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Demand-side mobile money drivers of financial inclusion: minimum economic growth thresholds for mobile money innovations

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Demand-side mobile money drivers of financial inclusion: minimum economic growth thresholds for mobile money innovations**Simplice A. Asongu & Raufhon Salahodjaev**

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Abstract

This study provides minimum economic growth (or GDP growth) critical masses or thresholds that should be exceeded in order for demand-side mobile money factors to favorably drive mobile money innovations for financial inclusion in developing countries. The considered mobile money innovations are: mobile money accounts, the mobile phone used to send money and the mobile phone used to receive money. The empirical evidence is based on Tobit regressions. For positive net relationships that are established, an extended analysis is engaged to provide minimum GDP growth levels required to sustain the positive net nexuses. From this extended analysis, in order for economic growth to modulate demand-side mobile money drivers to favorably influence mobile money innovations, minimum GDP growth rates are: (i) 3.875% for the nexus between bank accounts and the mobile phone used to send money; (ii) 3.769 % for the relationship between automated teller machine (ATM) penetration and the mobile used to send money and (iii) 3.666% for the nexus between ATM penetration and the mobile phone used to receive money.

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

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

1. Introduction

The focus of this study on the importance of economic growth in stimulating the effect of mobile money demand factors (i.e. bank accounts, automated teller machines or ATMs penetration and bank concentration) on mobile money innovations (i.e. mobile money accounts, the mobile phone used to send money and the mobile phone used to receive money) for financial inclusion is motivated by two main factors in the scholarly and policy literature, notably: (i) the relevance of mobile banking in promoting inclusive and sustainable development in developing countries, especially in the light of the global policy agenda pertaining to sustainable development goals (SDGs) and (ii) identified gaps in the relevant inclusive development literature¹. These critical elements are expanded in the following passages.

First, there is a growing body of literature on the importance of mobile phones and corresponding externalities such as mobile banking and financial access in driving financial inclusion, inclusive development and by extension, sustainable development in the post-2015 era of SDGs (Gosavi, 2018; Tchamyou, Asongu, Odhiambo, 2019; Anarfo, Abor & Osei, 2020; Morsy, 2020; Asongu, Nnanna & Acha-Anyi, 2020a, 2020b). There are growing concerns as to whether more bank accounts and associated favourable externalities are leading to sustained financial inclusion in developing countries (Klapper, El-Zoghbi & Hess, 2016). This implies, *inter alia*, that the connections between inclusive development (i.e. facilitated by mobile phones and mobile banking), sustained development (i.e. given the concerns of Klapper et al., 2016 in the policy literature) and sustainable development (in the light of SDGs) merit critical attention. *“It is important to note that the concepts of inclusive development and sustainability are linked in the view that for sustained development to be sustainable it must be inclusive, and in order for inclusive development to be sustainable, it should be sustained (Amavilah, Asongu, & Andrés, 2017)”* (Asongu & Odhiambo, 2019, p. 26). The present study takes the underlying concerns on board by assessing how economic growth can sustain the importance of mobile money demand factors in driving mobile money innovations for financial inclusion. It is important to note that the concern of financial inclusion which is the targeted outcome is tailored to be sustained by economic growth. Moreover, when the concept of inclusive development is sustained in the light of the conceptual clarifications provided above, there is evidence of sustainable development which is consistent with the SDG agenda. In order to achieve the stated objective, this study provides

¹ Throughout the study, “mobile phones” and “the mobile” are used interchangeably. Mobile money innovations represent mobile money accounts, mobile used to send money and mobile used to receive money.

economic growth critical masses or thresholds that should be exceeded in order for demand-side mobile money factors to favorably drive mobile money innovations for financial inclusion. The findings are particularly relevant to policy makers because they provide actionable thresholds that policy makers can use in order to influence the role of economic growth in financial inclusion by means of innovations in the use of mobile money. The relevance of the findings is also based on the fact that the positioning of the study departs from the extant literature.

