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Bringing Rigour and Evidence to Economic Policy Making in Africa

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Abstract

The fourth-generation technological innovations coupled with Fintech has evolved into global transition to e-money. In Uganda the uptake and usage of e-money services have exponentially grown since the introduction of mobile money services in 2009. This study examines the theoretical foundation of e-money economics and employs time-series econometric approaches on Uganda data for the period 2009Q1-2022Q4 to assess their implication on the stability of the money demand function and transmission of monetary policy. The test for stability following the estimation of the money demand function with autoregressive distributed lag (ARDL) and transmission mechanisms in the vector autoregressive (VAR) model indicate that, e-money distorts the stability of the money demand function in the short-run and is procyclical with monetary policy shock (policy interest rates adjustments). These attributes of e-money are likely to adversely affect the effectiveness of monetary policy transmissions.

Keywords: Money demand, policy transmission, e-money, monetary policy

JEL classification: E41, E43, E59 E5

1. Introduction

The last two decades has witnessed remarkable advance in information and communication technology (ICT), which has permeated various aspect of the economy and the momentum continuous unabated. In finance sector, advance in ICT coupled with innovations in payment systems led to emergence and growth of electronic money or e-money that exhibit intrinsic characteristics of money[1]. E-money is safe, secure, and more cost-effective form for payments, storage, and financial transfers. According to Feyen *et. al.*, (2021) the growth in e-money is likely to revolutionize monetary economics. At its current growth pace, e-money is poised to become the dominant form of currency. However, the rate of uptake and usage varies among countries due largely to the level of infrastructure development, ICT integration, financial inclusion, and the policy framework in place (Mbiti and Weil, 2016; Johnen, Parlasca and MuBhoff, 2022; Davoodalhosseini & Rivadeneyra, 2020; and Tobias and Mancini-Griffoli, 2021). The issue of the impact of this shift in form of money on the economy and policy is crucial for the future of monetary economics. Despite the progress, the key facet of the e-money transition has received limited attention – with concerns about its dynamics on the money multiplier, impact on stability of the money demand, and implications on monetary policy transmissions.

In most developing countries with under-developed financial infrastructure, e-money and related services has enhanced access and usage of financial services, including among the traditionally un-banked rural population. Indeed, e-money products namely, mobile money, internet banking, debit cards, etc. have enhanced the level of financial inclusion and economic activities, especially among rural women and youths. E-money products facilitate the provision of a range of services namely, payments, transfers, savings, access to micro-credits, investments, and insurance services. Ideally, the benefits to the low-income earners are relatively higher due to lower transactions costs, efficiency, less stringent collateral requirements for e-credits, to mention a few. The effects these-money services have been more pronounced in Sub-Saharan Africa (SSA) countries where it has increased the levels their financial inclusion (Mbiti and Weil, 2016; Demirguc-Kunt *et. al.,* 2020). The growth in e-money in these economies has largely been driven by

[1] The International Monetary Fund defines e-money as a payment instrument whereby monetary value is electronically stored on a physical device or remotely in server, which represents claims on the issuers and represents general purchasing power (MFSMCG, 2016, para.4.38).

mobile money services. In fact, the SSA region has the largest percentage of mobile money account ownership, averaging 10 percent for adult population[2]. Moreover, the Global Findex 2021 indicates that at least 55 percent of adults in SSA owned an account, and 33 percent have a mobile money account (Demirgüç-Kunt et. al., 2022). Despite the improvement, the level of financial inclusion remains disproportionate among SSA countries - with most remaining low (Demirguc-Kunt *et.al.,* 2020; Demirgüç-Kunt et. al., 2022). The differences could be attributed to differences in the level of e-money uptake in each country (Mbiti and Weil, 2016). Therefore, to harness equity, there is a need for evidence-based policy interventions to ensure equitable and sustainable progress.

