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On the diffusion of mobile phone innovations for financial inclusion

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Abstract

"*Replications are an important part of the research process because they allow for greater confidence in the findings*" (McEwan, Carpenter & Westerman, 2018, p. 235). This study extends Lashitew, van Tulder and Liasse (2019, RP) by addressing the concern of multicollinearity that affects the signs and significance of estimated coefficients. This article investigates nexuses between innovations in mobile money and financial inclusion in developing countries. Demand and supply factors that affect the diffusion of mobile services as well as macro-level institutional and economic factors are taken on board. The empirical evidence is based on Tobit regressions. The study finds that when the empirical analysis is robust to multicollinearity, two main tendencies are apparent: the significant findings of Lashitew et al. (2019) are confirmed and many new significant estimated coefficients emerge. While this study confirms the findings of the underlying research, it also goes further to improve the harmony in narratives between the predictors and the outcome variables. Accordingly, by accounting for multicollinearity, the earlier findings are now more consistent across the set of predictors (i.e. demand and supply factors) and the attendant financial inclusion outcomes (i.e. mobile money accounts, mobile used to send money and mobile used to receive money).

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

1 .Introduction

This study is motivated by two main factors: the relevance of mobile money innovations in achieving sustainable development in the post-2015 development era and the importance of improving existing scholarship that is relevant to the underlying sustainable development in order to better inform policy makers. These factors are put in more perspective in the following passages.

First, the importance of mobile money innovation in promoting economic development outcomes in both developed and developing countries has been substantially documented in the contemporary literature (Afutu-Kotey, Gough & Owusu, 2017; Minkoua Nzie, Bidogeza & Ngum, 2018; Gosavi, 2018; Abor, Amidu & Issahaku, 2018; Uduji & Okolo-Obasi, 2018a, 2018b; Issahaku, Abu & Nkegbe, 2018; Humbani & Wiese, 2018; Tchamyou, Asongu & Odhiambo, 2019a; Tchamyou, Erreygers & Cassimon, 2019b; Lashitew, van Tulder & Liasse, 2019; Asongu & Odhiambo, 2020). The attendant literature is broadly consistent on the position that innovations in mobile phones are enabling a previously unbanked fraction of the population (especially in developing countries) to gain access to more financial services. However, it is important for policy implications from the attendant literature to be informed by robust empirical analysis, which is not always the case owing to the growing importance of replicating studies in social science (Cook, 2014; Pridemore, Makel & Plucker, 2918; McEwan, Carpenter & Westerman, 2018).

Second, in the light of the above, it is relevant to replicate existing studies for a plethora of reasons, *inter alia*: "*Replications are an important part of the research process because they allow for greater confidence in the findings*" (McEwan et al., 2018, p. 235) and "*the replicability of research results is also a central tenet to the scientific research process*" (Cook, 2014, p. 233). This article investigates nexuses between innovations in mobile money and financial inclusion in developing countries by replicating Lashitew et al. (2019)[1] and addressing a concern of multicollinearity that affects the signs and significance of estimated coefficients. Accordingly, multicollinearity represents a tendency in which two or more explanatory variables in a model have a high degree of substitution and/or are highly related. Accordingly, in the presence of multicollinearity, the highly correlated variables enter into conflict and only a few emerge victorious in the estimation output with the expected signs

[1]Lashitew et al. (2019) and "underlying study" are used interchangeably throughout the study.

(Beck, Demirgüç-Kunt & Levine, 2003)[2]. Hence, a simple remedy to the concern consists of dropping one or more of the highly correlated explanatory variables (Beck et al., 2003)[3].

Given the insights above, the present study is concerned by the high correlation that is exhibited by some explanatory variables in Lashitew et al. (2019). Revisiting Lashitew et al. (2019) therefore, is an attempt to take the concern on board by means of avoiding highly correlated variables in the same specification. Hence, the expectation is that when the concern is addressed, the estimated explanatory variables would be potentially affected both in terms of signs (i.e. positive to negative or negative to positive) and level significance. Hence, the main research question this study aims to answer is the following: does the significance of estimated coefficients of the findings of Lashitew et al. (2019) change when the concern of multicollinearity is addressed in the estimation exercise? The corresponding testable hypothesis is:the significances of estimated coefficients of the findings of Lashitew et al. (2019) change when the concern of multicollinearity is addressed.

