DOI: 10.28934/ea.19.52.2.pp12-27

ORIGINAL SCIENTIFIC PAPER

Gauging the Effects of Modern Payment Technologies Adoption on the Demand for Money in Nigeria

Tersoo Iorngurum[1*]

[1] Veritas University Abuja, Faculty of Social Sciences, Department of Economics, Federal Capital Territory (FCT), Nigeria, West Africa

ABSTRACT

In contrast to the global intermediate goals of monetary policy, "financial exclusion" remains prevalent. Therefore, using the Nigerian economy as a point of reference, this paper attempts to shed more light on the role played by modern payment technologies in promoting financial inclusion, especially as it relates to the provision of currency in the hands of the Nigerian public for liquidity services during the period 2009:Q1 to 2017:Q4. In actualizing this objective, the Johansen cointegration method is employed to test for cointegration alongside vector error correction modeling (VECM) techniques, while the Gregory-Hansen cointegration method is employed to test for structural breaks and regime shifts. Subsequently, empirical results from the Johansen cointegration test and the normalized cointegrating coefficients of the estimated vector error correction model (VECM) reveal that real currency in the hands of the Nigerian public is positively cointegrated with real modern payment technologies transactions as well as real Gross Domestic Product (GDP), but negatively cointegrated with real savings interest rates, real quarterly time deposits interest rates, and inflation rate. On the other hand, empirical results from the Gregory-Hansen cointegration method indicate further that there are no structural breaks or regime shifts in the cointegrating coefficients during the period 2009:Q1 to 2017:Q4. In conclusion, the existence of a positive relationship between real modern payment technologies transactions and real currency in the hands of the Nigerian public implies that the former are partly responsible for the growth of the latter, thereby indicating that modern payment technologies are effective in promoting financial inclusion by providing access to liquidity services. Based on this finding the study recommends that the adoption of modern payment technologies should be promoted in order to further extend liquidity services to financially excluded Nigerians.

Key words: *modern payment technologies, money demand*

JEL Classification: E42, E41

INTRODUCTION

Apart from the core mandate which primarily aims at achieving economic growth and curtailing inflation, monetary authorities all over the world aim at facilitating adequate access to financial services and financial products, otherwise known as "financial inclusion", in their respective economies. In the Nigerian context, several policies and initiatives have been formulated and enacted in this regard, such as the Financial Stability Strategy (FSS2020), the Microfinance Policy, Non-Interest Banking, and until recently, the Cashless Policy Initiative

[*] E-mai: tersoodavid@gmail.com

which aims at extending digital financial services through modern electronic payment technologies (Kama & Adigun, 2013; CBN, 2014).

In spite of these however, it is pertinent to note that inadequate access to financial services and financial products, otherwise known as “financial exclusion”, remains prevalent. With regards to the Nigerian economy, this problem prominently manifests itself with the majority of households (60.3%) lacking access to basic financial services and products such as liquidity services, savings accounts, deposit accounts, and credit services (World Bank, 2018). If this problem is allowed to persist, then the ultimate goal of achieving economic development may be unattainable in the short-term. This paper therefore attempts to shed more light on the possible solutions to this problem by examining the role played by modern payment technologies in promoting financial inclusion with reference to the Nigerian economy, especially as it relates to the provision of currency in the hands of the Nigerian public for liquidity services during the period 2009:Q1 to 2017:Q4.

The empirical methods adopted in this study include the Johansen cointegration method, the Gregory-Hansen cointegration method, as well as theoretical considerations from Milton Friedman’s money demand theory. Further, in structuring the paper we adopt the following pattern: Section 2 deals with the literature review. Section 3 deals with the empirical methodology. Section 4 deals with the empirical results. And Section 5 deals with the conclusions.

LITERATURE REVIEW

In reviewing the empirical literature, a distinction is made between those early studies which focused on money demand and its conventional theoretical determinants such as income, inflation, interest rates, and exchange rates, and those contemporary studies which focused on money demand and modern payment technologies.

Money demand, income, interest rates, and inInflation in Nigeria

Pertaining to those early contemporary studies that laid empirical foundations for money demand investigations in Nigeria, Nwaobi (2002) examined the stability of money demand and the robustness of GDP as a scalar determinant of money demand in Nigeria during the period 1960 to 1995. With a relatively simple model-specifying vector valued autoregressive process, the hypothesis of the existence of cointegration vectors was tested and it was found that the demand for money was cointegrated with real income, interest rate and price level. Furthermore, adopting general to specific approach, an over parameterized dynamic money demand function was estimated. Thereafter, evidence gathered from the non-nested tests, suggested that income was the more appropriate scale variable in the estimation of the demand for money in Nigeria. These results sharply contradict most findings based on developed countries but are in tune with the majority of studies that used income as the appropriate scale variable in demand for money functions estimated through techniques of cointegration and error correction mechanism.

Akinlo (2006) examined the determinants of broad money demand in Nigeria and its functional stability during the period 1970Q1 to 2002Q4. In so doing, the study employed the bounds cointegration method and the CUSUM stability test. The bounds cointegration results showed that broad money was positively cointegrated with income, but negatively cointegrated with interest rate and exchange rate, while the CUSUM test reported a weakly stable money demand function.

Omotor and Omotor (2011) studied the functional stability of the demand for money in Nigeria during the period 1960 to 2008. The method employed was the Gregory-Hansen cointegration method. The empirical results revealed an endogenous break in Nigeria’s money demand function in 1994. However after estimation, money demand was found to be functionally stable, thereby confirming the findings of previous studies which found money demand to be functionally stable and also established the fact that the Central Bank of Nigeria can effectively use money supply as a monetary policy instrument.

Aiyedogbon, Ibeh, Edafe, and Ohwofasa (2013) investigated the stability of money demand in Nigeria during the period 1986 to 2010. The study employed the Johansen cointegration test and the CUSUM/CUSUMSQ stability tests to test for cointegration and parametric stability respectively. The results showed that interest rate, inflation rate and openness had negative impacts on real money demand, while gross capital formation, exchange rate and government expenditure had positive impacts. Further, the results showed that the money demand was functionally stable during the study period.