Second, in spite of the substantially documented literature on the importance of mobile phones and mobile banking innovations in driving inclusive development (Asongu, 2013; Ondiege, 2010; Uduji & Okolo-Obasi, 2018a, 2018b; Tchamyu, Erregers & Cassimon, 2019; Lashitew, van Tulder & Liasse, 2019; Asongu, Biekpe & Cassimon, 2020, 2021), most of the literature has focused on the role of innovation in driving economic growth (as discussed below), instead of the role of economic growth in modulating demand-side mobile money factors for mobile money innovations as in the present study. The contemporary strand of the studies that has focused on the incidence of innovation on economic growth has been articulated along the lines of, *inter alia*: knowledge-driven innovation for economic growth in Sub-Saharan Africa (SSA) (Oluwatobi, Olurinola, Alege & Ogundipe, 2020; Asongu & Kuada, 2020); country-specific innovation in environmental policy for economic growth (Azimi, Feng & Zhou, 2020); innovation in small and medium sized enterprises as a source of economic growth (Gherghina, Botezatu, Hosszu & Simionescu, 2020); innovation in scientific research for economic performance (HamidiMotlagh, Babae, Maleki & Isaai, 2020) and the relevance of innovation in driving the economic performance of family firms (Teixeira & Correia, 2020).

The study in the literature that is closest to the present inquiry is Lashitew et al. (2019) which has examined correlates of mobile money innovations in developing countries by leveraging on mobile money supply features, demand factors and macro-level aggregates. Instead of simply providing correlates of mobile money innovations, this study assesses how economic growth can complement mobile money demand factors to promote mobile money innovations by assessing thresholds of economic growth that are necessary for the mobile money demand factors to be favorably or positively associated with mobile money innovations. In essence, the present study argues that correlates of mobile money innovations are not enough to tailor policy implications towards mobile money innovations unless interactions of variables are taken on board and specific policy thresholds underlying the interactions are provided to policy makers.

In the light of the above, the study assesses how economic growth modulates the demand side factors used by Lashitew et al. (2019) to influence mobile money innovations in developing countries. For the purpose, Tobit regressions are employed as in Lashitew et al. (2019) to establish that in order for economic growth to modulate demand-side mobile money drivers to favorably influence mobile money innovations, required minimum GDP growth rates are: (i) 3.875% for the nexus between bank accounts and the mobile phone used to send money; (ii) 3.769 % for the relationship between automated teller machine (ATM) penetration and the mobile used to send money and (iii) 3.666% for the nexus between ATM and the mobile phone used to receive money.

While most of the highlighted studies have focused on innovation as a driver of economic growth, this study is focused on the opposite direction in the light of the intuition discussed in the preceding paragraph. Hence, this study is framed within the context of a theory-building empirical exercise. Accordingly, there is a growing strand of economic development literature supporting the view that applied economics that is founded on sound intuition is a relevant scientific activity because it can be leveraged for theory-building (Narayan, Mishra, Narayan, 2011; Costantini & Lupi, 2005; Asongu, le Roux, Nwachukwu & Pyke, 2019). This is essentially because, according to the narrative, the purpose of applied economics is not exclusively to accept or reject existing models (and theoretical underpinnings) and hence, it could be used for building theory especially in the light of a context on issues pertaining to relevant global policy concerns such as SDGs.

The positioning of this study departs from the extant knowledge economy literature that has largely focused on, *inter alia*: the role of knowledge economy in business (Tchamyou, 2017), economic resilience (Ngouhouo & Nchofoung, 2021), the role of information technology in knowledge management (Agrawal, Kumar & Mukti, 2021) and health (Kouton, Bétila & Lawin, 2021) outcomes, the nexus between information technology and scientific productivity (Sephehdoust, Tartar & Davarikish, 2021), as well as linkages between knowledge creation, information technology, productivity, innovation, and economic development (Asongu, 2021; El Ghak, Gdaira & Abassi, 2021; Klevenhusen et al., 2021).

