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The of role economic growth in modulating mobile connectivity dynamics for financial inclusion in developing countries

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The of role economic growth in modulating mobile connectivity dynamics for financial inclusion in developing countries

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Abstract

This study establishes economic growth needed for supply-side mobile money drivers in developing countries to be positively related to mobile money innovations in the perspectives of 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 the negative net relationships that are computed, minimum economic growth thresholds are established above which the net negative relationships become net positive relationships. The following minimum economic growth rates are required for nexuses between supply-side mobile money drivers and mobile money innovations to be positive: (i) 6.109% (6.193%) of GDP growth for mobile connectivity performance to be positively associated with the mobile phone used to send (receive) money and (ii) 4.590 % (4.259%) of GDP growth for mobile connectivity coverage to be positively associated with the mobile phone used to send (receive) money.

Keywords: Mobile money; technology diffusion; financial inclusion; inclusive innovation
JEL Classification: D10; D14; D31; D60; O30

1. Introduction

There are three motivational elements that underpin an inquiry into how economic growth modulates mobile connectivity dynamics for financial inclusion in developing countries, notably: (i) the importance of mobile phones and corresponding connectivity dynamics in sustainable development goals (SDGs); (ii) the relevance of mobile phones in financial inclusion and (iii) an apparent gap in the literature because the extant literature is sparse on how economic growth influences the importance of mobile phones and associated mobile connectivity dynamics in mobile money innovations by means of mobile money accounts, the mobile phone used to send money and the mobile phone used to receive money[1]. The attendant three motivational elements are expanded in the same chronology in the subsequent passages.

First, the importance of the mobile phone in SDGs can be articulated from the fact that the mobile phone is a fundamental enabler of sustainable development growth as well as a key contributor to the achievement of the United Nations (UN) post-2015 sustainable development agenda, which consists of 17 poverty and inequality related goals targeted to be achieved by 2030 (Granryd, 2018). It is also worthwhile to articulate that as early as 2016 in the post-2015 global development agenda, the mobile industry was the first world sector to commit to the underlying SDGs by pledging to considerably leverage on the underlying networks that operators in this mobile industry had already built and which were being used to deliver inclusive services to developing countries. According to the narrative, over the years, there has been ample real-world evidence showing the importance of mobile technologies in the achievement of all 17 SDGs, especially by means of enhanced financial access to the previously unbanked poor fractions of society.

Second, the importance of mobile phones in financial inclusion is apparent from a plethora of ways, with the lives of many in emerging countries changing owing to reducing poverty and inequalities (Jensen 2007; Goyal 2010; Granryd, 2018; Gosavi, 2018; Tchamyou, Asongu & Odhiambo, 2019; Asongu, Nnanna&Acha-Anyi, 2020a, 2020b; Morsy, 2020; Anarfo, Abor & Osei, 2020). A means of such inclusion isthe growing use of mobile money accounts because, as substantiated by Granryd (2018), towards the end of 2017, about 700 million registered mobile accounts were apparent which, was a rise of 62% from the previous

[1]In this study, the terms "mobile" and "mobile phones" are used interchangeably. Moreover, mobile money innovations are used interchanably with three main dynamics, namely: mobile money accounts, the mobile used to send money and the mobile used to receive money. Economic growth and GDP growth are used interchangeably throughout the study.

two years. According to the narrative, mobile money progressed as the principal platform of payment in the digital economy of many developing countries. It follows that mobile money innovations such as mobile money accounts, the mobile phone used to send money, and the mobile phone used to receive money are the main mobile money financial inclusion dynamics that are substantially contributing towards mitigating poverty and inequality in the light of SDGs. The present study aims to contribute to the understanding of this phenomenon by assessing how economic growth modulates supply-side mobile money drivers to affect mobile money innovations, owing to an apparent gap in the extant literature.

