high market power, users of financial services incur extra costs as they switch between mobile money services or are forced to use cash to create exchanges between different digital wallets (Donovan, 2012). These extra costs tend to disincentivise users and adversely affect the financial inclusion agenda.

Factors such as reduced costs and convenience due to digital interoperability have facilitated financial inclusion (Lammer et al., 2016; Donovan, 2012). Additionally, better

interoperability facilitates easy access to transactions accounts since it allows providers to create better products which also leads to improvements in financial inclusion (Cirasino et al., 2016). Financial service and mobile money interoperability has been touted as having the ability to facilitate swift financial transactions for people everywhere (GSMA, 2017; Peric et al., 2018). This proves particularly useful for rural folks who live in places where distance tends to be a barrier in accessing more formal financial services (N'dri & Kakinaka, 2020).

Regardless of all the advantages digital interoperability brings to financial inclusion, interoperability can only be achieved if there are stakeholders ready to embrace this vision (Lammer et al., 2016). Fernandes et al. (2021) find that in Malawi, digital financial services have a positive impact on financial inclusion and advocates for policies which will speed up interoperability between bank and non-bank financial institutions. Senyo et al. (2022) also argue that if we are to effectively tackle the low levels of observed financial inclusion then efforts must be made to enhance collaboration between traditional financial institutions and fintech companies. In their, view such collaborative efforts will help to tackle financial inclusion related challenges, including the delivery of financial services to the unbanked and low levels of financial infrastructure needed to facilitate interoperability between service providers.

2.3 Governance quality (GQ)and financial inclusion

Enhanced financial inclusion can be explained within the context of financial development (King & Levine, 1993; Rajan & Zingales, 1998). This implies that any factor that enhances financial development can be considered a promoter of financial inclusion (Koomson et al., 2020b). One of such factors is GQ which has been identified as having a positive effect on financial development (Cull & Effron, 2008; Guiso et al. 2008), and therefore enhancing financial inclusion due to its positive effect on bank account opening and remittance receipts (Asongu & Odhiambo, 2021; Berk Saydaliyev, et al., 2020; Dabla-Norris et al., 2020). Others asset that GQ increases financial inclusion because it fosters trust in financial institutions (Guiso et al. 2008; Shad et al., 2018)

3. Data and Variables

The secondary data used for this study are obtained from three sources, including: (i) Global Financial Inclusion Database 2017 (Global Findex 2017); (ii) Consultative Group to Assist the

Poor (CGAP) (Arabehety et al., 2016) and (iii) World Development Indicators (WDI) and World Governance Indicators (WGI) of the World Bank. Data on the dimensions and indicators of financial inclusion, and all the individual-level or demographic variables were extracted from the Global Findex 2017 database. The digital interoperability variables were obtained from the CGAP. The GDP per capita was obtained from the WDI while the GQ indicators which were used to construct a GQ index based on principal component analysis were sourced from the WGI of the World Bank. Our analysis included 33,194 individuals (15 years and above) located in 34 countries.[2] The selection of 34 countries is contingent on data availability at the time of study. The Global Findex database contains information on 35 countries in SSA, but the GDP per capita data for South Sudan was not available in the WDI database so we used the remaining 34 countries that consistently had data in both the WDI and Global Findex databases.

3.1 Financial Inclusion

Consistent with previous studies that have employed a multidimensional measure of financial inclusion, we use three dimensions—bank or mobile money account ownership, access to credit and receipt/sending of financial remittance via bank or mobile money account (Koomson et al., 2020a; Koomson, Abdul-Mumuni, et al., 2021; Koomson & Danquah, 2021; Zhang & Posso, 2017). Assigning an equal weight of 0.33 to each dimension (see **Table A1**), we apply the formula stated in Equation (1) to produce a multidimensional financial inclusion score for which a unit increase signifies an improvement in financial inclusion.

$$FI_i = w_1 I_1 + w_2 I_2 + \cdots + w_n I_n \tag{1}$$

where FI_i represents a respondent's multidimensional financial inclusion score, and $I_i = 1$ if a respondent provides an affirmative response for indicator i and $I_i = 0$ if otherwise. w_i is the weight attached to indicator i with $\sum_{i=1}^{n} w_i = 1$.

