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COINTEGRATION WITH STRUCTURAL BREAKS MONEY DEMAND, INCOME, INTEREST RATES AND EXCHANGE RATE MODELS: IMPLICATIONS FOR EFFECTIVENESS OF MONETARY POLICY IN UGANDA

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Abstract: *The study investigated the dynamic relationships between money demand, income, prices, real effective exchange rates, and the savings, lending, discount and deposit rates in Uganda using a modified ARDL model catering for cointegration and structural breaks. It was established that: cointegration with structural breaks existed in all cases; monetary policy is not effectively transmitted through lending rates but is effectively transmitted through the savings, deposit and discount rates in the short-run as well as the saving and deposit rate in the long-run; the exchange rate transmission channel is effective both in the short-run and in the long-run; after accounting for structural breaks, the equations for all the variables are stable except that for deposit rate which is partially stable; money demand has an inelastic positive effect on income in the long-run only, has an inelastic positive effect in the short-run but an elastic positive effect in the long-run on price; increasing the saving rate is a more effective means of increasing income in Uganda; and that the discount rate has a negative inelastic effect on money demand and income in the long-run. It is recommended that:*

continuous studies to determine the most effective monetary policy transmission channel(s) be conducted regularly by monetary authorities as a rule in all countries; and efforts to address the shortcomings devised on a continuous basis.

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1. INTRODUCTION

A solid and well-functioning financial sector plays a significant role in economic development. Monetary policy transmitted through the financial system plays a major role in ensuring that a country's output measured by gross domestic product (GDP) increases, which in turn leads to economic development. When GDP increases, for a given population, GDP per capita is expected to increase, ceteris paribus. This means that any country aiming at achieving a middle-income status, like Uganda as it is stated in the Uganda Vision (2040), should take measures aimed at ensuring that the monetary policies implemented are effectively delivered through the various channels, including the exchange rate, interest rate, asset prices, and credit aggregate channels. Laurens, Maino and Carare (n.d.) and Kamin, Turner and Van't Dack (1998) provide a good description of the four channels.

If the country implements a floating exchange rate system, the two major transmission channels are the exchange rate and interest rate channels. However, since developing countries are characterized by large informal sectors, with limited formal bank intermediaries that cater for a small proportion of the economic activities in the entire economy, the effectiveness of the interest rate channel is questionable. Also, the limited degree of integration with world financial markets puts to question the effectiveness of the exchange rate channel. This leads to the key question of whether monetary policy is effective in a developing country with floating exchange rates. This study investigates this question using Uganda as a case study.

Monetary policy development, implementation and monitoring evaluation must be based on the knowledge of the money demand function and its empirical attributes which are dynamic. Three attributes stand out; that is, its stability, stability of velocity of money and existence of structural breaks. According to Albulescu and Pépin (2018), a stable money demand, can impact economic activity and inflation, and as a result, monetary aggregates can effectively be used to achieve the monetary policy objective of stable economic growth with price stability. The velocity of money is a linear combination of production, money, and inflation. According to Bahmani (2008), testing the stability of money demand and testing the stability of the velocity of money achieve the same goal. The stability of the demand for money function and/or stability of the velocity of money is essential for stable economic growth. Structural breaks, among other attributes, also have key implications for monetary policy issues. Failure to cater for structural break in a money demand equation will lead to erroneous predictions of monetary policy effects on economic variables.

A stable money demand function has implications for monetary policy. It can be used to: guide the choice among the monetary policy instruments (Kumar, Webber and Fargher, 2013); predict the effects of money-supply shocks on the aggregate income given stable money multiplier (Narayan, 2010); provide valuable information for the nexus between money and inflation (Albulescu and Pépin (2018); and to predict the impact of various monetary policy options on macroeconomic aggregates in the real sector such as interest rates, savings, output, exchange rates, consumption, imports, exports, stock market, price level, and investment while these variables can also be used to predict money demand, implying invertibility of the money demand function (see Pradhan and Subramanian, 2003; Narayan and Narayan, 2008; and Nyong, 2014). Regarding the choice of instruments, Poole (1970) indicated that: with unstable liquidity preference, the interest rate targeting would be the appropriate option; if money demand is stable but the investment-savings relationship is unstable, monetary aggregate (M1 or M2) targeting is the suitable option for stabilizing the economy. Thus, knowledge of the stability of money demand or the lack of it is paramount for the implementation and formulation of appropriate monetary policy aimed at achieving stable economic growth with price stability.

Structural breaks, when they occur, signify changes in the parameters (constant, trend, and/or slope coefficients) of the initially stable money demand function. This implies that the relationship between money demand and the economic variables after the shock differs from that before the shock, thus relationships used to predict the effect of money demand on economic variables and vice versa, must be adjusted to account for the changes resulting from the shock(s).

Beginning with the early 1990s, the Government of Uganda, with the support the World Bank, undertook reforms in three broad areas, including: i) economic liberalization of interest rates and exchange rates; ii). institutional reforms to Bank of Uganda (BOU) and public sector Banks; and iii). banking laws and BOU Act legislative changes (Ating-Ego, 2022). With regard to monetary policy transmission, the Government through the Bank of Uganda, undertook measures aimed at strengthening the process of monetary transmission in Uganda. Das and Mandal (2000) reported that Uganda became more integrated with international financial markets, in a bid to strengthen the exchange rate channel of monetary transmission; and shifted from a base money monetary regime to an interest rate policy regime thereby making the interest rate transmission channel more effective. Further, there was more tracking and maintaining the inflation rates within specific limits, thus the greater reliance on monetary aggregates, especially M3 for tracking the future inflation in the policy formulation.

However, Montiel (2013) who investigated the effectiveness of the monetary system in Uganda for the period from December 2001 to 2011, when the central bank switched the monetary policy regime from monetary base targeting to interest rates targeting, reported a unique finding for a developing country whereby an increase in base money did not only lead to expected signs but also resulted in statistically significant coefficients for the bank lending rate, exchange rate, and the price level. However, he indicated that the impacts on the price level were quantitatively small; and that there was no significant impact on real economic activity in the short-run and no causal effect in the long-run. He attributed these results on the small formal financial system relative to the economy size. This brings to question the effectiveness of the policy instruments in affecting economic activities and moving the country into a middle income status.

Since 2010, the financial sector has had several reforms/developments that are expected to increase monetary policy effectiveness. Some of the developments that occurred after 2010 were highlighted by Ating-Ego (2022), including: i). launch of the Financial Inclusion Project by BOU in 2013; ii). issuance of Mobile Money Guidelines by BOU in 2013; iii). launch of the Financial Literacy Strategy 2013-2017 by BOU in 2013; iv). Financial Institutions Act amendment to accommodate agent banking, Islamic banking and bancassurance in 2016; v). launching of the Agent Banking Shared Platform by the agent banking company around the end of 2017; vi). launching of the 2017-2022 BOU and Ministry of Finance and Economic Development (MPED) Financial Inclusion Strategy (NFIS) 2017-2022 by the two institution in 2017; vii). development of the second Strategy for Financial Literacy in Uganda 2019-2024 by BOU and stakeholders in 2019; viii). ending implementation of NFIS 2017-2022 with the aim of streamlining the national financial inclusion agenda, with BOU as the Secretariat in September 2022; ix). Commencement of the development of the second NFIS 2022-2027 in 2022; x). passing of the National Payments System (NPS) Act 2020 in 2020; xi). gazetting of the implementation guidelines of NPS Act 2020 in 2021; and xii). Issuance of the NPS Consumer Protection Regulation by BOU in 2020.

Over the years, since 2010, the financial sector has been expanding as a response to the various reforms implemented in Uganda. Khisa (2011) reported that in October 2010, there were 22 licensed commercial banks, with nearly 400 bank branches and almost 600 automated teller machines and over 5 million bank accounts in Uganda. By January 2020, Uganda had a total of 11,000 banking agents and 13 million bank accounts (Busuulwa, 2020). According to Oketch (2022), there were UShs31 trillion deposits in the banking sector at the end of June 2021; bank accounts were UShs19.1 million for the period ended June 2021; while total bank assets were Shs39.7 trillion for the period ended June 2021. Further, Senyonyi (2023) reported that in December 2022, there were 25 commercial banks; USh45.44 trillion (approx. US$12.3 billion) total bank assets), of which 82.18 and 17.82 percent were held by the top 10 and remaining 15 commercial banks, respectively; while 57.54% of the total national banking assets were held by the 5 largest banks. According to Oketch (2023), commercial bank assets had grown to a tune of 48.3 trillion as of June 2023.

Over the years, the number of players in the banking sector in Uganda has grown to include non-commercial bank institutions in addition to the commercial banks. The non-commercial

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bank institutions include: Microfinance Deposit-taking Institutions (MDIS); Credit Institutions; Non- Deposit taking Microfinance Institutions (NDMF), Uganda Microfinance Regulatory Authority (UMRA) licensed money lenders, and licensed Saving and Credit Cooperative organizations (SACCOs), among others. As of March 2022, there were 150, 708 and 46 licensed NDMFs, UMRA licensed money lenders, and licensed SACCOs (UMRA, 2022). As of March 2023, there were still 25 licensed Banks (BOU, 31 March 2023a) and four licensed Credit Institutions (BOU, 31 March 2023b). As by August 2023, there were four Microfinance Deposit-taking Institutions (MDIS) in Uganda as of August 2023 ((BOU, 21 August 2023c).