Internationally, the transition to e-money ecosystem has enhanced efficiency of cross-border payments that facilitates trade and capital flows. The e-money revolution coupled with the integration of the global financial systems, continue to enhance safety, efficiency, and security of e-money, which facilitate the globalization of financial markets, and intermediation (Prasad et. al., 2021). In fact, e-payment reduces the transaction costs, enable economic agents to exploit arbitrage opportunities, and switch assets holdings that is required to facilitate effectiveness of monetary policy on inflation and exchange rates (Ahiakpor, Cantah, Brafu-Insaidoo and Bondzie, 2019). Nevertheless, there remains significant risks arising from cyber-attacks, fraud, and conveyance of exogenous economic shocks for open economies. Besides, e-money amplifies the speed of shock transmission, including bank runs, which can create systemic risks with negative consequences for the real economy and capital flows. Furthermore, Palley (2014) suggests that the impact of e-money on monetary economics requires in-depth investigation.

The key questions for policy include: what happens to stability of the money demand function? How effective is the interest rate and credit channel of monetary policy transmission? These concerns require empirical evidence considering e-money penetration levels and its influence on payment systems, and propagation of shocks through financial markets, and instability (Tobias and Mancini-Griffoli, 2021; Davoodalhosseini and Rivadeneyra, 2020). The objective of this paper is to explore the economics of e-money and examine its impact on the stability of the money demand function and the transmission of interest rate shocks.

Assessing the impact of e-money on the monetary economics requires disentangling its effect from other influences. The most obvious approach involves evaluation of the correlations using macro-econometric methods,

[2] Mobile money is a form of e-float stored and transacted through a network of mobile phones.

which require long time series datasets. However, the transition to e-money is emerging phenomenon for most countries. For instance, in Uganda the evolution of e-money can only be traced back to the year 2000 when digital financial services were introduced. The real paradigm shifts however begun in 2009 following the licensing of mobile money services. The mobile money platform has transformed the way entities conduct transactions, save, borrow, and transfer financial resources. In most countries e-money operates concurrently alongside traditional currency notes and coins, making it difficult to disentangle its effects on the economy. Our approach is to employ a mix of co-integration and vector autoregressive techniques to isolate these effects. In so doing, this study makes two contributions. First, it estimates the structural breaks cointegration to evaluate the stability of the money demand function. And then evaluate the response of key macroeconomic variables following an endogenous monetary policy shock. Uganda provides an interesting case considering its cautious approach to adoption of e-money and conduct of monetary policy, which allows the economy to adjust to the changes induced.

The remainder of this study is organized as follows: Section 2, provides the background and motivation. Section 3 presents the theoretical and empirical literature while section 4 provides the conceptual framework, empirical strategy, and data. Section 5 presents analytical results and discussions. Finally, the summary, and conclusions are in section 6.

2. Motivation

The advancement in ICT coupled with payments systems innovations have led to widespread use of e-money, which continues to influence access and usage of financial services. In Uganda, this transition is largely attributed to adoption of mobile money that has made it possible to provide convenient, fast, and secure e-payment services. These attributes have facilitated their acceptability for peer-to-peer, business-to-persons/government, government-to-person/businesses transactions, and vice-versa. Moreover, the financial sector provides wholesale settlement services, for example, Real Time Gross Settlement (RTGS), electronic funds transfers (EFT) and e-banking services that facilitate bulk transfers. The efficiency offered by these channels has led to a gradual switch from physical currency units to e-money. The transition to e-money could be deduced to translate into substitution between the demand for cash and e-money thereby altering the composition of money supply, which affects the relative weights of currency in circulation, and demand deposit. Under this scenario, the currency-to-deposit ratio become less effective indicator of changes in money supply.

