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The role of mobile characteristics on mobile money innovations

Simplice A. Asongu[1] and Nicholas M. Odhiambo[2]

Abstract

This study focuses on linkages between bank accounts and supply-side mobile money drivers for mobile money innovations. It seeks to understand how bank accounts can be complemented with mobile subscription and mobile connectivity dynamics (i.e**.,** mobile connectivity coverage and mobile connectivity performance) for mobile money innovations. The empirical evidence is based on quadratic Tobit regressions. First, there are positive net relationships from the roles of mobile subscriptions and mobile connectivity coverage in modulating bank accounts for mobile money innovations. Second, mobile connectivity performance does not significantly modulate bank accounts for mobile money innovations. Third, given the negative marginal relationships associated with the positive net relationships, thresholds for complementary policies in mobile money supply factors that are worthwhile for bank accounts to stimulate mobile money innovations are provided. The thresholds are: (i) mobile subscription rates of 87.50%, 80.50%, and 98.50% of the adult population for respectively, the mobile money accounts, the mobile used to send money, and the mobile used to receive money, and (ii) mobile connectivity coverages of 64.00%, 69.33%, and 78.00% for respectively, the mobile money accounts, the mobile used to send money, and the mobile used to receive money.

Keywords: Mobile money; technology diffusion; financial inclusion; inclusive innovation

JEL Classification: D10; D14; D31; D60; O30

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1. Introduction

There are three main elements that are central to the focus of the present study, notably: (i) the importance of bank accounts in financial inclusion in the global sustainable development agenda; (ii) the relevance of mobile banking associated with the attendant bank accounts and (iii) a gap in the literature in the light of the need to enhance the favorable externalities of bank accounts for financial inclusion. Such enhancement can be done by complementing bank accounts with mobile banking supply factors of mobile subscription and mobile connectivity dynamics of coverage and performance. Accordingly, the four central elements can be summarized into the following research question motivating this study: How can 'bank accounts' be complemented with mobile subscription and mobile connectivity dynamics (i.e. mobile connectivity coverage and mobile connectivity performance) for mobile money innovations (i.e. mobile money accounts, mobile used to send money and mobile used to receive money)?[3] The problem statement is also clearly articulated in the title of the study: The role of mobile characteristics on mobile money innovations. In order to put the above into more perspective, the three elements are critically engaged in the same chronological order in the following passages.

First, despite the substantially documented importance of bank accounts in promoting financial access and financial inclusion in developing countries (Gosavi, 2018; Tchamyou, Asongu, Odhiambo, 2019; Morsy, 2020; Asongu, Nnanna & Acha-Anyi, 2020a, 2020b), concerns about whether more bank account ownership in developing countries has been accompanied by financial inclusion, have not been given the deserved scholarly attention in the financial inclusion literature. Accordingly, Klapper, El-Zoghbi and Hess (2016) have been concerned that in spite of the promising and/or favorable progress in the ownership of bank accounts in developing countries, many of the attendant bank accounts are either still dormant in the formal financial institutions or are not being used as anticipated in, *inter alia*, person-to-person transfers, withdrawal of cash and depositing of cash. According to the narrative, the underlying issue has further raised concerns in policy circles as to whether financial inclusion externalities are being derived from the growing ownership of bank accounts in developing countries. The present study takes this concern on board by assessing how such bank accounts can be leveraged to promote financial inclusion by means of mobile money innovations when complemented with supply-side mobile money factors. Such a focus is also motivated by the documented importance of mobile banking in financial inclusion.

Second, mobile banking is promoting financial inclusion in developing countries because it is enabling a previously unbanked fraction of the population to have access to transactions and financial services via mobile bank accounts (Tchamyou, Erregers & Cassimon, 2019; Lashitew, van Tulder & Liasse, 2019; Asongu, Biekpe & Cassimon, 2020, 2021). Moreover, externalities of financial inclusion and greater financial access can be enhanced when the mobile accounts are connected to a formal banking institution such that the user leverages both on the services provided by the formal banking institution, as well as mobile money innovation externalities associated with non-formal and informal mobile banking operators (Asongu, 2013; Ondiege, 2013). However, despite this documented importance of mobile banking in financial access, especially in the light of challenges to sustainable development goals (SDGs), the literature is sparse on how mobile money supply factors can complement the importance of bank accounts in financial inclusion.

Third, this study focuses on the framework that the favorable incidences of banking in financial inclusion can be enhanced when bank accounts are tailored for mobile banking externalities in terms of mobile money innovations. This can be done by complementing bank accounts with mobile banking supply factors of mobile subscription and mobile connectivity dynamics of coverage and performance. Hence, this study argues that in the light of the attendant literature (as discussed in the next paragraph), a bank account which is a demand factor for mobile money innovation should be complemented with supply factors for more understanding of the possible tendencies that might clarify the concern from Klapper et al. (2016) as to why formal bank accounts may not be associated with anticipated inclusive development externalities. We attempt to show that, *inter alia*, such a concern may arise from the fact that the attendant supply factors become necessary but not sufficient conditions for financial inclusion. Hence, at the corresponding critical masses, supply-side mobile money innovation factors should be complemented with other policies.