The remainder of the study is organised in the following way. The data and methodology are covered in Section 2 while the empirical findings are disclosed and discussed in Section 3. Section 4 which is the last section concludes with implications and future research directions.

2. Data and methodology

2.1 Data

In the light of the problem statement in the introduction and the extant literature closest to the present inquiry, this study employs the same dataset as in Lashitew et al. (2019). This dataset entails averages of 2010 to 2014 from developing countries for which data were apparent at the time of the study by Lashitew et al. (2019). Many sources are used to obtain the relevant data. These include: (i) World Development Indicators (WDI) and World Governance Indicators (WGI) of the World Bank; (ii) the Findex database on Financial Inclusion Indices; (iii) Waverman and Koutroumpis (2011); (iv) the Global Financial Structure Database (GFSD) and (v) the Global System for Mobile Communications Association (GSMA).

In the light of the motivation in the introduction, three outcome variables are used to proxy for mobile money innovations, namely: mobile money accounts, the mobile used to send money and the mobile used to receive money. It is worthwhile to note that these same outcome variables have been used by Lashitew et al. (2019) and Asongu, Agyemang-Mintah and Nting (2021). How the present study departs from Lashitew et al. (2019) has already been clarified in the introduction. Hence, contrary to the underlying study which has focused on determinants of mobile money innovations by adopting supply-side features, demand-side factors and macro-level features of mobile money innovations as independent variables of interest, the present study: (i) exclusively considers demand factors as independent variables of interest or channels; (ii) engages economic growth (which is a macro-level factor) as the moderating variable; (iii) uses supply and macro-level factors as control variables and (v) aims to establish economic growth thresholds. In what follows the attendant supply factors, demand features and macro level factors used in the study are discussed.

While all the corresponding variables used in Lashitew et al. (2019) are discussed below, this study does not engage all the underlying variables, partly owing to concerns of multicollinearity identified in attendant replication studies (Asongu et al., 2020, 2021) which are discussed in subsequent paragraphs and sections. First, on the front of supply factors, the variables are: (i) mobile connectivity coverage and mobile connectivity performance from the GSMA; (ii) the mobile subscription rate from the WDI and the “gross and unique suscription” rate from the GSMA and (iii) telecommunications sector regulation from Waverman and Koutroumpis (2011).

Second, the corresponding demand-side factors are largely drawn from the GFSD and include: the number of automated teller machines (ATMs), bank concentration and the “percentage of adults with a bank account in a formal banking instituton”. Third, the

engaged macro-level factors are from the WGI (i.e. the rule of law) and the WDI (i.e. urbanization rate, GDP growth and GDP per capita) of the World Bank. The selection of underlying variables discussed in three strands is consistent with the contemporary financial inclusion literature (Muwanguzi & Musambira, 2009; Mas & Morawczynski, 2009; Waverman & Koutroumpis, 2011; Demirguc-Kunt & Klapper, 2012; Demirgüç-Kunt & Klapper, 2013; Gruber & Koutroumpis, 2013; Van der Boor, Oliveira & Veloso, 2014; Demirgüç-Kunt, Klapper & Van Oudheusden, 2015; World Bank, 2016; Asongu & Odhiambo, 2018b; GSMA, 2018; Murendo, Wollni, De Brauw & Mugabi, 2018; Asongu & Asongu, 2018).

The factors adopted in the conditioning information set in this study are expected to positively drive mobile money innovations in the light of the attendant literature. However, should an adopted control variable reflect both positive and negative values, an unanticipated outcome can be apparent. This can be the case of the rule of law from WGI which can be negatively skewed if the country is characterised by bad governance instead of good governance.

The appendices provide complementary information on the discussed variables. Appendix 1 provides the definitions of variables with corresponding sources while Appendix 2 discloses the corresponding summary statistics. The correlation matrix which is provided in Appendix 3 guides the study on concerns of multicollinearity which are highlighted in bold. More insights into the criterion for identifying multicollinearity thresholds are discussed in the next section.