In Uganda, access and usage of e-money has exponentially expanded and innovations within the industry continue to grow. The legal and institutional framework for digital finance services (i.e., e-money through digital payment channels) is largely contained in the National Payments Systems (NPS) Act, 2020 and its accompanying NPS Regulation, 2021. The NPS 2020 provides for among others safety, efficiency, resolution of disputes, and Bank of Uganda's regulatory roles. The Act has opened room for innovations, especially for fintech and financial service providers which have facilitated rapid increase in access and usage of e-money products that meets local demand in the digital ecosystem. Like most developing African countries, Uganda's unprecedented growth in e-money is driven by mobile telephony – largely due to simplicity of the second-generation Global System for Mobile (GSM) Communication for transmitting sms information that operates on any mobile device. For instance, the number of registered mobile money subscribers exponentially expanded from 552,047 in 2009 to 40,891,557 by end 2022[3]. Access and usage of e-money services have increased the level of financial inclusion. However, sustaining this progress require secure and reliable telecommunications connectivity to maintain confidence in the system (not just mobile money). In fact, access stood at 13.92 million by January 2022, equivalent to 29.1 percent penetration rate[4]. Moreover, it has facilitated virtual 24/7 access and transactions for the share of this population. Over the same period, the numbers of points of sale (POS) machine or debit/credit card readers reached 4.54 million, equivalents to 9.4 percent a penetration rate with more growth expected in this segment as related challenges concerns are addressed[5].

The retail e-money products are largely provided by Mobile Network Operators (MNO) together with fintech while the wholesale e-payment services by the central bank. Transaction in the latter has expanded due to growth in both volume and value of EFT and RTGS transactions (see, Figure 1). The figure reveals the exponential expansion in volume and value of Uganda shillings (UGX) transaction during the period 2009-2022. Furthermore, cross-border e-payment systems has simultaneously evolved as uptake of the integrated East African Payment Systems expand with bilateral trade among

[3] This comprise of corporate and personal mobile money number for all thew networks providing such services in Uganda. There are many individuals who have registered multiple mobile money account as a measure to reduce the cost of transacting across networks and in areas where some networks have poor connectivity.

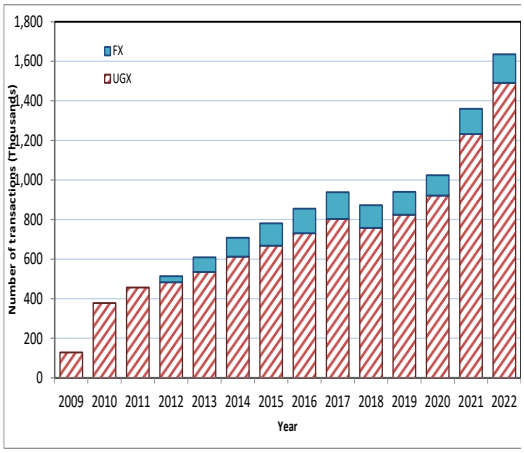
[4] The details are updated on the site: https://datareportal.com/reports/digital-2022-uganda

[5] See, https://www.statista.com/outlook/dmo/fintech/digital-payments/mobile-pos-payments/uganda for trends in usage of POS services in Uganda.

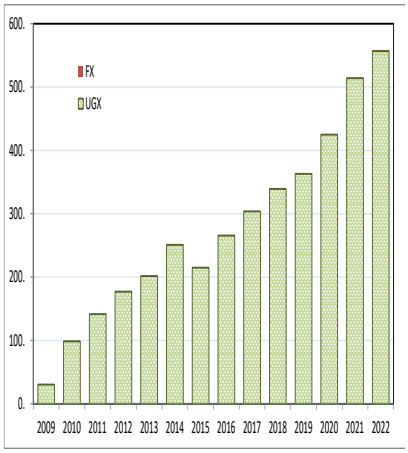
member countries since 2012[6]. However, the trends indicate declines in volume of transactions in 2017-2019 due to tax changes on mobile money transactions. However, slow-down was reversed from 2020 spurred by Covid-19 lockdowns, which encourage the use of e-money for transactions.

Figure 1: Trends in RTGS transaction Uganda

1(a). RTGS Transaction Volume (UGX.)