The closest studies in the literature to the present paper are Lashitew et al. (2019) and Asongu and Odhiambo (2021). Lashitew et al. (2019) has investigated determinants of mobile money innovations using demand, supply and macro-level factors. Asongu and Odhiambo (2021) have extended Lashitew et al. (2019) by assessing how enhancing supply factors of mobile technologies affect mobile money innovations for financial inclusion.This study argues that simply providing linkages between the attendant factors and mobile money inclusion outcomes is not enough for policy makers to leverage upon and drive financial inclusion unless actionable critical masses or thresholdsare provided to concerned policy makers on the subject. In other words, empirical frameworks based on linear additive models,

as in Lashitew et al. (2019), provide the groundwork for understanding factors that drive mobile money innovations. However, understanding how these attendant factors interact with one another to affect financial inclusion has the potential to inform policy makers with policy-relevant thresholds that are important in promoting mobile money innovations. To this effect, the present study departs from Lashitew et al. (2019) by focusing on how one demand factor (i.e., bank accounts) can be complemented with supply factors (i.e., mobile phone subscriptions, mobile connectivity coverage and mobile connectivity performance) in order to influence mobile money innovations within the framework of interactive regressions. Moreover, contrary to Asongu and Odhiambo (2021), who enhance supply factors within the remit of quadratic regressions, this study complements supply factors with bank accounts within the framework of interactive regressions.

The positioning of the study also departs from contemporary technology in society literature, which has largely focused on, *inter alia*: comprehending the use of mobile banking in rural areas (Malaquias & Silva, 2020); barriers in the adoption of internet banking (Arif, Aslam & Hwang, 2020); how technology has affected the role of the citizen-customer (Lammi & Pantzar, 2020); poverty, inequality and sustainable development implications associated with nexuses among microfinance, information and communication technology, and financial inclusion (Mushtaq & Bruneau, 2020; Hoque, 2020) and drivers of information technology adoption (Karakara & Osabuohien, 2019; Alderete, 2020). While the first two studies on mobile and internet banking are closest to the present study in terms of conceptual focus on mobile banking, differences in scope and positioning are apparent in the light of the discussed objective of the present study above.

The rest of the study is organized as follows: Section 2 provides theoretical underpinnings underlying the association among bank accounts, mobile phones and mobile banking. The data and methodology are clarified in section 3. The empirical results and corresponding discussion are covered in Section 4, while section 5 concludes with implications and future research directions.

2. Theoretical underpinnings

The importance of this section in the problem statement being investigated is informed by the relevance of providing theoretical connections between bank accounts and supply-side mobile money drivers for mobile money innovations in financial inclusion. To clarify this theoretical context, two strands are discussed. The two strands articulate: (i) the linkage between bank accounts and innovations in mobile banking and (ii) the information asymmetry theory

(Asongu, 2020; Asongu & Odhiambo, 2022). The attendant strands are expanded in the same chronology as highlighted in the passages that follow.

First, the connections between bank accounts and mobile banking, as documented by Ondiege (2013) and Asongu (2013), are important for this study because they are essential in clarifying nexuses among mobile phones, bank accounts, mobile banking, mobile money supply factors (mobile subscription rate, mobile connectivity performance and mobile connectivity coverage) and mobile money innovations as conceived in this study (i.e.,mobile money accounts, mobile used to send money and mobile used to receive money). Accordingly, it is worth articulating that the concept of mobile banking as emphasised in the attendant theoretical underpinnings literature is consistent with mobile money innovations and financial inclusion externalities. Four perspectives from the corresponding literature underlying the nexuses between mobile phones, mobile banking, mobile money innovations and financial inclusion are worth engaging to clarify the theoretical context.

(i) The mobile phone represents a bank card that can be virtual. Institutions and clients leverage on it to reduce intermediary and transaction costs that are often characteristics of traditional or classical bank cards. In essence, mobile phones are inherently associated with a subscriber identity model (SIM). Such a SIM card also plays the role of a smart card that can enable the mobile phone to perform similar functions as a virtual bank card; (ii) Another characteristic of a mobile phone is the point of sale (POS) terminal; It enables the user to make transactions and communicate with banks since the latter are provided with complementary mechanisms for soliciting and authorising transactions. It follows that many functionalities of a traditional bank card can be handled by a mobile phone when it is acting like a POS terminal; (iii) Automated teller machine (ATM) features are also part and parcel of the mobile phone because the previously discussed POS characteristics are consistent with a mobile phone that is also being used for banking purposes; (iv) The mobile banking externalities are enhanced when the mobile phone is connected to the internet because many functions underlying mobile banking are enhanced. Some of these functions include the reception and sending of money, as well as the payment and receipt of bills.

