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The Relations between Telephony Money Transactions and Inflation Determination: Evidence from Kenya using ARDL Approach

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Abstract
The purpose of the paper was to examine the relationship between telephony money transactions and inflation in Kenya in the period 2007 to 2017 firstly, due to the fears allayed that the advent of mobile money transactions could be increasing inflation, and secondly, to determine the existence of causality between telephony money transactions and inflation. The ARDL Bounds test of co-integration is employed and the findings reveal that there is insignificant relationship between telephony money transactions and Inflation in the long run and the null hypotheses are accepted, however, the error correction terms are negative and significant showing bidirectional causality between inflation and the telephony money transactions constructs implying that there is need for continuous implementation of interdependent policy actions for effective monetary and inflation targeting.

Keywords: Telephony Money Transactions, Inflation, ARDL, Kenya

1. INTRODUCTION

Inflation determination is key in helping the Central bank to adjust its monetary policy to control inflation [1]. However, inflation determination is a challenging exercise [2] in emerging markets and especially Kenya given the many structural and institutional adjustments, the high weight of volatile food and energy in the consumer price index and exchange rate volatility. Non-linearities can also matter as the speed of price changes tends to rise with larger shocks, also in consideration is the extent to which structural shifts are still playing out (financial innovation via the spread of mobile money) [3], [4].

According to the African Development Bank [5] report as captured by [6], the rise in inflation in Kenya is not an isolated event, other African countries are facing the same problem. According to [7] the year 2010-11 is the most eventful year for world inflation. East Africa witnessed in October 2011 a considerable surge in inflation reaching on average 20%. Kenya in the same year and month recorded an inflation rate of 18.9% [8], [9]. [10] noted that the Central bank of Kenya (CBK) has fallen short of its inflation target several times over due to the use of different forecasting tools that have not been efficient in identifying accurate forecast values for inflation prediction and monitoring. CBK's objective of maintaining the inflation rate below 5% target has for most years remained elusive [11].

Monetary policy alone in Kenya does not seem to be effective in stabilizing inflation around the 5% target [10]. According to the International Monetary fund [12], [13] one of the challenges identified is the uncertainty of the impact of money growth and money velocity due to the increased use of mobile money. African Development Bank [5] identified key drivers of inflation in Kenya as being global oil price changes, money expansion due to the growth of money supply in the short-run, world food prices and cereal production, adverse weather conditions and especially the reduction in rainfall over the past have been attributed to affect local food production. They recommended the inclusion of rainfall measure to capture local food supply shocks and effects of M-pesa use to identify the effects of money growth and supply.

[14] confirmed that the use of M-pesa has escalated the money velocity in Kenya since its inception and has thus had a significant effect on the overall money supply which affects the inflation rates. This is because M-pesa moves more money in Kenya than Western Union does globally [5]. The use of mobile money also extends mobile banking capabilities that cater to more than 70% of the population in Kenya , [15], [16]. Thus, the use of M-pesa has led to an increase in money velocity which ultimately affects inflation expectations [5].

[16] predicted that increased transactions could induce spending thus increase velocity of circulation, and this will in turn increase 'effective money' and hence inflation. In the short-run, higher mobile balances might signal plans for impending spending and so proxy a short- term demand increase. Also, the advent of mobile money might transfer spending power to households with a higher propensity to spend, and so reduce savings.[16].

[3], [4] investigating whether mobile money is relevant in forecasting inflation models with the application of sophisticated econometric forecasting VAR model to Uganda and which was successfully used in South Africa and the US states that there is confusion in literature on the effects of variations in the money stock on inflation, while neglecting possible benign linkages between mobile money and inflation in the mechanism proposed by [16] which is based on the monetarist notion which links demand for money with inflation and can be reversed to give an inflation equation, and which has long been discredited by [18] on the basis that the inflation equation lacks micro-foundations and they give several reasons to support their criticisms and conclude that there is no serious evidence of a link between mobile money and food and non-food inflation However, they state that a causal channel between money growth and inflation can arise because liquid assets are the most spendable part of the private sector wealth.

The point by [3], [4] on the need to determine the linkages between mobile money and inflation and about the existence of a causal channel between money growth and inflation forms the basis for this paper. The paper is motivated to adopt an empirical evidence approach by examining the relations between telephony money transactions and inflation and their possible causal linkages in order- to determine whether telephony money transactions can be used for determining inflation. The significance of the paper in this perspective is to build literature for studies that focus on establishing whether telephony money transactions are necessary in determining inflation.
With this background, the first objective of the paper was to examine the relationship between telephony money transactions operationalized as number of transactions (in millions) and value of deposits (in billions) and inflation in Kenya. The specific objectives were to determine the relationship between number of transactions and inflation in Kenya and to assess the relationship between number of deposits and inflation in Kenya. In view of the stated objectives the study sought to answer the following hypotheses: Ho_1: number of transactions and inflation have an insignificant relationship. Ho_2: number of deposits and inflation have an insignificant relationship.

The second objective of the paper is to determine the causality between telephony money transactions and inflation using the telephony money transactions constructs. In view of this objective the paper will seek to answer the following hypotheses: Ho_1: number of transactions and inflation have no causality. Ho_2: number of deposits and inflation have no causality. This is because telephony money transactions are a component of M2 (broad money) and are held in the mobile phone as deposits, of which also broad money is a part of the money supply. subsequently, this view means that as telephony money transactions grow, broad money also grows, and as broad money grows it causes inflation and the rise in inflation also causes increase in telephony money transactions which are a part of broad money supply.

This paper cannot claim to tackle all the issues surrounding the relations between telephony money transactions and inflation determination, but it has endeavoured to provide sufficient empirical evidence with a claim that firstly, using a univariate approach such as ARDL which is a single dynamic equation model also provides a better forecasting tool and especially if there is a stable co-integrating relationship between inflation and the telephony money transactions constructs. Also, the Akaike Information Criteria (AIC) is used as the optimal information criterion since it is a superior method, it provides relatively efficient estimates, and the lags captures the shocks within the various periods.

Secondly, the existence of causality between inflation and the telephony money transactions constructs (number of transactions and value of deposits) which will be determined by the significance of the error correction terms may prove the view held by [16]. This means that there should be continuous implementation of interdependent policy actions for inflation and monetary targeting. Thirdly, the use of monthly data for inflation and telephony money transactions for the period 2007 -2017 covers the period since the advent of telephony money in Kenya.
Accordingly, the rest of the paper is divided into four sections: section two presents the literature review; section three presents the methodology; section four proffers the results and section five presents, the conclusions, and recommendations for policy action.

2. LITERATURE REVIEW

This section presents theoretical and empirical literature, conceptual framework, and literature gap.

2.1. Theoretical Literature

The theories are selected because of their contribution towards the relationship between telephony money transactions and inflation determination.

2.1.1. Quantity Theory of Money

Quantity theory is one of the oldest economic theories that were developed in the middle centuries. It hypothesizes about major changes in purchasing power. According to the theory the changes in purchasing power are determined by the quantity of money that is in circulation. In this view, the quantity theory states that the abundance of money is what determines the price of goods [19]. Quantity theory states that the quantity of money and price of goods and services have a direct relationship and can be expressed by Fishers [20] equation as follows:

$$MV = PT$$

Where: M = Money supply
V = Velocity of circulation
P = Average price level
T = Volume of transactions of goods and services

In this equation, Mr. Fisher had made the following assumptions as follows: the velocity of money circulation and volume of transactions are constant, and the quantity of money is the determinant of the price of goods and services. According to the quantity theory inflation can be controlled by increasing quantity of money substantially and deflation can be controlled by decreasing the quantity of money appreciably [21]. This means in order to control inflation the supply of money must be equivalent to the supply of goods and services.