Doguwa, Olowofeso, Uyaebo, Adamu, and Bada (2014) studied Nigeria's broad money demand function during the period 1991:Q1 to 2013:Q4. The procedures employed included the Gregory-Hansen cointegration method and the CUSUMSQ stability test. The Gregory-Hansen cointegration results revealed both intercept and regime shifts in 2007:Q1, thereby indicating that structural breaks existed in the long run relationship between real broad money demand, real income, real monetary policy rate, exchange rate spread and exchange rate movements in Nigeria. Further, the CUSUMSQ test provided evidence of a stable money demand function before and after the 2008/2009 global financial crisis. In conclusion, the study recommended that since the relationship among the aforementioned variables held over a fairly long period of time, the estimated money demand model can provide important foundations for monetary policy setting in Nigeria.

Folarin and Asongu (2017) studied the long-run demand for money and its stability in Nigeria during the period 1992:Q1 to 2015:Q4. In this study, the bounds cointegration method was employed alongside the CUSUM/CUSUMSQ stability tests to determine the existence of a cointegrated and stable relationship between money demand and its determinants. On this note, the empirical results showed that a stable and cointegrated relationship existed between money demand, income, interest rate, and inflation. Also, inflation rate was found to be a better opportunity cost variable in explaining money demand when compared to interest rate.

Tule, Okpanachi, Ogiji, and Usman (2018) investigated the determinants of broad money demand in Nigeria and its stability during the period 1985:Q1 to 2016:Q4. The procedures employed were the bounds cointegration method and the CUSUMSQ stability test. The empirical results of this study revealed that a stable long-run relationship existed between broad money (M2) and its determinants namely GDP, stock prices, foreign interest rates and real exchange rate. Particularly, stock prices showed a significant and positive effect on long-run broad money demand, which in some ways reflected increased "financialization" and integration of the Nigerian economy into the global economic system. Overall, the findings of this study gave credence to the continued relevance of broad money (M2) as a benchmark for monetary policy implementation in Nigeria.

Nwude, Offor, and Udeh (2018) examined the determinants of broad money demand in Nigeria during the period 1991:Q1 to 2014Q4. The procedures employed included the bounds cointegration method and the CUSUM stability test. The empirical results showed that a cointegrated and stable relationship existed between real broad money, real income, domestic interest rate, inflation rate, exchange rate and foreign interest rate. To be precise, real income and exchange rate were found to be positively related to the demand for real broad money while domestic interest rate, inflation rate and foreign interest rate were found to be negatively related to the demand for real broad money.

Money demand, modern payment technologies, and financial innovation in Nigeria

Pertaining to those contemporary studies that attempted to investigate the impact of modern payment technologies and financial innovations on money demand in Nigeria, Odularu and Okunrinboye (2009) studied the impact of the financial innovations on the demand for real currency in Nigeria during the period 1970 to 2004. The procedure employed was the Engle and Granger Two Step Cointegration method. The empirical findings revealed that financial innovations did not significantly affect the demand for real currency in Nigeria. However, the empirical findings revealed that income was positively related to the demand for real currency whereas interest rate was inversely related to the demand for real currency.

Oyelami and Yinusa (2013) examined the impact of modern payment technologies on money demand during the period 2008:M01 to 2010:M12. The procedures employed included Vector Error Correction Modeling (VECM) and impulse response function analysis. The findings revealed that money demand was cointegrated ATMs usage, PoS usage, web usage, and mobile money usage. Further, impulse response functions showed that money demand responded positively to innovations from Automated Teller Machines (ATM) and Point-of-Sales (PoS), but responded negatively to innovations from internet payment and mobile money.

Sowunmi, Amoo, Olaleye, and Salako (2014) investigated the effects of Automated Teller Machine (ATM) on demand for money in Isolo Local Government Area of Lagos State. The procedure employed included probit analyses. The results revealed that Automated Teller Machines (ATMs) has significantly increased the frequency of demand for money when compared with non-users of ATM. However, the average volume of money withdrawn through ATM was found to be significantly less than the amount withdrawn though cheque. The study also found that the ability of customers to meet their precautionary cash needs was enhanced by the use of ATMs because customers have access to cash during weekends and national strikes. Further, ATMs did not only reduce long queues in the banking halls but also reduced the average time spent in withdrawing cash. Among the problems encountered, most of the ATM users (45.5%) complained of inadequate service due to technical fault or power outages. Therefore, it was recommended that the quality of ATMs should be improved through adequate investment.

Egbetunde, Ayinde, and Adeyemo (2015) investigated the impact of modern payment technologies on broad money demand in order to determine the impact of Nigeria's cash policy on money demand during the period 2010:M1 to 2013:M8. The procedures employed included the Johansen cointegration method and Vector Error Correction Modeling (VECM). The empirical results revealed that a negative cointegrated relationship existed between money demand, ATMs usage, PoS usage, monetary policy rate, and exchange rate, while a positive cointegrated relationship existed between money demand, inflation, government expenditure, real GDP, and web transfer.

Apere (2017) studied the implications of financial innovations in modern payment technologies on money demand in Nigeria during the period 1981 to 2016. The procedures employed included impulse-response analysis and VAR Granger causality testing. The empirical results revealed that innovation in modern payment technologies is an important variable that affects money demand negatively. The results of the study also revealed that the long-run demand for money balances in Nigeria positively depends on income level but negatively depends on interest rate.

THEORETICAL FRAMEWORK

This study adopts Friedman's (1956) money demand theory. According to this theory, the demand for real (money) balances is determined by the real yields of other assets (bonds, equities, and physical assets), the rate of inflation, real wealth, the ratio of human to non-human wealth, and individuals' tastes and preferences. This is captured in the following money demand function:

$$m^d = \frac{M^d}{P} = f(r_1, \dots \dots, r_n, \pi, w, u, \frac{HW}{NHW}) \quad (1)$$

Here, m^d denotes demand for money balances in real terms, M^d denotes demand for money balances in nominal terms, P denotes price level, r_i denotes returns in real terms of the ith asset, π denotes rate of inflation, w denotes wealth in real terms, u denotes individuals' tastes and preferences, and HW/NHW denotes the ratio of human to non-human wealth.