2.2 Methodology

The threshold for identifying the concern of multicollinearity is 0.600. This threshold is consistent with contemporary improvements of Lashitew et al. (2019) to take on board the concern of multicollinearity (Asongu et al., 2020, 2021). According to this literature, a correlation level of 0.600 is the average of thresholds posited by two contending strands in the literature. In essence, Kennedy (2008) has argued for a 0.700 threshold while previously, Wichers (1975) and Obrien (2007) had argued for a 0.500 threshold.

Following the closest research to this paper that has used the same dataset (i.e. Lashitew et al., 2019), Tobit regressions are employed. The choice of the estimation technique is informed by the fact that, it is consistent with data behavior. Accordingly, the Tobit regressions literature is in line with the premise that the technique is robust to outcome variables that are situated within specific bounds (Kumbhakar & Lovell, 2000; Koetter &

Vins, 2008; Coccorese & Pellicchia, 2010; Ariss, 2010; Asongu & Nwachukwu, 2016; Ajide, Raheem & Asongu, 2019). It follows that in the light of the underlying Tobit-centric literature, the outcome variable in this study should have clearly defined minimum and maximum limits. This is the case with the mobile money innovation variables because they are theoretically defined between 0.00% and 100.00%. On a practical front, the attendant variables are defined between 0.00 (i.e. the theoretical minimum value) and a maximum variable that is specific to each of the three outcome variables. Accordingly, as apparent in Appendix 2, “0.00% to 58.39%”, “0.00% to 60.48%” and “0.00% to 66.65%” correspond to the minimum and maximum values for respectively, adoption rates ranges of mobile money accounts, the mobile used to send money and the mobile used to receive money.

In the light of the above, a double censored Tobit model is used because it censors both the minimum and maximum limits of the outcome variables. It is also relevant to note that the Ordinary Least Squares (OLS) is not tailored to take on board broad variations in the conditional probabilities of limited observations; a scenario that is apparent when adoption rates of 0.00% and/or 100% are characteristics of the outcome variables (Amemiya, 1984).

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

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

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. $N(0, \sigma^2)$ and is independent of $X_{i,t}$. As opposed to observing $y_{i,t}^*$, we observe

$y_{i,t}$:

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

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 surrounding the Tobit model are that, the residuals are normally distributed and the latent dependent indicators are connected to an unbounded and linear function of the independent variables of interest (Amemiya, 1984). In addition, there are two fundamental marginal relationships pertaining to the main predictors (i.e. bank accounts, ATM penetration and bank concentration). The first articulates the marginal nexuses of the principal predictors of the unobserved latent adoption rate of mobile money innovation whereas the second relates to the censored, observed rate of mobile money innovation. This

study is in accordance with Lashitew et al. (2019) in reporting only the marginal nexuses connected to the censored and observed rates of adoption of mobile money innovation because according to the corresponding literature, such disclosure is consistent with a more apparent analytical interpretation.

3. Empirical results

3.1 Presentation of results

The empirical findings are disclosed in this section in Table 1 which is comprised of three main categories, each corresponding to a mobile money demand factor taken on board, namely: bank accounts, ATM penetration and bank concentration. Accordingly, each of the attendant categories reflects interactions between economic growth (or GDP growth) and each mobile money demand factor, respectively. Every category is characterised by three main specifications, reflecting respectively, each of the outcome variables: mobile money accounts, the mobile phone used to send money and the mobile phone used to receive money.

In order to assess the incidence of economic growth in modulating the corresponding demand-side mobile money demand factors to influence mobile money innovations, net relationships are computed as apparent in contemporary literature on interactive regressions (Agoba, Abor, Osei & Sa-Aadu, 2019; Asongu & Odhiambo, 2020a, 2020b). In the light of the attendant literature, where at least one of the estimated relationships required for the computation of the underlying net relationships is not significant, net relationships cannot be computed and therefore “na” or “not applicable” is assigned to the corresponding space.

