Nampewo et al. Financial Innovation (2016) 2:13
DOI 10.1186/s40854-016-0033-x

Financial Innovation

RESEARCH Open Access

Determinants of private sector credit in Uganda: the role of mobile money

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Abstract

Background: Mobile money services have been associated with unprecedented access to financial services, notably to under-banked and unbanked populations. Thus, mobile money opens a channel through which to examine the supply of private sector credit in Uganda. This study investigates how mobile money services influence private sector credit growth.

Methods: We applied the vector error correction (VEC) model and Granger causality analysis to Ugandan data from March 2009 to February 2016, the period when mobile money services were introduced.

Results: The VEC model reveals that mobile money has a significant positive long-run association with private sector credit growth. Granger causality analysis reveals long-run unidirectional causality from mobile money to private sector credit.

Conclusions: Mobile money is critical for financial intermediation because it attracts resources from both the banked and the unbanked populations into the formal financial system, facilitating private sector credit growth.

Keywords: Mobile money, Private sector credit, Uganda

Background

Access to financial services remains a primary impediment to the growth and competitiveness of Uganda's economy ((MoFPED 2014) and National Development Plan, 2015). Private sector credit growth has remained relatively low, averaging about 23% versus the sub-Saharan average of 30.1% percent over the last 10 years (World Bank 2014). The advent in Uganda of mobile money, a transfer and payment service potentially available to anyone owning a mobile phone has generated unprecedented access to financial services, notably under-banked and unbanked populations (Aron et al. 2015). Mobile money opens a channel through which to examine the supply of private sector credit in Uganda.

The literature suggests that adoption of mobile money increases the mobilization of deposits from households (Lwanga & Adong 2016). In doing so, it may enhance the supply of loanable funds by reallocating capital and risks across the economy. That is, it enhances access to financial services and lowers their associated transaction costs (Masha 2016). Nonetheless, few studies examine how mobile money affects monetary aggregates and private sector credit, focusing instead on velocity of money, money demand, and the effectiveness of monetary policy in developing economies. This study examines how mobile money services influence private sector credit growth, and it

extends the literature in two ways. First, we develop a simple analytical framework linking mobile money balances to bank credit. Second, we test the model on Ugandan time series data using a vector error correction (VEC) model and Granger causality. Results reveal a positive long-run relationship between mobile money balances and private sector credit. This long-run relationship is confirmed by Granger analysis, which indicates long-run unidirectional causation from mobile money balances to private sector credit.

The study proceeds as follows: Section 2 reviews mobile money in Uganda. Section 3 explores earlier empirical literature. Section 4 presents our theoretical framework and Section 5 our methods and data. Section 6 analyzes estimation results. Section 7 concludes.

Overview of mobile money operations in Uganda

Mobile money in East Africa

According to Groupe Speciale Mobile Association (GSMA), sub-Saharan Africa leads the world in the penetration of mobile money (see Table 1), with East Africa dominant at 55% (Groupe Spécial Mobile 2015).

In 2007, Kenya became the first to launch a mobile money service M-Pesa, a product of Safaricom Telecom Company. Kenya leads the world with 58% of adults using mobile money in 2014 (Groupe Spécial Mobile 2015). Kenya's success is attributed to the range of mobile money financial products and services offered, including cash deposits and withdrawals, bill payments, savings, loans, and remittances. In 2008, telecom companies Vodacom and Zantel launched M-Pesa and Z-Pesa in Tanzania ((Muthiora 2015); (Di Castri & Gidvani 2014)). Uganda followed in 2009 with Mobile Telecommunications Network (MTN) Mobile Money (United Nations Conference on Trade and Development 2012). At year-end 2014, mobile transactions equalled 62.4% of the GDP in Kenya, 51.5% in Tanzania and 35.2% in Uganda (see Fig. 1).

Mobile money in Uganda

Status of mobile money services in Uganda

The 2013 FinScope survey for Uganda reveals that financial inclusion in Uganda rose from 70% in 2009 to 85% in 2013, mainly because of the non-bank sector and, particularly, growth in mobile money services (Economic Policy Research Centre 2013). Uganda's central bank indicates that mobile phone subscriptions (irrespective of age), rose from 500 thousand to 21.1 million between December 2009 and December 2015 (Bank of Uganda monetary survey statistics 2016). This dramatic growth is attributed to reductions in the cost of telecom services as competitors entered the industry. Deposit accounts at formal banking institutions grew less dramatically from 2.8 million to 5.5

Table 1 Percentage of developing markets with mobile money by region

Region	Mobile money penetration (%)
Europe & Central Asia	30
Middle East & North Africa	43
East Asia & Pacific	63
Latin America & the Caribbean	67
South Asia	75
Sub-Saharan Africa	82

Source: GSMA report, December 2015

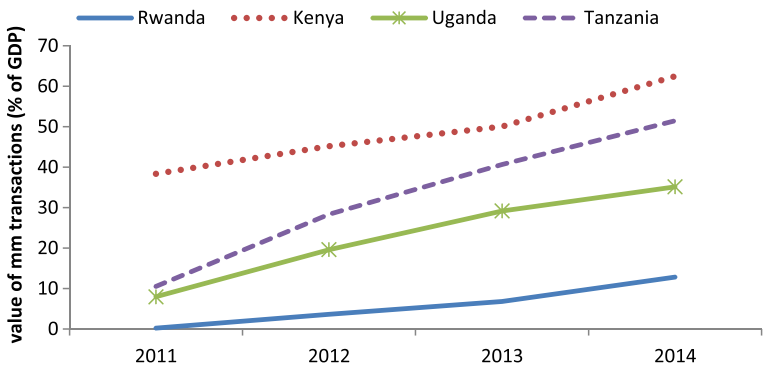

Fig. 1 Value of mobile money transactions (% of GDP), IMF Financial Access Survey, 2014

million over that period despite an increase in the number of commercial banks and branches (see Fig. 2).