Given that data on the ratio of human to non human wealth was not available at the time of Friedman's (1956) postulation, the empirical version of the money demand function was and/or is often expressed as:

$$m^d = \frac{M^d}{P} = f(r_1, \dots \dots, r_n, \pi, w) \quad (2)$$

Based on this equation, Friedman (1956) empirically argued that real wealth w, is positively related to the demand for real balances m^d, whereas the returns on other assets r_i and inflation π are inversely related to the demand for real balances m^d. Therefore, on the basis of this theory, it is expected that:

$$\frac{\partial m^d}{\partial w} > 0 \quad (3)$$

$$\frac{\partial m^d}{\partial r_i} < 0 \quad (4)$$

$$\frac{\partial m^d}{\partial \pi} < 0 \quad (5)$$

In order to introduce modern payment technologies, we assume that the liquidity services of money or currency in the hands of the public can be substituted (or complemented) by utilizing modern payment technologies like Automated Teller Machines (ATMs), Point of Sales (PoS) terminals, web payment systems, and mobile payment systems for transactionary and precautionary purposes. Under this assumption, individuals' decisions to use modern payment technologies in lieu of currency in the hands of the public for liquidity services at any given point in time reflects their tastes and preferences at that point in time. Therefore, assuming that the degree of individual's tastes and preferences for money (u) in Friedman's (1956) theory is proxied by the volume of modern payment technologies transactions (MPT) in the economy, it can be assumed that:

$$\frac{\partial m^d}{\partial u} \approx \frac{\partial m^d}{\partial MPT} \quad (6)$$

where MPT denotes modern payment technologies transactions, and all other variables remain as previously denoted. Further, it is intuitively inferable that:

$$\frac{\partial m^d}{\partial MPT} = \frac{\partial m^d}{\partial ATM} + \frac{\partial m^d}{\partial POS} + \frac{\partial m^d}{\partial web} + \frac{\partial m^d}{\partial mobile} \quad (7)$$

and:

$$\frac{\partial m^d}{\partial ATM} > 0 \quad (8)$$

$$\frac{\partial m^d}{\partial POS} > 0 \quad (9)$$

$$\frac{\partial m^d}{\partial web} < 0 \tag{10}$$

$$\frac{\partial m^d}{\partial mob} < 0 \tag{11}$$

such that the direction and magnitude of (6) depends on the predominance of (8) and (9) over (10) and (11). In other words, if ATMs and other cash-dispensing payment technologies are found to be predominant in the economy, it is expected that:

$$\frac{\partial m^d}{\partial MPT} > 0 \tag{12}$$

But if mobile payment systems and other cashless payment technologies such as internet payment systems are found to be predominant in the economy, it is expected that:

$$\boldsymbol{\frac{\partial m^d}{\partial MPT} < 0} \tag{13}$$

EMPIRICAL METHODS AND RESULTS

Data

The data used in carrying out this study is quarterly time series data covering the period 2009Q1 to 2017Q4. The data is obtainable from the statistical bulletin of the Central Bank of Nigeria (2019).

Model specification

In accordance with Friedman's (1956) money demand theory, the demand for real balances is specified as a function real wealth proxied by real Gross Domestic Product (y), real savings interest rate (r_1), real quarterly time deposits interest rates (r_2), inflation rate (π), and individuals' tastes and preferences proxied by real modern payment technologies transactions (MPT) as seen in (14):

$$m^d = f(y_t, r_{1t}, r_{2t}, \pi_t, mpt_t) \tag{14}$$

In VAR form we have:

$$m_t^d = \alpha_0 + \sum_{i=0}^{p} \alpha_{1i} y_{t-i} - \sum_{i=0}^{p} \alpha_{2i} r_{1t-i} - \sum_{i=0}^{p} \alpha_{3i} r_{2t-i} - \sum_{i=0}^{p} \alpha_{4i} \pi_{t-i} + \sum_{i=0}^{p} \alpha_{5i} mpt_{t-i} + \sum_{i=1}^{p} \alpha_{6i} m_{t-i}^d + \varepsilon_{1t} \tag{15}$$

$$y_t = \beta_0 + \sum_{i=1}^{p} \beta_{1i} y_{t-i} - \sum_{i=0}^{p} \beta_{2i} r_{1t-i} - \sum_{i=0}^{p} \beta_{3i} r_{2t-i} - \sum_{i=0}^{p} \beta_{4i} \pi_{t-i} + \sum_{i=0}^{p} \beta_{5i} mpt_{t-i} + \sum_{i=0}^{p} \beta_{6i} m_{t-i}^d + \varepsilon_{2t} \tag{16}$$

$$r_{1t} = \theta_0 + \sum_{i=0}^{p} \theta_{1i} y_{t-i} - \sum_{i=1}^{p} \theta_{2i} r_{1t-i} - \sum_{i=0}^{p} \theta_{3i} r_{2t-i} - \sum_{i=0}^{p} \theta_{4i} \pi_{t-i} + \sum_{i=0}^{p} \theta_{5i} mpt_{t-i} + \sum_{i=0}^{p} \theta_{6i} m_{t-i}^d + \varepsilon_{3t} \tag{17}$$

$$r_{2t} = \omega_0 + \sum_{i=0}^{p} \omega_{1i} y_{t-i} - \sum_{i=0}^{p} \omega_{2i} r_{1t-i} - \sum_{i=1}^{p} \omega_{3i} r_{2t-i} - \sum_{i=0}^{p} \omega_{4i} \pi_{t-i} + \sum_{i=0}^{p} \omega_{5i} mpt_{t-i} + \sum_{i=0}^{p} \omega_{6i} m_{t-i}^d + \varepsilon_{4t} \tag{18}$$

$$\pi_t = \varphi_0 + \sum_{i=0}^{p} \varphi_{1i} y_{t-i} - \sum_{i=0}^{p} \varphi_{2i} r_{1t-i} - \sum_{i=0}^{p} \varphi_{3i} r_{2t-i} - \sum_{i=1}^{p} \varphi_{4i} \pi_{t-i} + \sum_{i=0}^{p} \varphi_{5i} mpt_{t-i} + \sum_{i=0}^{p} \varphi_{6i} m_{t-i}^d + \varepsilon_{5t} \tag{19}$$

$$mpt_t = \psi_0 + \sum_{i=0}^{p} \psi_{1i} y_{t-i} - \sum_{i=0}^{p} \psi_{2i} r_{1t-i} - \sum_{i=0}^{p} \psi_{3i} r_{2t-i} - \sum_{i=0}^{p} \psi_{4i} \pi_{t-i} + \sum_{i=1}^{p} \psi_{5i} mpt_{t-i} + \sum_{i=0}^{p} \psi_{6i} m_{t-i}^{d} + \varepsilon_{6t} \quad (20)$$