For the above reforms to deliver results, in terms of ensuring the effectiveness of the monetary policy, and prediction of inflation based on monetary aggregates, it is necessary to establish the money supply-money demand equation empirical facts as well as the factors that influence money demand using various measures (Base money (M1), M2 and broad money (M3). This study will establish the nature of the money demand function as well as its usefulness in estimation and policy analysis in Uganda. Specifically, the study will: i). establish whether structural breaks have occurred for each of the variables in the money demand and income equations; ii). establish whether money demand and income are endogenously determined; iii). investigate the long-run (cointegration) and short-run relationships for income, money demand (M3), exchange rates, interest rates, and prices, and iv). determine whether the money demand and income equations are stable with or without structural breaks. This information will be used to guide monetary policy in Uganda while other countries can use the results as the basis for conducting similar studies and evaluating the effectiveness of their monetary policy systems.

2. OVERVIEW OF THE LITERATURE

Cointegration analysis can be done based on a single equation static model or a single equation dynamic model or by a full system model such as the vector auto-regression model (VAR) model, which does not require exogeneity assumption (Das and Mandal, 2000). However, Das and Mandal (2000) argued that single equations are only efficient when all the explanatory variables are weakly exogenous in the Engel, Hendry and Richards (1983) sense, otherwise violation of the exogeneity indicates that the estimation is biased and inefficient; and that the VAR has limited application because of the many parameters that would be estimated and the associated loss of degrees of freedom. The co-integration test was first introduced by Engle and Granger (1987) for a bi-variate setting. Other cointegration tests for testing the long-run equilibrium relationships in a multivariate setting were developed by Stock and Watson (1988), Johansen (1991), and Johansen and Juselius (1990). Engle and Granger (1987) indicated that the error correction model (ECM) contains information on both the short-run and long-run properties of the model with disequilibrium whereby the disequilibrium component is the process of adjusting to the long-run. Cointegration exists when a dynamic error correction form relating the variables in question exists. The concept of a stable long-run equilibrium is the statistical equivalence of cointegration (Granger, 1983 and 1986). Zivot (2003) provides a good overview of the different tests used to study structural changes.

The ECM approach has been used by several researchers to study the money demand using various definitions (M1, M2, M3, etc.) for the 1990s in several industrial and developing countries. Subramanian (2001) provides an excellent review of the techniques used, variables chosen, periods and frequencies selected and the major findings including the long-run income elasticities, interest elasticities or semi-elasticities as well as those of other variables included in the models (see Subramanian, 2001 for detailed discussions). Regarding the model specification, Subramanian, 2001 indicates that modeling the money demand should have scale, price and opportunity cost variables. The scale variable measures transactions related to economic activity, and can be represented by income, expenditure, and wealth concept, among other variables. The price variable chosen should be appropriate for the scale variable selected and may include the consumer price index, GDP deflator, wholesale price index, among others. The opportunity cost variable has two major ingredients, the own rate and the alternative return on money. If financial innovations have taken place in the economy, the own rate is key variable (Ericsson, 1998 presents further discussion on this). Increasing the discount rate reduces the amount of reserves in the banking system which in turn supports fewer loans. Consequently, the money supply falls while the market interest rates increase, thereby decreasing the demand for money Similarly, lowering the discount rate increases money demand. The alternative return on money refers to yields on domestic financial and real assets for a closed economy and foreign assets for an open economy. Yields on domestic financial asset can be measured using various instruments, including but not limited to the bank discount yield (also called bank discount basis or treasury bill rate), holding period yield, effective annual yield and money market yield. The yield on real assets is usually proxied by expected inflation while that on foreign assets can be proxied by foreign interest rate or an exchange rate variable. Regarding the expected signs, Subramanian (2001) indicated that: the expected sign for the scale variable is positive; that for own rate is positive; that for alternative returns is negative; that for expected inflation is negative; that for foreign interest rates is negative while that for expected exchange rate depreciation is expected to be negative.

According to Subramanian (2001), the income elasticity for real money demand for components of narrow money, narrow money and broad money range between 0.25 and 2.0, 0.25 and 2.0, and between 0 and 3.5, respectively, with means (medians) of 0.99 (0.95), 0.98 (0.89) and 1.22(1.13), respectively. There was no clear guidance on the acceptable magnitude of the elasticities/semi-elasticities of the opportunity cost variables.

3. METHODOLOGY/METHODS

Based on previous studies (Vasudevan, 1977; Parikh, 1994; Das and Mandal, 2000; Driscoll, 2004; Salha and Jaidi, 2014; among others), the nominal money demand equation is expressed as a function of the price level, level of income (Y), the opportunity cost of money and the exchange rate. The opportunity cost of money may be measured by the long-term interest rate, deposit rate, bank rate, treasury bill rate, call money interest rate or the spread between long-term and short-term interest rates. (The period to be considered covers the liberalization period, making it imperative to include exchange rates as one of the variables in the model). It is expected that when the exchange rate depreciates for a net debtor country, which is true for most developing countries, including Uganda, the home country value of wealth falls, thus money demand falls. The money demand equation can therefore be expressed as:

$$M = f(I, P, SR, OC, EX) \quad \ldots\ldots\ldots\ldots \quad 1$$

where

M = money demand

I = volume of transactions, income or wealth (scale variable)

P = price level,

SR = a set of interest rates,

OC = a set of alternative costs of holding money (opportunity costs of money)

EX = the exchange rate

The money demand in equation 1 can be expressed as either nominal or real demand. The nominal version is preferred since it can be used to test for its invertibility. The selected variables are set as follows: *M* is broad money current LCU (M3), *I* is real GDP (Y), *P* is the GDP deflator (P), *OC* is the selected interest rate variable based on availability of data such as the index of stock price, and *REER* is the real effective exchange rate.

By definition, M3 includes currency in circulation, overnight deposits, deposits with up to 2 years of maturity, deposits redeemable at a period of notice of up to 3 months, repurchase agreements, money market fund (MMF) shares/units and debt securities up to 2 years. Following Das and Mandal (2000), Driscoll (2004) and Salha and Jaidi (2014), the empirical nominal money demand model is a log-linear model expressed as

$$m3 = \alpha_0 + \alpha_1 y + \alpha_2 p + \alpha_3 sr + \alpha_4 reer + \varepsilon_t \quad \text{...} \quad 2$$

where the lowercase variables are the natural logarithms of the corresponding variables in capital letters described above. The set of interest rates (SR/OC) includes lending, deposit, bank (discount rates), treasury bill and saving interest rates. It is expected that real GDP and *reer* positively influence *m3*; the selected interest rates (*sr)* have negative effects while *oc* can have a negative effect if the substitution effect dominates but a positive effect if the wealth effect dominates.

As described by Engle and Granger (1987), for a single equation model, the explanatory variables in equation 2 are expected to be $I(1)$, e_t is $I(0)$ while the α_i's are the long-run cointegration parameters, which are time-invariant in the absence of structural breaks, but are time variant if structural breaks exist, implying parameter shifts after the structural breaks. Alternatively, these parameters may hold for a certain period, and then shift to another new 'long-run' relationship implying new cointegration parameters. The timing of the shift may be known but is often unknown. Empirically, it is even possible to have multiple shifts. These structural change(s) are reflected in changes in the intercept, the slope coefficient and/or the trend coefficient.

In a multivariate setting: (i). if the variables are $I(1)$ while e_t is $I(0)$ for all the equations in the system, cointegration exists and the vector error correction model (VECM) can be used to estimate both the short-run and long-run relationships; (ii). if cointegration does not exist for all equations in the system (e_t is $I(1)$ for all the equations), the VAR model can be used to estimate the parameters; and (iii). if e_t is $I(0)$ for some of the equations in the system but not for others, cointegration exists only for those equations where e_t is $I(0)$, the ECM can be estimated for only those equations while only the short-run model can be estimated for those equations where the e_t is $I(1)$ (Das and Mandal, 2000; Johansen (1988) and Hansen (1992). Further, if the variables are a mixture of $I(1)$ and $I(0)$, or mutually cointegrated (Frimpong and Oteng, 2006; Nasrullah et al., 2021), the autoregressive distributed lag (ARDL) model (Pesaran, Shin and Smith, 2001 approach) should be used to estimate both the short-run and long-run models. The ARDL model is appropriate for small sample sizes, it follows the ordinary least square (OLS) approach for cointegration between variables (Duasa, 2007) but it fails in the presence of *I(2)* in any variables (Frimpong and Oteng, 2006 and Nasrullah et al., 2021).

Testing for unit roots and cointegration

Testing for stationarity will be based on the Augmented Dickey and Fuller test **(**Dickey and Fuller, 1981) and the Phillips and Perron test (Phillips and Perron, 1988). Identification of the order of integration has implications for the applicability of the single equation models and the viability of the cointegration test. For the Engel and Granger approach, the system being investigated can only have variables that are *I(1)* (Engel and Granger (1987)), while for the ARDL approach, the variables are a mixture of ($I(1)$ and $I(0)$, with no higher orders such as I(2) (Frimpong and Oteng, 2006; Nasrullah et al., 2021). In either case, the residuals associated with each of the equations must be *I(0)* for cointegration to exist.