Mobile money transactions in Uganda mainly entail cash withdraws and deposits. Other transactions e.g., to pay for utilities, school fees, and airtime were minimal (Economic Policy Research Centre 2013). In 2016, Umeme, Uganda's leading electricity distribution company closed its cash points, and MTN Uganda and the Commercial Bank of Africa unveiled platforms to enable mobile money subscribers to seek loans and save by phones. These developments suggest a widening in the array and use of mobile money services in Uganda (see Table 2).

Description of mobile money operations in Uganda

MTN mobile money initially dominated mobile money operations because it entered a largely monopolized telecom market served by government-owned Uganda Posts and Telecommunications Corporation, and Airtel (Celtel previously). Other operators followed quickly. Airtel launched Airtel Money with 2000 subscribers in June 2009, followed in 2010 by Uganda Telecom Limited's introduction of M-Sente, a similar service.

The mobile money business model in Uganda is built on a partnership between a mobile money operator and a supervised financial institution (SFI). Initially, most mobile money operators were telecom companies, and their services were phone based. Providers now include non-telecom operators Ezee Money and M-Cash. The service platform now has six

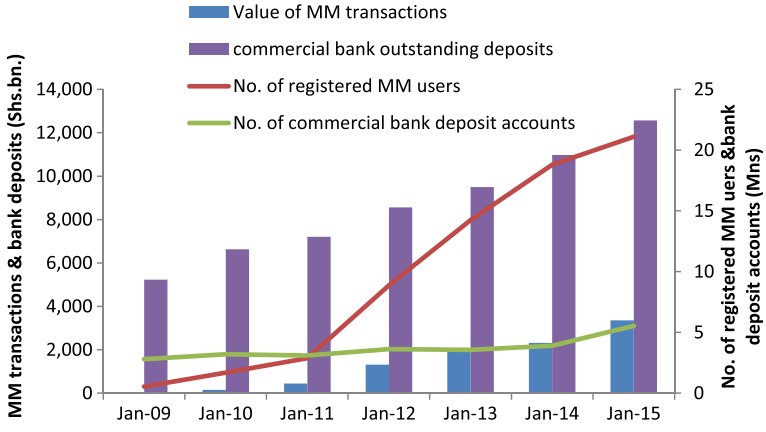

Fig. 2 Growth in Mobile Money and Commercial Bank Usage since 2009

Table 2 Current mobile money services being offered in Uganda

Product/service	Status
Domestic Transfers/Remittances P2P	Live
Merchant Payments – enabling SMEs and Corporates to receive payments P2B	Live
Statutory payments (Taxes) P2G	Live
Bulk Payments: Salaries, wages B2P e.g. Sugar, Tea and Construction firms	Live
Micro Loans and Savings	Pilot
Group wallets for SACCOs and VSLA	Pilot
Cross border	Live
Mobile banking; transfers from bank account to M-wallet	Live
Government payments (Social Benefits) G2P	Live

Source: Bank of Uganda, 2016

providers including: MTN Mobile Money, M-Cash, M-Sente, Airtel Money, Ezee-Money and Orange Money. All are regulated by the Bank of Uganda (central bank) and the Uganda Communications Commission (UCC). The UCC licenses and supervises mobile network operators; the Bank of Uganda approves and supervises mobile money services.

Each of Uganda's six mobile money providers must operate using an escrow account at an SFI. The Bank of Uganda mandates that the SFI and the mobile money provider be able to reconcile the balances of subscribers' accounts and escrow accounts daily ((Bank of Uganda 2013), p. 8). Thus, all mobile money deposits appear as liabilities on commercial bank balance sheets. Four Ugandan commercial banks link directly to the mobile money service providers: Stanbic, Equity, Centenary and Standard Chartered. Mobile money operators in turn operate through their mobile money agents country-wide.

Integration of mobile money operators systems with commercial banks' information technology systems has facilitated the development and provision of products such as automated teller cash withdrawals, quick saving and loans, quick cash loans and transfers into and from bank accounts. These and other innovations enable mobile phone customers to transact directly with commercial banks. Their ability to do so increases commercial banks' potential to transform deposits into credit as shown in Fig. 3.