1(b). RTGS Transaction Value (UGX.)



Source: *Authors' computation based on statistics from BoU*

The mobile money segment expanded exponentially from 2009 to 2022 as illustrated by the trends in subscriptions or uptake in Figure 2(a) with matching trends in transaction volumes and values or usage shown in Figure 2(b) and 2(c), respectively. Statistics from the Bank of Uganda indicate that the number of subscribers is approximately equal to adult population however, this includes business and multiple personal accounts. These developments therefore make e-money a crucial component of Uganda's monetary and financial system along with physical cash.

E-money creation and integration into economic activities changes the composition of the money supply, which could affect the stability of the money demand function[7]. The stability of the money demand function is fundamental for management of monetary aggregates, a quantity tool that is

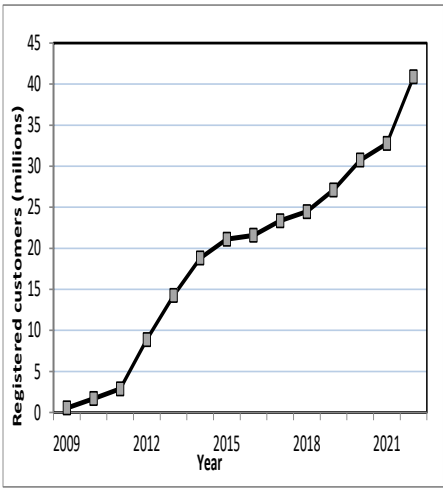
[6] The foreign transactions largely arise from activities on East African Payments System (EAPS) with the usage of foreign currencies, namely: the Euro (EUR), British pounds (GBP), Kenya shillings (KES) Rwanda Franc (RWF), Tanzanian shillings (TZS) and the United dollars (USD). They cover payments for imports and exports between the East African Countries.

[7] Availability of credit facilities on the digital platforms reduces rigidities in the money supply making it more volatile.

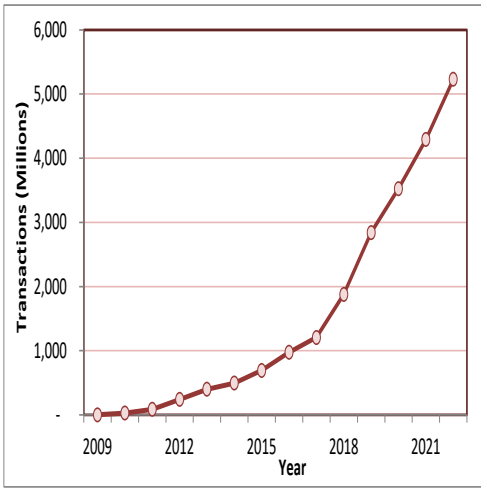
employed to fine-tune monetary policy action in intermittent periods even under the inflation targeting framework. Moreover, a weak and unpredictable relationship between aggregate money supply and income could reduce the impact of monetary policy with consequences for macroeconomic stability. Instabilities are likely to arise from the unexpected changes in the income velocity of money due to 24/7 access for transactions. Testing the stability of the money demand function provide evidence on its reliability for analysis and fine-tuning monetary policy actions under inflation targeting framework.