[2] The selected countries include Benin, Botswana, Burkina Faso, Cameroon, Central African Republic, Chad, Republic of Congo, Democratic Republic of Congo, Cote d'Ivoire, Ethiopia, Gabon, Ghana, Guinea, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, South Africa, Tanzania, Togo, Uganda, Zambia, and Zimbabwe

In robustness checks, we sequentially assign bigger weights (0.4) to each of the dimensions of financial inclusion to test whether the findings will be consistent. Apart from the Alkire-Foster methodology, we also follow the approaches used in existing studies to apply factor analysis and an additive method to generate the financial inclusion index. These approaches are detailed in Subsection 5.2 where they are applied.

3.2 Digital interoperability

Our measures of country-level digital interoperability platforms for sub-Saharan Africa are extracted from Consultative Group to Assist the Poor's (CGAP) survey of countries to identify the existence of interoperability platforms and the types that exist in these countries (Arabehety et al., 2016). At the end of the survey, three broad types of digital interoperability platforms were identified: third-party (***DOP3rdpty***), bilateral (***DOPbilat***) and multilateral (***DOPmulti***) platforms (see **Table A2**). Each type of digital interoperability platform is captured as a dummy variable, where '1=Yes' represents the existence of the type of platform and '0=No' means otherwise. Based on the data extracted, we constructed two other variables that were used for the analysis in addition to the platform types.

Our first measure (***Any form or DOPany***) is a binary indicator variable which represents the existence of least one type of digital interoperability platform in a country. The dummy variable is captured as 1 if any form of interoperability platform exists and 0 if otherwise. The second measure (***DOPdiv***) conceptualizes the diversity in digital interoperability platforms across countries. Here, we generate an additive index which is a sum of affirmative responses for all three types of interoperability platforms which ranges from a minimum of 0 to a maximum of 3. To understand the potential effect of each type of platform, we analyse the data using each of the types separately.

3.3 Mobile phone usage

Mobile phone ownership is captured as a binary variable for whether the respondent owns a mobile phone or not. Ownership of a mobile phone is assigned the value 1 and 0 otherwise. This has been used in prior research which capture mobile ownership in the analysis (see e.g., Demirgüç-Kunt et al., 2018; Koomson, Bukari, et al., 2021).

3.4 Governance quality (GQ)

Following existing studies, we apply principal component analysis (PCA) to measure GQ as a composite index using the six governance indicators—government effectiveness (GE), political stability/no violence (PS), rule of law (RL), voice and accountability (VA), corruption-control (CC), and regulation quality (RQ) (see e.g., Asongu & Nwachukwu, 2016; Singh & Pradhan, 2020). After applying the PCA, we retained components with eigen values greater or equal to one. From **Table A3**, we see that component 1 has an eigen value of 4.922 and also has a proportional contribution of 0.820. This implies that 82% of the information or characteristics of the six GQ indicators are contained in component 1 (Koomson, Abdul-Mumuni, et al., 2021; Lahai & Koomson, 2020).

Considering the Bartlett test of sphericity reported, we reject the null hypothesis of non-collinearity among the six indicators (at the 5% alpha level) (Koomson & Churchill, 2021). The Kaiser-Meyer-Olkin (KMO) value of 0.907 is above the 0.8 threshold considered adequate for PCA and for sampling adequacy (Koomson & Churchill, 2021; Lahai & Koomson, 2020). Based on these, we obtain our GQ index from component 1, where a unit increase in the measure reflects an improvement in in the quality of institutions. Summary statistics of the variables employed in this study can be found in Table A2.

4**. Estimation technique**

Since the individual-level data of respondents in the Global Findex database are clustered/nested in countries, we employ a multilevel model (MLM) to examine the relationship between our explanatory variables of interest and financial inclusion. The MLM is able to adequately capture the contextual elements which influence individuals in a particular country to exhibit similar financial behaviours. For instance, contextual factors have led to Kenyan's owning and using more of mobile money products compared to respondents from neighbouring countries of Uganda and Tanzania (Demirgüç-Kunt et al., 2018; Koomson, Bukari, et al., 2021). Similarly, the distribution of banks and mobile money agents are more in some countries than in others (Koomson, Bukari, et al., 2021).