To assess how Uganda's mobile money model operates, we use (Williams 2013) criteria which center upon financial regulators' platform of mobile money as a core or non-banking service in determining degrees of regulation. Although guidelines in Uganda do not explicitly recognize mobile money as a core banking service, they seemingly acknowledge its significance, potential and implications for banking and therefore underscore the role of SFIs. The guidelines read "[I]n essence, the mobile money service is approved as a product of the licensed institution which is provided by that institution partnering with a mobile money service provider" ((Bank of Uganda 2013), p. 9). Therefore, Uganda's mobile money service model is a bank led model. Such a model may reflect the benefits that the formal banking system perceives mobile money to offer its operations.

Literature review

Previous studies extensively examine the determinants of private sector credit in developing countries but a few address how mobile money contributes to private sector credit growth. This study fills that gap in the literature.

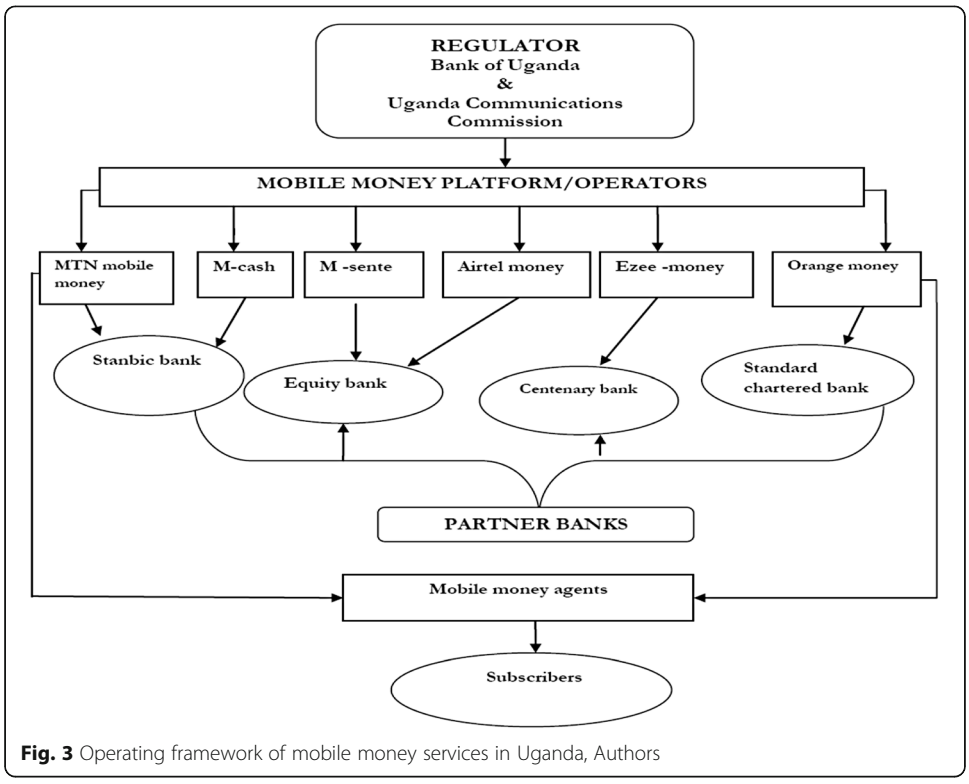

Fig. 3 Operating framework of mobile money services in Uganda, Authors

Supply-side determinants of private sector credit

Factors of demand and supply that affect credit to the private sector are interlinked, but existing studies create distinctions between them. Credit channel models identify two supply-side channels, bank lending and balance sheets that respectively measure the effects of changes in banks' financial positions and of borrowers on the availability of credit (Goyal et al. 2011). Studies based on these two credit channels identify four supply-side determinants of bank credit: the macro-economy, monetary policy, credit to the public sector and bank characteristics ((Carey 1998); (Gozgor 2014); (Everaert et al. 2015); (Rabab'ah 2015)). Empirical studies concerning their effects produce broadly similar results consistent with economic theory, although they document country-specific differences.

Macro-economy

Studies customarily use GDP growth, inflation and exchange rates as proxies for the macro-economy. Earlier studies examine how macro-economic demand-side and supply side factors affect private sector credit. Besides boosting demand for credit (Bernanke & Blinder 1988), GDP growth augments its supply. This is confirmed by (Shijaku & Kalluci 2014) who employ a VEC framework to examine demand and supply for bank credit in Albania. Their results reveal a significant long-term positive relationship between real bank credit and real GDP growth and a significant positive long run relationship between exchange rates and bank credit.

In their investigation of the credit cycle, (Everaert et al. 2015) include the exchange rate in their panel estimation to reflect that 400 banks in 20 Central and Southern European countries held significant quantities loans denominated in foreign currencies. However, they find no significance for the exchange rate, which they attribute to a high

correlation (0.5) between it and the inflation rate which exerted a negative and significant effect on credit growth. (Taiwo & Adesola 2013) also find a significant negative relationship between fluctuations in the exchange rate and the ratio of loan losses to total advances. They interpret their findings as an indication that exchange rate volatility affects lenders' ability to manage loans.

Monetary policy

Jimenez et al 2012 measure the effect of monetary policy on loan supply using changes in the interbank short-term interest rate to indicate monetary policy and find that tighter monetary policy substantially reduces loan supply. (Gozgor 2014) reaches a similar conclusion about bank credit in a dynamic panel estimation of 24 emerging economies. Results reveal that loose monetary policy exerts a positive effect on levels of domestic credit. Using an autoregressive distributed lag model, Imran and Nishat (2013) produce the same conclusion for Pakistan.