Third, despite the growing bulk of literature on the relevance of mobile phones and associated externalities in financial inclusion (Ondiege, 2010; Asongu, 2013; Uduji& Okolo-Obasi, 2018a, 2018b; Lashitew, van Tulder&Liasse, 2019; Tchamyou, Erregers&Cassimon, 2019; Asongu, Biekpe&Cassimon, 2020, 2021), most studies have built on the role of mobile money innovations in promoting economic prosperity. However, this study is concerned with the opposite direction (i.e. how growth affects mobile money innovations through supply-side mobile money drivers). Some of the contemporary studies which have focused on innovation stimulating economic growth include: innovation that is driven by knowledge for the ultimate purpose of promoting economic growth (Asongu & Kuada, 2020; Oluwatobi, Olurinola, Alege & Ogundipe, 2020); country-specific innovations within the framework of environmental policy for economic prosperity (Azimi, Feng & Zhou, 2020); innovations in small and medium sized corporations as a means to economic growth (Gherghina, Botezatu, Hosszu&Simionescu, 2020); the relevance of innovations in promoting the economic prosperity of family corporations (Teixeira & Correia, 2020) and scientific research innovations for economic performance (Hamidi Motlagh, Babaee, Maleki & Isaai, 2020).

A study by Lashitew et al.(2019), which has focused on the correlates of mobile money innovations in developing countries, is closest to the present research in the extant literature. The underlying study has been concerned with how macro-level, demand factors, and supply features affect financial inclusion through mobile money innovations in terms of mobile money accounts, the mobile used to send money and the mobile used to receive money. The present study departs from the underlying literature by arguing that it is not enough to provide linkages between determinants of mobile money innovations and financial inclusion. Accordingly, the present study argues that policy makers are more taken on board when the nexuses are conceived within the framework of interactive regressions such that specific policy thresholds at which a policy variable modulates the mobile money drivers to influence mobile money innovations are established. Hence, the present study is tailored to

provide minimum levels of economic growth that are required in order for supply-side mobile money drivers to positively influence mobile money innovations. Hence, instead of disclosing correlates between the predictors and outcomes as apparent in Lashitew et al. (2019), this study provides minimum economic growth thresholds that are relevant for the investigated nexuses. For this purpose, like in Lashitew et al. (2019), the Tobit regressions approach is employed, and the followingminimum economic growth rates are required for nexuses between supply-side mobile money drivers and mobile money innovations to be positive: (i) 6.109% (6.193%) of GDP growth for mobile connectivity performance to be positively associated with the mobile phone used to send (receive) money and (ii) 4.590 % (4.259%) of GDP growth for mobile connectivity coverage to be positively associated with the mobile phone used to send (receive) money.

The study is also framed as an applied economics research. This is essentially because while theoretical underpinnings of the extant literature from which this study departs have built on innovation as a determinant of economic prosperity, the present study is focusing on the opposite direction. In other words, the present study is assessing how economic growth moderates the incidence of mobile money drivers on mobile money innovations. Hence, the present research is consistent with contemporary applied economics literature in arguing that a study based on sound intuition is also a useful scientific activity. Accordingly, it is logical to expect that the degree by which supply-side mobile money drivers affect mobile money innovations is contingent on economic growth. This intuition essentially builds on the logic that higher economic growth levels offer more opportunities for investment and consumption activities as well as enhanced mobile phone supply-side dynamics (*inter alia*, mobile subscription, mobile connectivity coverage and mobile connectivity performance) that ultimately influence mobile money innovations. In the same vein of intuition, a country experiencing lower economic growth levels or negative economic growth is unlikely to be associated with comparatively higher levels of supply-side mobile money drivers and, by extension, mobile money innovations.

With the above intuition for the investigated nexuses discussed, this study is consistent with the growing strand of literature on the relevance of applied economics for theory-building, especially when such is based on strong intuition (Narayan, Mishra, Narayan, 2011; Costantini & Lupi, 2005; Asongu, le Roux, Nwachukwu & Pyke, 2019). According to the attendant literature, the sole aim of applied economics is not to exclusively accept or reject extant theoretical underpinnings, given that a study based on sound intuition could also

provide the basis for theory-building, especially if it pertains to concerns surrounding a phenomenon such as mobile money innovations that is relevant for the achievement of SDGs.

The rest of the study is structured as follows. Section 2 outlines the data and methodology, while Section 3 discloses the empirical results and engages the corresponding discussion. The last section concludes with future research directions.

2. Data and methodology

2.1 Data

This study uses the same dataset as Lashitew et al. (2019), following the motivation in the previous section. This dataset entails 2010 to 2014 averages from developing countries for which data was available at the time of the underlying study. The multitude of sources from which the data are obtained includes: (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).