Second, mobile phones enhance the collection of information on borrowers' credit histories and characteristics and hence, can contribute towards the mitigation of information asymmetry that is associated with mobile banking (Asongu & Biekpe, 2018). As documented by Pradeep (2011), the asymmetric information theory is essential in clarifying whether more of the poor fractions in society, especially those previously unbanked, can benefit from financial inclusion with the possession of a bank account. The concern of information

asymmetry is both from the lender or banking institution before the lending process (i.e., ex-ante of lending) and from the borrower (i.e., ex-post of lending) (Tchamyou & Asongu, 2017; Tchamyou, 2019). In order to connect the theory of information asymmetry to this framework, the concern of information asymmetry can affect how mobile bank clients benefit from access to finance and, by extension, financial inclusion. It is important to note that the problem statement is tailored such that bank accounts are complemented with supply-side mobile money factors, which implies that a traditional bank account within a formal financial institution is the channel of financial inclusion that is complemented with mobile subscription and connectivity dynamics. Moreover, a starting point for granting credit by a bank is a bank account which is the main channel for financial inclusion in this study. Hence, information asymmetry between the bank and clients can determine how the bank account is used by the client for financial access. This linkage is consistent with the concern of Klapper et al. (2016) on the fact that bank accounts are not being used as expected (see discussion in the introduction). It is fundamentally for the purpose of reducing information asymmetry in the banking industry that over the past decades, developing countries have been instituting information sharing offices such as public credit registries and private credit bureaus, which are meant to reduce information asymmetry that characterizes the lending process and limit financial access (Asongu, Nwachukwu & Tchamyou, 2016; Kusi, Agbloyor, Ansah-Adu & Gyeke-Dako, 2017; Boateng, Asongu, Akamavi & Tchamyou, 2018; Kusi & Opoku-Mensah, 2018; Asongu & Odhiambo, 2018a).

Theoretical underpinnings from the financial development literature are used to complement the socio-technical theory (SST) above. Accordingly, the SST is also relevant because the study deals with technical and human interactions (Durkin, Mulholland & McCartan, 2015). In essence, according to Cherns (1987), the socio-technical perspective articulates joint optimization of social and technical sub-systems rather than the optimation of one subsystem (i.e., the technical sub-system) and adaptation of another sub-system (i.e.,the social sub-system). This perspective is supported by Montano and Dillon (2005), who posit that the socio-technical view acknowledges that in organizations, the relationship between technical and social sub-systems is changed by technology. The STT is consistent with this study because the study is concerned with assessing mobile money characteristics that are shaped by human interactions. Accordingly, the technical sub-system is associated with the social sub-system because linkages between bank account and mobile money characteristics that are consistent with social interacts are assessed in order to understand how bank accounts can be complemented with mobile subscription and mobile connectivity dynamics (i.e.,

mobile connectivity coverage and mobile connectivity performance) for mobile money innovations.

3. Data and methodology

3.1 Data

In accordance with the motivation of this study covered in the introduction, the dataset used is the same as in Lashitew et al. (2019) and Asongu, Agyemang-Mintah and Nting (2021). The data which consist of 2010 to 2014 averages and entail countries for which data are available at the time of study are obtained from a plethora of sources, namely: (i) World Governance Indicators (WGI) and World Development Indicators (WDI) of the World Bank; (ii) the Financial Inclusion Indices (Findex) database; (iii) the Global Financial Structure Database (GFSD); (iv) Waverman and Koutroumpis (2011) and (v) the Global System for Mobile Communications Association (GSMA). The focus of the study is on all developing countries for which data are available at the time of the study.

The dependent variables, which are mobile money innovation proxies, are three in number, namely: mobile money accounts, the mobile used to send money and the mobile used to receive money. The outcome variables are from the Findex database. Contrary to Lashitew et al. (2019) and consistent with the motivation of this study, the bank account (which is a demand factor and the main channel) is complemented with some supply factors. Hence, departing from the underlying study, the present research is tailored such that: (i) the focus is on the complementarity between bank accounts and supply-side mobile money drivers and (ii) macro-level and continental factors are used as control variables given that demand- and supply-side factors are already taken on board as independent variables of interest.

It is also important to note that while all the variables are discussed to provide insights into how thepresent study departs from Lashitew et al. (2019), not all variables are engaged in the empirical analysis, partly because of specificities of the problem statement and partly because of concerns of multicollinearity which are not addressed by Lashitew et al. (2019) but taken on board in attendant replication studies (Asongu et al., 2020, 2021). In what follows, the three main types of independent variables are discussed.

First, the selected supply-side mobile money determinants consist of: (i) mobile connectivity dynamics (i.e. mobile connectivity performance and mobile connectivity coverage) obtained from the GSMA; (ii) telecommunications sector regulation from Waverman and Koutroumpis (2011); (iii) mobile penetration rate from the WDI and (iv) “gross and unique subscription” rates from the GSMA. Second, the documented demand-side