Thus, it is expected that respondents located in countries with more bank branches and mobile money agents are more likely to own and use more of financial products and vice versa. The suspected country-level clustering in financial inclusion due to within-country similarities in

sub-Saharan Africa justifies the application of MLM procedures to account for the influence of country-level heterogeneities on financial inclusion. Using ordinary least squares (OLS) to model such relationships is likely to produce heteroskedastic errors or biased estimates.

$$FI_{ij} = \gamma_0 + \gamma_1 DOP_{ij} + X_{ij}\beta + \mathrm{T}_j\lambda + u_{0j} + v_{ij} \quad (2)$$

where, FI_{ij} represents multidimensional financial inclusion score for individual i in country j. DOP represents any of the measures of digital interoperability. X is a vector of individual-level variables while T is a vector of country level (macroeconomic) variables which have been identified as determinants of financial inclusion in the existing literature (Asongu et al., 2021a 2021b; Aterido et al., 2013; Koomson et al., 2020b). $\gamma_0,\ \gamma_1, \beta\ and\ \lambda$ represent fixed parameters to be estimated, u_{0j} and v_{ij} denote country- and individual-level residuals, respectively.

5. Empirical results

Table 1 reports estimated results from the multilevel regression. The intraclass correlation coefficients (ICC) for estimates in Columns 1 to 5 range from 0.101 to 0.113 and are all greater than 10%. Consistent with Lee (2000) and Chowa et al. (2014), an ICC greater than 10% provides enough justification to use a multilevel model. It is apparent from the findings that all dimensions of digital interoperability consistently improve financial inclusion apart from the multilateral platform. This positive nexus is also consistently confirmed for the two moderating variables, namely: mobile phone ownership and GQ.

Specifically, in Column 1, we observe that any form of digital interoperability platform is associated with an increase in financial inclusion by 0.059. In Column 2, we see that an increase in diversified forms of digital interoperability is associated with an increase in financial inclusion by 0.025. Considering the types of digital interoperability, third-party and bilateral platforms are respectively associated with increases in financial inclusion by 0.081 and 0.068. Although multilateral platforms are positively associated with financial inclusion, the link is not statistically significant. Mobile phone ownership is associated with an increase in financial inclusion by 0.162. These results are consistent with previous studies that identified digital interoperability as a crucial element required to for maximize the potential of financial technology to increase financial inclusion (Arner et al., 2020; Lammer et al., 2016; Donovan, 2012). They are also in line with

earlier research that found a positive relationship between technological advancement and financial inclusion (Asongu et al., 2021a; Koomson, Bukari, et al., 2021). Also, GQ is associated with an increase in financial inclusion between 0.015 and 0.017.

Concerning the control variables: (i) being a female is negatively associated with financial inclusion. This is consistent with the attendant literature on female exclusion from formal financial services, particularly in sub-Saharan Africa (Aterido et al., 2013). (ii) The fact that being employed is positively correlated with financial inclusion is logical and straight forward. Accordingly, being employed provides opportunities for interaction with banking institutions owing to constant flow of financial resources in terms of periodic salaries. (iii) Both secondary and tertiary education are also positively connected to financial inclusion, notably, because in accordance with the extant literature, education, especially at higher levels (where the magnitude of estimated effect is higher) is positively associated with financial literary and socio-economic opportunities such as employment that are related to financial transactions and connection with banking institutions (Atkinson & Messy, 2013). (iv) The effect of age on financial inclusion is non-linear (in the light of the quadratic specification) such that a Kuznets shape is apparent. Accordingly, in the initial ages of a person, an increase in age is positively related to financial inclusion before such a positive trend eventually declines as the person grows older, probably because old age is linked to retirement from economic activities and by extension, less nexuses with financial activities and banking institutions. Also, technological advancements and the fintech revolution which drive financial inclusion are embraced more by young people compared to their older folks (Koomson et al., 2020a).