In accordance with Lashitew et al. (2019) and Asongu, Agyemang-Mintah & Nting (2021), three main outcome variables are used for the study. These are: mobile money accounts, the mobile used to send money and the mobile used to receive money. These dependent variables are obtained from the Findex database. As opposed to Lashitew et al. (2019), which has focused on assessing correlates of mobile money innovations by leveraging on demand, supply and macro-level factors, the present study: (i) uses supply-level factors as the independent predictors of interest; (ii) employs a macro-level factor (i.e., economic growth) as the moderating variable and (iii) uses both demand and macro-level factors as control variables. The motivation for such a departure in focus relative to Lashitew et al. (2019) has been discussed in the introduction. It is also important to note that because of concerns pertaining to multicollinearity thatare robustly identified in corresponding replication studies (Asongu et al., 2020, 2021), not all variables documented in Lashitew et al. (2019) are taken on board in the empirical exercise. However, the appendices disclose all these variables in order to further clarify the departure of the present study from Lashitew et al. (2019). In what follows, the corresponding macro-level, demand-side and supply-side mobile money drivers are discussed.

First, the attendant supply factors are four in number: (i) regulation of the telecommunications sector from Waverman and Koutroumpis (2011); (ii) “gross and unique

subscription rate" obtained from the GSMA; (iii) mobile subscription rate from WDI and (iv) mobile phone connectivity dynamics of coverage and performance from the GSMA. Second, the corresponding demand factors which are sourced from the GFSD are the number of automated teller machines (ATMs), bank sectorconcentration, and the "percentage of adults with a bank account in a formal banking institution". Third, macro-level features are: (i) the rule of law from WGI of the World Bank and (ii) GDP growth, GDP per capita and urbanization rate from WDI of the World Bank. The selection of these variables is motivated by the attendant literature on financial inclusion (Mas & Morawczynski, 2009; Muwanguzi & Musambira, 2009; Waverman & Koutroumpis, 2011; Demirguc-Kunt & Klapper, 2012; Demirgüç-Kunt & Klapper,2013; Van der Boor, Oliveira & Veloso, 2014; Gruber & Koutroumpis, 2013; Demirgüç-Kunt, Klapper & Van Oudheusden, 2015; World Bank, 2016; Asongu & Odhiambo, 2018b; GSMA, 2018; Murendo, Wollni, De Brauw & Mugabi, 2018; Asongu & Asongu, 2018). With the exceptions of bank concentration and the rule of law, the documented demand, supply and macro-level factors are broadly anticipated to promote mobile money innovations. It is worthwhile to clarify the potential negative signs from bank sector concentration and the rule of law.

First, the incidence of the rule of law on mobile money innovations may either be positive or negative, contingent on the skewness of the variable to reflect either good governance or bad governance. Accordingly, good governance indicators of the World Bank can either take positive or negative values. Hence, they can reflect both positive and negative signals as they can either be positively or negatively skewed. Positive skewness, therefore, translates into good governance, while negative skewness reflects bad governance. A variable is negatively skewed when: (i) it has a negative mean value and (ii) its maximum positive value is lower in terms of magnitude than its corresponding maximum negative value. This is the case with the rule of variable, as apparent in Appendix 2.

Second, bank concentration is a proxy for market power (see De Guevara, Maudos & Pérez, 2005; Ryan, O'Toole & McCann, 2014), which has been established to limit financial access because banks with high market power tend to leverage on the existence of such market power to price loans in excess of associated marginal costs, in order to enjoy a quiet life (Asongu, Nwachukwu & Tchamyou, 2016; Asongu & Biekpe, 2018; Boateng, Asongu, Akamavi & Tchamyou, 2018). This is the reason that, *inter alia*, over the past decades, information sharing offices have been introduced in developing countries to mitigate information asymmetry and increase inter-bank competition that ultimately engenders more

financial access (Tchamyou & Asongu, 2017; Kusi, Agbloyor, Ansah-Adu & Gyeke-Dako, 2017; Asongu & Odhiambo, 2018a; Kusi & Opoku-Mensah, 2018; Tchamyou, 2019).

The summary statistics provide complementary information to the discourses in this section, especially in the light of the definitions and sources of the variables (Appendix 1), the summary statistics (Appendix 2), and the correlation matrix (Appendix 3). The correlation matrix informs the study on how to avoid entering variables with a high degree of substitution into the same specification. The choice of a correlation level of 0.600, which is the threshold criterion for the presence of multicollinearity, is discussed in the next section.