factors in Lashitew et al. (2019) from the GFSD include: bank sector concentration; the number of ATMs and "percentage of adults with a bank account in a formal banking institution". Third, the corresponding macro-level variables are from WGI (i.e., the rule of law) and WDI (i.e., GDP per capita, GDP growth and urbanization rate) of the World Bank. The choice of the control variables is also informed by the corresponding literature on financial inclusion (Mas & Morawczynski, 2009; Muwanguzi & Musambira, 2009; Waverman & Koutroumpis, 2011; Demirgüç-Kunt & Klapper, 2013; Van der Boor, Oliveira & Veloso, 2014; Gruber & Koutroumpis, 2013; Demirgüç-Kunt, Klapper & Van Oudheusden, 2015; Asongu & Odhiambo, 2018b; World Bank, 2016; Murendo, Wollni, De Brauw &Mugabi, 2018; Asongu & Asongu, 2018; GSMA, 2018). All adopted elements in the conditioning information set are expected to positively influence mobile money innovations. However, if the variables reflect both positive and negative signals, the negative skewness of the variables cantranslate into unexpected signs. For instance, the regulation quality, which has both positive and negative values, is negatively skewed because the mean value is negative on the one hand, and on the other, the maximum negative value is higher than the maximum positive value.

Complementary information on the data is provided in the appendices. The definitions of variables and corresponding sources are disclosed in Appendix 1, whereas the summary statistics are provided in Table 1. The correlation matrix inTable 2 enables the study to avoid concerns of multicollinearity which are highlighted in bold. The threshold of 0.600, which is the criterion for the avoidance of combinations of variables in the same specification, is further clarified in the last paragraph of the following section.

Table 1: Summary Statistics

Variables	Mean	S.D	Min	Max	Obs
Dependent variables					
Mobile accounts (%)	3.30	7.90	0.00	58.39	145
Sending money (%)	3.10	7.58	0.00	60.48	146
Receiving money (%)	4.47	9.58	0.00	66.65	146
Demand factors					
Account at formal fin. Institution (%)	45.72	31.73	0.40	99.74	147
ATM penetration	43.28	45.03	0.33	279.71	148
Banking sector concentration	71.94	20.70	9.49	100.00	143
Supply factors					
Unique mobile subscription rate	61.73	23.29	4.23	133.64	199
Mobile connectivity (performance)	11.92	14.69	0.04	67.19	147
Mobile connectivity (coverage)	62.18	27.29	8.88	99.60	147
Telecom regulation	0.41	0.17	0.00	0.74	128
Macro-level factors					
GDP per capita (PPP)	17,874	19,677	648	132,468	152
GDP growth	3.90	2.82	-4.92	11.10	153
Rule of Law	-0.09	1.01	-2.42	1.98	157
Urbanization (%)	58.22	22.85	8.81	100	155

Notes:- The average values for the dependent variables are calculated across all countries, including those in which mobile money services are not available.

Table 2: Correlation matrix

	Mobile inclusion variables			Demand Factors			Supply Factors				Macro-level Factors				Region dummies			
	MMA	SendM	Receiv.M	BankAc	ATM Pen	BankSC	UMSr	MCP	MCC	TSR	GDPpc	GDPg	RL	Urban	Africa	Asia	Americas	Middle East
MMA	1.000																	
Send M	0.640	1.000																
Receiv.M	0.597	0.980	1.000															
Bank Ac	-0.292	-0.227	-0.266	1.000														
ATM Pen	-0.319	-0.248	-0.279	**0.708**	1.000													
BankSC	-0.079	-0.028	-0.026	0.051	-0.171	1.000												
UMSr	-0.237	-0.116	-0.142	0.411	0.305	-0.045	1.000											
MCP	-0.320	-0.272	-0.300	**0.821**	**0.779**	-0.053	0.270	1.000										
MCC	-0.385	-0.300	-0.323	**0.815**	**0.701**	-0.091	0.525	**0.780**	1.000									
TSR	-0.088	-0.070	-0.067	0.549	0.363	-0.008	0.237	0.466	0.473	1.000								
GDPpc	-0.420	-0.209	-0.228	**0.825**	**0.690**	-0.078	**0.644**	**0.729**	**0.872**	0.535	1.000							
GDPg	0.376	0.189	0.176	-0.532	-0.481	-0.058	-0.300	-0.477	-0.527	-0.433	-0.553	1.000						
RL	-0.271	-0.273	-0.308	**0.850**	**0.623**	0.040	0.374	**0.838**	**0.772**	**0.605**	**0.772**	-0.457	1.000					
Urban	-0.396	-0.212	-0.220	0.566	0.567	-0.051	0.364	0.598	0.731	0.349	**0.788**	-0.381	0.583	1.000				
Africa	0.533	0.415	0.444	-0.558	-0.519	0.123	-0.462	-0.487	**-0.681**	-0.288	**-0.683**	0.407	-0.418	-0.560	1.000			
Asia	-0.101	-0.076	-0.088	0.087	0.077	-0.009	-0.013	0.153	-0.006	-0.129	0.007	0.244	0.014	-0.075	-0.199	1.000		
Americas	-0.098	-0.116	-0.095	-0.176	-0.016	-0.004	0.092	-0.198	-0.029	0.001	0.045	0.025	-0.221	0.158	-0.268	-0.278	1.000	
Middle East	-0.086	-0.072	-0.082	-0.0001	0.047	0.019	-0.010	0.035	0.124	-0.131	0.140	0.040	0.017	0.237	-0.101	-0.105	-0.141	1.000

MMA: Mobile Money Accounts. Send M: Sending Money. Receiv M: Receiving Money. Bank Ac: Bank Accounts. ATM Pen: ATM Penetration. BankSC: Bank Sector Concentration. UMSr: Unique Mobile Subscription rate. MCP: Mobile Connectivity Performance. MCC: Mobile Connectivity Coverage. TSR: Telecom Sector Regulation. GDPpc: Gross Domestic Product per capita in PPP (in logs). GDPg: GDP growth. RL: Rule of Law. Urban: Urbanization.