Estimation procedures

Unit root testing with break points

The order of integration of the given time series, y_t, may be examined by a unit root test which accounts for structural breaks. For this purpose we adhere to Peron (1989) by utilizing a parametric approach to evaluate a null of non-stationarity (Φ = 0) against an alternative of broken trend-stationarity (Φ < 0) with the following equations:

$$y_t = \mu + \theta DU_t(T_b) + \omega D_t(T_b) + \alpha y_{t-1} + \sum_{i=1}^{k} \Phi_i \Delta y_{t-1} + u_t \quad (21)$$

$$y_t = \mu + \beta t + \theta DU_t(T_b) + \omega D_t(T_b) + \alpha y_{t-1} + \sum_{i=1}^{k} \Phi_i \Delta y_{t-1} + u_t \quad (22)$$

$$y_t = \mu + \beta t + \gamma DT_t(T_b) + \alpha y_{t-1} + \sum_{i=1}^{k} \Phi_i \Delta y_{t-1} + u_t \quad (23)$$

$$y_t = \mu + \beta t + \theta DU_t(T_b) + \gamma DT_t(T_b) + \omega D_t(T_b) + \alpha y_{t-1} + \sum_{i=1}^{k} \Phi_i \Delta y_{t-1} + u_t \quad (24)$$

Here, (21) represents a non-trending level-break model which allows for a change in level; (22) represents a trending level-break model which also allows for a change in level with a trend specification; (23) represents a trending trend-break model in which allows for a change in trend; and (24) represents a trending level/trend-break model which allows for a change in both level and trend.

Further, in (21) to (24) the three dummy variables characterize the break points. The first is a level-break dummy defined by:

$$DU_t(T_b) = \begin{cases} 0, & if\ t \le T_b \\ 1, & if\ t > T_b \end{cases} \quad (25)$$

The second is a trend-break dummy defined by:

$$DT_t(T_b) = \begin{cases} 0, & if\ t \le T_b \\ 1(t - T_b + 1), & if\ t > T_b \end{cases} \quad (26)$$

And the third is a one-time break dummy defined by:

$$D_t(T_b) = \begin{cases} 0, & if\ t \ne T_b \\ 1, & if\ t = T_b \end{cases} \quad (27)$$

Lag length selection

In determining the optimal lag length of the VAR, it is pertinent to adopt appropriate information criteria. On this note, we adopted the Akaike Information Criterion (AIC) and the Schwarz Information Criterion (SIC) which involves the following computations:

$$AIC = T * log\left|\Sigma\right| + 2N \quad (28)$$

$$SIC = T * log\left|\Sigma\right| + N * log(T) \quad (29)$$

Here, AIC denotes Akaike information criterion statistic, SIC denotes Schwarz information criterion statistic, T denotes number of usable observations, $\log\left|\Sigma\right|$ denotes natural log of covariance matrix, and N denotes total number of parameters to be estimated in the VAR (Lutkepohl, 2005).

Cointegration Testing

In testing for cointegration, Johansen's (1995) method utilizes two tests: the Maximum Eigenvalue test and the Trace test. The Maximum Eigenvalue test evaluates a null of *r* cointegrating relations against an alternative of *r*+1 cointegrating relations. The test statistic is computed as:

$$LR_{max}(r|r+1) = -T\,log(1-\lambda_{r+1}) = LR_{tr}(r|k) - LR_{tr}(r+1|k) \qquad (30)$$

for *r = 0,1, …, k-1*. On the other hand, the Trace test evaluates a null of *r* cointegrating relations against an alternative of k cointegrating relations, where k is the number of endogenous variables, for *r = 0, 1, …, k-1*. The alternative of k cointegrating relations corresponds to the case where none of the series has a unit root such that a stationary VAR may be specified in terms of the levels of all the series. The trace test statistic for the null of *r* cointegrating relations is computed as:

$$LR_{tr}(r|k) = -T\sum_{i=r+1}^{k} log(1-\lambda_i) \qquad (31)$$

where λ_i denotes the i-th largest eigenvalue of the Π matrix (Johansen, 1995).

Vector Error Correction Modeling (VECM)

When evidence of cointegration abounds, Granger's representation theorem allows one to estimate a vector error correction model which takes the following form:

$$\Delta y_t = \sum_{i=1}^{k-1} \Gamma_i\, \Delta y_{t-1} + \Pi_i y_{t-k} + \mu + \varepsilon_t \qquad (32)$$

Here, y_t is a px1 vector of endogenous I(1) variables; μ is a px1 vector of intercepts; ε_t is a px1 vector of stationary random processes with zero mean and constant variance; Γ is a pxp matrix of short-run coefficients; and Π is a matrix decomposed into $\beta'\alpha$, where β' is an pxr matrix of cointegrating vectors and α is a pxr matrix of error correction coefficients (Johansen, 1995).

Statistical and econometric evaluation

The t-test and the f-test may be utilized to impose restrictions on the estimated coefficients of the vector error correction model (VECM) and the cointegrating vectors in order to test for statistical significance. Further, a plethora of econometric tests may be employed to ensure that the estimated models possess the necessary second order econometric properties. To be precise, reference will be made to the Breusch-Godfrey test, the Breusch-Pagan-Godfrey test, and the Jarque-Bera test in order to test for serial correlation, heteroskedasticity, and normality respectively.