2.2 Methodology

As discussed in the previous section, not all variables are taken on board because theconcerns surrounding multicollinearity,which are not considered by Lashitew et al. (2019) are avoided, in accordance with subsequent replication studies (Asongu et al., 2020, 2021) that are guided by the need to avoid multicollinearity. Along the same analytical lines, a threshold of 0.600 is adopted to acknowledge variables that are highly correlated because it is the average of two values (i.e., 0.700 and 0.500) posited by two conflicting strands in the literature on multicollinearity. Accordingly, while Kennedy (2008) argues for a 0.700 threshold, Wichers (1975) and Obrien (2007) argue for a threshold of 0.500.

The adopted empirical strategy is in line with Lashitew et al. (2019). Moreover, the choice of the empirical strategy (i.e., Tobit regressions) is also consistent with the data behavior of outcome variables. Accordingly, as documented in the attendant Tobit-centric regressions literature (Kumbhakar & Lovell, 2000; Koetter & Vins, 2008; Ariss, 2010; Coccorese & Pellecchia, 2010; Asongu & Nwachukwu, 2016; Ajide, Raheem & Asongu, 2019), the choice of the empirical approach is worthwhile when the outcome variables are defined within specified limits, such that minimum and maximum values are clearly apparent. This is the case of the mobile money innovation adoption rates used as outcome variables in the study because they are theoretically defined between the range of 0.00% and 100.00% adoption rates. On the practical front, as apparent in Appendix 2, the corresponding adoption ranges for mobile money accounts, the mobile phone used to send money and mobile phone used to receive money are respectively, 0.00% to 58.39%, 0.00% to 60.48%, and 0.00% to 66.65%.

In the light of the above, a double censored Tobit regressions model is consistent with the data behavior because the regression approach is censored on both sides of the distribution

of the outcome variables. It is worthwhile to articulate that, when there are broad differences in the conditional probabilities of limited observations, an Ordinary Least Squares (OLS) approach is inappropriate for examining the underlying linkages between the predictors and the outcome variables (Amemiya, 1984).

Building on the mainstream Tobit regression studies (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 $y_{i,t}$:

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

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 following assumptions are considered by the Tobit regressions model: (i) it is acknowledged that residuals are distributed normally, and (ii) the latent dependent variables that are also unbounded represent a linear function of the predictors (Amemiya, 1984). Moreover, two main marginal relationships are apparent that connect the main predictors (supply-side mobile money drivers and economic growth) with the mobile money innovation outcome variables. The first translates marginal nexuses of the principal predictors of the unobserved latent rate of mobile money adoption, whereas the second pertains to the censored, observed rate of mobile money innovation in terms of adoption rate. In line with the corresponding literature employing the same dataset (Lashitew et al., 2019; Asongu et al., 2020, 2021), only marginal nexuses that are connected with the observed and censored rates of adoption of the attendant mobile money innovations are provided in the empirical section because they are consistent with a more obvious analytical interpretation.

3. Empirical results

3.1 Presentation of results

The empirical findings are provided in this section in Tables 1-2. Table 1 shows findings on nexuses between economic growth, the mobile subscription rate, and mobile connectivity performance, while Table 2 discloses results on linkages between economic growth, mobile connectivity coverage, and telecommunications (or telecom) sector regulation. Each table is characterisedby six main specifications with every supply-side mobile money

driver linked to three specifications, corresponding to each of the mobile money innovation drivers, namely: mobile money accounts, the mobile phone used to send money and the mobile phone used to receive money. To put this clarification into more perspective, the left-hand side of Table 1 (consisting of three main specifications), which shows regressions related to interactions between the economic growth rate and the unique mobile subscription rate,entails specifications targeting the following outcomes: (i) mobile money accounts (in the first specification or second column); (ii) the mobile phone used to send money (in the second specification or third column) and (iii) the mobile phone used to receive money (in the third specification or fourth column).