If the tested hypothesis withstands empirical scrutiny, there are obvious scholarly and policy implications. First, on the scholarly front, this study will contribute to the body of literature on the rigour of research in scientific scholarly communication in order to provide findings that are associated with robust confidence (Cook, 2014; McEwan et al., 2018; Pridemore et al., 2018). Second, because financial inclusion is very relevant in the achievement of most sustainable development goals (SDGs) (Tchamyou et al., 2019b), policy makers should be informed on whether: (i) the significance of the main findings in the underlying study change and (ii) the narratives pertaining to significant nexuses between the predictors and the outcome variables can be extended to other predicators and financial inclusion outcomes. Accordingly, a policy variable with an inaccurate sign (owing to multicollinearity) can lead to misplaced policy implications and misallocation of public resources. This concern extends to an issue of insignificant predictors which become significant when the empirical analysis is robust to the control of multicollinearity. These underlying concerns have motivated the replication of studies in the literature, *inter alia*: the

[2] "*The political indicators sometimes enter negatively and significantly, perhaps because the predicted components of the political and adaptability channels are highly correlated. Although we did obtain the same results when we added many additional instrumental variables, we interpret these results cautiously and note that they do not imply that the political channel is unimportant in general*" (Beck et al., 2003, p. 671).

[3]"*Our sample comprises 43 countries with British common law, 61 countries with French civil law, six countries with German civil law and five Scandinavian civil law countries. We omit the Scandinavian legal origin from the regressions to avoid multicollinearity*" (Beck et al., 2003, p. 663).

debate between Kaufmann, Kraay and Mastruzzi (2007a, 2007b) versus Kurtz and Schrank (2007a, 2007b) on the quality and consistency of governance indicators from the World Bank.

Beyond the above scholarly considerations, multicollinearity is apparent in Lashitew et al. (2019) for at least two main reasons: (i) as discussed in the empirical section, a correlation matrix is used in this study to show that some independent variables of interest are characterized by a high degree of substitution and (ii) the underlying study did not account for multicollinearity. The second point is put into more perspective. In order to ascertain that Lashitew et al. (2019) did not employ a user built Stata module that automatically takes on board the concern of multicollinearity, we requested their replication commands to ascertain this is not the case. Hence, authors of the underlying study did not use available Stata modules that address the concern of multicollinearity by employing ridge regressions that do not require the purging of independent variables of interest with a high degree of substitution. This is essentially because, to the best of our knowledge, Tobit regressions have not yet been taken on board available "user-written Stata modules"[4].

In the light of the above, the approach of addressing multicollinearity in this study is not to eliminate variables that are less meaningful from a theoretical perspective or specificities of a problem statement. The purpose is to demonstrate that when the concern of multicollinearity is taken board, more reliable estimates can be derived because in a Tobit model, high correlations among independent variables of interest lead to unstable and unreliable regression coefficients. The rest of the study is structured as follows. The data and methodology are covered in Section 2 while the empirical results are provided in Section 3. Section 4 concludes.

2. Data and methodology

2.1 Data

The variables from Lashitew et al. (2019) consist of averages from the years 2010-2014 that are obtained from various sources, namely: (i) World Development Indicators (WDI) of the World Bank; (ii) World Governance Indicators (WGI) of the World Bank; (iii) the Global System for Mobile Communications Association (GSMA); (iv) Waverman and Koutroumpis (2011); (v) Financial Inclusion Indices (Findex) database and (vi) Global Financial Structure Database (GFSD). It is also important to clarify that the sample is for all

[4] The interested reader can find more information on the attendant user-written Stata modules at: https://www.statalist.org/forums/forum/general-stata-discussion/general/1338475-check-multicollinearity-panel-data

developing countries (in Asia, Africa, Middle East and the Americas) for which the relevant data is available.