The alternative of cointegration testing with structural breaks

In Johansen's (1995) method, the cointegrating coefficients may be biased if structural breaks actually exist in the cointegrating coefficients. A more suitable approach which allows for cointegration testing with structural breaks is Gregory and Hansen's (1992b) method. In this method, the null of hypothesis of "no cointegration" is evaluated against four distinct alternative hypotheses of cointegration with structural breaks. The first alternative hypothesis (GH 1) assumes that there is a level-break in the cointegrating relationship:

$$y_{1t} = \mu_1 + \mu_2\varphi_{tr} + \alpha^T y_{2t} + e_t \quad (33)$$

The second alternative hypothesis (GH 2) assumes that there is a level break with a trend specification:

$$y_{1t} = \mu_1 + \mu_2\varphi_{tr} + \beta t + \alpha^T y_{2t} + e_t \quad (34)$$

The third alternative hypothesis (GH 3) assumes that there is a regime-shift:

$$y_{1t} = \mu_1 + \mu_2\varphi_{tr} + {\alpha_1}^T y_{2t} + {\alpha_2}^T y_{2t}\varphi_{tr} + e_t \quad (35)$$

The fourth alternative hypothesis (GH 4) assumes that there is a regime shift and a trend break:

$$y_{1t} = \mu_1 + \mu_2\varphi_{tr} + \beta_1 t + \beta_2 t\varphi_{tr} + {\alpha_1}^T y_{2t} + {\alpha_2}^T y_{2t}\varphi_{tr} + e_t \quad (36)$$

In order to evaluate the null of "no cointegration" against the aforementioned alternative hypotheses, Gregory and Hansen's (1992b) method employs the Philips tests (Z_t and Z_α) and the augmented Dickey-Fuller (ADF) test. However, the non-parametric Phillips tests are preferable because they are robust against misspecification and structural breaks which might encountered in parametric estimations.

Empirical results

Unit root test results

The results of the unit root tests are presented in Table 1.

Table 1. Unit Root Test Results

Variables	Lags Included	Trend Specification	Break Date	ADF Test Statistic	5% Critical Value	Remarks
m_t^d	1	Trend	2011Q4	-5.1573	-5.1757	I(1)
Δm_t^d	2	No Trend	2011Q4	-5.9083	-4.4437	I(0)
mpt_t	1	Trend	2015Q3	-3.9637	-5.1757	I(1)
Δmpt_t	0	No Trend	2011Q1	-6.1528	-4.4436	I(0)
y_t	4	Trend	2011Q1	-3.6790	-5.1757	I(1)
Δy_t	0	No Trend	2017Q2	-6.8611	-4.4437	I(0)
r_{1t}	0	Trend	2013Q2	-4.0692	-5.1757	I(1)
Δr_{1t}	0	No Trend	2016Q1	-7.8116	-4.4436	I(0)
r_{2t}	1	Trend	2015Q3	-3.2078	-5.1757	I(1)
Δr_{2t}	0	No Trend	2011Q1	-5.0090	-4.4436	I(0)
π_t	3	Trend	2016Q1	-3.7669	-5.1757	I(1)
$\Delta\pi_t$	2	No Trend	2015Q4	-8.3801	-4.4436	I(0)
Lag selection based on Schwarz Information Criterion (SIC)						

Source: Result processed using Eviews 9.

For each variable, the null of non-stationarity is evaluated against the alternative of stationarity with a break point. In the level form, the null of non-stationarity is accepted at the 5% level of significance. But in the first difference, the null hypothesis of non-stationarity is rejected at the 5% level of significance. Therefore, in compliance with the Johansen cointegration method, the unit root test results shows that each variable is difference-stationary.

Lag Length Selection Results

The results of the *AIC* and the *SIC* are presented in Table 2. The *AIC* and the *SIC* both suggest that 4 lags should be utilized. Therefore in testing for cointegration with the Johansen method, 4 lags will be incorporated in estimating the VAR model.

Table 2. Lag Length Selection Results

Lag Length	AIC	SIC
0	25.5078	25.7827
1	19.8126	21.7364
2	19.9453	23.5180
3	19.0485	24.2701
4	13.8920*	20.7626*

*Note: * indicates lag order selected by criterion*

Source: Result processed using Eviews 9.

Cointegration Test Results

Table 3 presents the Trace test results while Table 4 presents the Maximum Eigenvalue test results.

Table 3. Unrestricted Cointegration Test Results

Trace Test				
Null Hypothesis	**Eigen-value**	**Trace Statistic**	**5% critical Value**	**P-value**
None*	0.8731	124.5164	95.7537	0.0001
At most 1	0.5804	60.5175	69.8189	0.2198
At most 2	0.4707	33.5922	47.8561	0.5242
At most 3	0.2462	13.8672	29.7971	0.8480
At most 4	0.1314	5.1039	15.4947	0.7977
At most 5	0.0235	0.7371	3.8415	0.3906

Notes: Trace test indicates 1 cointegrating equation

** denotes rejection at 5% level*

Source: Result processed using Eviews 9.

Table 4. Unrestricted Cointegration Test Results

Maximum Eigenvalue Test				
Null Hypothesis	**Eigen-value**	**Trace Statistic**	**5% critical Value**	**P-value**
None*	0.8731	63.9989	40.0776	0.0000
At most 1	0.5804	26.9253	33.8769	0.2674
At most 2	0.4707	19.7250	27.5843	0.3605
At most 3	0.2462	8.7634	21.1316	0.8510
At most 4	0.1314	4.3668	14.2646	0.8187
At most 5	0.0235	0.7371	3.8415	0.3906

Notes: Maximum eigenvalue test indicates 1 cointegrating equation

** denotes rejection at 5% level*

Source: Result processed using Eviews 9.

The decision rule is to reject the null of "no cointegrating vectors" if the Trace and Maximum eigenvalue statistics are greater than their corresponding 5% critical values. Therefore, from Tables 3 and 4, the null hypotheses of no cointegrating vectors are rejected at the 5% level of significance, thereby indicating that 1 cointegrating vector exists for the relationship between money demand and the other endogenous variables of the VAR.

Vector Error Correction Modeling (VECM) Results

The evidence of cointegration in Table 3 and Table 4 allows us to estimate a vector error correction model based on Granger's representation theorem. The estimates of the vector error correction model are presented in Table 5, while the corresponding normalized cointegrating coefficients are presented in Table 7.