It is relevant to better illustrate the narrative above by clarifying the computations of net relationships apparent in Table 1 with an example. In the first specification (or second column) of Table 1, the net relationship cannot be computed because both the unconditional relation of bank accounts with the mobile money accounts (or -0.032) and the conditional relationship between bank accounts and GDP growth on the mobile money accounts (or 0.009) are insignificant. In the same vein, in the fourth column (or third specification) of Table 1, the net relationship cannot be computed because only one relationship that is relevant for the computation is significant. However in the third column or second specification of the table, the net relationship of GDP growth in bank accounts for mobile phones used to send money is $0.0004([0.016 \times 3.90] + [-0.062])$. In this calculation, the average value of GDP growth is 3.90, the unconditional nexus between bank accounts and the mobile phone used to send money is -0.062 whereas the conditional relationship (i.e. on GDP growth) between bank accounts and the mobile used to send money is -0.002.

Given the above insights the following findings are apparent in Table 1: (i) GDP growth modulates bank accounts to establish a net positive relationship with the mobile used to send money. (ii) GDP growth modulates ATM penetration to induce a net positive relationship with the mobile phone used to send money and the mobile phone used to receive money. (iii) No significant net nexuses are apparent in the role of GDP growth in modulating the incidence of bank concentration on mobile phone innovations.

Table 1: GDP growth, demand-side mobile phone innovations and financial inclusion

	Dependent variables: Mobile money accounts, Mobile used to send money & Mobile used to receive money								
	GDP growth and Bank Accounts			GDP growth and ATM Penetration			GDP growth and Banking Sector Concentration		
	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
GDP growth	0.370 (0.142)	-0.281 (0.421)	-0.314 (0.513)	0.700*** (0.000)	0.007 (0.976)	-0.045 (0.893)	1.310** (0.035)	0.171 (0.794)	0.218 (0.792)
Bank Accounts (BA)	-0.032 (0.280)	-0.062* (0.090)	-0.062 (0.202)	---	---	---	---	---	---
ATM	---	---	---	-0.012 (0.516)	-0.049** (0.034)	-0.055** (0.049)	---	---	---
Bank Concentration (BC)	---	---	---	---	---	---	-0.001 (0.968)	-0.012 (0.710)	-0.011 (0.783)
GDP growth × BA	0.009 (0.116)	0.016** (0.035)	0.016* (0.085)	---	---	---	---	---	---
GDP growth × ATM	---	---	---	0.002 (0.640)	0.013** (0.024)	0.015** (0.031)	---	---	---
GDP growth × BC	---	---	---	---	---	---	-0.007 (0.263)	0.001 (0.833)	-0.0001 (0.985)
Mobile Subscription	0.017 (0.448)	0.050* (0.051)	0.046 (0.121)	0.015 (0.490)	0.032 (0.193)	0.026 (0.389)	0.013 (0.538)	0.041* (0.096)	0.035 (0.228)
Telecom Regulation	5.033* (0.063)	4.274 (0.129)	6.645* (0.051)	7.936*** (0.000)	6.337** (0.045)	9.054** (0.016)	5.913** (0.028)	5.276 (0.120)	7.083* (0.069)
Rule of Law	-1.019 (0.217)	-3.222** (0.010)	-4.591*** (0.003)	-1.204* (0.079)	-3.356*** (0.001)	-4.510*** (0.000)	-1.220** (0.044)	-3.700*** (0.000)	-4.898*** (0.000)
Urbanization	-0.049 (0.123)	-0.001 (0.967)	0.019 (0.715)	-0.034 (0.226)	-0.002 (0.949)	0.009 (0.858)	-0.035 (0.183)	-0.009 (0.809)	0.004 (0.919)
Africa	6.383*** (0.001)	2.715 (0.132)	4.479** (0.041)	6.436*** (0.000)	1.869 (0.253)	3.161 (0.114)	6.805*** (0.000)	2.675* (0.092)	4.210** (0.044)
Asia	2.048 (0.192)	-1.922 (0.257)	-1.517 (0.441)	2.364 (0.147)	-2.143 (0.145)	-2.072 (0.217)	2.719* (0.091)	-0.909 (0.532)	-0.456 (0.797)
Americas	4.374** (0.013)	-1.838 (0.159)	-1.915 (0.206)	3.700** (0.021)	-2.837** (0.029)	-3.086** (0.035)	3.849** (0.014)	-1.846 (0.142)	-1.859 (0.213)
Middle East	4.686** (0.024)	-3.925** (0.041)	-3.188 (0.123)	5.506*** (0.009)	-3.617* (0.056)	-2.493 (0.238)	4.462** (0.035)	-2.885 (0.142)	-1.878 (0.371)
Net Relationships	na	0.0004	na	na	0.0017	0.0035	na	na	na
Thresholds	na	3.875	na	na	3.769	3.666	na	na	na
Observations	112	118	118	119	123	123	117	121	121