Three main outcome variables from the Findex database are used, namely: mobile money accounts, mobile used to send money and mobile used to receive money. The independent variables of interest considered in the study are associated with three principal features, namely: demand, supply and macro-levels factors. First, the demand factors from the GFSD are: (i) the percentage of adults who have an account at a formal financial institution; (ii) the number of automated teller machines (ATMs) and (iii) banking sector concentration. Second, the supply factors include: (i) mobile phone penetration and "gross and unique subscription" rates which are from WDI and GSMA; (ii) mobile connectivity performance and mobile connectivity coverage from the GSMA and (iii) telecommunications (hence, telecom) sector regulation from Waverman and Koutroumpis (2011). Third, the macro-level factors which are sourced from WGI are: (i) the rule of law from WGI and (ii) Gross domestic product (GDP) per capita, GDP growth and the urbanization rate from WDI.

It is important to clarify that the choice of the underlying indicators is also informed by the attendant literature on financial inclusion (Demirguc-Kunt & Klapper, 2012; Demirgüç-Kunt, Klapper & Van Oudheusden, 2015; Asongu & Asongu, 2018; Asongu & Odhiambo, 2018) as well as on demand (Muwanguzi & Musambira, 2009; Van der Boor, Oliveira & Veloso, 2014; Demirguc-Kunt et al., 2015), supply (Van der Boor et al., 2014; Demirgüç-Kunt & Klapper,2013; Mas & Morawczynski, 2009; Gruber & Koutroumpis, 2013; GSMA, 2018; Waverman & Koutroumpis, 2011) and macro-level (Murendo, Wollni, De Brauw & Mugabi, 2018; World Bank, 2016) factors of financial inclusion. The definitions and sources of variables are disclosed in Appendix 1. The summary statistics are provided in Appendix 2 while the correlation matrix is presented in Appendix 3.

2.2 Methodology

2.2.1 Estimation technique

Consistent with the motivation of the study, the adopted estimation technique is a Tobit regression empirical strategy as in Lashitew et al. (2019). Moreover, the chosen method for the empirical analysis is also consistent with the attendant Tobit-centric literature because the dependent variable is situated within a specified range (Asongu & Nwachukwu, 2016; Ajide, Raheem & Asongu, 2019). Hence, the adoption of a Tobit approach is in accordance with a strand of more authoritative studies on the subject which has argued that the attendant empirical approach is convenient when outcome variables are within specified minimum and

maximum intervals (Kumbhakar & Lovell, 2000; Koetter & Vins, 2008; Ariss, 2010; Coccorese & Pellecchia, 2010).

In the light of the above, the three outcome variables (i.e. financial inclusion proxies) in this study are situated within specific intervals as apparent in Appendix 2. Accordingly, the underlying adoption measures are expressed in terms of adoption rates in percentages and hence, by construction, the attendant variables are censored from 0 to 100. It follows that estimation by the standard Ordinary Least Squares (OLS) approach would result in estimates that are inconsistent because the OLS approach is not tailored to take on board variations in the conditional probability of adoption for limit observations such as countries with 100% adoption rate and/or countries with 0% adoption rate (Amemiya, 1984). Consequently, the estimation procedure in the light of the specificities in the dependent variables builds on a nonlinear two-limit or double censored Tobit estimation strategy that controls for the censoring of mobile money adoption on both sides of the corresponding distribution.

Equations (1) and (2) below, in the light of seminal research on Tobit regressions (Tobin, 1958; Carson& Sun, 2007), represent the standard Tobit estimation procedure.

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

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.

In the underlying Tobit model, there are assumptions of: (i) residuals being normally distributed and (ii) the presence of latent outcome adoption variables that are unbounded and a linear function of the independent variables (Amemiya, 1984). Two marginal effects are apparent for the independent variables of interest: (i) one being appreciating marginal impacts of the explanatory variables on the latent, unobserved rate of adoption and (ii) the other depicting the observed, censored rate of adoption. In line with Lashitew et al. (2019), in the next section on empirical results, only the marginal impacts on the censored, observed rates of adoption are reported because they are characterized by a more apparent economic interpretation. However, in order to ensure that the replication procedure is robust when

accounting for multicollinearity, this study departs from Lashitew et al. (2019) by: (i) reporting estimates with three decimal places instead of two decimal places and (ii) disclosing p-values instead of standards errors. Hence, the study first confirms the findings of the underlying study before articulating how accounting for multicollinearity produces estimates of independent variables of interest with different significance levels.