In order to assess the overall incidence of economic growth in modulating the supply-side mobile money drivers on mobile money innovations, net relationships are computed in accordance with contemporary studies on interactive regressions (Agoba, Abor, Osei & Sa-Aadu, 2019; Asongu & Odhiambo, 2020, 2021). Accordingly, for the computation of the net relationships to be worthwhile, both the unconditional and conditional nexuses should be significant. Hence, when at least one of the underlying nexuses is not significant, the net relationships are not computed and "not applicable" (or "na") is assigned to the corresponding spaces.

It is worthwhile to articulate the computation of net relationships with an example from Table 1. In the penultimate column of Table 1, the net relationship from the role of economic growth in modulating mobile connectivity performance to influence the mobile used to send money is -0.121([0.055× 3.90] + [-0.336])[2]. In this computation, the average value of economic growth is 3.90%, the unconditional nexus of mobile connectivity performance on the mobile used to send money is -0.336, while the conditional relationship (from the interaction between economic growth and mobile connectivity performance) is 0.055. In the same vein, in the last column of Table 1, the net relationship from the role of economic growth in modulating mobile connectivity performance to influence the mobile used to send money is -0.142 ([0.062 × 3.90] + [-0.384]). In this computation, the average value of economic growth is 3.90%, the unconditional nexus of mobile connectivity performance on the mobile used to receive money is -0.384, while the conditional relationship (from the interaction between economic growth and mobile connectivity performance) is 0.062.

[2]The computations are based on partial derivations. The computations are based on differentiating the equation of the outcome variable with respect to respective supply-side factors. Equation (1) is simplified to enhance readability and flow and such partial derivations from Equation (1) are straight forward and self-apparent.

In the light of the above clarifications, the following findings are apparent from Tables 1-2. First, net negative relationships are apparent from the role of economic growth in modulating mobile connectivity performance to influence the mobile phone used to send/receive money. Second, net negative nexuses are apparent from the role of economic growth in modulating mobile connectivity coverage to influence the mobile phone used to send/receive money. Third, net significant relationships cannot be established from the relationships between unique mobile subscription rate and economic growth. Fourth, while net relationships are not also apparent from the role of economic growth in moderating telecommunications sector regulation, corresponding positive conditional or interactive nexuses are consistently significant for all three mobile money innovation proxies. Fifth, the significant control variables largely reflect the expected signs.

Table 1: GDP growth, supply-side mobile innovations andfinancial inclusion (1)

	Dependent variables: Mobile money accounts, Mobile used to send money & Mobile used to receive money					
	GDP growth and Unique Mobile Subscription rate			**GDP growth and Mobile Connectivity Performance**		
	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	0.214	-0.167	-0.372	**0.329***	-0.178	-0.286
	(0.589)	(0.676)	(0.478)	**(0.099)**	(0.410)	(0.336)
Unique Mobile Subscription rate (UMS)	-0.001	0.008	-0.003	---	---	---
	(0.962)	(0.804)	(0.927)			
Mobile Connectivity Performance (MCP)	---	---	---	-0.122	**-0.336*** **	**-0.384*** **
				(0.130)	**(0.000)**	**(0.002)**
GDP growth ×UMS	0.002	0.004	0.006	---	---	---
	(0.612)	(0.434)	(0.359)			
GDP growth ×MCP	---	---	---	0.025	**0.055*** **	**0.062*** **
				(0.134)	**(0.004)**	**(0.006)**
Bank Sector Concentration	**-0.049****	-0.017	-0.023	**-0.046****	-0.012	-0.016
	(0.021)	(0.373)	(0.314)	**(0.037)**	(0.562)	(0.516)
Rule of Law	-0.503	**-2.840*** **	**-3.852*** **	-0.218	**-1.403****	**-2.243*** **
	(0.332)	**(0.000)**	**(0.000)**	(0.701)	**(0.036)**	**(0.008)**
Urbanization	-0.038	-0.012	-0.004	-0.025	0.015	0.029
	(0.111)	(0.698)	(0.902)	(0.321)	(0.698)	(0.542)
Region dummies						
Africa	**8.084*** **	**3.001***	**4.311****	**7.504*** **	1.637	2.955
	(0.000)	**(0.052)**	**(0.031)**	**(0.000)**	(0.272)	(0.109)
Asia	**3.189***	-1.339	-1.122	2.691	-1.580	-1.225
	(0.066)	(0.324)	(0.494)	(0.103)	(0.253)	(0.450)
Americas	**5.340*** **	-1.205	-1.185	**4.710*** **	**-2.761****	**-2.901****
	(0.001)	(0.220)	(0.304)	**(0.003)**	**(0.031)**	**(0.040)**
Middle East	**5.184****	-2.312	-2.152	**4.210****	**-4.039****	**-3.870****
	(0.010)	(0.122)	(0.165)	**(0.031)**	**(0.010)**	**(0.021)**
Net Relationships	na	na	na	na	-0.121	-0.142
Thresholds	na	na	na	na	6.109	6.193
Observations	138	140	140	134	136	136

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 relationships and thresholds is not significant.