In a multivariate setting, the Johansen (1988) vector auto-regression (VAR) and the Hansen (1992) approaches are used to test for cointegration if the variables are $I(1)$ while e_t is $I(0)$ for all the equations in the system; while for the ARDL model (mixture of both I(1) and I(0)), the Bounds test (Pesaran, Shin and Smith (2001) is used to test for cointegration (see Das and Mandal, 2000). However, for multiple cointegration relationships, some of the variables may have unexpected results. It is anticipated that the variables in equation 1, thus in all the system of equations to be estimated are a mixture of *I* (1) and *I*(0) variables, thus, only the ARDL model and the Bounds test are described below.

Estimating the ARDL model

Before estimating the long-run and short-run relationships that exist between the variables using ARDL Approach, the Bounds test must be performed to confirm whether cointegration exist (Pesaran, Shin and Smith, 2001). However, the ARDL model does not cater for structural breaks therefore it is imperative to adjust the ARDL model specification to cater for any structural breaks which may be inherent in the data. Since the structural break periods are unknown *apriori*, they will be determined endogenously using the data set available. The Zivot and Andrews (1992) endogenous structural break test based on minimizing the ADF, a sequential test that is based on the full sample and utilizes a different dummy variable for each possible break date will be used. The period where it is most unlikely for a unit root null hypothesis to hold constitutes the break date and corresponds to the point where the minimum ADF t-statistic (most negative but largest value in absolute terms) for a unit root is obtained (See Zivot and Andrews, 1992; Glynn, Perera and Verma, 2007 for description of the test). The usual Unit root test equation is in this case modified to include the constant, trend and slope structural breaks as indicated in equation 3.

$$Y_t = \beta_0 + \beta_1 D_Y + \alpha_1 T + \alpha_2 D_Y * T + o_1 Y_{t-1} + o_2 D_Y * Y + \sum_{j=1}^{k} \tau_j \Delta Y_{t-j} + \varepsilon_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \quad 3$$

The innovation break type will be assumed (see Fox, 1972; Muirhead, 1986; Hotta and Neves, 1992; Barnett and Lewis, 1994; Mira and Sanchez, 2004; Caroni and Karioti, 2004; and Duchesne, 2004 for detailed discussions on the innovation break type). The equation for the innovation outlier is given by $\overline{Y} = \hat{\partial}\overline{Y}_{t-1} + \sum_{j=1}^{k} \hat{\tau}\Delta\overline{Y}_{t-1}$ where $\overline{Y}_t$ are the residuals from a regression of Y_t on a constant, time trend and the trend break variable (DT_B). The trend break period is represented by T_B and $DT_B = t - T_B$ if $t \succ T_B$ and zero otherwise.

If the residuals corresponding to the levels equation with the minimum ADF test statistic are stationary, the equation is further examined to determine whether the constant, trend and/or slope breaks coefficients are significant; otherwise the test procedure is repeated for the first difference. If the residual from the first difference equation with the minimum ADF statistic is non-stationary, (implying variables with integration orders higher that *I(1)*) for any of the variables in the system, the ARDL is not the appropriate procedure. The identified structural breaks (constant, trend and/or slope breaks which are significant) are then incorporated into the ARDL model. It is assumed that all the breaks (constant, trend and slope) for a specific variable occur in the same period. The maximum lags in this case will be determined using the Schwarz criterion (Schwarz, 1978). The ARDL models (long-run, conditional ARDL, short-run and ECM models) to be estimated are described below. For illustration, only those for money demand are presented in the sections that follow. Similar equations are constructed and estimated (where applicable) for each of the variables in the system, that is, *y*, *p*, *reer*, and the four interest rates.

The long-run model for money demand is specified as

$$m3 = \alpha_0 + \alpha_1 y + \alpha_2 p + \sum_{1}^{4} \omega_i sr + \alpha_3 reer + \alpha_4 D_m + \alpha_5 t + \alpha_6 D_m t$$

$$+ \sum_{1}^{4} \beta_i sr.* D_i + \theta_1 y * D_Y + \theta_2 p * D_P + \theta_3 reer * D_{reer} + \varepsilon_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 4$$

The dummy for *m3* is D_m where $D_m = 0$ for all periods before and the period of the break in the series; and $D_m = 1$ for all periods after the break. The dummies D_y, D_p and D_{reer} for *y*, *p* and *reer*, respectively, are constructed using the same format (All the dummies, hereafter are constructed following this format which is consistent with the format adopted for the Eviews package). The four interest rates adopted for this study are represented by *Sr*. The subscript *i* represents the saving interest rate *(savir),* deposit interest rate (*depir),* lending interest rate *(lendir), and* discount interest rate (*disir).*

During estimation, the ARDL estimation procedure adds lagged independent variables as may empirically be established. The actual model estimated depends on the structural break identified for *m3* for the C, (constant break -Dummy), trend (trend break-TB) on one hand and the slope (slope break-SB) for each of the variables on the left-hand side.

The conditional ARDL model can be written as (with both short-run and long-run components as well as the constant, trend and slope structural breaks) specified as

$$\Delta m3 = \nu_0 + \sum_{k=1}^{n} o_1 \Delta y_{t-k} + \sum_{k=0}^{n} \upsilon_2 \Delta p_{t-k} + \sum_{i=1}^{4}\sum_{k=0}^{n} \phi_i \Delta sr_{t-k} + \sum_{k=0}^{n} \pi_3 \Delta reer_{t-k} + \sigma_1 D_m + \lambda_2 t_t + \lambda_3 D_m t_t$$
$$+ \varpi_1 y_{t-1} + \varpi_2 p_{t-1} + \sum_{1}^{4} \rho_i sr_{t-1} + \varpi_3 reer_{t-1} + \sum_{i=1}^{4}\sum_{k=0}^{n} \psi_f sr_{t-k} .* D_{f,t-k} + \sum_{k=0}^{n} \delta_i y_{t-k} * D_{,Y,t-k}$$
$$+ \sum_{k=0}^{n} \theta_i p_{t-k} * D_{P,t-k} + \sum_{k=0}^{n} \varphi_i reer_{t-k} * D_{reer,t-k} + \varepsilon_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 5$$

where

Δ = the difference operator

D_m = is the dummy for m3 where D_m = 0 for all periods before and the period of the break in the series; and D_m =1 for all periods after the break.

f = number of interest rate variables (*sr*) in the model

k = number of lags of the independent variable in question

δ = the coefficient on the interactive slope variable for the different independent variables

Only the current slope dummies (*k* = 0) will be included in the estimated model to save the degrees of freedom.

Testing for cointegration using ARDL Bound test

The ARDL bounds test (Pesaran, Shin and Smith (2001) is performed on the conditional version of the ARDL model. It is a powerful test used in estimating of various long-run level relationships for time series with varying underlying properties including systems with: $I(0)$ cointegrated variables; $I(1)$ cointegrated variables; non-cointegrated variables of the same integration order after appropriate differencing; jointly co-integrated variables; and those with series that are integrated of different orders, that is, a mixture of series that may be I(0), I(1) and/or fractionally integrated. However, it cannot be applied if any of the series has an integration order greater than $I(1)$. When the data generating process underlying a time series is unknown, the test uses the F and T- statistics to test the significance of the lagged levels of the variables in a univariate equilibrium correction system. The data generating process may be either trend or first difference stationary. The null hypothesis is that of a no levels relationship (no cointegration), which is rejected whenever the F statistic (T-statistic) is greater than the significance level for $I(1)$ in absolute terms for a given level of significance; and is not rejected whenever the F statistic (T-statistic) is less than the significance level for $I(0)$ in absolute terms for a given level of significance. If the statistic lies between the test statistic for $I(0)$ and that for $I(1)$ in absolute terms, the test is inconclusive (Pesaran and Shin, 1999; Pesaran, Shin and Smith, 2001).

VAR/VECM/ECM model estimation (short-run and long-run models)

The Bounds test results are used to determine appropriate estimation procedure for the short-run and long-run models. The VECM is estimated if cointegration exists for all the equations in the system while the VAR is estimated in the absence of cointegration for all the system equations. However, if cointegration exists for some equations in the system but not for others, the ECM is estimated for only those equations where cointegration exists while the short-run model is estimated for those equations where cointegration does not exist. The VECM is a correction of ECM equations for all system variables and provides the cointegrating vectors. The ECM for m3 is represented as

$$\Delta m3 = v_0 + \varsigma T_t + \sum_{k=1}^{n} o_1 \Delta y_{t-k} + \sum_{k=0}^{n} \upsilon_2 \Delta p_{t-k} + \sum_{i=1}^{4}\sum_{k=0}^{n} \phi_i \Delta sr_{t-k} + \sum_{k=0}^{n} \pi_3 \Delta reer_{t-k} + \sigma_m D_m + \theta_m D_m * T +$$

$$\sum_{j=1}^{7} \varpi_j D_j * X_j + \Omega_1 ECT_{t-1} + \varepsilon \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 6$$

where

D_m = the structural break dummy for *m3*

T = the trend variable

X_j = represents the explanatory variables, where *j=1, 2, …, 7* represents variables *y, p, reer* and the four interest rates, respectively.

D_j = the structural dummy for variable j

σ_m = the constant break coefficient for variable *m3*

θ_m = the trend-break coefficient for variable *m3*

ϖ_j = the slope break coefficient for variable j.