GDP: Gross Domestic Product. PPP: Purchasing Power Parity. *, **, ***: significance levels of 10%, 5% and 1% respectively. The mean value of GDP growth is 3.90. na: not applicable because at least one estimated coefficient needed for the estimation of net relationship and threshold is not significant.

The insignificant nexuses in the regressions related to bank concentration may be traceable to the fact that bank concentration is considered as an indicator of market power in the literature (Ryan, O'Toole & McCann, 2014; De Guevara, Maudos & Pérez, 2005).

Moreover, market power has been documented to potentially limit financial access in developing countries (Boateng, Asongu, Akamavi & Tchamyou, 2018) which is the reason information sharing offices are being instituted in developing countries to partly address the concern (Tchamyou & Asongu, 2017; Kusi, Agbloyor, Ansah-Adu & Gyeke-Dako, 2017; Tchamyou, 2019; Asongu & Odhiambo, 2018a; Kusi & Opoku-Mensah, 2018). It is worthwhile to also clarify that bank concentration or market power reflects the ability of financial institutions to set the prices of loans above attendant marginal costs (Asongu & Biekpe, 2018). Moreover, these financial institutions have been established to abuse their market powers by restricting financial access (Asongu, Nwachukwu & Tchamyou, 2016), which by extension, is a restriction of financial inclusion through a plethora of mechanisms which can hypothetically dampen mobile money innovations by means of mobile bank accounts and use of the mobile phone to send/receive money.

While most of the significant control variables have the expected signs, the rule of law reflects an unexpected negative relationship. This is consistent with the narrative in the data section, notably, on the fact that the governance indicators of the World Bank can be construed as bad governance indicators if they are negatively skewed. In this context, it is apparent from the summary statistics that the rule of law is negatively skewed because: (i) its average value is negative and (ii) its maximum positive value is lower in magnitude compared to its corresponding minimum negative value.

3.2 Extended analysis for minimum economic growth thresholds

Consistent with the problem statement, this section is tailored to address the concern of which economic growth thresholds are relevant for the demand-side mobile money drivers to be positively related with the engaged three mobile money innovation outcomes, notably: mobile money accounts, the mobile phone used to send money and the mobile phone used to receive money. In order for the section to be relevant for the research, the stated objective should be consistent with tendencies from conditional and unconditional nexuses in Table 1. Fortunately, it is apparent from the findings that in the combinations for which net relationships have been computed in the previous section, the conditional nexuses are consistently positive while the unconditional relationships are consistently negative. This implies that whereas the unconditional nexuses of relationships between demand-side mobile money factors and the outcomes can be negative, conditional on economic growth, the overall incidence on the outcome variables can become positive. In other words, it implies that at certain thresholds or critical masses of economic growth, the net relationship between the

attendant demand-side mobile money drivers and mobile money innovations become positive. This tendency motivates the computation of minimum economic growth levels that are relevant for the underlying mobile money demand factors to be positively related to mobile money innovations.