Table 1: Multilevel model for digital interoperability and financial inclusion

	(1)	(2)	(3)	(4)	(5)
	Any form	Diversified platforms	Types of Interoperability platforms		
			Third-party	Bilateral	Multilateral
Financial inclusion index	DOPany	DOPDiv	3rdparty	Bilat	Multi
Fixed Effects					
Digital interoperability	0.059**	0.025**	0.081***	0.068**	0.014
	(0.027)	(0.012)	(0.027)	(0.029)	(0.035)
Mobile phone ownership	0.162***	0.162***	0.162***	0.162***	0.162***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Age	0.004***	0.004***	0.004***	0.004***	0.004***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Age squared	-0.002***	-0.002***	-0.002***	-0.002***	-0.002***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Female	-0.022***	-0.022***	-0.022***	-0.022***	-0.022***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)

Employed	0.069***	0.069***	0.069***	0.069***	0.069***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Educational status (Base: Pry & below)					
Secondary	0.134***	0.134***	0.134***	0.134***	0.134***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Tertiary	0.256***	0.256***	0.256***	0.256***	0.256***
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
Macro-level variables					
ln(GDP per capita growth)	0.013	0.012	0.015	0.017	0.006
	(0.017)	(0.017)	(0.016)	(0.017)	(0.018)
GQ index	0.016***	0.016***	0.015***	0.015***	0.017***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Random Effects (Variance)					
Country-level intercept (σ^2_{u0})	0.0035***	0.0035***	0.0028***	0.0035***	0.0043***
	(0.009)	(0.009)	(0.0008)	(0.0009)	(0.0011)
Model Fit Indices					
ICC	0.105	0.106	0.100	0.106	0.113
LR test (χ^2): (01)	1615.76***	1617.12***	1457.14***	1593.22 ***	1830.82***
Observations	33,194	33,194	33,194	33,194	33,194
Number of groups	34	34	34	34	34

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

5.1 Complementarity in digital interoperability

Table 2 builds on the model in Table 1 by estimating interactive regressions to assess the relevance of complementing digital interoperability platforms with policy dynamics of mobile phones and GQ. This is consistent with the theoretical underpinning discussed in Section 2.1 and the motivation of the study articulated in the introduction. To assess the overall influence of mobile phones and GQ in moderating digital interoperability platforms to influence financial inclusion, net effects of digital interoperability platforms are computed for specifications in which both the conditional and unconditional (or interactive) effects are significant.

Building on contemporary interactive regression literature (Tchamyou & Asongu, 2017), the following net effects are apparent:

(i) Any form of digital interoperability platform: 0.049+(0.031×0.682×0.214) = 0.054

(ii) Diversity in digital interoperability platforms: 0.019+(0.013×0.682×0.214) = 0.021

(iii) Third party digital interoperability platforms: 0.069+(0.033×0.682×0.214) = 0.074

To put the above computation into perspective, it is worthwhile to highlight how the first net effect is computed using the estimates displayed in Table 2. In the first computation (see Column 1), (i) 0.049 is the unconditional effect of any form of digital interoperability on financial inclusion; (ii) 0.031 is the conditional or interaction effect of any form of digital interoperability

on financial inclusion and (iii) 0.682 and 0.214 are respectively, mean values of mobile phone usage and GQ displayed in the summary statistics (Table A2). In this interaction model, the marginal effect of any interoperability platform is 0.049 but the net or joint effect along with mobile phone ownership and improvements in GQ is 0.054.

From the above computation, it is apparent that complementing digital interoperability platforms with mobile phone and GQ dynamics engender synergy effects, given that the unconditional incidence of interoperability platforms is enhanced by conditional effects pertaining to nexuses between the attendant platforms and policy variables of mobile phones and GQ. Such a notion of synergy is consistent with the contemporary literature on interactive regressions (I. Ofori et al., 2021; Diop et al., 2021; P. Ofori et al., 2021). The synergy effects are also found for diversified and third-party interoperability platforms. While the synergy effects result in 0.005 marginal improvements in financial inclusion for any and third part-party platforms, the marginal improvement is 0.002 for diversified platforms.