ECT_{t-1} = the error correction term

Ω_1 = the coefficient of the error correction term

Other variables remain as defined earlier.

The short-run model for *m3* if no cointegration exists would be estimated as

$$\Delta m3 = \nu_0 + \sum_{k=1}^{n} o_1 \Delta y_{t-k} + \sum_{k=0}^{n} \upsilon_2 \Delta p_{t-k} + \sum_{i=1}^{4}\sum_{k=0}^{n} \phi_i \Delta sr_{t-k} + \sum_{k=0}^{n} \pi_3 \Delta reer_{t-k} + \sigma_1 D_{\Delta m}$$

$$+ \theta_m D_m * T + \sum_{j=1}^{7} \varpi_j D_j * X_j \varepsilon_t \quad \ldots \quad 7$$

where i is the number of interest rate variables (sr) included in the model, k is the number of lags on the interest rate variable and δ is the coefficient on the interactive slope variable for the different independent variables.

Tests for parameter stability

The cumulative sum of the deviations of the sample values from a target value (CUSUM) and the cumulative sum of squares (CUSUMSQ) will be used to test for parameter stability. The CUSUM test (Brown, Durbin and Evans, 1975) assesses the stability of coefficients β in a multivariate regression model of the form y = Xβ + ε. Inference is based on a sequence of sums (CUSUM test), or sums of squares (CUSUM square test), of recursive residuals. The residuals are standardized one-step-ahead of the forecast errors which are computed iteratively from nested sub-samples of the data (Brown, Durbin and Evans, 1975). The CUSUM test which identifies systematic changes in the regression coefficients will be used to establish the stability of the model; while the CUSUM Square which detects sudden changes from the constancy of the regression coefficients will be used to identify structural breaks (Pesaran and Pesaran, 1997). Stability for both tests occurs when the plot of the CUSUM statistic and that of the CUSUMSQ statistic, lies within the 5 percent critical bands confidence intervals of parameter stability, otherwise systematic parameter instability exists for the CUSUM while structural breaks exist for the CUSUMSQ.

Tests for goodness of fit of the model

Goodness of fit of the model will be determined using tests performed on the residual series, including the Breusch-Godfrey (BG) serial correlation LM test (Breusch, 1978; Godfrey, 1978) with the null hypothesis (H_0) of no serial correlation against the alternative hypothesis (H_1) of serial correlation in the residual series; Breusch-Pagan-Godfrey (BPG) heteroscedasticity test (Breusch and Pagan, 1979) with the null hypothesis (H_0) of homoscedasticity against the alternative hypothesis (H_1) of heteroscedasticity; and the Jarque Bera (JB) test (Jarque and Bera, 1980, 1987) that tests the null hypothesis (H_0) of normality against the alternative hypothesis (H_1) of skewness. The Breusch-Pagan-Godfrey test is the chi-squared test, with the null hypothesis normally rejected for p-value < 0.05.

Data sources

The data was obtained from World Development Indicators (WDI) database (*https://databank.worldbank.org/source/world-development-indicators*) as well as the International Monetary Fund database (*https://data.imf.org/?sk=4c514d48-b6ba-49ed-8ab9-52b0c1a0179bhttps://data.imf.org/?sk=4c514d48-b6ba-49ed-8ab9-52b0c1a0179b; https://data.imf.org/regular.aspx?key=61545855*. The lending interest rate for 1993 was missing. It was filled by interpolation of the 1992 and 1994 figures.

4. RESULTS

I. Identification of Break Points and Unit Root Tests with Structural Breaks

The structural break and unit root with structural break tests were performed using the innovational outlier break type for the trend and intercept specification (both trend and the break). The break selection was based on minimizing the Dickey-Fuller t-statistic (see Zivot and Andrews (1992). The lag selection was automatically done using the Schwarz information criterion with a maximum of six (6) lags. The null hypothesis was that the variable in question had a unit root against the alternative hypothesis of the variable not having a unit root. Table

1 presents the results while Table 2 presents the Vogelsang (1993) asymptotic one-sided critical p-values.

Table 1: Break Points and Unit Root Tests with Structural Breaks Based on the minimizing Augmented Dickey-Fuller Unit Root Test Statistic

Variables	Sample period [Sample size]	Break Date	Lag length	ADF test statistic	Conclusion	Order of integ. of series level	Structural break form[4]
m3	1982-2018 [37][1]	1986	0	-10.37*** (< 0.01)[2]	No UR[3] I(0)	I(0)	C/T/TB/SB
Δ*m3*	1982-2018 [37]	1993	0	-3.3884[ns] (0.4491)	UR I(1)		C/SB
Y	1983-2018 [36]	2015	0	-3.485[ns] (0.8199)	UR	I(1)	C/T
Δ*y*	1984-2018 [35]	1987	0	-5.686*** (< 0.01)	No UR I(0)		Slope interactive break
lendir	1984-2018 [35]	2008	3	-4.288[ns] (0.3434)	UR	I(1)	C/CB/T
Δ*lendir*	1982-2018 [37]	1986	0	-5.865*** (<0.01)	No UR (I(0)		C/SB
p	1983-2018 [36]	1986	0	-8.711*** (<0.01)	No UR I(0)	I(0)	C/T/TB/SB

Δp	1984-2018 [35]	1989	0	-4.4353* (0.0513)	No UR I(0)		C/SB
reer	1983-2018 [36]	1994	2	-10.22*** (<0.01)	No UR I(0)	I(0)	C/CB/T/TB/S
Δ*reer*	1986-2018 [33]	1996	4	-7.454*** (<0.01)	No UR I(0)	I(0)	C/CB/SB
savir	1982-2018 [37]	1992	0	-5.6334** (0.0140)	No UR I(0)	I(0)	C/CB/SB
Δ*savir*	1982-2018 [37]	1993	0	-5.363*** (<0.01)	No UR I(0)		C^{ns}/CB
depir	1985-2018 [34]	1992	0	-5.6498** (0.0133)	No UR I(0)	I(0)	C/CB/SB
Δ*depir*	1986-2018 [33]	1993	0	-6.226*** (<0.01)	No UR I(0)		C^{ns}/CB
disir	1986-2015 [30]	1993	5	-5.3311** (0.0330)	No UR I(0)	I(0)	C/SB
Δ*disir*	1983-2015 [33]	1996	1	-8.725*** (<0.01)	No UR I(0)	I(0)	C/T/TB/SB

Notes to Table: *1. Values in square brackets are sample sizes. 2. The values in parenthesis are Vogelsang (1993) asymptotic one-sided p-values. 3. The symbol 'UR' stands for unit root. 4. The symbols C, CB, T, TB and SB stand for constant, constant break, trend, trend break and slope break, respectively. Source: Data processed by the author*

Table 2: Vogelsang (1993) Asymptotic One-sided Probability Values

Significance level	Test critical values for:	
	Levels	First differences
1% level	-5.7191	-4.9491
5% level	-5.1757	-4.4436
10% level	-4.894	-4.1936

Source: Test Statistics from Eviews package

The unit root with structural break tests indicated that real GDP and the lending interest rate variables were I(1) and had structural breaks. All the other variables were I(0) but also with structural breaks. This signifies that the best model is an ARDL model. The structural break for money demand, real GDP, lending rates, prices, real effective exchange rates, saving rates, deposit rates and discount rates occurred in 1986, 2015, 2008, 1986, 1994, 1992, 1992 and 1993, respectively. All the variables had a constant; the real effective exchange rate, saving rate, lending rate and deposit rates had a constant break; all variables had a trend with the exception of the discount rate, saving rate and deposit rate variables; real effective exchange rates, money demand and prices had a trend break; while all the variables had slope breaks with the exception of the income and lending rate variables.

II. ARDL Models and Bounds Cointegration Results

The selected ARDL models with structural breaks identified above were estimated and the bounds cointegration test was performed. Table 3 presents the results. The treasury bill rate was not included in the analysis due to an insufficient number of observations.

Table 3: Selected ARDL Models and Bounds Cointegration Results

Dep. Variable	Struct. Break for the dependent variable	Sample Size	Selected ARDL model	Bounds test results		
				F-test	t-test	Conc.

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Savir	C/CB/SB	32	(2,1,1,1,1,0,1,0)	26181.8***	-365.95***	Coint.
reer	C/CB/T/T B/SB	32	(1,1,1,1,1,1,0,1)	49.233***	-7.772***	Coint.
lendir[1]	C/CB/T	32	(1,0,1,0,0,1,0,0)	7.215***	-4.572*	Coint.
depir	C/CB/SB	31	(1,1,0,1,1,1,1,1)	7562.72***	-198.57***	Coint.
disir	C/SB	31	(1,1,0,1,1,0,1,1)	5.9475***	-1.87^{ns}	Coint. F-test
p	C/T/TB/SB 1	31	(1,1,0,0,0,0,1,0)	6.112***	-4.192^{nc}	Coint.
y	C/T	32	(1,0,0,1,1,1,1,1)	8.8155***	-1.561^{ns}	Coint. F test
m3	C/T/TB/SB	32	(1,1,1,0,0,0,1,1)	6.758***	-5.295**	Coint.
m3	C/T/TB/SB	32	(1,1,1,0,0,0,1,1)	7.528***	-5.254**	Coint.