2.1.2. Monetarist view

The monetary school of thought is led by Milton Friedman and Schwartz in the 1970's through their influential book on the monetary history of the United States. They argued that 'inflation is always and everywhere a monetary phenomenon' [22]. Monetarists believe that the source of inflation is fundamentally derived from the growth rate of money supply and that a rapid increase in money supply may lead to a rapid increase in inflation [22]. The quantity theory of money forms the cornerstone of monetarism [23]. Subsequently, this group of economists are of the view that money supply should be kept within an acceptable bandwidth so that the levels of inflation can be controlled [22]. However, the predicted relationship between money supply and inflation remains disputed according to [24]. One possible explanation for this dispute is that the empirical relationship between money growth and inflation holds only over time periods that are so long that the relationship is uninformative for practitioners and policymakers, who are more concerned about inflation next month or next year [24].

2.2. Empirical Literature

[25] using time series data from 1984-2012 and Vector Error Correction Model to determine the relationship between inflation and money supply in Kenya found significant positive long run relationship between money supply and inflation in Kenya. He also found unidirectional causality using granger causality tests validating monetarist theory.

2.3. Literature Gap

There is inadequacy in literature on the relationship between telephony money transactions and inflation determination in Kenya, and consequently, the existence of causality between telephony money transactions and inflation is not yet determined. It is in view of this, that the paper focuses on examining the relationship between telephony money transactions and inflation in Kenya and determining the causality between telephony money transactions and inflation in Kenya.

2.4 Conceptual Framework

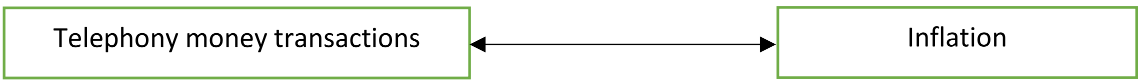

Fig. 1: Conceptual Framework

3. METHODOLOGY

3.1 Data, Study Variables, Research design and Target population

The data is time series, and the frequency is monthly. Inflation is measured by the monthly inflation rate. Telephony money transactions is operationalized as number of transactions measured in millions and the value of deposits measured in billions. The data is obtained from the Central Bank of Kenya Statistical Bulletin [26]. The source of the data is preferred because of ease of access and retrieval and its credibility for research purposes. Descriptive research design is used to describe the characteristics of the variables under study. The target population is the monthly inflation rates and monthly telephony transactions constructs (number of transactions and value of deposits).

3.2. Model specification

An ARDL model can be specified in general as:

$$(L)y_t = \varphi + \sum_{i=1}^{k} \theta_1 (L) X_{1t} + \sum_{i=1}^{k} \theta_2 (L) X_{2t} + \ldots\ldots\ldots \sum_{i=1}^{k} \theta_k (L) X_{kt} + u_t \ldots\ldots\ldots (1)$$

Where: **L** is the lag operator to each component of a vector; $\mathbf{y_t}$ is the dependent variable; $\boldsymbol{\varphi}, \boldsymbol{\theta}$ are the coefficients; $\mathbf{X_{1t}, X_{2t}, \ldots X_{kt}}$ are the independent variables; **t** is time; **k** is the lag length; **u** is the error term independent of $\mathbf{X_t, X_{t-1}}$ and $\mathbf{y_t, y_{t-1}}$.

Similarly, an ARDL model for the study can be specified as:

$$\Delta \text{Inflation}_t = \lambda_0 + \sum_{i=0}^{k} \delta_i \Delta \text{ Log Transactions1}_t + \sum_{i=0}^{k} \pi_i \Delta \text{ Log Deposits1}_t + u_t \ldots\ldots\ldots (2)$$

Where Δ is the difference operator; Inflation at time t; Transactions at time t, Deposits at time t; t represents time; Log stands for logarithms; k is the lag length and u is the error term assumed to be serially uncorrelated. The parameter θ_i , δ_i , π_i are the short run dynamic coefficients of the ARDL model.

The following regression model was then adopted in the study to examine the relationship between telephony money transactions and inflation. The regression model investigates the short run and long run relationships between telephony money transactions and inflation.

$$\text{Inflation}_t = f(\text{Transactions}_t, \text{Deposits}_t) + \varepsilon_t \ldots\ldots\ldots (3)$$

Where: Inflation_t = Inflation at time t, Transactions_t = Transactions at time t, ε_t = represents variables outside the model.

3.3. Data analysis Procedure

The first step in the data analysis procedure is the descriptive statistics which is estimated to provide explanations on the characteristics of the variables in the study. The second step is the use of the Autoregressive Distributed lag (ARDL) bounds test of co-integration approach to estimate the short and long run relationships among the variables. This method was developed by [27], [28] and [29].

The ARDL bounds test of co-integration approach includes a preliminary unit root test, optimal information criterion selection, co–integration test and error correction model (ECM), and for each equation in the ECM, diagnostic tests that include normality test, serial correlation test, multicollinearity test, heteroscedasticity test and model stability test are carried out. After the diagnostic tests the third step involves testing the model for robustness and consistency using the Johansen co-integration procedure, vector error correction model (VECM) and post estimation tests that include normality test, serial correlation test, impulse response functions and predicted co–integrating equation. The model is then fitted to show the long run coefficients, short run coefficients and error correction terms. Stata software was used for this data analysis procedure.

4. RESULTS

This section presents the results of comprehensive data analysis but as a preliminary the characteristics of data was first checked using descriptive statistics, then an ARDL bounds test of co-integration approach, diagnostic tests, robustness check and post estimation test results were carried out. The results are proffered in the following subsections 4.1, 4.2 and 4.3.

4.1: Descriptive statistics

TABLE 1: Descriptive statistics of the variables

Variable	Inflation %	Number of transactions	Amount of money deposited
Observations	126	126	126
Mean	8.4280	55.9396	134.5593
Std. Dev	4.6587	44.7690	98.3946
Minimum	1.85	.0217	.0643905
Maximum	19.72	156.85	320.18
Skewness	1.0665	.6423	.2667951
Kurtosis	3.0342	2.3716	1.808573

The descriptive statistics are shown in Table 1 above. The data collected in the research was 126 observations for each of the 3 variables. Therefore, the research had a total of 378 individual observations over the course of 126 months. All the variables showed positive skewness and normal kurtosis. The minimum transaction at kshs .0217 million was observed in March 2007 when the mobile transfers were first introduced in Kenya while the maximum observed number of transactions was Kshs 156.85 million in May 2017. This shows a clear growth of the number of transactions in the market and acceptance of the mobile money transfers in the economy. The mean number of transactions was Kshs 55.93 million which was very high and shows a high number of transactions occurring on a daily basis.

Monthly deposits were also on an upward trajectory, the minimum amount of money deposited being recorded on the first month of mobile money transfer inception of Kshs .0643 billion, while the maximum number of deposits valued at Kshs 320.18 billion was recorded on March 2017 showing an increased growth from the initial deposits. Inflation has a minimum rate of 1.85% recorded in April 2007 while the maximum rate was in November 2011 standing at 19.72% these being attributed to both mobile money transactions and other market forces in the economy at the set times. Inflation has a mean rate of 8.42% showing that it had no significant trend but fluctuated due to market forces.