Table 2: Digital interoperability and financial inclusion: Moderating roles of mobile phone ownership and GQ

Variables	(1) Any form	(2) Diversity	(3) Types of Interoperability platforms	(4)	(5)
			Third-party	Third-party	Third-party
Financial Inclusion	DOPany	DOPDiv	3rdparty	Bilat	Multi
Digital interoperability	0.049*	0.019*	0.069**	0.046	0.011
	(0.027)	(0.011)	(0.027)	(0.029)	(0.035)
Mobile phone (Mbofon)	0.158***	0.157***	0.157***	0.155***	0.160***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
GQ index (GQ)	0.015***	0.014***	0.014***	0.014***	0.016***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
DOPany×mobfon×GQ	0.031***				
	(0.004)				
DOPdiv×mobfon×GQ		0.013***			
		(0.002)			
DOP3rdpty×mobfon×GQ			0.033***		
			(0.005)		
DOPbilat×mobfon×GQ				0.038***	
				(0.005)	
DOPmulti×mobfon×GQ					0.034***
					(0.005)
Other individual-level variables	Yes	Yes	Yes	Yes	Yes
ln(GDP per capita growth)	Yes	Yes	Yes	Yes	Yes
Random Effects (Variance)					
Country-level intercept (σ^2_{u0})	0.0037***	0.0037***	0.0034***	0.0037***	0.0043***
	(0.009)	(0.0009)	(0.0008)	(0.0009)	(0.0010)
Model Fit Indices					
ICC	0.105	0.106	0.100	0.106	0.113

LR test (χ^2): (01)	1602.64***	1634.82***	1488.32***	1609.02 ***	1862.23***
Observations	33,194	33,194	33,194	33,194	33,194
Number of groups	34	34	34	34	34
Standard errors in parentheses	*** p<0.01, ** p<0.05, * p<0.1		GQ=Governance Quality		

5.2 Robustness/sensitivity checks

In this section, we test for the robustness of our findings on the link between digital interoperability platforms and financial inclusion by engaging in several sensitivity analyses. First, we assign alternative weights to the three dimensions of the financial inclusion index. Considering our main measure used in the analyses above, each dimension was given an equal weight of 0.33. For the index used in **Table 3**, we sequentially assign a relatively bigger weight to each of the three dimensions. In Panel A, we report the results of the financial inclusion index in which 'bank account' is assigned a weight of 0.4, while access to credit and remittance are given equal weights of 0.3. In Panel B, we employ a financial inclusion index in which 'access to credit' is weighted 0.4, while bank account and remittance are given a weight of 0.3 each. In Panel C, we followed the same approach by assigning a weight of 0.4 to 'remittance'. The estimates reported in Panels A to C of Table 3 are all consistent with those reported in Table 1. This implies that the positive association between digital interoperability and financial inclusion is consistently established irrespective of the weighting schemes used in generating the multidimensional financial inclusion index. This also provides an opportunity to account for different dimensions of the financial inclusion construct that are mainly adopted in different countries within sub-Saharan Africa. For example, in countries where remittances drive inclusion more than access to credit, the last weighting scheme will better tell their story but produces a consistent positive relationship.

Second, we employ alternative methods which have been applied in existing studies to produce the financial inclusion index and present the results in **Table 4**. In Panel A, we apply factor analysis (Koomson & Danquah, 2021) while in Panel B, we employ an additive method to sum up affirmative responses for the financial inclusion indicators which produces a score between 0 and 3 (Koomson & Ibrahim, 2018). In Columns 1 to 4 of Panel A, we observe that digital interoperability is associated with an increase in financial inclusion between 0.058 and 0.187. In Panel B, we see that digital interoperability is linked to an increase in financial inclusion between 0.075 and 0.241. These findings also imply that the positive association between digital

interoperability and financial inclusion is robust to alternative methods used on generating the financial inclusion index.