Credit to the public sector

The literature establishes credit to the public sector as an important supply-side determinant of private sector credit. Empirical evidence suggests that public borrowing crowds-out credit to the private sector (Carey 1998).

(Söğüt 2008) uses panel cross-sectional fixed effects to investigate financial developments and private sector credit for 85 developing and industrial countries using annual data spanning 1980–2006. He finds that increases in public sector credit and central government debt reduce private sector credit among in low-income and lower-middle income counties. (Cottarelli et al. 2003) empirically estimate of the determinants of credit growth to the private sector in 15 Central and Eastern European economies and find a significant inverse relation between private sector credit and the ratio of public debt to GDP. Using a VEC model, (Shijaku & Kalluci 2014) find a significant negative relation between the stock of public debt and bank credit.

Bank characteristics

The literature shows that banks' characteristics determine the supply of bank credit. (Shijaku & Kalluci 2014) find that lower bank lending costs, as measured by the spread between weighted average lending and deposits, have a significant positive relation to bank credit. (Rabab'ah 2015) empirical investigation of bank credit in Jordan reveals that bank's size has a significant positive relation to credit, whereas ratios of non-performing loans and liquidity ratios relate negatively and significantly to the ratio of credit facilities to total bank assets.

Mobile money and bank credit

Despite the voluminous literature concerning determinants of private sector credit, empirical studies of how mobile money influences private sector credit growth remains scant. Earlier literature highlights the potential for mobile money to promote financial inclusion and the long-term impact of enabling excluded populations to save and borrow (Jenkins 2008). (Weil et al. 2014) argue that mobile money complements the banking sector because it stimulates demand and access to products such as credit. (Jack et al. 2013) strongly associate of mobile money with a disproportionate expansion of credit through the credit creation hypothesis. We build on this hypothesis to assess how mobile money influences private sector credit growth in Uganda.

Theoretical framework

We develop a simple theoretical framework linking mobile money to private sector credit in a country with limited access to financial services. We develop our framework within financial development theory, which suggests that financial innovations influence intermediation through increased access to financial services (Levine 2005). We assume a household can hold financial assets (H_t) as cash, deposits in financial institutions, and mobile money balances (Eq. 1).

$$H_t = c_t + d_t + m_t, \tag{1}$$

H_t is the household's total financial assets, c_t denotes real cash balances, d_t deposits, and m_t real mobile money balances $d_t = 0$ for households without bank accounts. We next define B_t, as a financial institution where households H_t deposit real money balances. B_t holds these deposits in an escrow account. The commercial bank's total deposits D_t from household H_t are the sum of the household's bank and mobile money balances as detailed in Eq. 2.

$$D_t = d_t + m_t, \tag{2}$$

d_t denotes a household's deposits and $m_{t,}$ its real mobile money balances at any time t.

Evidence suggests that mobile money is easy and less risky to use compared to holding cash (Jack et al. 2013). Evidence further suggests that mobile money increases demand for and access to banking products (Weil et al. 2014). Thus, households lacking bank accounts can cash balances as mobile money. Mobile money balances including subscribers' and agents' balances, are in escrow at a commercial bank. This implies that commercial bank deposits, (D_t) rise as households replace cash balances with mobile money. As a result, for all $(\forall)$ increases in mobile money balances cash in circulation declines and bank deposits increase:

$$\begin{aligned} &\Delta D_t = \Delta(d_t + m_t), \\ &\forall \frac{\partial D_t}{\partial m_t} > 0, \text{ as, } c_t \rightarrow 0 \end{aligned} \tag{3}$$

Commercial banks facilitate intermediation. They mobilize as many deposits from as many economic agents as they can and reallocate them as credit. Because banks' balance sheets record deposits as liabilities and loans as assets, increased deposits enable them to create credit through balance sheet expansion. Therefore, the total deposits (D_t) of commercial bank (B_t) are an increasing function of aggregate deposits from other sources and mobile money balances from households, such that

$$D_t = f\sum\nolimits_1^t (d_t + m_t) > 0, \tag{4}$$

We assume banks' accumulated deposits are demand deposits, time deposits and required or precautionary reserves. Demand deposits (D_1D_t) are short-term liabilities on the bank balance sheet that depositors can claim at any time. Thus, demand deposits constitute a proportion of total deposits that are not loaned. We assume mobile money may boost long-term time deposits/loanable funds through overnight/short-term interbank deals. Time deposits (D_2D_t) are longer-term deposits a proportion of which can be loaned or invested in government securities. Thus, loan supply is a function of time deposits available for credit:

$$L_t^s = \gamma\, D_2 D_t, \tag{5}$$

γ is the proportion of time deposits available for credit or government securities. We define the balance sheet of a profit-maximizing commercial bank, as

$$L_t + S_t = D_t + C_t, \tag{6}$$

L_t, is the loan volume, S_t government securities, D_t deposit volume, and C_t bank capital.