Table notes: *The ***, **, *, ns and nc imply significance at 1%, 5%, and 10% levels of significance, not significant and not conclusive, respectively. Six slope dummies were included for all models except for p where the slope dummy for p was not included; m3 where one equation included a trend break but no slope dummy for m3; and y where no slope dummy for m3 was included. 'Coint.' signifies cointegration based on both the F and T tests while 'Coint. F-test' signifies cointegration based on the F test only. Source: Data processed by the author*

The Bound's F-test statistic was significant in all equations while Bound's T-test was not significant for *y* and *disir, was* inconclusive for *p but was significant for all other equations.* Based on these results, especially the F-test results, it is concluded that cointegration existed for all the equations estimated, thus the variables in equation 4 are cointegrated and the VECM can be estimated. However, due to the small size of the sample, the VECM corresponding to the identified structural breaks could not be estimated (near singular matrices). Instead, the ECM for each equation was estimated. Tables 4 and 5 present the levels long-run equations while Tables 6 to 8 present the short-run (ECM) equations. The detailed results for the conditional ARDL long-run form with structural breaks used to derive the long-run levels (cointegration equations) and short-run models can be obtained from the author on request.

Goodness of fit of the long-run model

The BG test for serial correlation and the BPG test for heteroscedasticity for all the conditional long-run ARDL models with structural breaks estimated indicated no serial correlation and no heteroscedasticity, respectively. The Jacque Bella test of normality indicated normally distributed error terms for all variables at the 5% level of significance except those for the saving rate and deposit interest rate models, which were normally distributed (1% level of significance); and those for *m3* which were not normally distributed at those levels. However, it has been established that the violation of the normality assumption should not cause problems for samples > 30 or 40 and thus does not hinder parametric analysis (Elliot and Woodward, 2007; Pallant, 2007; Ghasemi and Zahediasl, 2012), which is the case for this study since all the samples for all equations (including that for m3) are larger than 30.

Stability of the models

The CUSUM tests were performed on all the models estimated. The CUSUM Square test for all equations indicated stability of the models as identified with the exception of the price model where possible additional structural breaks were identified for 2007, 2008 and 2009; and the deposit rate equation where a possible structural break was identified for 2013. Thus after catering for structural breaks, the models for money demand, income and the saving, lending and deposit rates are stable based on both the CUSUM and CUSUM Square tests, while the price and deposit rate models are partially stable (stable based on CUSUM test but unstable based on the CUSUM square tests. (Details for CUSUM and CUSUM square tests can be obtained from the author by request). These results are particularly important for the money demand and the income equations. They imply that the structural breaks identified and incorporated in the model adequately capture the ensuing parameter changes and that the models are stable before the structural break, and stability is re-established with new coefficients after the structural break.

The stable money demand equation for Uganda after catering for structural breaks implies that the quantity of money is related predictably to several variables in the real sector, including but not limited to interest rates, exchange rate, stock market, price level, savings, consumption expenditure, investment, import, export, GDP at factor cost, among others and these variables can affect the money demand. Thus, the monetary authorities can use an empirical money demand function to implement and formulate appropriate monetary policy options to achieve the desired objective of economic growth with price stability. This is a key finding for a developing country since stability of the models in the dynamic system is crucial for the implementation effective monetary policy. Also, the money demand equation can be inverted to determine its effects on prices, and income, thus the economic activities in the country.

The above results further imply that if all the structural breaks are accounted for, all 8 variables would be stable in the long-run. This signals the importance of capturing structural breaks (including multiple structural breaks) for investigations dealing with time series. Not accounting for structural breaks may lead to the wrong conclusion of an un-stable money demand equation instead of a stable one in the long-run. Stability of the money demand model in developing countries has been established by studies, such as those of Nchora and Adamec (2016) who reported stable money demand based on CUSUM tests but no structural breaks for Ghana; and Asongu, Folarin and Biekpe (2019) who revealed stable money demand based on both CUSUM tests for Botswana, the Democratic Republic of Congo (DRC), Lesotho, Malawi, South Africa and Swaziland but partial stability (based on either the CUSUM or CUSUMSQ but not both) for Zambia, Seychelles, Madagascar and Mauritius).

Long-run cointegration parameters: Levels equations

Tables 4 and 5 present the long-run cointegration parameters, derived using the ARDL model with structural breaks.

Table 4: Long-run Cointegration Parameters for Money Demand, Real Effective Exchange Rates, and prices

Independent variable	Dependent Variable and Equation Number				
	m3	***m3***	***Y***	***P***	***Reer***
	Eq. 8	**Eq.9**	**Eq.10**	**Eq.11**	**Eq.12**
m3			0.5021* (0.0924)	1.6484*** (0.0069)	0.5595* (0.0554)
y	2.1843*** (0.0028)	2.1973*** 0.0030		0.6921^{ns} (0.6656)	0.5813 ^{ns} (0.3127)
P	1.5684*** (0.0000)	1.6335*** (0.0000)	-0.5429* (0.0676)		1.1575** (0.0186)
Depir	5.5203*** (0.0002)	5.598*** 0.0001	-3.391** (0.0398)	-2.1194^{ns} (0.5339)	5.8610*** (0.0099)
Disir	-0.0911* (0.0564)	-0.0913* 0.0573	-0.0262^{ns} (0.7465)	-0.0355^{ns} (0.7858	-0.1227** (0.0325)
lendir	0.1949^{ns} (0.2885)	0.1974^{ns} 0.2867	-0.0459^{ns} (0.0.1256)	0.5985 ^{ns} (0.3190)	0.1394^{ns} (0.4369)
savir	-5.8487*** (0.0002)	-5.930*** (0.0001)	3.6048** (0.0370)	1.9366^{ns} (0.5857)	-6.6157*** (0.0070)
reer	-0.038 ^{ns} (0.6818)	-0.037^{ns} 0.6918	0.1622^{ns} (0.2986)	0.4988* (0.0564)	
Long-run slope structural breaks derived from the corresponding conditional ARDL model					
D1986*p	-1.5292*** (0.0000)	-1.6023*** (0.0000)	0.1511^{ns} (0.2248)		-0.8376*** (0.0006)
D1994*reer	-0.0491** (0.0127)	-0.0494** (0.013)	-0.0155** (0.0480)	-0.071* (0.0542)	1.0092*** (0.0001)
D1992*depir	-5.881*** (0.0011)	-5.99*** (0.0009)	1.1311* (0.0770)	1.548 ^{ns} (0.613)	-3.7782*** (0.0009)

D1993*disir	0.0953** (0.0346)	0.0965** (0.034)	-0.0590*** (0.0046)	-0.1668** (0.0463)	0.1365*** (0.0001)
D1992*savir	6.1785*** (0.0010)	6.284*** (0.0009)	-1.1732* (0.0791)	-1.6248 ^{ns} (0.6074)	3.9751*** (0.0008)
D1986*m3		-0.0103** (0.030)		-0.108^{ns} 0.4118)	-0.0022^{ns} (0.4809)

Notes to Table: *The ***, ** and * indicate significance at the 1%, 5% and 10% levels of significance while ns implies lack of significance (no significance). Values in parentheses are probabilities.* Six slope break dummies (*m3, p, reer, savir, depir and disir*) *were included in the models with the exceptions indicated. Equation 8 corresponds to the short-run model with a trend break but without a slope break for m3 while the short-run model for equation 9 has a slope break for m3 but has no trend break. The equation for m3 with both trend and slope break could not be estimated. Equation 10 has no slope break for m3 (It was eliminated due to insignificance). Equation 11 corresponds to the short-run model without a slope break for p (the equation could not be estimated with the slope dummy). Source: Data processed by the author*

Equation 8 shows that in the long-run, income, price (GPD deflator), deposit rate, discount rate, and the saving rate cause money demand with elasticities of 2.184, 1.568, 5.52, -0.0911 and -5.849, respectively. The alternative specification, equation 9 has coefficients that only differ slightly from those in equation 8 as indicated Table 4. Suffice to note that the slope break for m3 was significant at the 5 % level of significance. Money supply is inelastic to the discount rate but is elastic to income, price, deposit rate and the saving rate. Increases in the deposit rate increase the money demand since it increases the money available in the financial system and this is used to create more money, thus the increase in money supply. Increasing the saving rate decreases the amount of money people wish to hold. The lending rate as well as the real effective exchange rate do not cause money demand in the long-run.

Equation 10 shows that money demand, price, deposit rate and the saving rate cause income in the long-run, with elasticities of 0.5021, -0.5429, -3.391 and 3.6048, respectively. Income is elastic to the deposit rate which reduces it and to the saving rate which increases it. It is inelastic to money demand which increases it and to price which decreases it. The discount rate, lending rate as well as the real effective exchange rate have a negative effect on income in the long-run but it is insignificant, implying no significant causal effect in the long-run. Equation 11 shows that only real effective exchange rate and money demand cause the price in the long-run, with elasticities of 0.499 and 1.648, respectively. All the other variables do not have a causal relationship with the price in the long-run. Equation 12 shows that money demand, price, deposit rate, discount rate, and saving rate cause real effective exchange rate in the long-run with elasticities of 0.5595, 1.158, 5.861, -0.1227, and -6.6157, respectively. The lending rate and income do not cause real effective exchange rate in the long-run.