Table 3: Digital interoperability and financial inclusion (Alternative weights)

	(1)	(2)	(3)	(3)	(5)
	Any form	Diversified	Types of Interoperability platforms		
Financial inclusion index		platforms	Third-party	Bilateral	Multilateral
	DOPany	DOPDiv	3rdparty	Bilat	Multi
Panel A: With more weight (0.4) on Account					
Fixed Effects					
Digital interoperability	0.060**	0.025**	0.083***	0.068**	0.015
	(0.028)	(0.012)	(0.028)	(0.030)	(0.036)
Other individual-level variables	Yes	Yes	Yes	Yes	Yes
Macro-level variables	Yes	Yes	Yes	Yes	Yes
Random Effects (Variance)					
Country-level intercept (σ_{u0}^2)	0.0040***	0.0040***	0.0037***	0.0040***	0.0046***
	(0.0010)	(0.0010)	(0.0009)	(0.0010)	(0.0011)
Model Fit Indices					
ICC	0.113	0.113	0.104	0.114	0.120
LR test (χ^2): (01)	1656.41***	1655.39***	1497.46***	1633.69***	1875.74***
Observations	33,194	33,194	33,194	33,194	33,194
Number of groups	34	34	34	34	34
Panel B: With more weight (0.4) on credit					
Fixed Effects					
Digital interoperability	0.052**	0.022**	0.072***	0.060**	0.011
	(0.025)	(0.011)	(0.025)	(0.027)	(0.032)
Other individual-level variables	Yes	Yes	Yes	Yes	Yes
Macro-level variables	Yes	Yes	Yes	Yes	Yes
Random Effects (Variance)					
Country-level intercept (σ_{u0}^2)	0.0032***	0.0032***	0.0029***	0.0031***	0.0036***
	(0.008)	(0.009)	(0.0007)	(0.0008)	(0.0009)
Model Fit Indices					
ICC	0.112	0.102	0.108	0.102	0.108
LR test (χ^2): (01)	1580.71***	1577.76***	1433.72***	1547.17***	1779.08***
Observations	33,194	33,194	33,194	33,194	33,194
Number of groups	34	34	34	34	34
Panel C: With more weight (0.4) on credit					
Fixed Effects					
Digital interoperability	0.064**	0.027**	0.087***	0.075**	0.015
	(0.028)	(0.012)	(0.029)	(0.031)	(0.037)
Other individual-level variables	Yes	Yes	Yes	Yes	Yes
Macro-level variables	Yes	Yes	Yes	Yes	Yes
Random Effects (Variance)					
Country-level intercept (σ_{u0}^2)	0.0042***	0.0042***	0.0038***	0.0041***	0.0048***
	(0.0010)	(0.0010)	(0.0009)	(0.0010)	(0.0012)
Model Fit Indices					
ICC	0.101	0.102	0.101	0.102	0.109

LR test (χ^2): (01)	1726.22***	1724.01***	1558.85***	1679.95***	1977.12***
Observations	33,194	33,194	33,194	33,194	33,194
Number of groups	34	34	34	34	34
Standard errors in parentheses	*** p<0.01, ** p<0.05, * p<0.1				

Table 4: Digital interoperability and financial inclusion (Alternative measures/methods)