In Tables 5 and 7, and the subsequent equations, m^d still denotes real currency in the hands of the public, y still denotes gross domestic product which serves as a proxy for wealth, r_1 still denotes real savings interest rate, r_2 still denotes real quarterly time deposits interest rate, π still denotes inflation rate, and *mpt* still denotes real modern payment technologies transactions.

Table 5.: Estimates of the Vector Error Correction Model (VECM)

Eqn.	Δm^d_t	Δmpt_t	Δy_t	Δr_{1t}	Δr_{2t}	$\Delta \pi_t$
Δm^d_{t-3}	0.0814 (0.1563) [0.5209]	0.1422* (0.0673) [2.1115]	2.8012 (1.3838) [2.0241]	0.0779 (0.0872) [0.8929]	0.1554 (0.1584) [0.9811]	-0.6301* (0.2628) [-2.3970]
Δmpt_{t-3}	-1.1109* (0.4511) [-2.4625]	-0.2500 (0.1943) [-1.2877]	1.0590 (3.9936) [0.2651]	0.2452 (0.2518) [0.9739]	0.8453 (0.4571) [1.8491]	0.2581 (0.7586) [0.3403]
Δy_{t-3}	-0.04007 (0.0207) [-1.9318]	-0.0174* (0.0089) [-1.9517]	0.3530 (0.1836) [1.9225]	0.0144 (0.0115) [1.2450]	0.0145 (0.0210) [0.6930]	-0.0176 (0.0348) [-0.5059]
Δr_{1t-3}	0.1448 (0.6912) [0.2095]	0.0826 (0.2977) [0.2774]	-15.4736* (6.1187) [-2.5288]	-0.2020 (0.3858) [-0.5236]	-0.2419 (0.7004) [-0.3453]	-0.4603* (1.1623) [-0.3960]
Δr_{2t-3}	-0.4504 (0.2424) [-1.8579]	-0.2233* (0.1044) [-2.1392]	4.4526* (2.1459) [2.0749]	-0.0229 (0.1353) [-0.1692]	-0.0399 (0.2456) [-0.1625]	0.4736 (0.4076) [1.1620]
$\Delta \pi_{t-3}$	0.17808 (0.1725) [1.0327]	0.0197 (0.0742) [0.2664]	-2.2950 (1.5266) [-1.5033]	0.0629 (0.0962) [0.6543]	0.0965 (0.1747) [0.5524]	-0.4812 (0.2900) [-1.6596]
C	0.01431 (0.2584) [0.0554]	0.3345* (0.1113) [3.0053]	3.3837 (2.2875) [1.4791]	-0.0184 (0.1442) [-0.1278]	-0.3041 (0.2618) [-1.1616]	0.1274 (0.4345) [0.2933]
ECT_{t-1}	-0.0202* (0.0089) [-2.2592]	-0.0046 (0.0038) [-1.2021]	0.3932* (0.0789) [4.9796]	0.0007 (0.0049) [0.1530]	-0.0306* (0.0090) [-3.3884]	-0.0150 (0.0150) [-1.0045]

*Notes: * indicates significance at 5% level of significance*

Standard errors in parenthesis ( ), t-statistics in square brackets [ ]

Source: Result processed using Eviews 9.

Table 6. Summary Statistics of the Vector Error Correction Model (VECM)

	Δm^d_t	Δmpt_t	Δy_t	Δr_{1t}	Δr_{2t}	$\Delta \pi_t$
R-squared	0.5814	0.4640	0.6479	0.2056	0.4624	0.3451
Adj. R-SQ	0.4593	0.3077	0.5452	-0.0259	0.3057	0.1541
F-statistic	4.7628	2.9688	6.3101	0.8877	2.9501	1.8070
BG(4)	36.2591	{0.4565}				
BPG(294)	309.5488	{0.2553}				
JB(12)	3.8144	{0.9865}				

Notes: P-values in brackets { }

F-test 5% critical value equals 2.49, at v_1=6 and v_2=26 degrees of freedom

BG(4) denotes Breusch-Godfrey LM test for 4th order serial correlation

BPG(294) denotes Breusch-Pagan-Godfrey heteroskedasticity test at 294 degrees of freedom

JB(12) denotes Jarque-Bera joint normality test at 12 degrees of freedom, 2 for each of 6 components

Source: Result processed using Eviews 9.

Table 7. Normalized Cointegrating Coefficients

m^d_t	C	mpt_t	y_t	r_{1t}	r_{2t}	π_t
1	-9.6496	-10.0091*	-0.5762*	11.8729*	7.7256*	5.3337*
		(1.8327)	(0.2046)	(4.9138)	(1.9776)	(1.3068)
		[-5.4614]	[-2.8163]	[2.4163]	[3.9066]	[4.0814]

*Notes: * indicates significance at 5% level of significance*

Standard errors in parenthesis ( ), t-statistics in square brackets [ ]

Source: Result processed using Eviews 9.

For ease of interpretation, the estimates in Table 5 are also presented linearly in (37) to (42), while the coefficients in Table 7 are also presented linearly in (43).

$$\Delta m_t^d = 0.0143 + 0.0814\Delta m_{t-3}^d - 1.1109\Delta mpt_{t-3} - 0.0401\Delta y_{t-3} + 0.1448\Delta r_{1t-3} - 0.4504\Delta r_{2t-3} + 0.1781\Delta\pi_{t-3} - 0.0202ECT_{t-1} + u_{1t} \quad (37)$$

$$\Delta mpt_t = 0.3345 + 0.1422\Delta m_{t-3}^d - 0.250\Delta mpt_{t-3} - 0.0174\Delta y_{t-3} + 0.0826\Delta r_{1t-3} - 0.2233\Delta r_{2t-3} + 0.0197\Delta\pi_{t-3} - 0.0046ECT_{t-1} + u_{2t} \quad (38)$$

$$\Delta y_t = 3.3837 + 2.8012\Delta m_{t-3}^d + 1.0590\Delta mpt_{t-3} + 0.3530\Delta y_{t-3} - 15.4736\Delta r_{1t-3} + 4.4526\Delta r_{2t-3} - 2.2950\Delta\pi_{t-3} + 0.3932ECT_{t-1} + u_{3t} \quad (39)$$