Figure 2: Trends in Mobile Money transaction Uganda

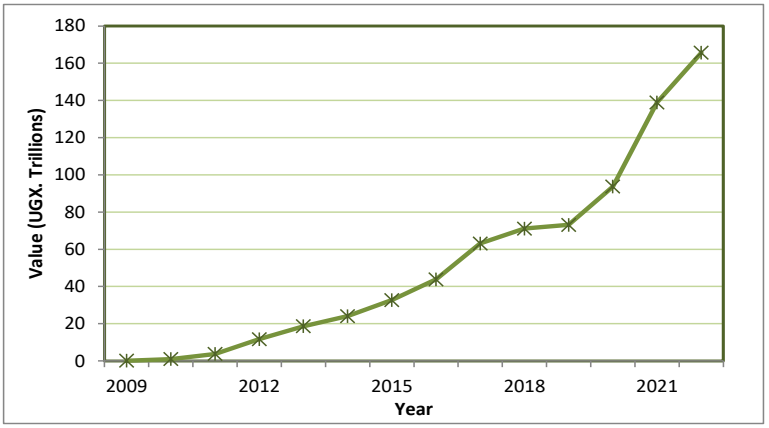
2(a). Customer subscription



2(b). Volume of transactions



2(c). Value of transactions (UGX. Trillions)



Source: *Authors' computation based on data from BoU*

The analysis of these issues is based on the assumptions that e-money adoption affects the income velocity of money demand. The latter arises from lags in the adjustments of money demand to income levels even if the monetary policy rates and other macroeconomic variables remains unchanged. Changes in income velocity is considered transitory and predictable under the monetary targeting framework; however, it is likely to become persistent with e-money. Moreover, complete, or partial adoption of e-money could shift the money demand function as parameters might become unstable due to unexpected changes in velocity of money. The consequence of this is a shift of interest elasticity of monetary demand and reserves. In the short run, the path of money supply may not necessarily correspond to the optimal level of the real money balance. This could induce large and unexpected changes in velocity that affects the stability of the money demand function.

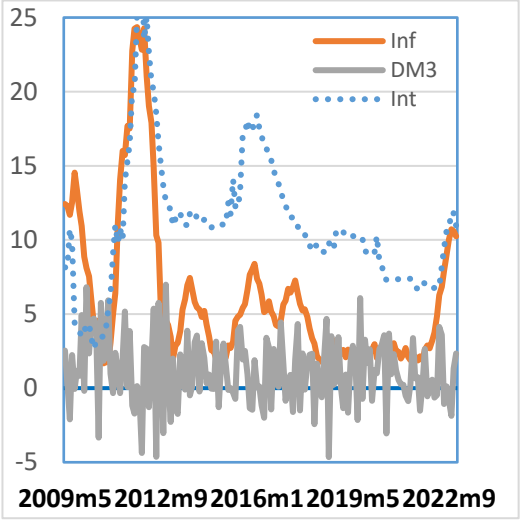
The primary objective of Uganda's monetary policy is price stability, which is defined as low and stable core inflation of 5 percent in the medium-term. The central banks employ the inflation targeting monetary framework with the policy rate referred to as the central bank rate (CBR) as the main instrument of policy. This is a price-based approach where the CBR is adjusted to influence aggregate demand in response to medium-term inflation expectations. A positive shoch (increase in CBR) tends to tighten demand when core inflation is expected to rise and vice versa. In addition to the interest rates, the policymakers have at their discretion a variety of instruments to influence financial conditions such that all other short-term remains within the CBR bandwidth. These policy instruments comprise of price based and quantity tools, namely, the Bank of Uganda bill, repurchase agreements (REPOs), cash reserve ratio (CRR), standing lending facility (SLF) to manage the liquidity levels and ensure money market rates are consistent with the policy. This implies that money supply and demand remain important component of monetary policy.

The e-money aggregate exhibit higher volatility as illustrated by its growth trends compared with inflation, and interest rates over the period 2009m4 - 2022m12 in figure 3, which reveal Uganda's three episodes of volatility. First, figure 1(a) show that, inflation respond to interest rate adjustments with lags of 1 – 4 quarters, reiterating its importance in managing effective demand. Preliminary estimates in figure 3(a) suggest that money supply growth does not seem to track inflation, an indication of unreliable strong and a predictable relationship over the period. On the other hand, e-money increases the volatility and has weak correlation with the policy interest rates (see, Figure 3(b)). This could adversely affect the transmission of monetary policy even