	(1)	(2)	(3)	(3)	(5)
	Any form	Diversified platforms	Types of Interoperability platforms		
			Third-party	Bilateral	Multilateral
Financial inclusion index					
	DOPany	DOPDiv	3rdparty	Bilat	Multi
Panel A: Financial inclusion (Factor analysis)					
Fixed Effects					
Digital interoperability	0.136**	0.058**	0.187***	0.156**	0.033
	(0.061)	(0.026)	(0.062)	(0.067)	(0.080)
Other individual-level variables	Yes	Yes	Yes	Yes	Yes
Macro-level variables	Yes	Yes	Yes	Yes	Yes
Random Effects (Variance)					
Country-level intercept (σ_{u0}^2)	0.0196***	0.0197***	0.0177***	0.0193***	0.0224***
	(0.0048)	(0.0049)	(0.0044)	(0.0048)	(0.0055)
Model Fit Indices					
ICC	0.107	0.108	0.113	0.108	0.115
LR test (χ^2): (01)	1692.79***	1691.29***	1527.66***	1659.05***	1930.75***
Observations	33,194	33,194	33,194	33,194	33,194
Number of groups	34	34	34	34	34
Panel B: Financial inclusion (Additive index)					
Fixed Effects					
Digital interoperability	0.174**	0.075**	0.241***	0.201**	0.043
	(0.081)	(0.034)	(0.082)	(0.088)	(0.105)
Other individual-level variables	Yes	Yes	Yes	Yes	Yes
Macro-level variables	Yes	Yes	Yes	Yes	Yes
Random Effects (Variance)					
Country-level intercept (σ_{u0}^2)	0.0339***	0.0339***	0.0307***	0.0334***	0.0384***
	(0.0084)	(0.0084)	(0.0076)	(0.0082)	(0.0095)
Model Fit Indices					
ICC	0.105	0.106	0.105	0.106	0.112
LR test (χ^2): (01)	1668.05***	1665.00***	1509.17***	1635.61***	1893.57***
Observations	33,492	33,492	33,492	33,492	33,492
Number of groups	34	34	34	34	34
Standard errors in parentheses	*** p<0.01, ** p<0.05, * p<0.1				

6. Concluding implications and future research directions

This study complements the extant literature by assessing how mobile phone usage and GQ moderate the incidence of digital interoperability platforms on financial inclusion in sub-Saharan

Africa. Five digital interoperability dynamics (any form, diversified, third-party, bilateral, and multilateral digital interoperability platforms) are used to provide empirical evidence based on multilevel model (MLM) regressions. The findings show that mobile phone usage, GQ and all digital interoperability platforms, unconditionally promote financial inclusion. It is also apparent from the findings that complementing three digital interoperability platforms (i.e., any, diversified and third-party platforms) with two moderating variables (i.e., mobile phone and GQ) engenders synergy effects, given that the unconditional incidence of interoperability platforms is enhanced by conditional effects pertaining to nexuses with the two moderating variables.

The main policy implication is that the establishment of digital interoperability platforms should be complemented with mobile phone usage and GQ in order to enhance the potential benefits in terms of financial inclusion. In other words, while digital interoperability platforms constitute a necessary condition for the promotion of financial inclusion, it is important to simultaneously complement the establishment of digital interoperability platforms with policies designed to improve GQ and mobile phone usage/penetration.

Mobile phone usage can be improved by engaging in reforms that facilitate the construction of the much-needed ICT infrastructure that is essential to limit constraints in access. Moreover, measures are needed that would be geared towards liberalising the ICT sector to promote competition within the sector; competition that is favourable to low pricing, more coverage of rural areas and enhancements in adoption and usage of mobile technology. The policy suggestion towards boosting mobile usage is worthwhile in sub-Saharan Africa because of the mobile phone penetration potential of the sub-region. Accordingly, while it is the sub-region with lowest ICT penetration, it is equally the sub-region with the highest potential for ICT growth (Abdulqadir & Asongu, 2022).

GQ can also be improved through the following policies tailored to enhance the four main constituents of the institutional index, namely: (i) Government effectiveness can be improved by *inter alia*, ensuring public services of quality, making sure that public service is independent and free from political pressures, ensuring policy formulation and policy implementation of high standard and maintaining credibility as concerns the commitment of government to implementing formulated policies. (ii) Political stability and the absence of violence can be promoted by putting in place measures that reduce the likelihood of overthrow of governments or its destabilization by violent and unconstitutional mechanisms. (iii) Regulatory quality can be improved by ensuring

that governments always formulate and implement conducive policies that are destined to facilitate the development of the private sector. (iv) The rule of law can be promoted by implementing policies that increase the likelihood of economic agents having confidence in and abiding by societal rules, especially when it concerns the courts, the police, property rights and qualitative enforcement of contract.