4.1.1: Trend Analysis

The line graph for inflation in Fig.2 shows there is seasonality in the fluctuations of the inflation rate. Inflation is observed to have two peaks which are all above 19% inflation rate while the rest of the data oscillated along the mean of inflation rate at 8.42%.

On the other hand, the observations for number of transactions were observed to exhibit signs of containing a trend and seasonality which were much more frequent than that of inflation. The growth rate and consistent increase of mobile transactions indicates that transactions have a clear trend that is observable from the graphical representation. The graphical line representation of inflation is represented above and shows the distortion due to the trend observed in the transactions, thus the researchers chose to use the log of transactions so as to de-trend the number of transactions and eliminate the trend and seasonality.

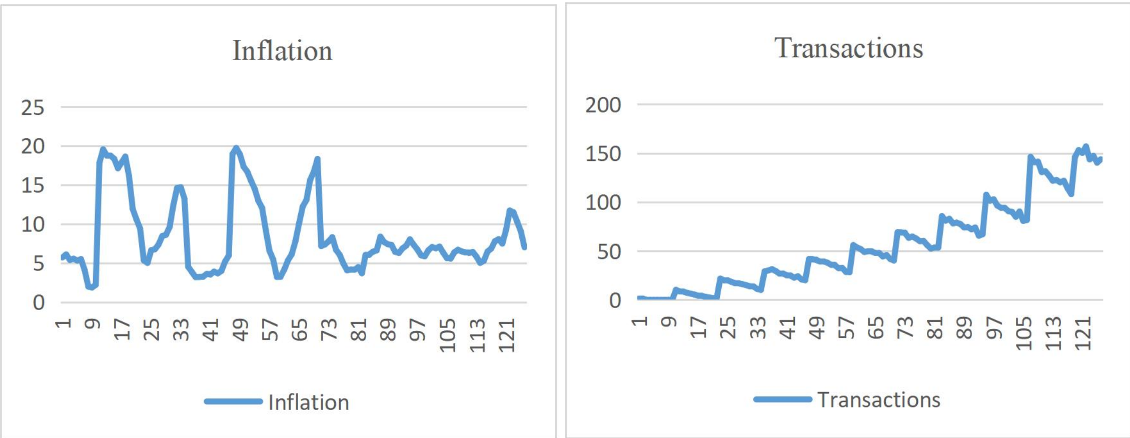

Fig. 2: Trend of Monthly Inflation and Mobile Phone transactions (in KSHS Millions) in Kenya

Source of Data: Central Bank of Kenya Statistical Bulletin

Fig.3 shows the trend between monthly inflation and log of transactions**.** The data illustrates a negative relationship between the increase of inflation and number of transactions. The research found out that an increase in inflation leads to a decrease in the number of transactions on the mobile money networks in Kenya. In April 2009 a decrease in inflation from 12.42 percent to 9.61 percent lead to an increase of mobile money transactions from Kshs 13.776 million to Kshs 15.048 million in the month of May. The higher and growing rate of transfers and use of mobile payments increase money velocity in the economy making finance more accessible to a larger number of people in the population. Increase in money velocity is generally related to inflation.

The research collected data of 126 months and it indicated a consistent growth of value of mobile money deposits since the setting up of Mpesa and even the entrance of other mobile money service providers such as Airtel Money and Equitel. Further the researchers observed that there was a large increase in value of mobile money deposits when inflation reduced causing the liquidity to increase in the market.

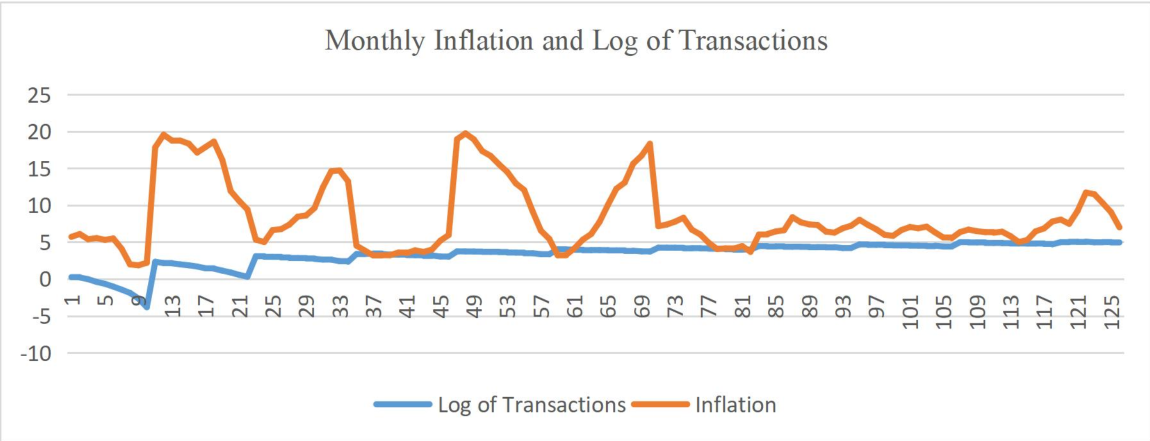

Fig.3: Monthly Inflation and Log of Transactions
Source of data: Central Bank of Kenya Statistical Bulletin

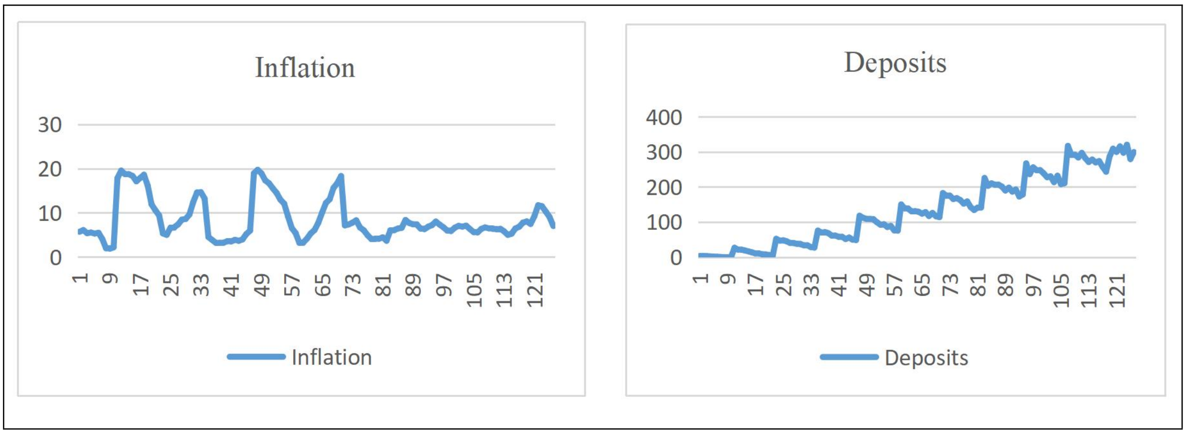

Fig. 4. Monthly Inflation and the amount of monthly deposits (in KSHS Billions)
Source of Data: Central Bank of Kenya Statistical Bulletin

The data line graph for mobile money deposits in Fig. 4 above shows that deposits and inflation have a relationship. The deposit volume shows that they display a trend and seasonality which is clearly shown in the significant growth illustrated in the line graph. The data illustrates that inflation went to a maximum of 19.72% while the deposits are increasing on a monthly basis and show seasonality month to month. The data is analysed using logs in order for the trend and seasonality to be eliminated, the line graph in Fig. 5 below shows the de-trended deposits. The economic effect of growth in deposits shows that there is high money circulation in the economy which is a precursor for high inflation rates.