These results reveal that the money demand causes price in the long-run and the reverse is true. This means that money demand (broad money) can potentially be used to predict inflation, which inflation in turn affects aggregate activity. Also, money demand causes income in the long-run and the reverse is true implying that money demand is endogenous in the income equation in the long-run. These results indicate s that the monetary policy impact on income is positive but is inelastic in the long-run. The effect of the saving rate on income is positive and elastic implying that the higher the saving rate, the higher the income growth. Money demand causes real effective exchange rates but the reverse is not true. This implies that monetary policy has an impact on economic activity via its effects on the real effective exchange rate, thus the exchange rate channel of monetary transmission is effective in transmitting monetary policy actions. The lending rate does not have a significant effect on money demand, income, real effective exchange rate and prices.

Table 5: **Long-run Cointegration Parameters for Saving, Lending, Deposit and Discount Rates**

Independent variable	**Dependent variable and Equation Number**			
	Savir	*Lender*	*depir*	*Disir*
	Eq. 13	Eq. 14	Eq.15	EQ. 16
m3	-0.1085*** (0.0000)	0.3229^{ns} (0.2723)	0.1266*** (0.0000)	-5.1094^{ns} (0.2364)
y	0.2677***	-0.8787^{ns}	-0.3109***	12.6495^{ns}

	(0.0000)	(0.2069)	(0.0000)	(0.2364)
p	0.2029*** (0.0000)	-0.5612^{ns} (0.2289)	-0.2377*** (0.0000)	7.0893^{ns} (0.2574)
depir	0.8666*** (0.0000)	-4.8894** (0.0369)		35.0432^{ns} (0.2574)
disir	-0.0022^{ns} (0.5830)	0.1158* (0.0691)	0.0028^{ns} (0.6119)	
lendir	0.0478*** (0.0007)		-0.0524*** (0.0062)	5.5312^{ns} (0.1909)
savir		5.3124** (0.0315)	1.1550*** (0.0000)	-37.460 ^{ns} (0.2566)
reer	0.0167*** (0.0066)	-0.1248^{ns} (0.3903)	-0.0189** (0.0142)	-0.2566 ^{ns} (0.7288)
Long-run slope structural breaks derived from the corresponding conditional ARDL model				
*D1986*p*	-0.1921*** (0.0000)	0.7959^{ns} (0.1120)	0.2237*** (0.0000)	-4.4664*** (0.0200)
*D1994*reer*	-0.006*** (0.0002)	0.0528** (0.0376)	0.0071*** (0.0008)	-0.1189^{ns} (0.3603)
*D1992*depir*	-0.8668*** (0.0000)	5.2295** (0.0307)	1.0053*** (0.0000)	-22.6712** (0.0259)
*D1986*m3*	-0.001*** (0.0066)	-0.0080^{ns} (0.3118)	0.0013** (0.0329)	0.0112^{ns} (0.7532)
*D1992*savir*	0.9803*** (0.0000)	-0.5433** (0.0310)	-1.1371*** (0.0000)	23.7222** (0.0250)
*D1993*disir*	0.0132*** (0.0000)	-0.1000* (0.0760)	-0.01579*** (0.0001)	0.7632** (0.0175)

Source: Data processed by the author

Equation 13 shows that money demand, income, price, deposit rate, real effective exchange rate and lending rates cause the saving rate in the long-run, with elasticities of -0.1085, 0.268, 0.2029, 0.867, 0.0167 and 0.048, respectively. The saving rate is not elastic to any of the variables included. The discount rate does not cause the saving rate. Equation 14 shows that only the deposit rate, discount rate and saving rate cause the lending rate in the long-run, with elasticities of -4.889, 0.1158 and 5.3124, respectively. Increases in the deposit rate increase the funds in the financial systems (loanable funds) which reduces the lending rate while increasing the discount rate reduces the funds available for lending which increases the lending rate. Increasing the saving rate increases the lending rate. The lending rate is elastic to changes in the deposit rate and saving rate but is inelastic to changes in the discount rate. Money demand, income, real effective exchange rate and price do not cause lending rates. The lack of a causal relationship between money demand (broad money) and lending rates may signal the ineffectiveness of the lending rate transmission channel for monetary policy. This may be because of the limited access to credit to the informal sector which constitutes a large proportion of the economy

Equation 15 shows that money demand, income, prices, lending rate, real effective exchange rate and saving rate cause the deposit rates in the long-run, with elasticities 0.127, -0.311, -0.238, -0.0524, -0.0189 and 1.155, respectively. Money demand and saving rates have a positive effect on the deposit rates while the others have a negative effect. Deposit rates are only elastic to saving rates. The discount rate does not cause the deposit rate in the long-run. Equation 16 shows that the discount rate is not significantly caused by all the variables investigated in the long-run, implying that it is exogenously determined. A finding that is consistent with reality since the discount rate is operationally determined by the monetary authorities.

Money demand causes the saving and deposit rates, and the reverse is true but it has no causality with lending rates in both directions in the long-run. It is caused by discount rates but the reverse is not true. The money demand function is therefore invertible with respect to savings and deposit rates but not with respect to lending and discount rates since no causality exists in the long-run between money demand on one side and each of the two interest rates on the other. Consequently, the interest rate channel based on the lending rates of monetary transmission is not effective in transmitting monetary policy actions; the saving rate and deposit rate constitute effective channels for transmitting monetary policy actions aimed at increasing aggregate demand; and the discount rate is an effective tool for controlling money supply.

Short-run ARDL error correction models (ECM) (Short-run dynamic elasticities- Short-run causal effects)

The short-run ARDL error correction model results corresponding to the long-run equilibrium relationship and the levels equations above are presented in Tables 6 to 8.

Table 6: Short-run ARDL Error Correction Models for Money Demand and Prices

	Eq. 17		**Eq. 18**		**Eq. 19**	
Dep. Var. (ARDL MODEL)	***Δp***		***Δm3***		***Δm3***	
Variable	**Coefficient**	**Prob.**	**Coefficient**	**Prob.**	**Coefficient**	**Prob.**
C	-27.77***	0.0001	-25.44***	0.0000	-26.56***	0.0000
@TREND	-0.794***	0.0000	0.0116***	0.0008	0.066***	0.0004
*D1986*TREND*	0.622***	0.0002			-0.055***	0.0015
Δsavir)			-6.432***	0.0000	-6.324***	0.0000
Δsavir(-1))						
Δlendir						
Δreer			-0.702***	0.0000	-0.697***	0.0000
Δm3	0.451**	0.0216				
Δy			0.3359^{ns}	0.4000	0.3422^{ns}	0.3222
Δp			1.564***	0.0000	1.4903***	0.0000
Δdepir	-1.599***	0.0000				
Δdisir						
*D1994*reer*	-0.071***	0.0055	-0.0494***	0.0000	-0.049***	0.0000
*D1992*depir*	1.548***	0.0000	-5.99***	0.0000	-5.888***	0.0000
*D1986*p*			-1.602***	0.0000	-1.529***	0.0000
*D1986*m3*	-0.108***	0.0000	-0.010***	0.0001		

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*D1992*savir*	-1.625***	0.0000	6.284***	0.0000	6.1785***	0.0000
*D1993*disir*	-0.167***	0.0007	0.097***	0.0005	0.0953***	0.0007
*CointEq(-1)**	-0.846***	0.0000	-1.07***d	0.0000	-1.069***d	0.0000
R-squared	0.9618		0.9919		0.9921	
Adjusted R-squared	0.9428		0.9868		0.9870	
S.E. of regression	0.0784		0.03065		0.0303	
Sum squared resid.	0.1230		0.0178		0.0175	
Log likelihood	41.715		74.462		74.786	
F-statistic	50.418		193.67		197.67	
Prob. (F-statistic)	0.0000		0.0000		0.0000	
Bounds test F-stat (k=7)	6.111***		7.528***		6.758***	
Bounds test t-stat	-8.673***		-9.765***		-9.252***	

Source: Data processed by the author

Table 7: Short-run ARDL Error Correction Models for Real Effective Exchange Rates, Real GDP, and Deposit Rates

Equation No.	**Eq. 20**		**Eq. 21**		**Eq. 22**	
Dep. Var. (ARDL MODEL)	***Δreer***		***Δy***		***Δdepir***	
Variable	**Coefficient**	**Prob.**	**Coefficient**	**Prob.**	**Coefficient**	**Prob.**
C	4.403***	0.0000	3.944***	0.0000	3.581***	0.0000
D1992					0.2985***	0.0000
D1994	-10.387***	0.0000			0.299***	0.0000
@TREND	-0.526***	0.0000	-0.003***	0.0036		
*D1994*TREND*	0.463***	0.0000				
Δsavir)	-4.001***	0.0000	1.1109***	0.0000	1.159***	0.0000
Δsavir(-1)						
Δlendir			-0.0499*	0.0537		