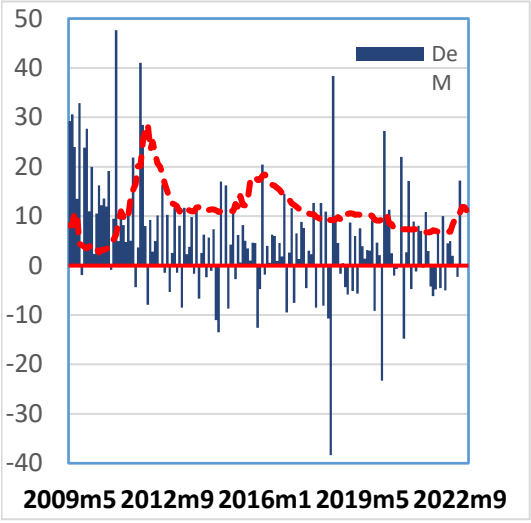
under inflation targeting. The presence of large structural liquidity influences the money demand function that could make it impracticable for policy interest rates to counteract business cycle shocks to restore stability.

Figure 3: Growth trends of key macroeconomic indicators

(a). Money supply, inflation and interest rates



(b). e-Money growth, and interest rates



Source: *Authors' computation based on data from BoU*

The stability money demand function has traditionally been an indicator that money supply has impact on both economic activities and inflation. In an economy that largely operates with s cash, this remains a good indicator for monetary policy. The changes induced by the e-money revolution are, however, likely to affect these relationships. This paper empirically investigated the existence of this relationship in a framework with and without e-money.

3. Literature review

The issue of e-money and its implications on the economy has received increased attention in the recent literature. These strands of the literature have continued to evolve with emerging theoretical approach that underpin econometric and micro-founded models for empirical investigations. At present, there are theoretical foundations and four aspects, namely the effects of e-money on money supply, demand, and the possible impact monetary policy.

Overview and theory

Advance in communication technology and financial innovations in the 21st century have led to emergence of e-money, which transformed commerce. The term e-money is defined as a store-of-value electronic product with features for storage, access, and transfers to pre-funded accounts in financial institutions, servers, and financial cards[8]. It may be stored or transmitted via the internet, payment cards, or mobile phones reducing the demand for the physical currency notes and coins (Staschen and Meagher, 2018). E-money is considered efficient, portable and secure means of handling finances. These attributes have facilitated the exponential growth of e-money and is likely to replace physical cash as a means of transactions and storage.

Theoretical foundation

The theoretical foundation for analysis of the impact e-money on the economy has continued to evolve with the advancement in financial technology (Fintech), usage, and customer behaviours. In most cases, the issue of substitution between physical cash and e-money in the narrow definition of broad money is crucial for financial inclusion and development of e-commerce. To underpin this argument, Jack, Suri, and Townsend (2011) formulated a theoretical framework for the interaction between cash and e-money based on the operation of M-PESA in Kenya. The model focusses directly on improvements in communication technology and the degree of financial interconnectedness between agents. The model assumes that increased connectedness among entities with e-payments, will enhance specialization of labour and consumption leading to shifts away from fiat money. On monetary policy interaction, Walsh (2010) uses monetary aggregates and the interest rate channel to provide a framework for analysis of velocity, substitutability, agent networks, and payment with spatial separation. Other theories in the literature centred on the drivers and implications of e-money on payment systems, monetary policy, and financial stability (Davoodalhosseini and Rivadeneyra, 2020). Consistent with the advancement in micro-founded agency models, Ngotran (2020), developed a dynamic stochastic general equilibrium (DSGE) model that incorporates e-money as a form of reserves for transactions between banking institutions and zero-maturity deposits for non-bank private sector. This approach allows the

[8] The term "e-money" is used to denote value paid or stored in conjunction within a variety of electronic retail payment systems, referred to as stored-value products or SVPs. On the SPVs, a record of the value available to the consumer is kept on an electronic device or records with a financial institution. The SVPs are not the same as the products that allow consumers to access the value of their e-money from their bank accounts or fintech.

central bank to simultaneously adjust the policy rate, intermediate target rate and the money supply to influence aggregate demand in the economy[9]. The DSGE model of Ngotran (2020) and Luo, Zhou and Zhou (2021) are extension of the neoclassical microeconomic model of Klein (1971), where the direct influence of the central bank reduces the adverse impact of e-money on monetary policy. Moreover, there is a growing application of network theory using big data analysis approach for examining the interaction among agents in the digital finance and e-commerce ecosystem.