3.2 Methodology

Following the closest study to this inquiry, the Tobit regressions technique is adopted as the empirical approach (Lashitew et al., 2019; Asongu & Odhiambo, 2022). The contemporary literature, which is based on the same outcome variables, is consistent with less non-contemporary literature on the essence of adopting the Tobit regressions estimation approach when the outcome variables are situated within specified limits (Kumbhakar & Lovell, 2000; Koetter & Vins, 2008; Coccorese & Pellecchia, 2010; Ariss, 2010; Asongu & Nwachukwu, 2016; Ajide, Raheem & Asongu, 2019). In other words, both contemporary and non-contemporary literature are consistent on the view that when minimum and maximum values of the dependent variable are clearly defined and distinguished, a Tobit regression approach can be feasibly adopted.

The underpinnings for the adoption of the Tobit regression model are consistent with the data behavior of outcomes variables in this study because these outcomes variables are theoretically and practically between 0.00% and 100%. In other words, adoption rates range from 0% to 100%. As apparent in Appendix 2, the adoption ratesranges of mobile money accounts, the mobile used to send money and the mobile used to receive money are respectively, 0.00% to 58.39%, 0.00% to 60.48% and 0.00% to 66.65%. This implies that all the outcome variables are censored on both sides of the distribution and hence an Ordinary Least Squares (OLS) estimation strategy is not appropriate for assessing the nexuses being examined in this study because the OLS technique is not designed to incorporate broad differences in the conditional probabilities of restricted observations which are very apparent when 0% and 100% adoption rates are characteristics of the outcome variables (Amemiya, 1984). Hence, a double censored Tobit regression model is adopted for this study because it censors both sides of the conditional distribution of the mobile money innovation variables.

From mainstream research on Tobit regression (Tobin, 1958; Carson & Sun, 2007), Equations (1) and (2) below reflect the main Tobit estimation process.

$$y_{i,t}^{*} = \alpha_0 + \beta X_{i,t} + \varepsilon_{i,t}, \qquad (1)$$

where $y_{i,t}^{*}$ is a latent response variable, $X_{i,t}$ is an observed $1 \times k$ vector of explanatory variables and $\varepsilon_{i,t} \approx$ i.i.d. N(0, σ^2) and is independent of $X_{i,t}$. As opposed to observing $y_{i,t}^{*}$, we observe $y_{i,t}$:

$$y_{i,t} = \begin{cases} y_{i,t,}^{*} \; if \; y_{i,t}^{*} > \gamma \\ 0, \; if \; y_{i,t}^{*} \leq \gamma, \end{cases} \qquad (2)$$

where γ is a non-stochastic constant. It follows that, the value of $y_{i,t}^{*}$ is missing when it is less than or equal to γ.

The assumptions underpinning the Tobit model are as follows: (i) residuals are normally distributed and (ii) the latent outcome variables which are related to an unbounded and a linear function of the explanatory variables (Amemiya, 1984). Furthermore, there are two principal marginal corresponding relationships connecting the main predictors (i.e., bank accounts, mobile connectivity performance, mobile connectivity coverage and mobile money accounts). The first underlines the marginal relationships of the main predictors of the unobserved latent rate of mobile money adoption, while the second corresponds to the censored, observed rate of mobile money adoption. Consistent with Lashitew et al. (2019) and Asongu et al. (2020a, 2020b), only marginal relationships linked to the observed and censored adoption rates of mobile money innovations are disclosed because, in line with the corresponding literature, such disclosure provides a more apparent analytical interpretation.

In accordance with the discussion in the introduction, not all variables from Lashitew et al. (2019) provided in the appendices are used for the empirical analysis because of the focus of the study and because the specifications are tailored to account for multicollinearity. In Appendix 3, a multicollinearity threshold of 0.600 is adopted because it is the average of two strands in the literature, namely: (i) 0.500 from Obrien (2007) and Wichers (1975) and (ii) 0.700 from Kennedy (2008).

4. Empirical results

4.1 Presentation of results

The empirical findings are disclosed in this section in Table 3 which is divided into three main components, each entailing three specifications pertaining respectively to mobile money accounts, the mobile phone used to send money and the mobile phone used to receive money. It follows that the first component is consistent with specificationson interactions between bank accounts with mobile money accounts; the second component shows interactions between bank accounts and mobile money connectivity performance, while the third is focused on nexuses between bank accounts and mobile money connectivity coverage.