Δ*reer*			0.1282***	0.0003	0.102***	0.0000
Δ*m3*	-0.117**	0.0163	-0.0236^{ns}	0.4587	0.088***	0.0000
Δ*y*	-0.019^{ns}	0.8908			-0.0655**	0.0301
Δ*p*	0.639***	0.0000			-0.200***	0.0000
Δ*depir*	3.647***	0.0000				
Δ*disir*	-0.141***	0.0000	0.0338***	0.0003	0.0148***	0.0000
*D1994*reer*	1.009***	0.0000	-0.0155***	0.0002	0.0071***	0.0000
*D1992*depir*	-3.778***	0.0000	1.1311***	0.0000	1.005***	0.0000
*D1986*p*	-0.8376***	0.0000	0.1511***	0.0000	0.224***	0.0000
*D1986*m3*	-0.0022**	0.0213			0.0013***	0.0000
*D1992*savir*	3.975***	0.0000	-1.1732***	0.0000	-1.137***	0.0000
*D1993*disir*	0.136***	0.0000	-0.0590***	0.0000	-0.0158***	0.0000
*CointEq(-1)**	-0.612***	0.0000	-0.3191***	0.0000	-0.996***	0.0000
R-squared	0.9984		0.9375		0.999979	
Adjusted R-squared	0.9965		0.8981		0.999960	
S.E. of regression	0.0093		0.0096		0.001852	
Sum squared resid.	0.0012		0.0017		5.49E-05	
Log likelihood	113.316		111.725		161.2951	
F-statistic	529.61***		23.7681***		53352.60	
Prob. (F-statistic)	0.0000		0.0000		0.000000	
Bounds test F-stat (k=7)	49.232***		8.8155***		7562.7***	
Bounds test t-stat	-28.066***		-10.567***		-327.96***	
Sample size	31		32		31	

Source: Data processed by the author

Table 8: Short-run ARDL Error Correction Models for Discount, Saving and Lending Rates

Equation No.	**Eq. 23**	**Eq. 24**	**Eq. 25**
Dep. Var.	***Δdisir***	***Δsavir***	***Δlendir***

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Variable	**Coefficient**	**Prob.**	**Coefficient**	**Prob.**	**Coefficient**	**Prob.**
C	-106.370***	0.0000	-3.1004***	0.0000	15.0711***	0.0000
@TREND					-0.0043^{ns}	0.3066
Δ*savir(-1))*			-0.0022*	0.0809		
Δ*lendir1993*	1.9637***	0.0028				
Δ*reer*	-3.2663***	0.0000	-0.0895***	0.0000	0.3497***	0.0087
Δ*m3*	-1.4377**	0.0293	-0.0774***	0.0000		
Δ*y*			0.0487**	0.0455		
Δ*p*	3.8982***	0.0000	0.1712***	0.0000	-0.4845***	0.0002
Δ*depir*	22.723***	0.0000				
Δ*disir*			-0.0120***	0.0000		
*D1994*reer*	-0.1189**	0.0290	-0.006***	0.0000	0.0528***	0.0001
*D1992*depir*	-22.671***	0.0000	-0.8668***	0.0000	5.2295***	0.0000
*D1986*p*	-4.4664***	0.0000	-0.1921***	0.0000	0.7957***	0.0000
*D1986*m3*	0.0112^{ns}	0.1549	-0.001***	0.0000	-0.0080***	0.0013
*D1992*savir*	23.7222***	0.0000	0.9803***	0.0000	-5.4327***	0.0000
*D1993*disir*	0.7632***	0.0000	0.0132***	0.0000	-0.1000***	0.0012
D1992			-0.2566***	0.0000		
D2008					-0.0750*	0.0822
*CointEq(-1)**	-0.6400***	0.0000	-0.9939***	0.0000	-1.0613***	0.0000
R-squared	0.9268		0.999988		0.9368	
Adjusted R-squared	0.8781		0.999979		0.9021	
S.E. of regression	0.1389		0.0015		0.0428	
Sum squared resid.	0.3474		3.73E-05		0.0366	
Log likelihood	25.62956		173.1699		62.9854	
F-statistic	19.0004		105454.7		26.9536	
Prob. (F-statistic)	0.0000		0.0000		0.0000	

Bounds test F-stat (k=7)	5.9475***		26181.64***		.2146***	
Bounds test t-stat	-8.8238***		-596.72***		-9.4231***	
Sample size	31		32		32	

Source: Data processed by the author

All the slope structural breaks that were included in the different equations were significant with the exception of that for money demand for the discount rate (eq. 23) equation. Also, the constant and trend break variables are significant in all the equations where they were included, therefore the constant, trend and slope structural breaks were correctly identified. The R-adjusted is above 87.8% for all equations implying that the equations explain more than 87.8% of the variations in the dependent variable for the respective equations. Also, the cointegration coefficient was significant and negative in all equations implying that Granger causality exists at least for some variables in the respective equations in the short-run.

The error correction term coefficient was negative and significant at the 1% level of significance for all the eight equations implying that a long-run relationship corresponding to each of the short-run models exists and that Granger causality exists at least in one direction for some variables in the respective equations in the short-run, for all equations. However, in all cases, the cointegration relationships exist with structural breaks (constant, trend and/or slope structural breaks). A proportion of 86.6%, 31.9%, 61.2%, 99.6%, 64%, and 99.3% of the deviation from the long-run relationship is adjusted for in the short-run for the price, income, real effective exchange rate, deposit rate, discount rate and saving rate variables while 100% of the adjustment occurs in the short-run for money demand and lending rates (NB: The coefficient of the error correction term for the money demand and lending rates equations is not significantly different from -1). These results show that only 31.9% of the deviations from the long-run income level are adjusted in the short-run, signifying a very slow speed of adjustment.

In the short-run, changes in money demand significantly influence prices, real effective exchange rates, deposit rates, discount rates, and saving rates at the 1% or 5% with elasticities of 0.451, -0.117, 0.088, -1.438, and -0.077, respectively (see equations 17, 20, 21, 23, and 24);

but does not significantly influence income (see equation 21). It does not influence (no causal effect) lending rates in the short-run (equation 25). Only the discount rate has an elastic response to changes in money demand. Money demand is significantly influenced by saving rates, real effective exchange rates and prices at the 1% level of significance, with elasticities of -6.324, -0.697, and 1.490, respectively; but is not significantly influenced by income (equation 19). Deposit rate, lending rate and discount rate do not influence (no causal effects) money demand in the short-run. The lending rate does not influence and is not influenced by money demand in the short-run (eq.19). The slope structural breaks for the real effective exchange rate (1994), deposit rate (1992), price (1986), saving rate (1992) and discount rate (1993) in the money demand model (eq. 19) were significant at the 1% level of significance. The trend structural break is also significant at the 1% level of significance.

In the short-run, changes in income significantly influence deposit rate and saving rate at the 5% level of significance, with elasticities of -0.065 and 0.049, respectively (see equations 22 and 24); it does not significantly influence real effective exchange rate and money demand (equation 19 and 20); and does not influence (no causal effect) price and the discount rate. It is significantly influenced by the real effective exchange rate, discount rate and saving rate at the 1% level of significance, with elasticities of 0.128, 0.0338 and 1.1109, respectively; and by the lending rate at the 5% level of significance (elasticity of -0.0499); is not significantly influenced by money demand; and is not influenced (no causal effect) by price and the deposit rate (equation 21). The slope structural breaks for the real effective exchange rate (1994), deposit rate (1992), price (1986), saving rate (1992) and discount rate (1993) in the income equation (eq. 21) were significant at the 1% level of significance while that for money demand (1986) was not significant.

The price is significantly influenced by money demand and deposit rates in the short-run at the 1% level of significance, with elasticities of 0.451 and -1.599, respectively (equation 17). It is not caused by saving rate, lending rate, real effective exchange rate, income and discount rate in the short-run. The real effective exchange rate is significantly influenced in the short-run by price, deposit rate and discount rate, with elasticities of 0.639, 3.647 and -0.141 at the 1% level of significance as well as money demand with elasticity of -0.117 at the 5% level of significance, respectively (equation 20). It has no causal effect with the saving rate and lending rate. The deposit rate is significantly influenced in the short-run by the saving rate, real effective exchange rate, money demand, income, price and discount rate at the 1% level of significance, with elasticities of 1.159, o.102, 0.088, -0.066 and -0.200, respectively (equation 22). It is not caused by saving and lending rates. The discount rate is significantly influenced in the short-run by the lending rate, real effective exchange rate, price and deposit rate at the 1 % level of significance, with elasticities of 1.964, -3.267, 3.898 and 22.723, respectively at the 1% level of significance, as well as money demand with an elasticity of -1.438 at the 5% level of significance (equation 23). It is not caused by the saving rate and income. The saving rate is significantly influenced in the short-run by real effective exchange rates, money demand, income, price and discount rates at the 1% level of significance, with elasticities of -0.0895, -0.077, 0.049, 0.171 and -0.012, respectively (equation 24); but is not influenced by lending and deposit rates. The lending rate is significantly influenced in the short-run by the real effective exchange rate and price, with elasticities of 0.3497 and -0.485, respectively (equation 25); but is not caused by money demand, income, deposit rate and saving rate.

Bounds test result for short-run models

Table 9 presents the Bounds F and T-test statistics. Both the F and T-test statistics for all the short-run equations were significant at the 1% level of significance. These results further indicate that cointegration (a long-run equilibrium relationship) exists for all the equations.