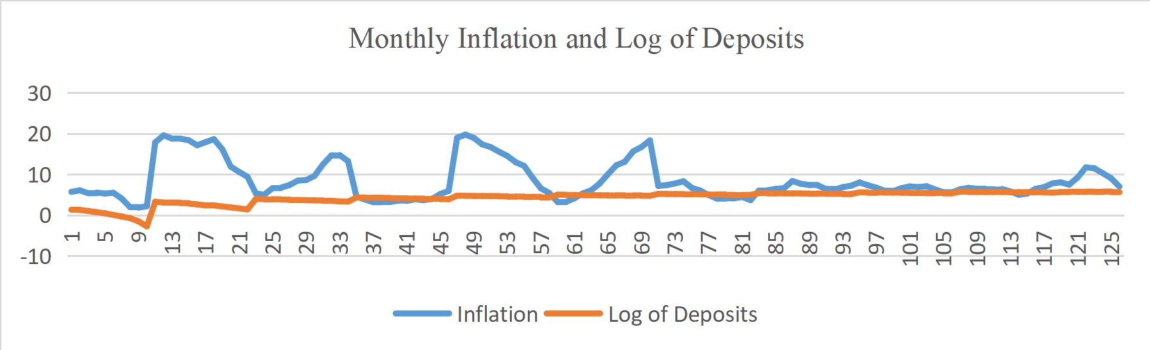

Fig. 5: Monthly Inflation and Log of Deposits

Source of Data: Central Bank of Kenya Statistical Bulletin

Next, Table 2 shows the summary of statistics after de-trending the variables.

TABLE 2: Descriptive statistics results (1)

Variable	Inflation %	Log of the number of transactions	Log of amount of money deposited
Observations	126	126	126
Mean	8.4280	3.3428	4.2722
Std. Dev	4.6587	1.6934	1.6274
Minimum	1.85	-3.8297	-2.7427
Maximum	19.72	5.0552	5.7688
Skewness	1.0665	-1.8726	-1.9049
Kurtosis	3.0342	6.6615	6.7787

Table 2 above shows the summary of descriptive statistics after generating the Logs of transactions and deposits to de-trend the variables. The findings show negative minimum values for Log of transactions and Log of deposits. The variables also show high Kurtosis levels which ranges > 3. The variables also show presence of negative skewness. To eliminate the negative values a constant value (10) is added to the values of transactions and deposits and then Logs of the variables are generated. Table 3 below shows the findings after generation of the logs of transactions1 and deposits1 and the variables are now labelled as Log of transactions 1 and Log of Deposits 1. Notably, kurtosis level is now in the normal range < 3. There is still presence of negative skewness.

TABLE 3: Descriptive statistics results (2)

Variable	Inflation %	Log of the number of transactions1	Log of amount of money deposited1
Observations	126	126	126
Mean	8.4280	3.9064	4.6054

Std. Dev	4.6587	.8179	1.0071
Minimum	1.85	2.3047	2.3090
Maximum	19.72	5.1170	5.7996
Skewness	1.0665	-.4632	-.8538
Kurtosis	3.0342	2.1928	2.6463

The next step is the correlation matrix which determines the relationship between the variables and their significance level.

TABLE 4: Correlation matrix results

Variable	Inflation	Log of transactions1	Log of deposits1
Inflation	1.0000	-	-
Log of Transactions 1	-0.1976* (0.0266)	1.0000	-
Log of Deposits 1	-0.1543 (0.0846)	0.9896* (0.0000)	1.0000

*Note *denotes significant*

The correlation matrix results show that there is negative and significant relationship between Log of Transactions 1 and inflation, and negative and insignificant relationship between Log of Deposits 1 and inflation. Log of Transactions1 and Log of Deposits1 have a positive and significant relationship though P > 0.8 indicating high correlation between the variables and thus presence of multicollinearity between the variables. The next step was to administer an ARDL bound test of Co-integration approach as described in the proceeding subsection to estimate the long run and short run relationships between the variables.

4.2. ARDL Bounds test of Co-integration approach
4.2.1. Preliminary unit root tests results

The first step is the Preliminary unit root analysis in Table 5 using Phillips–Perron test [30] which incorporates an automatic correction to the Dickey Fuller [31] procedure to allow for auto–correlated residuals shows that the variables Log of Transactions1 and Log of Deposits1 are I (1) and Inflation is I (0) and thus are applicable

TABLE 5: Unit root results

Variable	Phillips-Perron test					
	Test statistic		Test critical values z (t)			
	Level	First difference	1 %	5 %	10 %	Mackinnon p value for z (t)
Inflation	- 3.663	-9.200	-3.502	-2.888	-2.578	0.0000
Log of transactions 1	-1.341	-12.350	-3.502	-2.888	-2.578	0.0000
Log of deposits 1	- 1.708	- 12.882	-3.502	-2.888	-2.578	0.0000

for ARDL bounds test of Co-integration approach. The ARDL approach is applicable where the regressors' are I (0), I (1) or mutually co–integrated. Therefore, it does not require pretesting of the variables included in the model for unit roots like the Johansen and Juselius [32] approach. However, it is still necessary to conduct unit root tests because ARDL bounds test of co-integration approach fails for variables which are I (2) which leads to crashing of the ARDL technique.

4.2.2. ARDL regression using AIC as Optimal Information Criterion

Table 6 below shows the results after an ARDL regression is estimated using AIC as the optimal information criterion. AIC is chosen as the optimal information criterion since it is a superior method and gives relatively efficient estimates and thus allows the co-integration relationship to be estimated by OLS once the lag order of the model is identified.
After determining the optimal information criterion for ARDL model, the next step was to determine whether there was co-integration and long run relationship among the variables. The results are proffered in the following subsection 4.2.3.

TABLE 6: ARDL regression using AIC as Optimal Information Criterion

ARDL Regression Sample: 5 - 126			
Variable	Coefficient	Std. Error	P > | t |
Inflation *L1*	1.078759	.0821464	0.000
L2	-.2524737	.0812231	0.002
Log of Transactions 1	-21.1515951	4.493071	0.000
L1	20.07541	4.554412	0.000
Log of Deposits 1	16.86537	3.352772	0.000
L1	-16.07247	3.387018	0.000
Cons	2.077548	1.267124	0.104

4.2.3. ARDL Co-integration test results

To check for long run relationship among the variables the following model was adopted:

$$\Delta \textbf{Inflation}_t = \lambda_0 + \sum_{i=1}^{k} \theta_i \Delta \textbf{Inflation}_{t-1} + \sum_{i=0}^{k} \delta_i \Delta \textbf{ Log Transactions1}_{t-1} + \sum_{i=0}^{k} \pi_i \Delta \textbf{ Log Deposits1}_{t-1} + \beta_4 \textbf{ Inflation}_{t-1} + \beta_5 \textbf{LogTransactions1}_{t-1} + \beta_6 \textbf{ Log Deposits1}_{t-1} + u_t \quad \ldots\ldots (4)$$

Where Δ is the difference operator; Inflation at time t; Transactions1 at time t, Deposits1 at time t; t represents time; Log stands for logarithms; k is the lag length and u is the error term assumed to be serially uncorrelated. The parameter θ_i , δ_i , π_i are the short run dynamic coefficients of the ARDL model while β_4, β_5, β_6, are the long run parameters (elasticity's).