Table 2: GDP growth, supply-side mobile innovations andfinancial inclusion (2)

	Dependent variables: Mobile money accounts, Mobile used to send money & Mobile used to receive money					
	GDP growth and Mobile Connectivity Coverage			GDP growth and Telecom Sector Regulation		
	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	0.177	**-1.004*** **	**-1.328** **	-0.039	-0.544	**-0.718***
	(0.678)	**(0.009)**	**(0.017)**	(0.864)	(0.092)	**(0.073)**
Mobile Connectivity Performance (MCC)	-0.015	**-0.101** **	**-0.115** **	---	---	---
	(0.743)	**(0.015)**	**(0.025)**			
Telecom Sector Regulation (TSR)	---	---	---	-3.857	-5.189	-4.252
				(0.393)	(0.266)	(0.434)
GDP growth ×MCC	0.006	**0.022*** **	**0.027*** **	---	---	---
	(0.453)	**(0.001)**	**(0.002)**			
GDP growth ×TSR	---	---	---	**2.105** **	**2.320*** **	**2.593*** **
				(0.012)	**(0.007)**	**(0.009)**
Bank Sector Consentration	**-0.043** **	-0.018	-0.022	**-0.034***	-0.0009	-0.005
	(0.040)	(0.362)	(0.351)	**(0.096)**	(0.966)	(0.831)
Rule of Law	-0.547	**-2.287*** **	**-3.339*** **	-0.909	**-3.237*** **	**-4.437*** **
	(0.352)	**(0.001)**	**(0.000)**	(0.123)	**(0.000)**	**(0.000)**
Urbanization	-0.027	0.011	0.022	**-0.042***	0.002	0.013
	(0.306)	(0.794)	(0.680)	**(0.099)**	(0.956)	(0.786)
Region dummies						
Africa	**8.118*** **	2.141	**3.683***	**6.470*** **	1.687	**3.224***
	(0.000)	(0.139)	**(0.052)**	**(0.000)**	(0.234)	**(0.082)**
Asia	**2.987***	**-2.208***	-2.022	2.175	-1.599	-1.210
	(0.056)	**(0.078)**	(0.161)	(0.169)	(0.236)	(0.457)
Americas	**5.030*** **	**-2.751** **	**-2.905** **	**3.722** **	**-2.689** **	**-2.700***
	(0.003)	**(0.028)**	**(0.043)**	**(0.017)**	**(0.039)**	**(0.072)**
Middle East	**4.511** **	**-4.139** **	**-4.086** **	**4.059** **	**-3.754***	**-2.928**
	(0.022)	**(0.016)**	**(0.024)**	**(0.046)**	**(0.053)**	**(0.149)**
Net Relationships	na	-0.015	-0.009	na	na	na
Thresholds	na	4.590	4.259	na	na	na
Observations	134	136	136	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 relationships and thresholds is not significant.

3.2 Extended analysis with minimum thresholds for mobile money innovations

Consistent with the problem statement of this study, this research goes beyond the establishment of net relationships to establishing economic growth thresholds that modulate the corresponding supply-side mobile money drivers to favorably influence mobile money innovations. From the regressions for which net relationships are apparent, three main tendencies are worthwhile to understand the establishment of these anticipated thresholds: (i) the unconditional incidences of supply-side mobile money factors on the attendant mobile money innovations are consistently negative; (ii) the conditional relationships pertaining to the interactions between economic growth and supply-side mobile money factors are consistently positive and (iii) the attendant net relationships or nexuses are consistently

negative. These tendencies imply that at certain levels of economic growth, the computed net negative relationships can become positive. Within this framework, minimum levels of economic growth are required for the attendant supply-side mobile money drivers to positively influence the corresponding mobile money innovations. The narrative is substantiated in what follows with an example earlier used to clarify the computation of net relationships.