This study obviously leaves room for future research in several areas. First, some control variables from this study have been established to affect financial inclusion in specific directions. Hence, it would be worthwhile to assess how such control variables can complement the digital interoperability platforms to influence financial inclusion. Moreover, given that the concern of financial inclusion is relevant to SDGs, it is also interesting to assess how the considered independent variables of interest in this study affect other areas of SDGs such as gender inclusion, poverty mitigation and income inequality reduction.

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Appendices

Table A1. Dimensions, indicators, and weights for multidimensional financial inclusion

Dimension/indicator	Detail	(weight)
Bank/mobile money account	Respondent has a bank account (bank account includes savings, current, fixed deposit or microfinance account) or mobile money account	1/3
Loan/Credit	Respondent has access to credit	1/3
Financial remittance	Respondent has received or sent financial remittance using the bank, money transfer service provider or through mobile money	1/3

Table A2: Summary statistics, description, and source of variables

Variable	Description	Source/method	Mean	Std. Dev.
Financial inclusion index	Multidimensional financial inclusion score obtained from three dimensions—equal weight (0.33) on account ownership, credit access, & remittance	Alkire-Foster	0.295	0.302
Financial inclusion (account)	Multidimensional financial inclusion score obtained from three dimensions (0.4 weight on account)	Alkire-Foster	0.312	0.315
Financial inclusion (credit)	Multidimensional financial inclusion score obtained from three dimensions (0.4 weight on credit)	Alkire-Foster	0.272	0.283
Financial inclusion (remit)	Multidimensional financial inclusion score obtained from three dimensions (0.4 weight on remittance)	Alkire-Foster	0.301	0.312
Financial inclusion (factor)	Multidimensional financial inclusion score obtained from factor analysis	Factor analysis	0.301	0.312
Financial inclusion (Add)	Multidimensional financial inclusion score obtained from the additive method	Additive method	0.050	0.6840
DOPany	Dummy variable equals 1 if country has any form of interoperability platform	CGAP	0.214	0.410
DOPdiv	Additive score country's diversity in different forms of digital interoperability platforms	CGAP	0.501	0.985
DOP3rdpty	Dummy variable equals 1 if country has third-party digital interoperability platform	CGAP	0.178	0.382
DOPbilat	Dummy variable equals 1 if country has bilateral digital interoperability platform	CGAP	0.214	0.410
DOPmulti	Dummy variable equals 1 if country has multilateral digital interoperability platform	CGAP	0.109	0.312
Mobile phone	Dummy variable equals 1 if respondent owns a mobile phone	Global Findex 2017	0.682	0.466
Age	Age of respondent captured in years	Global Findex 2017	34.021	15.178
Age squared	Age of respondent squared	Global Findex 2017	1387.817	1323.788
Female	Dummy variable equals 1 if respondent is female	Global Findex 2017	0.513	0.500
Employed	Dummy variable equals 1 if respondent is employed	Global Findex 2017	0.708	0.455
Secondary	Dummy variable equals 1 if respondent's educational level is secondary	Global Findex 2017	0.416	0.493
Tertiary	Dummy variable equals 1 if respondent's educational level is tertiary	Global Findex 2017	0.049	0.216
ln(GDP per capita growth)	Natural log of GPG per capita growth	World Bank (WDI)	0.537	1.018
GQ index	GQ index generated from RL, CC, RQ, GE, PS and VA	PCA	0.214	2.074

GE: Government Effectiveness. PS: Political Stability and Absence of Violence/Terrorism
RQ: Regulatory Quality. RL: Rule of Law CGAP: Consultative Group to Assist the Poor
Global Findex 2017: Global Financial Inclusion (Global Findex) Database 2017

Table A3: Principal component analysis for the six GQ indicators

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	4.922	4.455	0.820	0.820
Comp2	0.466	0.137	0.078	0.898
Comp3	0.329	0.166	0.055	0.953
Comp4	0.162	0.086	0.027	0.980
Comp5	0.077	0.033	0.013	0.993
Comp6	0.044		0.007	1.000
Kaiser-Meyer-Olkin (KMO)				0.907
Bartlett test of sphericity (Chi2)				344000.00***

*** p<0.01, ** p<0.05, * p<0.1 Comp: Component