In order to assess the overall incidence of mobile money supply factors on bank accounts for mobile money innovations, net relationships are computed. These net relationships embody the unconditional relationship of bank accounts and the conditional relationships pertaining to the interaction between bank accounts and supply-side mobile money factors. To put this computation into more perspective, it is relevant to illustrate with

an example. Accordingly, in the second column (or first specification) of Table 3, the net relationship of mobile subscriptions in bank accounts for mobile money accounts is 0.051([-0.002 × 61.73] + [0.175]). In this calculation, the average value of mobile subscriptions is 61.73; the unconditional relationship between bank accounts and mobile money accounts is 0.175, while the conditional nexus between bank accounts and mobile subscriptions is -0.002. The computation is in line with contemporary interactive regressions literature (Asongu & Odhiambo, 2020a, 2020b). The sign "na", denoting "not applicable", is used to represent specifications where the net relationships cannot be computed because at least one of the corresponding estimated coefficients is not significant.

Table 3: Bank account, supply-side mobile money drivers and financial inclusion

	Dependent variables: Mobile money accounts, Mobile used to send money & Mobile used to receive money								
	Bank account and mobile subscription			**Bank account and mobile connectivity performance**			**Bank account and mobile connectivity coverage**		
	Mobile money accounts	**Mobile used to send money**	**Mobile used to receive money**	**Mobile money accounts**	**Mobile used to send money**	**Mobile used to receive money**	**Mobile money accounts**	**Mobile used to send money**	**Mobile used to receive money**
Bank Accounts	**0.175****	**0.161***	**0.197***	0.021	0.059	0.060	**0.128****	**0.208****	**0.234****
	(0.040)	**(0.098)**	**(0.096)**	(0.494)	(0.152)	(0.224)	**(0.029)**	**(0.011)**	**(0.016)**
Mobile Subscription (MS)	**0.103****	**0.122****	**0.145****	---	---	---	---	---	---
	(0.010)	**(0.010)**	**(0.012)**						
Mobile Con. Perf (MCP)	---	---	---	0.266	0.153	0.182	---	---	---
				(0.129)	(0.244)	(0.240)			
Mobile Con. Cov (MCC)	---	---	---	---	---	---	**0.065***	**0.086****	**0.121****
							(0.080)	**(0.030)**	**(0.014)**
Bank Accounts× MS	**-0.002****	**-0.002****	**-0.002****	---	---	---	---	---	---
	(0.025)	**(0.045)**	**(0.040)**						
Bank Accounts×MCP	---	---	---	-0.003	**-0.005****	**-0.006****	---	---	---
				(0.112)	**(0.013)**	**(0.017)**			
Bank Accounts× MCC	---	---	---	---	---	---	**-0.002*****	**-0.003*****	**-0.003*****
							(0.006)	**(0.002)**	**(0.003)**
GDP growth	**0.532*****	0.087	0.049	**0.517*****	-0.049	-0.140	**0.461*****	-0.102	-0.238
	(0.000)	(0.594)	(0.826)	**(0.008)**	(0.804)	(0.607)	**(0.009)**	(0.596)	(0.392)
Rule of Law	-0.207	**-3.066*****	**-4.228*****	-0.014	**-1.894****	**-2.959*****	0.521	**-1.936****	**-2.993****
	(0.796)	**(0.004)**	**(0.001)**	(0.984)	**(0.029)**	**(0.009)**	(0.441)	**(0.032)**	**(0.010)**
Urbanization	**-0.066****	-0.006	0.009	-0.037	0.031	0.057	-0.031	0.034	0.068
	(0.029)	(0.876)	(0.844)	(0.179)	(0.447)	(0.245)	(0.271)	(0.428)	(0.212)
Africa	**7.673*****	**4.738*****	**6.590*****	**8.645*****	**4.121****	**6.114*****	**7.887*****	**4.347*****	**6.453*****
	(0.000)	**(0.006)**	**(0.002)**	**(0.000)**	**(0.018)**	**(0.004)**	**(0.000)**	**(0.008)**	**(0.003)**
Asia	2.056	-1.055	-0.920	**3.923****	0.512	1.210	**3.177****	0.228	0.853
	(0.207)	(0.445)	(0.585)	**(0.018)**	(0.731)	(0.508)	**(0.046)**	(0.863)	(0.614)
Americas	**5.397*****	-0.709	-0.778	**6.088*****	-1.673	-1.849	**4.798*****	-2.022	**-2.602***
	(0.001)	(0.535)	(0.557)	**(0.002)**	(0.205)	(0.205)	**(0.004)**	(0.109)	**(0.091)**
Middle East	**5.037*****	-1.380	-1.379	**4.569****	**-2.962***	**-3.158***	**4.270****	**-3.005***	**-3.176***
	(0.007)	(0.331)	(0.368)	**(0.016)**	**(0.079)**	**(0.065)**	**(0.019)**	**(0.070)**	**(0.099)**
Net Relationships	0.051	0.037	0.073	na	na	na	0.003	0.021	0.047
Thresholds	87.500	80.500	98.500	na	na	na	64.000	69.333	78.000
Observations	131	137	137	126	132	132	126	132	127

GDP: Gross Domestic Product. PPP: Purchasing Power Parity. *,**,***: significance levels of 10%, 5% and 1% respectively. The mean value of mobile subscription is 61.73, the mean value of mobile connectivity performance is 11.92 while the mean value of mobile connectivity coverage is 62.18.na: not applicable because at least one estimatedcoefficient needed for the computation of net relationships and/or thresholds is not significant.