Table 7 below shows the findings for the co-integration test and the null hypothesis of no co-integration is rejected. This implies that there is long run relationship among the variables because the F statistic (4.668) is greater than the lower critical values for I (0) and upper critical values I (1) at 10% significance level and lower critical values I (0) at 5% significance level. Likewise, the T statistic (-3.684) is less than the lower critical values for I (0) and, upper critical values I (1) at 10% and 5% significance level and lower critical values I (0) at 1% significance level.

TABLE 7: ARDL Co-integration test results

Pesaran, Shin & Smith (2001) critical values	10%		5%		1%	
	I (0)	I (1)	I (0)	I (1)	I (0)	I (1)
	3.17	4.14	3.79	4.85	5.15	6.36
F statistic	4.668					
	10%		5%		1%	
	I (0)	I (1)	I (0)	I (0)	I (0)	I (1)
	-2.57	-3.21	-2.86	-3.53	-3.43	-4.10
T statistic	-3.684					
K (2): no of independent variables – Log of Transactions 1, Log of Deposits 1						

An ARDL Bounds test of Co-integration can only be applied when there is one co-integrating relationship and the Johansen and Juselius [31] approach becomes the alternative when there are multiple co–integrating vectors. But, since there was one co-integrating vector among the underlying variables an ARDL model of the following form was constructed:

$$\textbf{Inflation}_t = \delta_0 + \sum_{i=1}^{k} \lambda_i \textbf{ Inflation}_{t-1} + \sum_{i=0}^{k} \delta_{1i} \textbf{ Log Transactions1}_{t-1} + \sum_{i=0}^{k} \delta_{2i} \textbf{ Log Deposits1}_{t-1} + + u_t \quad \ldots\ldots (5)$$

Next, the ARDL model was re–parameterized into an error correction model (ECM) through a simple linear reparametrization. The reparametrization is possible because the ARDL is a dynamic single equation model and of the same form with the ECM. The re-parameterized result from the ARDL model in equation (5) gives the short run dynamics and long run relationship of the variables represented by equations (6), (7), (8) and (9) as shown in subsection 4.2.4 and for each equation an error correction test and diagnostic tests were carried out. Note: Due to the presence of multicollinearity between Log of Transactions1 and Log of Deposits1 they are not estimated within the same error correction equation in the ARDL error correction model.

4.2.4 ARDL Error Correction Model

$$\Delta\textbf{Inflation}_t = \varphi_0 + \sum_{i=1}^{k} \varphi_i \Delta \textbf{Inflation}_{t-1} + \sum_{i=0}^{k} \beta_i \Delta \textbf{ Log Transactions1}_{t-1} + \delta ECT_{it-1} + u_{1t} \ldots\ldots (6)$$

$$\Delta \textbf{ Log Transactions1}_t = \phi_0 + \sum_{i=1}^{k} \phi_i \Delta \textbf{ Log Transactions1}_{t-1} + \sum_{i=0}^{k} \tau_i \Delta \textbf{Inflation}_{t-1} + \alpha_i ECT_{it-1} + u_{2t} \ldots\ldots (7)$$

$$\Delta\textbf{Inflation}_t = \varphi_0 + \sum_{i=1}^{k} \varphi_i \Delta \textbf{Inflation}_{t-1} + \sum_{i=0}^{k} \beta_i \Delta \textbf{ Log Deposits1}_{t-1} + \delta ECT_{it-1} + u_{3t} \ldots\ldots (8)$$

$$\Delta \textbf{ Log Deposits1}_t = \phi_0 + \sum_{i=1}^{k} \phi_i \Delta \textbf{ Log Deposits1}_{t-1} + \sum_{i=0}^{k} \tau_i \Delta \textbf{Inflation}_{t-1} + \alpha_i ECT_{it-1} + u_{2t} \ldots\ldots (9)$$

Where Δ *is the first difference operator while* $\Delta Inflation_{t-1}$, $\Delta\ Log\ Transactions1_{t-1}$, $\Delta Log Deposits1_{t-1}$ *and captures the short run dynamics of the model;* u_t *'s are the error terms* *assumed to be uncorrelated;* ECT_{it-1} *'s are the error correction terms obtained from the equations. The coefficients of the ECT (δ &α) captures the adjustment towards long run equilibrium.*

4.2.4.1 Error correction results for equation 6

Table 8 below shows the findings for the error correction test for equation 6 above. The findings show long run relationship between Inflation and Log of Transactions1, but the coefficient is insignificant. This implies that there is insignificant relationship between Log of Transactions1 and inflation in the long run and a 1% increase in Log of Transactions1 results to a decrease in inflation by 1.46 percentage points. The short run relationship represents the disequilibrium caused by short run shocks of the previous period towards long run value. A unit increase in inflation results in an increase in inflation by 0.26 percentage points and significant at LD and an increase in inflation by 0.13 percentage points and insignificant at L2D. The adjusted inflation represents the error correction term which is negative and significant. This means that the dependent variable inflation adjusts back to long run equilibrium following shocks in the short run. The coefficient (-.22) represents the speed at which there is adjustment of the model from short run to the long run equilibrium at 22 per cent and shows that a 1 percent increase in random shocks to equilibrium will lead to 0.22 percent correction in the equilibrium. After the error correction test, an ARDL regression is run and diagnostic tests are administered and the findings are shown in Table 8 above. The findings show that the model has passed the tests for autocorrelation where p > 0.05 and null hypothesis is accepted and no multicollinearity where MVIF < 5. There is non-normality in inflation and Log

TABLE 8: Error Correction results for equation 6

D. Inflation		**LR**	**SR**	**Diagnostic Tests Results**
ADJ Inflation				BG LM = 0.3238 > 0.05
L1	-.228*** (0.00)			BP = 0.03 < 0.05 MVIF = 1.16 < 5
LD			.263*** (0.00)	SWILK = Inflation, Log of Transactions1 < 0.05
L2D			.137 (0.13)	Cusum squared test = parameter stability
Log of Transactions1		-1.46 (0.23)		
Constant			3.25*** (0.01)	
No. of observations = 122 R-squared = .16 Adj R-squared = .13 Sample = 5 - 126				

*Note: ***indicates significant at 1%. Numbers in parenthesis indicate p>t. BG LM =Breusch Godfrey langrange Multiplier test, BP = Breusch Pagan test, MVIF =Mean Variance Inflation Factor test, SWILK =Shapiro wilk test.* ***LR*** *= long run coefficients,* ***SR****= short run coefficients.* ***ADJ Inflation*** *=Adjusted inflation,* ***Log of Transactions1*** *= Log of the number of transactions.*

of Transactions1 using SWILK test where p < 0.05. There is presence of heteroscedasticity, and a regression is run using robust standard errors to eliminate heteroscedasticity. The model has passed the stability diagnostic test in the cusum squared test and this implies there is parameter stability if the cumulative sum is within the area between the 5% critical lines [33]. Next, an error correction test is administered for equation 7 and results are discussed in the next subsection 4.2.4.2.