2.2.2 Addressing the concern of multicollinearity

The approach of identifying multicollinearity in this study is a correlation matrix because to the best of our knowledge, the variance inflation factor (VIF) used to assess evidence of multicollinearity is not applicable for all regression models. More particularly, as concerns the Tobit regression model used in this study, the VIF test cannot be feasibly implemented, to the best of our knowledge because, with the Stata software used for the empirical exercise, an uncensored command is required to the get the corresponding VIFs. Unfortunately, the specifications underlying this study are left censored to 0 (ie. ll(0)) and right censored to 100 (i.e. ul(100)). It follows that a heuristic approach such as the correlation matrix is used instead. Moreover, such correlation tables are increasingly used to address the concern of multicollinearity in contemporary economic development literature (Asongu, Nwachukwu & Aziz, 2018; Tchamyou et al., 2019a, 2019b).

The concerns of multicollinearity which are identified in bold in Appendix 3 are premised on a threshold of 0.600. Hence, above this threshold, the independent variables of interest are identified as highly collinear. The choice of 0.600 as the threshold is based on a reconciliation of arguments in the literature, given that there is as yet, no consensus in the literature on an appropriate threshold for identifying highly collinear variables. Accordingly, while Kennedy (2008) has argued that independent variables are considered as multicollinear when their correlation values exceed 0.700, Wichers (1975) and Obrien (2007) instead posit that the threshold for identifying collinear variables is 0.500. This study takes both positions on board by considering the average of the two (i.e. 0.500 and 0.700) which is 0.600.

In the light of the above threshold of 0.600, the highlighted concerns of multicollinearity in Appendix 3 vary from a minimum of 0.605 (correlation between the rule of law and telecom sector regulation) to a maximum of 0.850 (correlation between the rule of law and holders of bank accounts).Given the identified multicollinearity issues, instead of entering all the independent variables of interest in one specification as done by Lashitew et al. (2019), the specifications in the following section are tailored to avoid:

(i) ‘Bank accounts’ appearing in the same specifications with ‘ATM penetration’, ‘mobile connectivity performance’, ‘mobile connectivity coverage’, ‘GDP per capita’ and ‘rule of law’;
(ii) ‘ATM penetration’ in the same specifications with ‘mobile connectivity performance’, ‘mobile connectivity coverage’, ‘GDP per capita’, ‘rule of law’ and ‘bank accounts’;
(iii) ‘Bank sector concentration’ in the same specification with no covariate;
(iv)‘Unique mobile subscription rate’ in the same specification with ‘GDP per capita’;
(v) ‘Mobile connectivity performance’ in the same specifications with ‘mobile connectivity coverage’, ‘GDP per capita’, ‘rule of law’, ‘bank accounts’ and ‘ATM penetration’;
(vi) ‘Mobile connectivity coverage’ in the same specifications with ‘GDP per capita’, ‘rule of law’, ‘African dummy’, ‘bank accounts’, ‘’ATM penetration and ‘mobile connectivity performance’;
(vii) ‘Telecom sector regulation’ in the same specifications with ‘rule of law’;
(viii) ‘GDP per capita’ in the same specification with the ‘rule of law’, ‘urbanization’, ‘African dummy’, ‘bank accounts’, ‘ATM penetration’, ‘unique mobile subscription rate’, ‘mobile connectivity performance’ and ‘mobile connectivity coverage’;
(ix) ‘The rule of law’ in the same specification with ‘bank accounts’, ‘ATM penetration’, ‘’mobile connectivity performance, ‘mobile connectivity coverage’, ‘telecom sector regulation’ and ‘GDP per capita’;
(x) ‘GDP growth’ in the same specification with no covariate;
(xi) Urbanization in the same specification with GDP per capita.

The above concerns are disclosed to elaborate detail and not summarized, in order to articulate the issues of multicollinearity when each predictor is considered individually as the starting independent variable of interest in a specification.

3. Empirical results

The empirical results are presented in this section in Tables 1-3. Table 1, Table 2 and Table 3 respectively, present findings pertaining to mobile money accounts, mobile used to send money and mobile used to receive money. The last columns of all the tables are a replication of the findings in Lashitew et al. (2019). Moreover, to ensure that the replications are robust, this study discloses three decimal places instead of two and uses p-values instead of standard errors. Accordingly, while both p-values and standard errors are reported in the estimation output, the assignment of corresponding asterisks (*,** & ***) is more practical with p-values.