To remain consistent in terms of analytical scope, the same example above is used to illustrate the computation of the relevant minimum economic growth thresholds. Still considering the third column or second specification of Table 1, the minimum GDP growth threshold or rate at which bank accounts are positively associated with the mobile phone used to send money is 3.875 % (0.062/0.016). It follows that when GDP growth is below 3.875%, bank accounts are negatively related to the mobile phone used to send money. For instance, if the GDP growth become 3.800%, the corresponding net relationship is negative or $-0.0012([0.016 \times 3.800] + [-0.062])$.

In the light of the above insights, in order for economic growth to modulate demand side mobile money drivers to favorably influence mobile money innovations, minimum GDP growth rates are: (i) 3.875% for the nexus between bank accounts and the mobile phone used to send money; (ii) 3.769 % for the relationship between ATM penetration and the mobile used to send money and (iii) 3.666% for the nexus between ATM and the mobile phone used to receive money. For the computed thresholds to make economic sense and be policy-relevant, they should be within the statistical limits provided in the summary statistics. The computed economic thresholds are policy worthwhile because they are situated between - 4.92% and 11.10% which are respectively, the minimum and maximum rates of economic growth disclosed in the summary statistics.

4. Conclusions and future research directions

This study assesses how economic growth (i.e. GDP growth) modulates the influence of mobile money demand factors in mobile money innovations for financial inclusion in developing countries. The considered mobile money innovations are: mobile money accounts, the mobile phone used to send money and the mobile phone used to receive money. It examines how economic growth can sustain the importance of mobile money demand factors in driving mobile money innovations for financial inclusion. In order to achieve the stated objective, this study provides economic growth critical masses or thresholds that should be exceeded in order for demand-side mobile money factors to favorably drive mobile money innovations for financial inclusion. Moreover, the study argues that contrary to previous

studies (Lashitew et al., 2019; Asongu et al., 2020, 2021), correlates of mobile money innovations are not enough to tailor policy implications towards mobile money innovations unless the interactions of attendant variables are taken on board and specific policy thresholds underlying the interactions are provided to policy makers.

The empirical evidence is based on Tobit regressions. The following net relationships have been established: (i) GDP growth modulates bank accounts to establish a net positive relationship with the mobile phone used to send money. (ii) GDP growth modulates ATM penetration to induce net positive relationships with the mobile phone used to send money and the mobile phone used to receive money. (iii) No significant net nexuses are apparent in the role of GDP growth in modulating the incidence of bank concentration on mobile money innovations.

For positive net relationships that are established, an extended analysis is engaged to provide minimum GDP growth levels required to sustain the positive net nexuses. From this extended analysis, in order for economic growth to modulate demand-side mobile money drivers to favorably influence mobile money innovations, minimum GDP growth rates are: (i) 3.875% for the nexus between bank accounts and the mobile phone used to send money; (ii) 3.769 % for the relationship between ATM penetration and the mobile used to send money and (iii) 3.666% for the nexus between ATM penetration and the mobile phone used to receive money. The computed economic growth thresholds are policy relevant because they are within the range of economic growth disclosed in the summary statistics.

This study has provided economic growth critical masses or thresholds that should be exceeded in order for demand-side mobile money factors to favorably drive mobile money innovations for financial inclusion in developing countries. However, the extant knowledge can be improved if with the passage of time, as the relevant data become abundant for country-specific studies; country-specific thresholds are established for more targeted country-specific policy implications. Moreover, with the availability of the corresponding data as time unfolds, panel studies can be engaged to establish causality and hence, complement the findings in this study which are understood as relationships between economic growth, mobile demand factors and mobile money innovations.

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Appendices

Table 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 variables telecom 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 remaining variables, averages are taken over the years 2010–2014 to smooth out potential year-to-year variations.

Appendix 2: 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 pre capita (log)	9.161	1.226	6.473	11.794	192
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.

Appendix 3: Correlation matrix

	Mobile inclusion variables			Demand Factors			Supply Factors				Macro-level Factors				Region dummies			
	MMA	Send M	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.

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