$$\Delta r_{1t} = -0.0184 + 0.0779\Delta m_{t-3}^d + 0.2452\Delta mpt_{t-3} + 0.0144\Delta y_{t-3} - 0.2020\Delta r_{1t-3} - 0.0229\Delta r_{2t-3} + 0.0629\Delta\pi_{t-3} + 0.0007ECT_{t-1} + u_{4t} \quad (40)$$

$$\Delta r_{2t} = -0.3041 + 1554\Delta m_{t-3}^d + 0.8453\Delta mpt_{t-3} + 0.0145\Delta y_{t-3} - 0.2419\Delta r_{1t-3} - 0.0399\Delta r_{2t-3} + 0.0965\Delta\pi_{t-3} - 0.0306ECT_{t-1} + u_{5t} \quad (41)$$

$$\Delta\pi_t = 0.1274 - 0.6301\Delta m_{t-3}^d + 0.2581\Delta mpt_{t-3} - 0.0176\Delta y_{t-3} - 0.4603\Delta r_{1t-3} + 0.4736\Delta r_{2t-3} - 0.4812\Delta\pi_{t-3} - 0.0150ECT_{t-1} + u_{6t} \quad (42)$$

Among the numerous coefficients, interest lies in the error correction coefficient (ECT_{t-1}) which shows the rate of adjustment to the long-run cointegrated relationship between m^d_t and the other endogenous variables. In (37), the error correction coefficient is expectedly negative and statistically significant, thereby signifying equilibrium and indicating that 2.02 percent of any discrepancies in long-run m^d_t will be corrected in each period. In (38), the error correction coefficient is negative but statistically insignificant, thereby implying that (38) is out of equilibrium. In (39), the error correction coefficient is positive and statistically significant, thereby implying that (39) is too high to be in equilibrium. In (40), the error correction coefficient is positive, but statistically insignificant, thereby implying that (40) is out of equilibrium. In (41), the error correction coefficient is negative and statistically significant, thereby implying that (41) reverts to equilibrium with respect to discrepancies in long-run m^d_t. In (42), the error correction coefficient is negative but statistically insignificant, thereby implying that (42) is out of equilibrium.

Further, based on the adjusted R^2s in Table 6, (39) seems to be the only component with a good fit (54.52%). On the other hand, based on the *f*-statistics, (37), (38), (39), and (41) seem to be statistically significant at the 5% level, while (40) and (42) seem to be statistically insignificant at the 5% level. Pertaining to the second order econometric criteria, the *p*-values (0.4564 and 0.2553) for the Breusch-Godfrey (*BG*) test and the Breusch-Pagan-Godfrey (*BPG*) test lead to the rejection of the null hypothesis of 4th order serial correlation and the null hypothesis of heteroskedasticity respectively, while the *p*-value (0.9865) for the Jarque-Bera (*JB*) test leads to the rejection of the null hypothesis of abnormally distributed residuals. Therefore, the VECM does not violate any of the second order econometric criteria.

For the long-run analysis, the normalized cointegrating coefficients in (41) will be interpreted accordingly.

$$m_t^d = 9.6496 + 10.0091mpt_t + 0.5762y_t - 11.8729r_{1t} - 7.7255r_{2t} - 5.3337\pi_t + e_t \qquad (43)$$

The coefficient of mpt_t is positive and statistically significant at the 5% level, thereby implying that a unit increase (decrease) in real modern payment technologies transactions causes real currency in the hands of the public to increase (decrease) by 10.0091 units. The coefficient of y_t is expectedly positive and statistically significant at the 5% level, thereby implying that a unit increase (decrease) in the level of real GDP causes real currency in the hands of the public to increase (decrease) by 0.5762 units. The coefficients of r_{1t} and r_{2t} are expectedly negative and statistically significant at the % level, thereby implying that a unit increase (decrease) in real savings interest rates and real quarterly time deposits interest rates cause real currency in the hands of the public to decrease (increase) by 11.8729 units and 7.7255 units respectively. The coefficient of inflation rate is expectedly negative and statistically significant, thereby implying that a unit increase (decrease) in inflation rate causes real currency in the hands of the public to decrease (increase) by 5.3337 units. Finally, the intercept of the cointegrating equation is positive and it implies that the real currency demand function has a positive autonomous magnitude of 9.6496 units.

Alternative evidence from cointegration testing with structural breaks

Unlike the Johansen cointegration method, the Gregory-Hansen cointegration method is employed as an alternative cointegration method which accounts for structural breaks. The Gregory-Hansen test results are presented in Table 8.

Table 8. Gregory-Hansen Test Results

Specification	**Break Date**	**Z_t Statistic**	**5% Critical Value**	**Accept H_0**
GH 1	2014Q4	-5.27	-5.56	Yes
GH 2	2010Q1	-5.38	-5.83	Yes
GH 3	2015Q2	-5.61	-6.41	Yes
Specification	**Break Date**	**Z_α Statistic**	**5% Critical Value**	**Accept H_0**
GH 1	2014Q4	-31.30	-59.40	Yes

GH 2	2010Q1	-32.99	-65.44	Yes
GH 3	2015Q2	-33.19	-78.52	Yes
Specification	**Break Date**	**ADF Statistic**	**5% Critical Value**	**Accept H_0**
GH 1	2014Q3	-5.29	-5.56	Yes
GH 2	2010Q1	-6.90	-5.83	No
GH 3	2014Q4	-5.61	-6.41	Yes

Note: r_2 was excluded in order to obtain 4 regressors

GH 4 was not computed due to limited observations

Source: Result processed using Stata 13.

In interpreting results, we adopt the non-parametric Z_t and Z_α statistics instead of the parametric ADF statistic because the former are robust against misspecification and structural breaks which might be encountered in parametric estimation.

On this note, Table 8 shows that the Z_t statistics are less than their 5% critical values, thereby leading to the acceptance of the null hypotheses of "no cointegration" in lieu of the alternative hypotheses of cointegration with level-break, level-break with trend, and regime shift. Similarly, Table 8 also shows that the Z_α statistics are less than their 5% critical values, thereby leading to the acceptance of the null hypotheses of "no cointegration" in lieu of the alternative hypotheses of cointegration with level-break, level-break with trend, and regime shift.