We assume that banks would rather make loans than buy government securities. However, extending credit presents the possibility of defaults and the bank credit market is confronted with frictions of asymmetric information and contract enforcement that make lending costly. Hence, we regard intermediation costs as an increasing and convex function of the volume of intermediated loans, such that

$$C = C(L), \text{ where } c' > 0 \text{ and } c'' > 0, \tag{7}$$

Consequently, banks charge a higher interest rate on loans to cover the costs and assure profits. From Eq. 5, their loan supply function becomes

$$L_t^s = L(\mathrm{iL}\gamma\, D_2 D_t),\ \mathrm{L}^{'} > 0, \tag{8}$$

where iL is the loan rate.

In addition, a less favourable domestic macro-economy constrains the volume of intermediated funds, such that:

$$L_t^s = \frac{1}{\tau}\mathrm{L}(iL\gamma\, D_2 D_t)\, L^{'} > 0, \tag{9}$$

where: τ captures the effect of the macro-economy on loans supply.

Recall from Eq. 4 that

$$D_t = f\sum\nolimits_1^i d_t + m_t > 0,$$

Substituting Eq. 4 into Eq. 9, the bank's loan supply function becomes an increasing function of total deposits of which mobile money balances are a significant portion. This is summarised in Eq. 10.

$$L_t^s = \frac{1}{\tau}\mathrm{L}\left(iL\gamma\, D_2 f\sum\nolimits_1^i d_t + m_t > 0_t\right), \tag{10}$$

Such that;

$$\frac{\partial L_t^s}{\partial m_\mathrm{t}} > 0 \text{ and } L^{'} > 0$$

From Eq. 10, we conclude the following. First, loan supply is related to the macro-economy (τ), such that the more unfavourable the macro-economy, the lower the loan supply. We proxy the macro-economy using the inflation rate and the exchange rate. Second, loan supply relates positively to interest rates. Third, loan supply relates positively to mobile money balances. Deposits rise with mobile money balances, increasing loanable funds. This is summarized in the expression $\tau < 0;\ iL > 0; m > 0$.

Methods

The vector error correction framework

VEC models are widely used to estimate short-and long-run multivariate relationships. Accordingly, we allow for dynamic adjustments to private sector credit related to changes in mobile money and to other variables in the model. We estimate our VEC model based on (Johansen 1988) maximum likelihood estimation as follows:

$$\Delta X_t = \rho X_{t-1} + \sum_{i=1}^{r-1} \tau \Delta X_{t-i} + \omega K_t + \varepsilon_t \tag{11}$$

Where Δ is the difference operator. X_t is a vector of endogenous variables. ρ is a *pxp* matrix of cointegrating relationships in the model. τ is a *pxp* matrix of coefficients. K_t is a (n x 1) vector of n deterministic terms, including constants, linear trends and a dummy to capture effects of the global financial crisis. ω is a (q x q) matrix of coefficients. $\varepsilon_t \tilde{} N(0, \delta^2)$ is a white noise error term. In addition, $\rho = \alpha\beta'$ is a *pxr* matrix where α is a vector representing the speed of adjustment to long-run equilibrium and β' is a vector of cointegration among variables.

Cointegration among variables reflects the presence of a long-run relationship in the system. Generally, if variables are integrated of order "d" and produce a linear combination, integrated of an order less than d (say "b"), they are cointegrated, and a long-run relationship exists in the model. We use (Johansen 1988) procedure to test for the existence of long-run relationships among the variables in the VEC model in Eq. 11. (Johansen 1988) derived two tests for cointegration: the λ – max (or maximum eigenvalue test) and the trace test. We adopt the latter because it is more robust against skewness and excess kurtosis and can be adjusted for small-sample bias.

Granger causality analysis

Once we establish the model's variables are cointegrated, we can conclude there must be Granger causality in at least one direction. Following (Granger 1969), a variable, (e.g. X) Granger-causes another (e.g. Y) if Y can be better predicted from the historical evolution of Y and X than from the history of Y alone. We performed causality tests to identify the presence and direction of causality among the model's variables, particularly mobile money balances and private sector credit. Conventional pair-wise Granger causality is summarized in Eqs. 12 and 13:

$$\Delta X_t = \alpha_0 + \sum_{i=1}^{k} \alpha_{1i} \Delta X_{t-i} + \sum_{i=1}^{k} \beta_{1i} \Delta Y_{t-i} + \varepsilon_t \tag{12}$$

$$\Delta Y_t = \beta_0 + \sum_{i=1}^{k} \alpha_{2i} \Delta Y_{t-i} + \sum_{i=1}^{k} \beta_{2i} \Delta X_{t-i} + \mu_t \tag{13}$$

From Eqs. 12 and 13, we deduce these testable hypotheses:

i) $\Sigma\beta_{12} = 0$ while $\Sigma\alpha_{11} \neq 0$, Y does not Granger-cause X
ii) $\Sigma\beta_{22} \neq 0$ while $\Sigma\alpha_{21} = 0$, X does not Granger-cause Y
iii) $\Sigma\beta_{i2} \neq 0$ and $\Sigma\alpha_{i1} \neq 0$, bidirectional causality exits between X and Y

iv) $\sum\beta_{i2} = 0$ and $\sum\alpha_{i1} = 0$, no causality exits between X and Y

Data

We study the effect of mobile money transactions on private sector credit growth using monthly data from March 2009 to February 2016, the period during which mobile money services were implemented in Uganda. Following are the specific data we use: LPSC (the natural log of private sector credit), LMMB (the natural log of mobile money balances), LR (interest rate on loans), LEXRT (the natural log of the nominal exchange rate) and LCPI (the natural log of the core consumer price index (CPI). Data for PSC, LR, and EXRT are from the Central Bank of Uganda, CPI data are from the Uganda Bureau of Statistics. Data are adjusted for seasonality and shown in levels and differences in Appendix 3. Descriptive statistics are shown in Table 3.