4.2.4.2 Error correction results for equation 7

Table 9 below shows the findings for the error correction test for equation 7 above. The findings show long run relationship between Inflation and Log of Transactions1, but the coefficient is insignificant. This implies that there is insignificant relationship between inflation and Log of Transactions1 in the long run and a unit increase in inflation results to a decrease in Log of Transactions1 by 7%. The variables do not present any disequilibrium caused by short run shocks of the previous period towards Long- run value. The Log of Transactions1 represents

Table 9: Error correction results for equation 7

D. Log of Transactions1		**LR**	**SR**	**Diagnostic Tests Results**
ADJ Log of Transactions1				BG LM = 0.3524 > 0.05 BP = 0.00 < 0.05
L1	-.036* (0.07)			MVIF = 1.06 < 5 SWILK = Inflation, Log of Transactions1 < 0.05
Inflation		-.07 (0.42)		Cusum squared test = parameter stability
Constant			.18** (0.04)	
No. of observations = 122 R-squared = .02 Adj R-squared = .01 Sample = 5 - 126				

*Note: ***indicates significant at 1%. Numbers in parenthesis indicate p>t. BG LM =Breusch Godfrey langrange Multiplier test, BP = Breusch Pagan test, MVIF =Mean Variance Inflation Factor test, SWILK =Shapiro wilk test.* ***LR*** *= long run coefficients,* ***SR****= short run coefficients.* ***ADJ Log of Transactions1*** *= Adjusted Log of the number of transactions.*

the error correction term which is negative and significant. This means that the dependent variable Log of Transactions1 adjusts back to long run equilibrium following shocks in the short run. The coefficient (-.03) represents the speed at which there is adjustment of the model from short run to the long run equilibrium at 3 per cent and shows that a 1 percent increase in random shocks to equilibrium will lead to 0.03 percent correction in the equilibrium. After the error correction test, an ARDL regression is run and diagnostic tests are administered, and the findings are shown in Table 9 above. The findings show that the model has passed the tests for autocorrelation where p > 0.05 and null hypothesis is accepted and no multicollinearity where MVIF < 5. There is non-normality in inflation and Log of Transactions1 using SWILK test where p < 0.05. There is presence of heteroscedasticity, and a regression is run using robust standard errors to eliminate heteroscedasticity. The model has passed the stability diagnostic test in the cusum squared test and this implies there is parameter stability if the cumulative sum is within the area between the 5% critical lines [33]. Next, an error correction test is administered for equation 8 and results are discussed in the next subsection 4.2.4.3.

4.2.4.3 Error correction test for equation 8

Table 10 below shows the findings for the error correction test for equation 8. The findings show long run relationship between Inflation and Log of Deposits1, but the coefficient is insignificant. This implies that there is insignificant relationship between Log of Deposits1 and inflation in the long run and a 1 % increase in Log of Deposits1 results to a decrease in inflation by 1.06 percentage points. The short run relationship represents the disequilibrium caused by short run shocks of the previous period towards long run value. 1 unit increase in inflation results to an increase in inflation by 0.2 percentage points and significant at LD. 1 unit increase in inflation results to an increase in inflation by 0.1 percentage points. 1% increase in Log of Deposits1 results in an increase in inflation by 1.81 percentage points and significant at D1. The adjusted inflation represents the error correction term which is negative and Significant. This means that the dependent variable inflation adjusts back to long run equilibrium following shocks in the short run. The coefficient (-.21) represents the speed at which

Table 10: Error correction test results for equation 8

D. Inflation		**LR**	**SR**	**Diagnostic Tests Results**
ADJ Inflation				BG LM = 0.3871 > 0.05
L1				BP = 0.00 < 0.05
	-.21***			MVIF = 1.13 < 5
	(0.00)			SWILK = Inflation, Log of
LD			.26***	Deposits1 < 0.05
			(0.00)	Cusum squared test = parameter
L2D			.13	stability
			(0.14)	
Log of Deposits1		-1.06		
		(0.31)		
D1			1.81**	
			(0.05)	
Constant			.18**	
			(0.04)	
No. of observations = 122				
R-squared = .18				
Adj R-squared = .15				
Sample = 5 - 126				

*Note: ***indicates significant at 1%. Numbers in parenthesis indicate p>t. BG LM =Breusch Godfrey langrange Multiplier test, BP = Breusch Pagan test, MVIF =Mean Variance Inflation Factor test, SWILK =Shapiro wilk test.* ***LR*** *= long run coefficients,* ***SR****= short run coefficients.* ***ADJ Inflation*** *= Adjusted Inflation,* ***Log of Deposits1*** *= Log of amount of deposits transferred.*

there is adjustment of the model from short run to the long run equilibrium at 21 per cent and shows that a 1 percent increase in random shocks to equilibrium will lead to 0.21 percent correction in the equilibrium. After the error correction test, an ARDL regression is run and diagnostic tests are administered, and the findings are shown in Table 4.10 above. The findings show that the model has passed the tests for autocorrelation where $p > 0.05$ and null hypothesis is accepted and no multicollinearity where MVIF < 5. There is non-normality in inflation and Log of Deposits1 using SWILK test where $p < 0.05$. There is presence of heteroscedasticity, and a regression is run using robust standard errors to eliminate heteroscedasticity. The model has passed the stability diagnostic test in the cusum squared test and this implies there is parameter stability if the cumulative sum is within the area between the 5% critical lines [32]. Next, an error correction test is administered for equation 9 and results are discussed in the next subsection 4.2.4.4.

4.2.4.4 Error correction test results for equation 9

Table 11 below shows the findings for the error correction test for equation 9. The findings show long run relationship between Inflation and Log of Deposits1, but the coefficient is insignificant. This implies that there is insignificant relationship between inflation and Log of Deposits1 in the long run and a unit increase in inflation results to a decrease in Log of Deposits1 by 9%. The short run relationship represents the disequilibrium caused by short run shocks of the previous period towards long run value. 1% increase in Log of Deposits1 by 1% results in a decrease on Log of Deposits by 12% and insignificant at LD. 1 unit increase in inflation results to an increase in Log of Deposits1 by 19% and significant at D1. The adjusted Log of Deposits1 represents the error correction term which is negative and Significant. This means that the dependent variable Log of Deposits1 adjusts back to long run equilibrium following shocks in the short run. The coefficient (-.04) represents the speed at which there

TABLE 11: Error correction test for equation 9

D. Log of Deposits1		**LR**	**SR**	**Diagnostic Tests Results**
ADJ Log of Deposits1				BG LM = 0.6233 > 0.05 BP = 0.00 < 0.05
L1	-.04** (0.03)			MVIF = 1.07 < 5 SWILK = Inflation, Log of Deposits1 < 0.05
LD			-.12 (0.15)	Cusum squared test = parameter stability
Inflation		-.09 (0.35)		
D1			.19** (0.02)	
Constant			.28*** (0.01)	
No. of observations = 122 R-squared = .08 Adj R-squared = .05 Sample = 5 - 126				

*Note: ***indicates significant at 1%. Numbers in parenthesis indicate p>t. BG LM =Breusch Godfrey langrange Multiplier test, BP = Breusch Pagan test, MVIF =Mean Variance Inflation Factor test, SWILK =Shapiro wilk test.* ***LR*** *= long run coefficients,* ***SR****= short run coefficients.* ***ADJ Log of Deposits1*** *= Log of amount of deposits transferred.*

is adjustment of the model from short run to the long run equilibrium at 4 per cent and shows that a 1 percent increase in random shocks to equilibrium will lead to 0.04 percent correction in the equilibrium. After the error correction test, an ARDL regression is run and diagnostic tests are administered, and the findings are shown in Table 11 above. The findings show that the model has passed the tests for autocorrelation where $p > 0.05$ and null hypothesis is accepted and no multicollinearity where MVIF < 5. There is non-normality in inflation and Log of Deposits1 using SWILK test where $p < 0.05$. There is presence of heteroscedasticity, and a regression is run using robust standard errors to eliminate heteroscedasticity. The model has passed the stability diagnostic test in the cusum squared test and this implies there is parameter stability if the cumulative sum is within the area between the 5% critical lines [33]. The next step was to determine a robustness check as shown in the next subsection 4.3.