The following findings can be established from Table 3. First, there are positive net relationships from the roles of mobile subscriptions and mobile connectivity coverage in modulating bank accounts for mobile money innovations in terms of mobile money accounts, the mobile used to send money and the mobile used to receive money. Second, mobile connectivity performance does not significantly modulate bank accounts for mobile money innovations. Third, most of the control variables are significant with the expected signs.

4.2 Extended analysis with thresholds for complementary policies

Consistent with the problem statement and the imperative of providing findings with more policy implications, this study does not stop at the level of positive net relationships from the roles of supply-side mobile money drivers in stimulating bank accounts for mobile money innovations. The consistent negative marginal relationships is an indication that at certain critical masses of supply-side mobile money factors, the attendant supply-side factors become necessary but not sufficient conditions for mobile money innovations, which is also an indication of the fact that, at the attendant thresholds, complementary policies should be taken on board in order to enhance the positive relevance of supply factors in modulating the incidence of bank accounts on mobile money innovations.

Still considering the example used to illustrate the computation of net relationships in the previous section, in the second column or first specification of Table 3, the critical mass or threshold of mobile subscriptions at which complementary policies are worthwhile is 87.500 (0.175/0.002). This implies that when mobile subscriptions have reached 87.500% of the adult population, the net relationship from their incidence in modulating bank accounts for mobile money accounts is zero or nul. Accordingly, 0.000= ([-0.002 × 87.500] + [0.175]). Hence, above the critical limit of 87.50 mobile subscriptions as a percentage of the adult population, complementary policies are worthwhile.

In the light of the above, the following are thresholds for complementary policies in mobile money supply factors that are worthwhile for bank accounts to stimulate mobile money innovations: (i) mobile subscription rates of 87.50%, 80.50% and 98.50% of the adult population for respectively, mobile money accounts, the mobile used to send money and the mobile used to receive money and (ii) mobile connectivity coverages of 64.00%, 69.33% and 78.00% for respectively, mobile money accounts, the mobile used to send money and the mobile used to receive money.

In accordance with the contemporary threshold literature (Asongu & Odhiambo, 2020c, 2020d), in order for the established thresholds to make sense from an economic

perspective and be policy-relevant, they should be within the defined limits or ranges of the variables in the summary statistics. Hence, the computed thresholds above make economic sense and are relevant to policy makers because they are within the statistical ranges disclosed in the summary statistics, notably: "4.23 to 133.64" for mobile subscriptions and "8.88 to 99.60" for mobile connectivity coverage.

The first complementary policy worth taking on board is to improve mobile connectivity performance. This is essentially because the mobile money supply factor of mobile connectivity performance has not been significant in modulating bank accounts to induce positive net dynamics on the engaged mobile money innovations. This could also lead the study to infer, albeit with caution, that the thresholds for complementary policies in mobile subscriptions and mobile connectivity coverage might have been higher had mobile connectivity performance been significant in modulating bank accounts for favorable outcomes in mobile money innovation dynamics. This inference is partially motivated by the fact that two corresponding marginal relationships pertaining to nexuses between mobile connectivity performance and bank accounts are significant, which is further evidence of the fact that the unconditional positive nexus from mobile connectivity performance (i.e., which is insignificant) can be improved. Measures of improving mobile connectivity performance should be tailored around enhancing the speed at which data from the mobile network is downloaded and uploaded.

The link of the results with financial inclusion is apparent because mobile penetration levels below the thresholds are favorable for financial inclusion and it is only above the thresholds that complementary policies are worthwhile. Hence, complementary policies are needed only when almost all the population has been covered or financially included.

5. Concluding implications and future research directions

The study focuses on linkages between bank accounts and supply-side mobile money drivers for mobile money innovations. It seeks to understand how bank accounts can be complemented with mobile subscription and mobile connectivity dynamics (i.e., mobile connectivity coverage and mobile connectivity performance) for mobile money innovations (i.e., mobile money accounts, mobile used to send money and mobile used to receive money). The empirical evidence is based on quadratic Tobit regressions.

The following findings are established. First, there are positive net relationships from the roles of mobile subscriptions and mobile connectivity coverage in modulating bank accounts for mobile money innovations in terms of mobile money accounts, the mobile used

to send money and the mobile used to receive money. Second, mobile connectivity performance does not significantly modulate bank accounts for mobile money innovations. Third, given the negative marginal relationships associated with the positive net relationships, the following are thresholds for complementary policies in mobile money supply factors that are worthwhile for bank accounts to stimulate mobile money innovations: (i) mobile subscriptions rates of 87.50%, 80.50% and 98.50% of the adult population for respectively, mobile money accounts, the mobile used to send money and the mobile used to receive money and (ii) mobile connectivity coverages of 64.00%, 69.33% and 78.00% for respectively, mobile money accounts, the mobile used to send money and the mobile used to receive money. In other words, Kuznets or inverted U-shaped linkages are apparent between bank accounts and the attendant supply-side mobile money drivers. Hence, at specific critical masses, the supply-side factors become necessary, but not sufficient factors in the complementarity of bank accounts for mobile money innovations. In what follows, some complementary policies are discussed.