Time series properties of the data

We examine the time series properties of the data using the augmented Dickey-Fuller (ADF) and Phillips-Peron (PP) unit-root tests. We use two approaches because unit-root tests involve different assumptions about error terms. For instance, the ADF test follows the distribution in Eq. 14, where the error term is assumed to be white noise:

$$\Delta y_t = \alpha_0 + \beta_T + \phi_t y_{t-1} + \sum \gamma_t \Delta y_{t-i} + \varepsilon_t \tag{14}$$

where α and β are constant and time trend, respectively and $\varepsilon_t \tilde{} N(0, \delta^2)$

However, economic variables are seldom normally distributed with a white noise error term. All variables we analysed are not normally distributed, except for the natural log of the nominal exchange rate (Table 4). Thus, we used PP to allow for heterogeneity in error terms, as shown in Eq. 15:

$$y_t = \varphi_1 y_{t-1} + \varphi_2 \left(t - \frac{T}{2} \right) + \varepsilon_t \tag{15}$$

where $\varepsilon_t \sim (0, \delta_i^2)$.

The null hypothesis for the ADF and PP tests is that the data series has a unit root. Results indicate that all variables appear to have at least one unit root and become stationary after first-differencing (see Table 4).

Table 3 Descriptive statistics of the variables in the model

Variable	LPSC	LMMB	LR	L EXRT	LCPI
Mean	8.93	1.36	22.62	7.84	5.23
Std. Dev.	0.21	0.39	2.35	0.08	0.14
Min	8.43	-0.67	18.82	7.68	4.95
Max	9.30	1.71	27.57	8.07	5.39
obs	84	84	84	84	84
Jacque-Bera	7.223 (0.027)	327.603 (0.000)	7.74 (0.024)	2.954 (0.229)	37.839 (0.000)

Source: Authors' computations

Table 4 Unit root tests

	Levels		First difference		
	ADF	PP	ADF	PP	Order of integration
LMMB	-0.021	-1.877	-9.201[a]	-14.299[a]	I(1)
LPSC	-2.049	-1.681	-6.709[a]	-7.099[a]	I(1)
LCPI	-0.601	-0.672	-6.588[a]	-9.236[a]	I(1)
LR	-0.005	-0.040	-9.929[a]	-9.891[a]	I(1)
LEXRT	-1.103	-1.482	-5.372[a]	-5.524[a]	I(1)

Notes: The superscript [a] denote rejection of the hypothesis of a unit root at 1% significance level
Source: Authors' computations

Results and discussion

Lag length criteria

We imposed two lags on all variables, the optimum suggested by Hannan-Quinn and Schwarz information criteria (see Table 5). The Langrage Multiplier (LM) test for serial correlation also confirms no serial correlation with two lags (see Appendix 2).

Co-integration and long-run analysis

Table 6 reveals one cointegrating relation. The trace statistic exceeds the critical value, and the associated *p*-value is significant, implying the null hypothesis of "no cointegration" is rejected in favor of the alternative at 5% significance. All characteristic roots lie inside the unit circle in Appendix 1. The system is stable and converges toward its long-term equilibrium. The one cointegrating relation is normalized in Eq. 8, for the monthly change in private sector credit to interpret the estimated coefficients.

Long-run analysis reveals that mobile money balances relate positively and significantly to private sector credit. This finding suggests evidence for the balance sheet expansion theory whereby mobile money boosts loanable funds. Other macroeconomic determinants of private sector credit, including core CPI and the lending rate, are significant at 5% and 10%, respectively. As expected, they also relate negatively and positively respectively, to private sector credit. The negative effect of CPI on private sector credit growth supports the findings of (Everaert et al. 2015) and implies that inflation reduces bank lending by raising the cost of doing business.

The positive effect of loan interest rates on private sector credit confirms traditional supply-side views of credit markets (McKinnon,1973; Shaw, 1973) that attract deposits and allow banks to expand credit. Although the exchange rate carries the expected negative sign, it is not significant in the long-run cointegrating equation of private sector credit. We surmise that the coefficient of the exchange rate is insignificant because in Uganda mobile

Table 5 Statistics for selecting the optimal lag order

Lag	AIC	HC	SBIC
1	-3.16	-3.10	-2.99
2	-14.42	-14.03*	-13.43*
3	-14.50	-13.78	-12.69
4	-14.65*	-13.10	-12.02
5	-14.35	-13.00	-10.89