4.3. Robustness check

The findings of the ARDL bounds test approach in subsection 4.2.1 were tested for robustness and consistency using the Johansen co-integration test, VECM approach and post estimation tests as shown in the proceeding subsections 4.3.3, 4.3.4 and 4.3.5 but as a preliminary the unit root test and optimal lag length selection were carried out first.

4.3.1 Unit root results

The first step was to determine the unit root results as shown in Table 12 below and ensure the variables are I (1) at first difference using the Phillips Perron [29] test as discussed in subsection 3.2. The results are similar in both models since the same procedure is used to determine the unit root test.

TABLE 12: Unit root results

Variables	Phillips-Perron test					
	Test statistic		Test critical values z (t)			
	Level	First difference	1 %	5 %	10 %	Mackinnon p value for z (t)
Inflation	- 3.663	-9.200	-3.502	-2.888	-2.578	0.0000
Log of transactions 1	-1.341	-12.350	-3.502	-2.888	-2.578	0.0000
Log of deposits 1	- 1.708	- 12.882	-3.502	-2.888	-2.578	0.0000

Next step is the optimal lag length selection as shown in the next subsection 4.3.2.

4.3.2. Optimal lag length selection results

The second step is the optimal lag length selection, and the findings show that the optimal lag length was lag 1 – using the AIC criterion since it has the smallest value and is significant. Thus, lag 1 was chosen as an optimal lag for the analysis of the proceeding findings.

TABLE 13: Optimal lag length selection results

Sample 5-126		No. of observations - 122		
lag	p	AIC	HQIC	SBIC
1	0.000	1.09614*	1.20816*	1.37195*

*Note: * denotes significance*

Next, the third step determines co-integration and long run relationship using the Johansen co-integration technique which gives the number of co-integrating equations and their significant lag length as shown in Table 14 below.

4.3.3. Johansen co-integration test results

Table 14 below presents the findings of the Johansen co- integration test which shows no multiple co-integrating equations at lag 1. The findings show some consistency with the ARDL bounds test approach because the ARDL model would only be inappropriate if there were multiple co-integrating vectors.

TABLE 14: Johansen test for co-integration results

Johansen tests for co- integration
Trend: constant — Number of obs = 125
Sample: 5 - 126 — Lags = 1

Maximum Rank	Parms	LL	Eigenvalue	Trace Statistic	5% Critical Value
0	3	-62.774108		18.6929*	29.68
1	8	-56.953164	0.08893	7.0510	15.41
2	11	-54.091394	0.04476	1.3274	3.76
3	12	-53.427682	0.01056		

Maximum Rank	Parms	LL	Eigenvalue	SBIC	HQIC	AIC
0	3	-62.774108		1.120265*	1.079962*	1.052386
1	8	-56.953164	0.08893	1.220263	1.112786	1.039251
2	11	-54.091394	0.04476	1.290354	1.142574	1.041462
3	12	-53.427682	0.01056	1.318361	1.157146	1.046843

*Note: *indicates significant*

After the Johansen co-integration test, the next step was to determine the short run coefficients and the error correction terms using the Vector Error Correction Model shown in Table 15 below.

4.3.3. Vector error-correction model results

The findings of the VECM in Table 15 below shows there is consistency in the results for both the ARDL model

TABLE 15: Vector error correction model results

Vector Error-Correction Model					
Sample:2 - 126		No. of obs = 125		AIC = 1.039251 HQIC = 1.112786 SBIC = 1.220263	
Equation	Parms	RMSE	R-sq	Chi2	p > chi2
D_ Inflation	2	2.44352	0.0753	10.01498	0.0067
D_ Log of transactions1	2	.170902	0.0307	3.895522	0.1426
D_ Log of Deposits1	2	.230166	0.0380	4.854054	0.0883
D_ Inflation Ce1 *L1* -.13***			D_ Log of Transactions 1 Ce1 *L1* -.004		
D__ Log of Deposits1 Ce1 *L1* - .007*					

****, ** and * indicates significant at 1%, 5% and 10% respectively*

and VECM for Inflation where the co-integrating equation one has an error correction term with the value (-.22) for the ARDL model and (-.13) for the VECM. After determining the short run coefficients and error correction term, the next step was to carry out the post estimation tests as shown in subsection 4.3.4 below. This includes the normality test, serial correlation test, impulse response functions and predicted co-integrating equation.

4.3.4 Post estimation test results

4.3.4.1. Normality of residuals and serial correlation results

The normality of residuals is tested using the Jarque-bera test, skewness test and kurtosis test. The findings on Table 16 show non-normality of the residuals for all the variables where $p < 0.05$. The Langrange multiplier test is used to test for serial auto correlation. The findings in Table 4.16 shows that the $p > 0.05$ therefore the null hypothesis of no autocorrelation at lag order is accepted.

TABLE 16: Normality of residuals and serial correlation test results

Variable	**Jarque-Bera test Prob > chi2**	**Skewness test Prob > chi2**	**Kurtosis test Prob > chi2**	**Langrange-Multiplier test Lag Prob > chi2**
D_ Inflation	0.00000	0.00000	0.000000	1 0.94715
D_ Log of Transactions1	0.00000	0.00000	0.00000	2 0.86939
D_ Log of Deposits1	0.00000	0.00000	0.00000	
ALL	0.00000	0.00071	0.00000	

The next step in the post estimations test is to estimate the orthogonalized impulse response functions as shown in Fig. 6 in subsection 4.3.4.2.

4.3.4.2. Orthogonalized impulse response function results

Fig. 6 below shows the findings for the orthogonalized impulse response functions which were estimated by setting 10 as the forecast horizon. The variables display the effect of insignificant and permanents shocks on themselves and on each other for all periods.