The first complementary policy worth taking on board is to improve mobile connectivity performance, as discussed in Section 4.2. Other complementary measures could be oriented towards improving the supply-side mobile money demand factors in at least three main dimensions (Sy, 2019): (i) enhancing the value chain corresponding to financial services because doing so allows for a plethora of relevant innovations such as increased availability of loans, opening of savings accounts, borrowing of energy and investment in government securities; (ii) taking on board more aspects of digital inclusion and innovation because it fosters the transition to the digital economy from fintechs (i.e. financial technologies) services and (iii) acknowledging the need to engage fintechs beyond the scope of financial services because it enables the economy to leverage on untapped economic resources in the light of improving overall productivity.

Both theoretical perspectives from the financial development literature and the socio-technical theory (STT) are relevant in providing the theoretical basis for the established findings, especially in the light of thedocumented stance on the lack of a robust theoretical framework on the nexus between social-oriented technologies and financial services (Durkin, Mulholland & McCartan, 2015). Accordingly, the relevance of the STT for this study buildson the fact that the assessment of linkages between bank accounts and supply-side mobile money drivers for mobile money innovations (as in the current study) involves interactions of social (human) and technical dimensions.

Future research can focus on assessing how other demand factors can be complemented with supply factors to enhance mobile money innovations for financial inclusion. Such a future research direction is worthwhile because synergy effects can be apparent from the underlying interactions, and hence, thresholds for complementary policies would not be required. Moreover, given that only relationships can be established in this study in the light of data availability constraints, as more data become available, it would be worthwhile to assess how the established findings can reflect causality when the relevant panel data econometrics techniques are employed on the corresponding panel data. Accordingly, the study is an extension of Lashitew et al. (2019) with the same dataset. Hence, there is a need to consider more recent data when new studies are considered in alternative frameworks. Given that bank accounts cannot be automatically assimilated to financial transactions, it is worthwhile for future research to consider financial transactions in place of bank accounts within the remit of panel data analysis. In engaging the suggested future research directions, contingent on data availability, it would also be worthwhile to consider the effects of banking application usability, the importance of digital literacy and the relevance of 2G, 3G and 4G networks.

Appendices

Appendix 1: Definitions and sources of variables

Variables	Descriptions	Sources
Dependent variables		
Mobile Accounts	Percentage of adults who have personally used mobile phone to pay bills, send or receive money in the past 12 months using a GSMA recognized mobile money service	Financial Inclusion Indices (Findex) database
Sending Money	Percentage of adults who used a mobile phone to send money in the past 12 months	
Receiving Money	Percentage of adults who used a mobile phone to receive money in the past 12 months	
Demand factors		
Account at formal financial institution	Percentage of adults who have an account at a formal financial institution	Global Financial Structure Database (GFSD)
ATM access	Number of ATMs per 100,000 people	
Banking sector concentration	The percentage share of the three largest commercial banks in total banking assets	
Supply factors		
Mobile phone penetration - Gross & unique subscription rates	Gross mobile subscription rates refer to the percentage of adults in a country with subscriptions to mobile phones based on data from WDI. We used additional data from GSMA (2014) to calculate unique mobile subscription rates by correcting for double SIM-card ownership, which differs between rural and urban areas. This correction is based on survey evidence that urban and rural users own 2.03 & 1.18 active SIM-cards respectively.	World Development Indicators (WDI), GSMA
Mobile connectivity quality	Measures the average speed of uploading and downloading data through mobile network in 2014 &2015.	GSMA
Mobile connectivity coverage	Measures the weighted average of share of populations covered by 2 G, 3 G and 4 G mobile data networks (normalized to range between 0 and 100).	GSMA
Telecom regulation	Measures the regulatory quality of the telecom sector in terms of four major criteria: transparency, independence, resource availability, and enforcement capability of the regulator. The index is based on dozens of indicators taken from the International Telecommunication Union's regulatory database.	Waverman and Koutroumpis (2011)
Macro-level factors		
Rule of Law	A measure of the extent to which agents have confidence in and abide by the rules of society	WDI
GDP per capita	GDP per capita in purchasing power parity	WDI
GDP growth	The rate of total GDP growth	WDI
Urbanization rate	Percentage of population living in urban areas	WDI

Notes: Mobile Accounts is based on the second wave of the survey (2014) and Sending Money and Receiving Money are based on the first wave (2011). The variablestelecom regulation is based on data for 2011. The two variables measuring mobile connectivity are based on average values for the years 2014 & 2015. For the remainingvariables, averages are taken over the years 2010–2014 to smooth out potential year-to-year variations.

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