Source: Authors' computations

Table 6 Johansen's Cointegration test and long-run analysis

Null	Alternative	Eigen-value	$\hat{\lambda}_{trace}$	95% C.V (trace)
$r = 0$	$r = 1$	0.52	119.08	88.80
$r \leq 1$	$r = 2$	0.35	67.49	68.88
$r \leq 2$	$r = 3$	0.22	37.49	42.92
$r \leq 3$	$r = 4$	0.16	20.00	25.87

Normalized Cointegrating Equation:

$$\underset{}{LPSC} = \underset{}{0.474} + \underset{(2.321)}{0.014LMMB} + \underset{(2.324)}{0.005LR} - \underset{(-0.624)}{0.018LEXRT} - \underset{(-2.601)}{0.001LCPI} \quad (16)$$

Notes: The Trace test indicates 1 cointegrating equation at the 0.05 level and in parentheses are t-values
Source: Authors' computations

money is denominated in shillings and the bulk of bank credit is shilling, rather than foreign, denominated.

Short run dynamics of the vector error correction model

Results of the VEC model estimation appear in Table 7. Estimated coefficients of the error correction terms (ECTs) for private sector credit, mobile money balances (LMMB) and core CPI are significant and bear the expected negative signs. ECTs for the lending rates (LR) and the exchange rate (LEXRT) are not significant. In the equation concerning mobile money balances and core CPI, private sector credit is adjusted by 1.4% and 2.1% of the previous month's deviation from equilibrium, suggesting mobile money and core CPI Granger-cause private sector credit over the short-run, although short-run adjustment is slow. The significant and expected negative sign for the private sector credit ECT implies the private sector credit equation is equilibrium-correcting in the long run.

Analysis suggests that the cointegration among private sector credit, mobile money balances, core CPI, exchange rates, and loan interest rates confirms Granger causality in at least one direction. We conducted Granger causality analysis on the basis of the cointegrated series. We wanted to answer three questions: Do mobile money balances Granger-cause private sector credit or vice versa? Do lending rates Granger-cause private sector credit and, if so, is the reverse true? Does the exchange rate Granger-cause private sector credit or vice versa? Does core CPI Granger-cause private sector credit and, if so, is the reverse true? Results are in Table 8.

The first result reveals a long-run unidirectional causation from mobile money balances to private sector credit. This finding is consistent with financial development theory (Levine 2005), which suggests that financial innovations such as mobile money expand the depth and breadth of financial intermediation. The finding is also consistent with the long-run cointegration equation, which reveals a positive and significant effect of mobile money balances on private sector credit.

Table 7 Results from the vector error correction model (VECM)

	D (LMMB)	D (LPSC)	D (LCPI)	D (LEXR)	D (LR)
Constant	0.157 (2.612)	0.016 (3.747)	-0.002 (-0.727)	-0.526 (-2.459)	0.005 (0.797)
ECT (-1)	-0.0141 (-4.817)	-0.005 (-2.271)	-0.021 (-2.227)	0.002 (0.627)	-0.089 (0.871)
R-squared	0.65	0.59	0.50	0.37	0.33
Adj. R-squared	0.52	0.45	0.44	0.15	0.13

Notes: t-values are in parentheses
Source: Authors' computations

Table 8 Granger causality tests

Null hypothesis	F-statistic	*P*-value	Conclusion
Mobile money balances does not Granger Cause Private sector credit	0.350	0.003	Reject
Private sector credit does not Granger Cause Mobile money balances	1.633	1.409	Fail to reject
Lending rates do not Granger Cause private sector credit	1.997	0.066	Reject
Private sector credit does not Granger Cause Lending rates	1.231	0.231	Fail to reject
Exchange rates does not Granger Cause Private sector credit	1.321	0.252	Fail to reject
Private sector credit does not Granger Cause Exchange rates	1.549	0.001	Reject
Core CPI does not Granger Cause Private sector credit	2.256	0.038	Reject
Private sector credit do not Granger Cause core CPI	3.341	0.004	Reject

Source: Authors' computations

The second result reveals unidirectional causation from loan interest rates to private sector credit, confirming their long-run relationship. The third result indicates unidirectional causation from private sector credit to the exchange rate. The reverse is not true. This implies that exchange rates do not necessarily affect private sector credit. Indeed, results from the normalized cointegrating equation reveal that exchange rates are not significant in the long-run private sector credit equation. Similarly, short-run dynamics in the VEC model show that the coefficient of the ECT in the exchange rate equation is not significant although it bears the expected negative sign. The fourth result reveals bi-directional causation between core CPI and private sector credit, implying that inflation affects private sector credit and that the reverse is also true.

Conclusions

Using a VEC model and Granger causality techniques, this study analysed relationships between mobile money and private sector credit in Uganda from March 2009 to February 2016, the period during which mobile money services were introduced. Key results are as follows.

There was a long-run stationary relation among mobile money balances, lending rates, core CPI and private sector credit during the period examined. Normalizing the only relation for the monthly change in private sector credit reveals that mobile money balances were positively and significantly associated with private sector credit in the long-run. This finding implies that increases in mobile money balances should prompt long-term increases in private sector credit.

The interest rate on loans and core CPI exhibit a significant and negative relation to private sector credit. The coefficient of the exchange rate displays no significant relation to private sector credit even though it bears the expected sign.