Table 9: Bounds test critical values for short-run models

Bounds[1] Test for Cointegration: F-Test significance levels			**Bounds Test for Cointegration: T-test significance levels**	
Significance level	**I(0)**	**I(1)**	**I(0)**	**I(1)**
10%	2.03	3.13	-2.57	-4.23
5%	2.32	3.5	-2.86	-4.57
2.5%	2.6	3.84	-3.13	-4.85
1%	2.96	4.26	-3.43	-5.19

Notes to Table: *The bounds test was proposed by Pesaran, Shin and Smith (2001). The null hypothesis for both the F and T-test is that of no levels relationship (no cointegration) exists.*

It is rejected whenever the F statistic (T-statistic) exceeds the significance level for I(1) in absolute terms for each of the different levels of significance. The null hypothesis (H_o) is not rejected whenever the F statistic (T-statistic) is below the significance level for I(0) in absolute terms for the different levels of significance. The test is inconclusive when the statistic lies between the test statistics for I(0) and that for I(1) in absolute terms. Source: Test statistics from the Eviews package.

Summary of short-run and long-run causality for the different models

Table 10 summarises the causality effects based on short-run and long-run ARDL models presented in Tables 4 to 9. A plus sign signifies a significant positive causal effect; a minus sign signifies a significant negative causal effect; while symbols *ns* and *nc* signify a non-significant coefficient and no causality, respectively.

Table 10: Summary of Short-run and Long-run Causality for the Different Models

X variable	**Y variable: Dependent variable**															
	m3		***y***		***P***		***reer***		***savir***		***depir***		***lendir***		***disir***	
	SR[1]	LR[2]	SR	LR	SR	LR	SR	LR	SR	LR	SR	LR	SR	LR	SR	LR
m3			ns	+	+	+	-	+	-	-	+	+	nc	ns	-	ns
Y	Ns	+			Nc	ns	ns	ns	+	+	-	-	nc	ns	Nc	ns
P	+	+	nc	-			+	+	+	+	-	-	nc	ns	+	ns
depir	Nc	+	nc	-	-	ns	+	+	nc	+			Nc	-	+	ns
lendir	Nc	Ns	-	ns	Nc	ns	nc	ns	nc	+	Nc	-			+	ns
savir	-	-	+	+	Nc	ns	nc	-			+	+	nc	+		ns
reer	-	Ns	+	ns	Nc	+			-	+	+	-	+	ns	-	ns

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disir	Nc	-	+	ns	Nc	ns	-	-	-	-	-	ns	nc	+		ns

Notes to Table: *1. SR signifies short-run. 2. LR signifies long*-run. *Source: Data processed by the author.*

5. CONCLUSIONS AND RECOMMENDATIONS

Structural breaks occurred for money demand, real GDP, lending rates, prices, real effective exchange rates, saving rates, deposit rates and discount rates in 1986, 2015, 2008, 1986, 1994, 1992 1992 and 1993, respectively. These breaks were either constant, trend and/or slope structural breaks. Additional structural breaks may have occurred for the price in 2007, 2008 and 2009; and for deposit rates in 2013.

Cointegration with structural breaks existed for all equations including the money demand, price, income, exchange rate, and the four interest rate variables. The long-run elasticities of money demand to price, income, deposit rate, discount rate, and saving rate are 1.568, 2.184, 5.52, -0.0911 and -5.849, respectively. It is not influenced by lending rates and real effective exchange rates.

The long-run elasticities of income to money demand, price, deposit rate, and saving rate are 0.5021, -0.5429, -3.391 and 3.6048, respectively. The discount rate, and real effective exchange rate and lending rate do not cause income in the long-run. The long-run elasticities of price to money demand and real effective exchange rate are 1.648 and 0.499, respectively. The long-run elasticities of real effective exchange rate to money demand, price, deposit rate, discount rate, and saving rate are 0.5595, 1.158, 5.861, -0.1227, and -6.6157, respectively. The long-run elasticities of the saving rate to money demand, income, price, deposit rate, lending rate and real effective exchange rate are -0.1085, 0.268, 0.2029, 0.867, 0.048 and 0.0167, respectively. The long-run elasticities of the lending rate to the deposit, discount and saving rates are -4.889, 0.1158 and 5.3124, respectively. The long-run elasticities of deposit rate to money demand, income, prices, lending rate, saving rate and real effective exchange rate are 0.127, -0.311, -0.238, -0.0524, 1.155 and -0.0189, respectively. The discount rate is not significantly caused by any of the variables investigated in the long-run.

The short-run elasticities of broad money to saving rates, real effective exchange rate, and price are -6.324, -0.697 and 1.49, respectively. Broad money is elastic to the saving rate (negative effect) and the price (positive effect). Money demand does not influence (no causal effect) lending rates in the short-run. Income has a positive effect on broad money but it is insignificant in the short-run. The short-run elasticities of price to broad money, deposit rates are 0.45 and -01.593, respectively. The short-run elasticities of income to the saving rate, real effective exchange rate and lending rate are 1.1109, 0.128 and -0.0499respectively. Broad money has a negative but non-significant effect on income. The short-run elasticities of the real effective exchange rate to saving rates, broad money, price, deposit rates and discount rates are -4.00, -0.117, 0.639, 3.647 and -0.141, respectively. It is elastic to the saving rate and deposit rate. Income has a non-significant negative effect on the real effective exchange rate. The short-run elasticity of deposit rate to saving rate, real effective exchange rate, broad money, income, price and discount rate are 1.159, 0.102. 0.088, -0.066, -0.200 and 0.015, respectively. The short-run elasticities of the discount rate to lending rate, real effective exchange rate, broad money, price and deposit rate are 1.964, -3.266, -1.438, 3.898, and 22.72, respectively. The short-run elasticities of the saving rate to real effective exchange rate, broad money, income, price and discount rate are -0.0895, -0.0774, 0.0487, 0.171 and -0.012, respectively. The short-run elasticities of the lending rate to the real effective exchange rates and price are 0.3497 and -0.4845, respectively.

In conclusion, the above results based on a modified ARDL model which caters for structural breaks showed that in Uganda:

i). cointegration with structural breaks existed for all the equations corresponding to the above variables;

ii). the interest rate transmission channel for monetary policy is only effective through the savings, deposit and discount rates in the short-run and through the saving and deposit rate in the long-run;

iii). lending rates do not influence and are not influenced by money demand in the short-run, while in the long-run the effect is not significant in either direction, thus lending rates are not an effective channel for monetary policy transmission;

iv). the exchange rate transmission channel is effective regardless of the period considered, (short-run and long-run);

v). money demand has a significant inelastic positive effect on income in the long-run but a non-significant effect in the short-run, which implies that monetary policy based on broad money affects aggregate economic activities in the long-run but not in the short-run;

vi). money demand has an inelastic positive effect on price in the short-run but an elastic positive effect in the long-run implying that M3 can be used as an indicator for tracking future inflation in the policy formulation;

vii). money demand equation after accounting for identified structural breaks is stable and can be inverted to study its effects on the real variables in the economy;

viii). the income, real effective exchange rate, saving rate, lending rate and discount rate equations are also stable but the deposit rate equation is partially stable.

ix). increasing the saving rate is a more effective means of increasing income in Uganda compared to other variables included the income equation;

x). the discount rate (monetary policy variable) does not cause money demand in the short-run but has a significant negative though small effect in the long, thus in reality it may fail to cause large enough changes in the money supply, thus making its effect on aggregate activity via its effect on money supply small in magnitude; and

xi). the discount rate has a significant inelastic negative effect on income in the long-run but a significant positive effect in the short-run.

The above effects of monetary aggregates on economic activity, are in line with those of Montiel (2013) who reported statistically significant effects of base money on the price and exchange rate in the direction predicted by theory, however, in this case, the effect on prices is elastic unlike his findings; also money demand has a significant positive but an inelastic effect on income in the long-run but no effect in the short-run unlike his finding of a positive but non-significant effect of base money on income only in the short-run; also money demand (broad money) in this case has no short-run nor long-run effect on the lending rate, unlike his finding of significant effect of base money on lending rates. Further, the long-run elasticity of income to broad money (0.5021) obtained in this study lies within the range reported (0 and3.5) for the income elasticity for real money demand (broad money) reported by Subramanian (2001) who conducted a survey of empirical demand models for several industrial and developing countries. However, he indicated that there was no clear guidance on the acceptable magnitude of the elasticities or semi-elasticities of the opportunity cost variables.

It is recommended that:

i). empirical studies of money demand should be based on dynamic models with structural breaks due to prevalence of structural breaks in the time series variables and the endogeneity relationships among the variables of interest, thus structural break tests should be conducted prior to econometric modelling involving time series variables as a rule and money demand models in particular to signal the appropriate modelling approach;

ii). the Government of Uganda should implement measures that encourage people to save through the formal financial system by requiring the banks to pay favorable saving rates, since this may be a more effective interest rate transmission channel for monetary policy compared to the lending rate;

iii). monetary authorities in Uganda and developing countries in general should conduct continuous studies to establish the effectiveness of both the interest rate and exchange rate channels for transmitting monetary policy over time; and design policy measures that target the deposit and saving rates as key monetary policy transmission channels since they could be more effective than the traditional lending rate transmission channel;

iv). research to establish why the lending rates may not effectively transmit monetary policy actions in a developing country (as the indicated for Uganda) should be conducted for purposes of identifying remedial measures; and to establish whether the discount rate has an inelastic effect on money demand (as is the case for Uganda) in order to come up with measures aimed at increasing the effectiveness of the discount rate approach in controlling money supply; and that

v). mechanisms to increase the levels of savings should be devised to ensure economic growth.

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