In the last column of Table 1, the corresponding economic growth threshold is 6.193 % (0.384/0.062). It implies that an economic growth rate of 6.193% is the minimum growth rate required for mobile connectivity performance to have a positive relationship with the mobile phone used to receive money. To put this articulation into more perspective, when the economic growth rate is 6.193%, net relationship becomes zero or 0=([0.062 × 6.193] + [-0.384]). Hence, when the economic growth rate is above the established threshold, a positive relationship between mobile connectivity performance and the mobile phone used to receive money becomes apparent. For instance, for an economic growth rate of 6.5%, the net relationship becomes 0.019=([0.062 × 6.500] + [-0.384]).

Given the above insights into the computation of thresholds, the following minimum economic growth rates are required for nexuses between supply-side mobile money drivers and mobile money innovations to be positive: (i) 6.109% (6.193%) of GDP growth for mobile connectivity performance to be positively associated with the mobile phone used to send (receive) money and (ii) 4.590 % (4.259%) of GDP growth for mobile connectivity coverage to be positively associated with the mobile phone used to send (receive) money.These computed thresholds are policy worthwhile and make economic sense because they are situated within the established ranges in the summary statistics. In other words, in order for the established thresholds to make economic sense and be policy-relevant, they should be within the minimum and maximum values of respectively -4.92% and 11.10% GDP growth rates as apparent in Appendix 2 or the summary statistics.

4. Concluding implications and future research directions

This study complements the extant literature by establishing minimum levels of economic growth that are essential in order for supply-side mobile money drivers in developing countries to be positively related with mobile money innovations in the perspectives of mobile money accounts, the mobile phone used to send money and the mobile phone used to receive money. The present study departs from the extant literature by arguing that it is not enough to provide linkages between determinants of mobile money innovations and financial inclusion.

Accordingly, the present study argues that policy makers are more taken on board when the nexuses are conceived within the framework of interactive regressions such that specific thresholds at which a policy variable modulates mobile money drivers to influence mobile money innovations are established.

The empirical evidence is based on Tobit regressions. The following net nexuses are established. First, net negative relationships are apparent from the role of economic growth in modulating mobile connectivity performance to influence the mobile used to send/receive money. Second, net negative nexuses are apparent from the role of economic growth in modulating mobile connectivity coverage to influence the mobile used to send/receive money. Third, net significant relationships cannot be established from the relationships between unique mobile subscription rate and economic growth. Fourth, while net relationships are not also apparent from the role of economic growth in moderating telecommunications sector regulation, corresponding positive conditional or interactive nexuses are consistently significant for all three mobile money innovation proxies.

For the negative net relationships that are computed, minimum economic growth thresholds are established above which the net negative relationships become net positive relationships. The following minimum economic growth rates are required for nexuses between supply-side mobile money drivers and mobile money innovations to be positive: (i) 6.109% (6.193%) of GDP growth for mobile connectivity performance to be positively associated with the mobile phone used to send (receive) money and (ii) 4.590 % (4.259%) of GDP growth for mobile connectivity coverage to be positively associated with the mobile phone used to send (receive) money. The computed thresholds make economic sense and are policy relevant because they are situated within the statistical range disclosed in the summary statistics.

The findings above obviously leave avenues for further research, especially as it pertains to leveraging on panel data to assess if the established nexuses in the perspective of relationships can withstand empirical scrutiny within the view of causality. Moreover, with the passage of time, as the apparently sparse mobile banking data become available, it would also be worthwhile to engage country-specific studies in order to establish findings that reflect more targeted country-specific implications. Moreover, while this study inherits and follows the model adopted by Lashitev et al. (2019), alternative models such as the fractional response technique and two-stage procedures) as employed by Simar and Wilson (2007) should be considered in future studies. This suggestion is motivation by the fact thatsuch Beta regression techniques are also appropriate when the outcome variable is bounded between 0

and 1.In the same vein, while we build on the data provided by Lashitev et al. (2019) and such data do not have alternative measurements of the outcome variables based on the volume of transactions, future studies should put emphasis on the volume of transactions as opposed to the number of transactions.

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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 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.

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 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.

Appendix 3: 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.

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