The ECT is statistically significant in the equations for mobile money, private sector credit, and inflation. Analysis of the long-run Granger causality reveals unidirectional causality from mobile money to private sector credit; from loan interest rates to private sector credit, and from private sector credit to exchange rates. During the period studied, there was a causal feedback effect from core CPI to private sector credit and vice versa.

By confirming a statistically significant positive relationship between mobile money transactions and private sector credit, our results support our theoretical assumption that mobile money increases bank deposits and thus loanable funds. Our empirical results for the sample period alert policy makers that mobile money is critical for financial intermediation because it attracts resources from the banked and unbanked populations to the formal financial system and those resources may transform into bank credit.

Appendices

Appendix 1

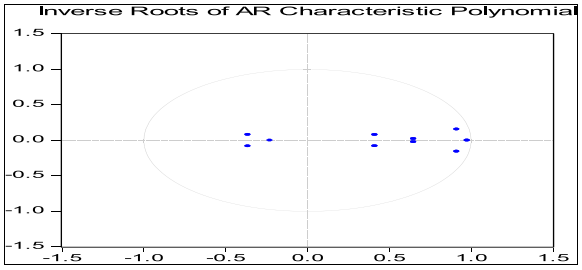

Fig. 4 Test for parameter stability

Appendix 2

Table 9 LM Test for serial correlation

VAR Residual Serial Correlation LM Tests		
Null Hypothesis: no serial correlation at lag order h		
Lags	LM-Stat	Prob
1	31.47654	0.0117
2	22.71713	0.1215
3	15.95729	0.4559
4	10.98506	0.8104
5	9.466408	0.8930
6	17.29076	0.3670

Appendix 3

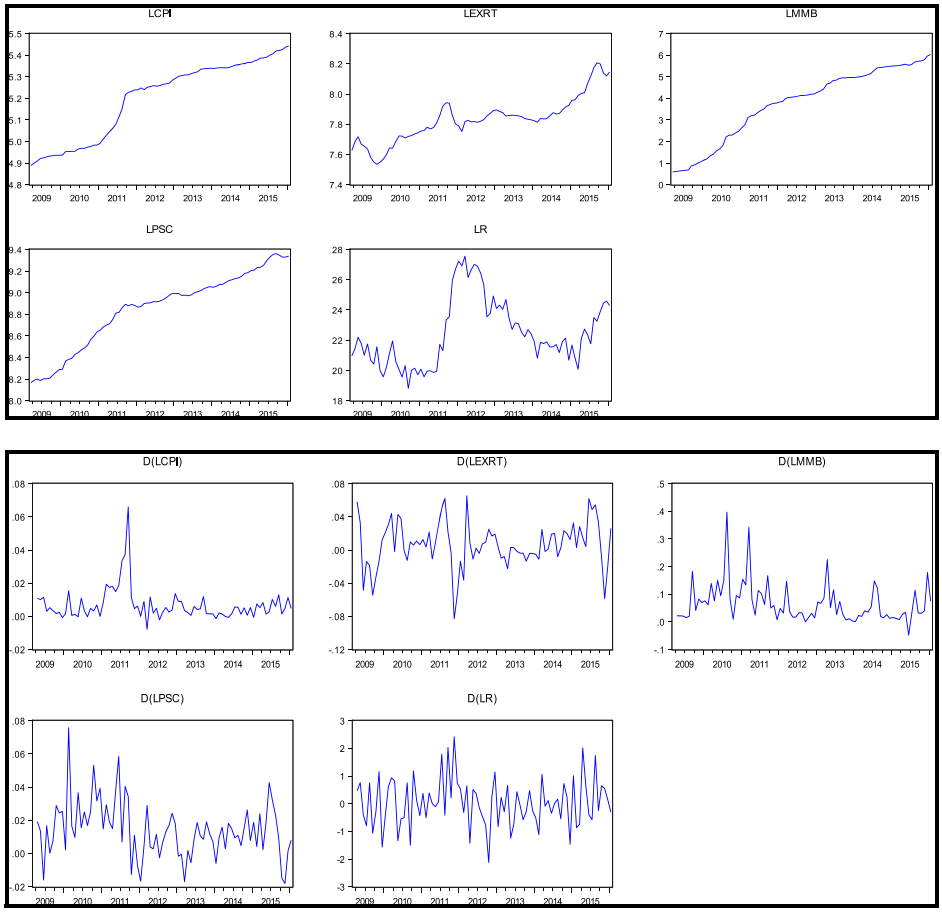

Fig. 5 Graphical exposition of the data in levels and in first differences, Authors' computations

Acknowledgements
The authors wish to thank the Bank of Uganda for the financial contributions towards this work. The authors also thank their colleagues in the economics research department of the Bank of Uganda for their vital critique and overall assessment of the paper.

Authors' contributions
DN participated in the general write-up and sequence alignment of the study in addition to performing the statistical analysis. DRK wrote an overview of mobile money operations in Uganda. GAT and GWS participated in the review of literature in the study. All authors read and approved the final manuscript.

Competing interests
The authors declare that they have no competing interests.

Received: 3 June 2016 Accepted: 11 November 2016
Published online: 21 November 2016

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