Two main steps are followed in the replication exercise. First, as discussed in the previous section, all possible combinations of multicollinearity (based on a threshold of 0.600) are identified. Second, for each of the dependent variables, the specifications are tailored to avoid the concerns of multicollinearity identified in the first stage. Third, the first-four specifications are compared with the last specification which is a replication of Lashitew et al. (2019) that ignores the concern of multicollinearity.

In the light of the above steps, when the concern of multicollinearity is taken on board, the following comparative findings are apparent in Table 1. First, all significant estimates from Lashitew et al. (2019) are confirmed with the expected signs. Second, two more significant estimated coefficients emerge, notably, mobile connectivity coverage and urbanization are negatively associated with mobile money accounts.

Table 1: Mobile money accounts and mobile money innovations

	Dependent variable: Mobile money accounts				
	Replications while controlling for multicollinearity				Lashitew et al. (2019)
Demand Factors					
Bank Accounts	-0.013	---	---	---	0.023
	(0.532)				(0.524)
ATM penetration	---	**-0.017***	---	---	**-0.024***
		(0.091)			**(0.078)**
Bank sector concentration	-0.036	**-0.053****	**-0.041***	-0.025	**-0.050***
	(0.153)	**(0.030)**	**(0.078)**	(0.273)	**(0.064)**
Supply Factors					
Unique Mobile Subscription. rate	0.013	0.014	0.006	-0.001	0.046
	(0.537)	(0.496)	(0.757)	(0.934)	(0.121)
Mobile Connectivity Performance	---	---	-0.027	---	0.047
			(0.499)		(0.379)
Mobile Connectivity Coverage	---	---	---	**-0.080*****	0.046
				(0.000)	(0.116)
Telecom Sector Regulation	3.524	**5.521****	3.805	2.965	**6.963*****
	(0.183)	**(0.033)**	(0.128)	(0.290)	**(0.009)**
Macro-level factors					
GDP per capita PPP (log)	---	---	---	---	-1.367
					(0.189)
GDP growth	**0.652*****	**0.663*****	**0.688*****	**1.047*****	**0.597*****
	(0.001)	**(0.000)**	**(0.001)**	**(0.000)**	**(0.001)**
Rule of Law	---	---	---	---	-1.509
					(0.150)
Urbanization	**-0.052***	-0.040	-0.046	---	-0.028
	(0.097)	(0.133)	(0.111)		(0.442)
Region dummies					
Africa	**7.589*****	**7.899*****	**7.640*****	---	**8.871*****
	(0.002)	**(0.000)**	**(0.000)**		**(0.000)**
Asia	**3.591****	**3.633****	**3.519****	**-2.007***	**4.147****
	(0.035)	**(0.038)**	**(0.038)**	**(0.066)**	**(0.013)**
Americas	**5.407****	**5.206*****	**5.083*****	-0.038	**5.833*****
	(0.010)	**(0.003)**	**(0.005)**	(0.961)	**(0.004)**
Middle East	**5.305****	**6.306*****	**5.189****	0.617	**7.069*****
	(0.026)	**(0.006)**	**(0.020)**	(0.694)	**(0.006)**
Observations	108	112	116	116	102

GDP: Gross Domestic Product. PPP: Purchasing Power Parity. *,**,***: significance levels of 10%, 5% and 1% respectively.