Empirical literature

The research interest on the contributions and impact of e-money on the monetary economics, networks, financial inclusion, and socio-economic transformation has continued to grow largely on money supply (multiplier), demand (velocity) and the transmission of monetary shocks. The implications depend on structure of the economy and operational framework for e-money.

Impact on Money Supply

In economies where e-money is included in the monetary aggregates, it tends to increase the money multiplier, and thus the money supply. The empirical evidence of the impact on money supply dynamics however remains mixed and inconclusive. Azhar, Putra, and Huljannah (2020), and Fung, Molico, and Stuber (2014), established that e-money influences the stability of money supply in the short-run, mainly through growth. Its most liquid category, M1 - comprises of currency in circulation and demand deposits. Although e-money increases the money supply through base money and the money multiplier, the central bank employs interest rates, cash reserve ratio, and quantitative tools to reduce its impacts on money supply. However, Azhar, Putra, and Huljannah (2020) showed that in the long-run effects are muted. These results are based on evidence from an economy with privately issued e-money backed by bank deposits.

In contrast, the CBDC issued by the central bank tends to transform all aspects of the monetary system through facilitation of systematic and transparent conduct of monetary policy (Bordo and Levin, 2017). This implies that the choice of the central bank to issue either wholesale or retail CBDC has no repercussion on monetary policy, since it maintains control over the supply. In the retail CBDC strategy however, the direct dealing of the central bank with customer is thought to affect financial intermediation through the supply of

[9] They show that path of the interbank rate alone does not provide full information on the stance of monetary policy since endogenous money supply can decline even when the policy rate is near zero for a long time.

loanable funds. In fact, Andolfatto (2021), employed the dual framework based on the Diamond (1963) model of government debt and the Klein (1971) and Monti (1972) model of a monopoly bank to show that CBDC does not have adverse effect on bank credit extensions. A higher monopoly deposit rate, driven by market competition, decreases the profit margin on each loan but enhances savings (loanable funds) through financial inclusion. Therefore, the emergence and penetration of e-money have changed the structure of money supply, affecting liquidity and monetary economics.

Impact on Money Demand

The impact of e-money on the money demand transpires through velocity of money in circulation and its substitution with physical cash. Mobile money services have been the major driver for the increased demand and growth of e-money in the East African region (including Uganda) through inclusion of the unbanked share of the population (Mbiti and Weil, 2016). In terms of frequency of usage, the influence of e-money on monetary velocity remains a complex nexus. Using firm-level data Mbiti and Weil (2016) established that the introduction of M-Pesa led to substantial reductions in mobile banking, increased the frequency of money transfers, and reduced the use of informal saving mechanisms for the urban, educated, banked, and affluent households. The mobile money services therefore complement services provided by banking institutions, in the sense that their usage have increased the demand for digital banking services. According to Morawczynski and Pickens (2009) M-Pesa users send small but regular remittances to meet transaction needs of their relatives' – usually in rural areas, that adds-up to large values over time. In fact, they established that recipients of M-Pesa habitually keep float balances, which implies that mobile money accounts provide easily accessible saving platforms that ensure safety and availability to meet precautionary demand, especially for travelers (Burrell, 2010). This, therefore, implies that the uptake of e-money services accelerates the velocity of money demand through ease of access (i.e., available 24/7) for transaction purposes.