Therefore, based on the Z_t and Z_α statistics we accept the null of "no cointegration" but reject the alternative hypotheses of cointegration with structural breaks.

CONCLUSION

In order to evaluate the role of modern payment technologies in promoting financial inclusion in the Nigerian economy, this study mainly attempted to examine the effects of modern payment technologies adoption on the availability of currency in the hands of the Nigerian public during the period 2009:Q1 to 2017:Q4. On this note, the Johansen cointegration method was employed to test for cointegration alongside vector error correction modeling (VECM) techniques, while the Gregory-Hansen cointegration method was employed to test for structural breaks and regime shifts. Thereafter, empirical results from the Johansen cointegration test and the normalized cointegrating coefficients of the vector error correction model (VECM) revealed that real currency in the hands of the Nigerian public was positively cointegrated with real modern payment technologies transactions as well as real Gross Domestic Product (GDP), but negatively cointegrated with real savings interest rates, real quarterly time deposits interest rates, and inflation rate. On the other, empirical results from the Gregory-Hansen cointegration method indicated further that there were no structural breaks or regime shifts in the cointegrating coefficients during the period 2009:Q1 to 2017:Q4.

In conclusion, the existence of a positive relationship between real modern payment technologies transactions and real currency in the hands of the Nigerian public indicated that the former were partly responsible for the growth of the latter during the period under investigation, thereby implying that modern payment technologies were effective in promoting financial inclusion by providing more access to liquidity services. Therefore, it was recommended that wide-spread adoption of modern payment technologies should be promoted in order to further extend liquidity services to financially excluded Nigerians.

ACKNOWLEDGEMENTS

I humbly wish to acknowledge my dissertation supervisor who also doubles as Chairman of Economics Department and visiting professor of the African Union, Distinguished Professor G.C. Nwaobi for his indispensible guidance during the preparation of this manuscript.

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APPENDIX

Table A.1: Data

Obs.	Quarter	m^d	y	r_1	r_2	π	mpt
1	2009Q1	27.0800	60.1500	0.8629	11.3629	1.5500	1.6000
2	2009Q2	24.9400	62.7400	-0.4864	9.8736	2.8200	1.6400
3	2009Q3	23.4800	67.3000	-2.3838	7.6329	4.5800	1.8500
4	2009Q4	25.4700	68.1800	0.6174	10.8641	2.3100	1.6400
5	2010Q1	23.6300	120.5800	-0.6108	6.7925	3.8600	0.6700
6	2010Q2	22.9000	121.2000	0.3386	3.9153	2.3600	0.8300
7	2010Q3	22.5200	128.4100	-2.8753	0.2114	4.6800	1.1600
8	2010Q4	25.1600	130.6100	-0.1617	3.0250	1.8400	1.3800
9	2011Q1	27.1300	115.1000	-1.7568	1.8032	3.6300	3.1400
10	2011Q2	27.0500	115.8400	-0.2459	3.7408	1.9000	3.3400
11	2011Q3	25.4800	121.2900	-1.4598	2.4969	3.4200	3.3400
12	2011Q4	26.8000	123.7900	-0.9654	4.6613	2.8900	4.0000
13	2012Q1	25.3000	106.1300	-3.3073	3.1027	6.0500	3.5400
14	2012Q2	24.7900	106.9000	-0.4012	5.9955	2.8600	3.7600
15	2012Q3	23.6100	114.4300	-0.2625	6.5142	2.7500	3.8700
16	2012Q4	25.6700	114.5500	-0.7601	6.4866	3.3500	4.2700
17	2013Q1	24.9100	101.6600	-0.3474	6.3093	2.9100	4.7000
18	2013Q2	23.8300	103.5800	0.1098	5.7931	2.7700	5.1100
19	2013Q3	23.3900	111.1400	0.8520	6.1720	2.3000	5.5300
20	2013Q4	26.4300	113.3600	0.3996	5.8396	3.0800	6.2600
21	2014Q1	25.1400	100.1400	1.2885	7.4018	3.0400	6.0600
22	2014Q2	23.8200	102.1900	1.3249	7.2716	3.2300	6.4200
23	2014Q3	23.9100	108.9300	1.4159	7.1226	3.0600	7.5500
24	2014Q4	24.6300	111.2100	1.7262	7.7895	2.7500	7.6900
25	2015Q1	24.9600	96.1000	1.2356	7.0656	3.8100	6.8800
26	2015Q2	21.5100	96.0100	0.9297	6.6130	4.4600	6.9100
27	2015Q3	20.2400	102.4700	1.3624	8.0991	3.9400	7.1600
28	2015Q4	21.9500	103.7900	1.7043	5.7176	3.1500	7.6400
29	2016Q1	22.5800	85.7900	-0.7968	2.7332	7.2700	7.4300
30	2016Q2	21.3300	82.0500	-2.7846	0.5487	11.8200	7.5500
31	2016Q3	20.4700	85.1500	-0.3403	3.4064	8.5000	8.2000
32	2016Q4	23.3000	86.1100	1.5801	5.9601	5.3600	9.7900
33	2017Q1	22.3800	72.1000	0.6222	5.4422	7.6000	9.5600
34	2017Q2	19.9900	70.8000	-0.9766	4.1867	11.2000	9.5500
35	2017Q3	18.4000	123.1400	0.2332	6.1899	8.8500	9.2300
36	2017Q4	19.6100	127.5000	1.7387	7.5054	5.6000	10.7400

Notes: m^d denotes real currency in the hands of the Nigerian public, y denotes real Gross Domestic Product, r_1 denotes real savings interest rate, r_2 denotes real quarterly time deposits rate, π denotes inflation rate, and mpt denotes real modern payment technologies transactions. m^d, y, and mpt are in billions of Naira. π is calculated as change in Consumer Price Indices; r_1 and r_2 are expressed in percentages.

Source: Central Bank of Nigeria (2019).

Article history:	Received: October 9, 2019
	Accepted: November 3, 2019