Table 2: Mobile used to send money and mobile money innovations

	Dependent variable: Mobile used to send money				
	Replications while controlling for multicollinearity				Lashitew et al. (2019)
Demand Factors					
Bank Accounts	**-0.065****	---	---	---	-0.003
	(0.024)				(0.939)
ATM penetration	---	**-0.052****	---	---	-0.031
		(0.027)			(0.195)
Bank sector concentration	-0.006	-0.038	-0.010	-0.017	0.000
	(0.815)	(0.125)	(0.670)	(0.416)	(1.000)
Supply Factors					
Unique Mobile Subscription. rate	0.037	0.036	0.017	0.036	0.004
	(0.121)	(0.154)	(0.430)	(0.191)	(0.883)
Mobile Connectivity Performance	---	---	**-0.272*****	---	-0.139
			(0.001)		(0.120)
Mobile Connectivity Coverage	---	---	---	**-0.096*****	0.017
				(0.002)	(0.630)
Telecom Sector Regulation	-0.698	-1.641	0.428	-1.050	2.875
	(0.793)	(0.563)	(0.885)	(0.692)	(0.357)
Macro-level factors					
GDP per capita PPP (log)	---	---	---	---	**3.128****
					(0.016)
GDP growth	0.192	0.209	0.137	**0.468***	0.254
	(0.474)	(0.432)	(0.551)	**(0.063)**	(0.284)
Rule of Law	---	---	---	---	**-4.026*****
					(0.009)
Urbanization	-0.015	-0.013	0.001	---	-0.033
	(0.743)	(0.744)	(0.977)		(0.443)
Region dummies					
Africa	**3.431***	**3.084***	1.770	---	**3.322***
	(0.076)	**(0.097)**	(0.325)		**(0.087)**
Asia	0.234	-0.285	-0.465	**-2.269****	-1.410
	(0.875)	(0.840)	(0.781)	**(0.042)**	(0.417)
Americas	-0.102	-0.173	-2.019	**-1.403***	**-3.592****
	(0.945)	(0.891)	(0.162)	**(0.099)**	**(0.033)**
Middle East	-2.631	-1.442	-2.719	**-3.925****	-4.999
	(0.262)	(0.558)	(0.203)	**(0.019)**	(0.112)
Observations	114	116	120	120	108

GDP: Gross Domestic Product. PPP: Purchasing Power Parity. *,**,***: significance levels of 10%, 5% and 1% respectively.

The following findings are apparent in Table 2. First, the GDP per capita and rule of law estimates that are significant in Lashitew et al. (2019) are not involved in our specifications because of the concerns of multicollinearity discussed previously. It is important to note that the non-involvement of these two variables in the specifications is not arbitrary, but informed by the analytical procedure discussed in the previous section. Second, compared to Lashitew et al. (2019), seven more significant estimates are now apparent, notably: (i) bank accounts, ATM penetration, mobile connectivity performance and mobile

connectivity coverage are negatively associated with the mobile phone used to send money; (ii) GDP growth is positively linked to the outcome variables and (iii) while the positive nexus of the African dummy is confirmed, the Asian and Middle East dummies are now negatively correlated with the outcome variable.

Table 3: Mobile used to received money and mobile money innovations

	Dependent variable: Mobile used to receive money				
	Replications while controlling for multicollinearity				Lashitew et al. (2019)
Demand Factors					
Bank Accounts	**-0.089****	---	---	---	-0.011
	(0.012)				(0.840)
ATM penetration	---	**-0.062****	---	---	-0.030
		(0.024)			(0.253)
Bank sector concentration	-0.011	**-0.053***	-0.020	-0.026	-0.003
	(0.706)	**(0.069)**	(0.496)	(0.314)	(0.919)
Supply Factors					
Unique Mobile Subscription. rate	0.031	0.029	0.004	0.027	-0.013
	(0.272)	(0.318)	(0.879)	(0.398)	(0.707)
Mobile Connectivity Performance	---	---	**-0.345*****	---	**-0.177***
			(0.001)		**(0.095)**
Mobile Connectivity Coverage	---	---	---	**-0.124*****	0.038
				(0.001)	(0.369)
Telecom Sector Regulation	-0.704	-1.857	0.520	-1.603	4.503
	(0.824)	(0.568)	(0.883)	(0.611)	(0.212)
Macro-level factors					
GDP per capita PPP (log)	---	---	---		**3.952****
					(0.013)
GDP growth	0.067	0.120	0.012	0.477	0.160
	(0.839)	(0.716)	(0.966)	(0.106)	(0.850)
Rule of Law	---	---	---	---	**-5.342*****
					(0.004)
Urbanization	-0.004	-0.008	0.015	---	-0.028
	(0.934)	(0.868)	(0.762)		(0.852)
Region dummies					
Africa	**5.219****	**4.959****	3.251	---	**5.861****
	(0.037)	**(0.045)**	(0.158)		**(0.016)**
Asia	1.056	0.529	0.287	**-2.800****	-0.394
	(0.537)	(0.765)	(0.889)	**(0.044)**	(0.837)
Americas	0.472	0.714	-1.835	-1.403	**-3.333***
	(0.786)	(0.648)	(0.271)	(0.200)	**(0.071)**
Middle East	-1.535	0.183	-1.574	**-2.978***	-4.023
	(0.551)	(0.944)	(0.503)	**(0.085)**	(0.192)
Observations	114	116	120	120	108