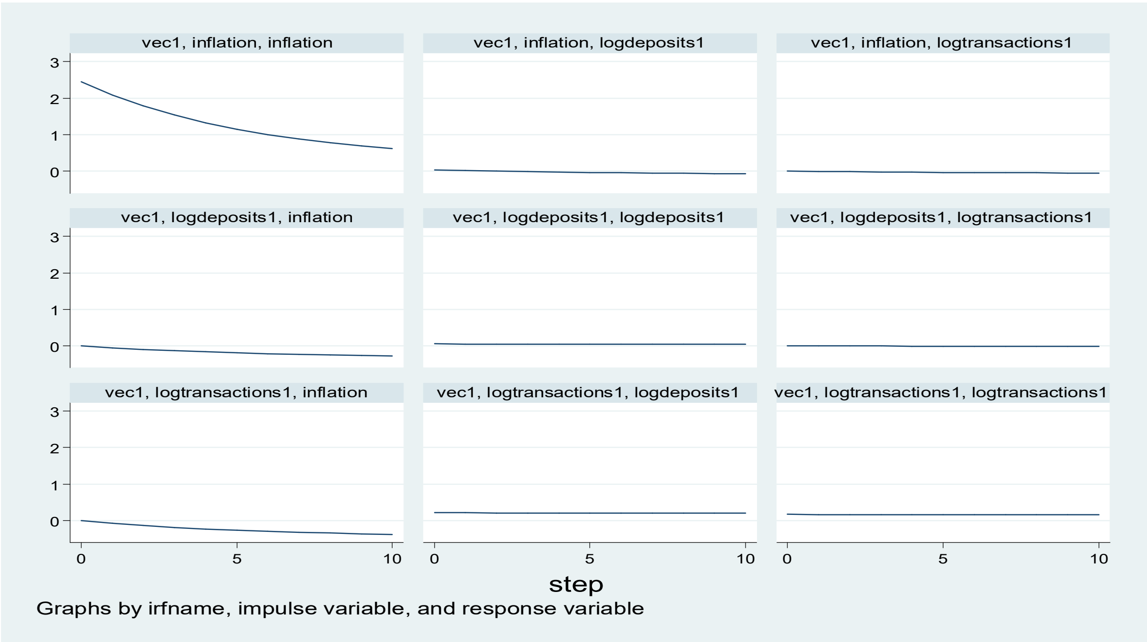

Fig. 6: Orthogonalized Impulse response functions

The next step in the post estimations test is to graph the predicted values of the co-integrating equation as shown in Fig. 7 in subsection 4.3.4.3.

4.3.4.3. Graph of the predicted values of co-integrating equation

The graph of the predicted values as shown in Figure 7 below shows that the model is stable and has the characteristics of a stationary series.

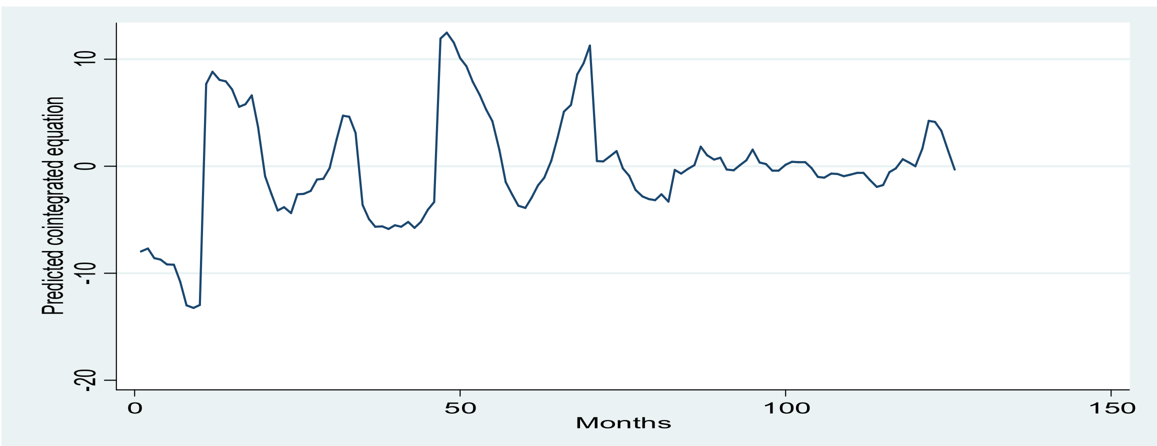

Fig. 7: Graph of predicted values of co-integrating equation

Next, the model is fitted as shown in subsection 4.4 next.

4.4. Model fitting

The ARDL Error Correction Model was represented by equations which are fitted as follows;
The fitted equation (6) is as follows for the short run and long run coefficients and ECT;

$$\textbf{Inflation}_t = 3.25 + 0.26_{\text{Inflation}} - 0.13_{\text{Inflation}} - 1.46_{\text{Log of Transactions1}} - 0.22_{\text{Inflation}} \quad (10)$$

The fitted equation (7) is as follows for the short run and long run coefficients and ECT;

$$\textbf{Log of Transactions1}_t = 0.18 - 0.07_{\text{Inflation}} - 0.03_{\text{Log of Transactions1}} \quad (11)$$

The fitted equation (8) is as follows for the short run and long run coefficients and ECT;

$$\textbf{Inflation}_t = 0.18 + 0.13_{\text{Inflation}} + 0.26_{\text{Inflation}} + 1.81_{\text{Log of Deposits1}} - 1.06_{\text{Log of Deposits1}} - 0.21_{\text{Inflation}} \quad (12)$$

The fitted equation (9) is as follows for the short run and long run coefficients and ECT;

$$\textbf{Log of Deposits1}_t = 0.28 - 0.12_{\text{Log of Deposits1}} + 0.19_{\text{Inflation}} - 0.04_{\text{Log of Deposits1}} \quad (13)$$

5. CONCLUSIONS AND RECOMMENDATIONS

This chapter presents the conclusions, recommendations for policy action and highlights the areas for further research.

5.1 Conclusion

The first objective of the paper was to examine the relationship between telephony money transactions and inflation in Kenya in the period 2007-2017. The findings show negative and insignificant relationship between inflation and number of mobile phone transactions and inflation and value of mobile phone deposits in the long run. The insignificant relationship can be explained by the fact that telephony money transactions only form a small proportion of broad money which is a component of the total money supply.

The second objective was to determine the causality between telephony money transactions and inflation and was formed on the basis of the point by [3], [4] on the need to determine the causal channel between money growth and inflation which can arise because liquid assets are the most spendable part of the private sector wealth. The findings show that the error correction terms are negative and statistically significant thus revealing bidirectional causality between inflation and number of transactions and inflation and value of deposits therefore the null hypotheses are rejected. This therefore means that there is bidirectional causality between the telephony money transactions constructs and inflation. Consequently, this means that an increase in telephony money transactions causes an increase in inflation and an increase in inflation causes an increase in telephony money transactions which are a part of broad money which is also a component of the total money supply.

The findings support the view held by [16] that increased telephony money transactions promotes increased velocity of circulation, and this will increase ‘effective money’ and hence inflation. However, it is also evident that so far, the CBK’s objective of regulating telephony money transactions are effective because only a certain amount of money can be held and transacted by a telephony money account holder and also the M-kesho savings account under M-pesa charges small interest rates for transactions this helps to counter- balance the effect on inflation.

5.2 Recommendations for policy action

The evidence of bidirectional causality implies that there should be continuous implementation of effective monetary and inflation targeting mechanisms which will prove to be effective in managing inflation and money supply using tools such as interest rates, because interest rates and inflation rates tend to move in opposite directions, and the likely actions a Central Bank will take to raise or lower interest rates become more apparent under an inflation targeting policy and advocates of inflation targeting think this leads to increased economic stability.

Inflation and monetary targeting mechanism require, that firstly, the Central Bank is able- to conduct monetary policy with some degree of independence and, secondly, is the willingness and ability of monetary authorities not to target other indicators, such as wages, the level of employment, or the exchange rate. Kenya as an emerging economy to fully realise effective monetary and inflation targeting mechanisms must accompany the adoption of inflation targeting with better fiscal policies. This means enhancement of technical capacity in the Central Bank and improvement of macroeconomic data, because inflation targeting also depends to a large extent on the interest rate channel to transmit monetary policy and taking steps to strengthen and develop the financial sector. Thus, the monetary policy outcomes after the adoption of inflation targeting may reflect broader economic, and not just monetary policy making.

5.3. Areas for future research

A further area for research is the use of ARDL model to examine the effect of telephony money transactions on inflation in Kenya while controlling for the effects of other factors on inflation because the study was limited to the telephony money transactions constructs and inflation.

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