GDP: Gross Domestic Product. PPP: Purchasing Power Parity. *,**,***: significance levels of 10%, 5% and 1% respectively.

The following findings are apparent in Table 3. First, like in the previous narrative, the GDP per capita and rule of law estimates that are significant in Lashitew et al. (2019) are not involved in our specifications because of the concerns of multicollinearity discussed previously. Second, compared to the underlying study, the negative (positive) relevance of mobile phone connectivity performance (African dummy) on the outcome variable is

confirmed. However, the following new findings emerge: bank accounts, ATM penetration, bank concentration, mobile connectivity coverage; the Asian dummy and the Middle East dummy are all negatively associated with the mobile phone used to receive money.

4. Conclusion

This study extends Lashitew, van Tulder and Liasse (2019) by addressing the concern of multicollinearity that affects the signs and significance of estimated coefficients. The article investigates nexuses between innovations in mobile money and financial inclusion in developing countries. Demand and supply factors that affect the diffusion of mobile services as well as macro-level institutional and economic factors are considered. The empirical evidence is based on Tobit regressions. The study finds that when the concern of multicollinearity is taken on board, two main tendencies are apparent: (i) the significant findings of the underlying study are confirmed and (ii) many new significant estimated coefficients emerge.

In the light of the above, this replication exercise does not negate the main findings of the study being replicated. However, this study has shown that more significant estimated coefficients and by extension, more policy implications can be apparent if specifications are robust to multicollinearity. In order to grasp the importance of replications in better communicating scientific research, the findings in this study improve the narratives of Lashitew et al. (2019) from three main standpoints relating to demand factors, supply factors and regional dummies.

First, on the front of demand factors, the narrative on the significance of ATM penetration and bank sector concentration pertaining to mobile money accounts, holds for bank accounts (i.e. number of people holding bank accounts) and extends to other financial inclusion dynamics (i.e. the mobile phone used to send money and the mobile phone used to receive money). This is essentially because the demand factors which were previously and/or exclusively significant in the regression related to mobile money accounts (i.e. Table 1), are now also significant in the regressions related to the mobile phone used to pay money (i.e. Table 2) and the mobile phone used to receive money (i.e. Table 3).

Second, the narrative of supply factors on mobile money accounts and mobile phones used to receive money can also be broadly extended to mobile phones used to pay money. This is informed by the fact that the significance of mobile connectivity performance in Table 3 (i.e. mobile used to receive money) is now apparent in Table 2 (i.e. mobile used to pay

money) on the one hand and on the other, mobile connectivity coverage which was previously not significant in any of the tables is now significant in predicting all three outcomes (i.e. money mobile accounts, mobile used to send money and mobile used to receive money).

Third, concerning regional/continental dummies, while the narrative on the dominance of Africa is further consolidated by the findings of these replications, the significant negative linkages observed in the underlying study for the Americas in mobile used to send money and mobile used to receive money, can be extended to Asia and the Middle East. This is essentially because significant negative nexuses are now apparent between these regions and the attendant financial inclusion outcomes.

In the light of the above, while this study confirms findings of the underlying research, it also goes further to improve the harmony in narratives between the predictors and the outcome variables. Accordingly, by accounting for multicollinearity, the earlier findings are now more consistent across the set of predictors (i.e. demand and supply factors) and the three financial inclusion outcomes. Hence, the tested hypothesis and corresponding scholarly and policy relevance of this study articulated in the introduction, withstand empirical scrutiny.

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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	WGI
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 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. Bold values represent concerns of multicollinearity among independent variables of interest, based on a threshold of 0.600.

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