Despite the progress, all is not rosy as awareness and connectivity issues remain a challenge that is slowing the transition in some cases. The uptake and usage of digital financial services (including mobile money) in rural areas and among the low-income households has been slow causing a shift towards the development of complex financial services that could suit their needs but without sufficient policy coverage (Aparicio, Huayta and Bohórquez, 2016). This is because households in these socio-economic groupings have low literacy levels, which limits their appreciation of the benefits of formal financial services and therefore trust in the system. Moreover, this behavioral response hinders the substitution of physical cash and deposits for e-money

at the micro-level. Evidence at the macro-level based on structural vector autoregressive (SVAR) model suggest that mobile money has weak effects on money demand in Uganda due to low levels of financial inclusion (Mawejje and Lakuma, 2019). In general, it may take many years for e-money and payments to be widely accepted due to the persistence of cultural rigidities and transaction charges that tend to be relatively large for low-income households.

Impact on monetary policy

The literature on the influence of e-money on monetary economics and the effectiveness of monetary economies has largely focused on the implication for transmission of monetary policy through the central bank's control of monetary supply. Rogoff (2015) provide diverse opinions on the economic effects of digital finance penetration. Using spatial econometric model Hong, Liu, and Song (2022) showed that the interaction between e-money (digital finance) and monetary policy is significantly positive even though the impact on economic growth is negative. This implies that the effectiveness of monetary policy could be strengthened through enhancing the digital finance space. Katusiime (2021) employed an autoregressive distributed lag (ARDL) model to show that in the short-run, mobile money usage positively affects inflation, but are negatively influenced by financial innovation, exchange rate, interest rates and mobile money tax. Their findings suggest that in the long-run however, mobile money usage is positively affected by output, inflation, and other issues like the COVID-19 pandemic. In contrast, they established that mobile money customer balances, interest rate, exchange rate, financial innovation and mobile money tax negatively affect mobile money usage. Mobile money therefore ameliorates monetary policy, primarily through the saving channel, improving the effectiveness of monetary policy (Mawejje and Lakuma, 2019). Despite the gradual shift to e-money, the banking institutions continue to support intermediation. Bejar *et al.,* (2022) underpined this argument using historical balance sheet data for 692 banks from the Fitch Connect Database in 9 countries for 1988-2018 to show that rapid increase of fintechs creates opportunities for improved banking sector competition and financial inclusion. Moreover, Nizam (2022) suggests that e-money provides an important price-based nominal anchor for monetary policy.

The contribution of the central bank's monetary policy and operation stance in the e-money ecosystem is crucial in mitigating its adverse effects on the economy. This argument is supported by Lagos and Wright (2005), as well as Zhu, and Hendry (2018), that observed that central banks whose objective is to maximize welfare tend to be motivated to increase inflation through expansion of the fiat money supply even where digital currency exists, which

in turn causes high inflation and a loss in welfare. The loss in welfare arises from the fact that private agents in the digital credit ecosystem are largely driven by profit maximization motives. Depending on the policymakers' choice, there could be a sizeable adverse effect to the extent of exclusion of monetary policy (Griffith, 2012; and Canton, 2021). This implies that a monetary system with e-money could pose challenges to the optimal policy interest rates determination, exposure to cyber fraud, and bank runs – that could create instability to the entire financial system. These arguments are supported by Griffith (2012) by showing that intensification of financial instability through growth in private e-money elasticity, or scarcity of wholesale e-money from central banks could create liquidity crunch. In addition, there are operational concerns that are likely to arise from security breach and counterfeiting of e-money – unauthorized issuance of e-money floats. The latter could adversely affect confidence on the financial system with consequences on monetary policy effectiveness. Addressing the identified limitations require targeted policy interventions to keep track of innovations and manage the effects of short-term dynamics on the economy. Besides, the introduction of central bank digital currency (CBDC) offers an alternative to directly provide e-money whose issuance and liquidity are controlled by the central bank.

The evidence against e-money arise from its impact on velocity and money demand on the effectiveness of monetary policy. Priyatama and Gunadarma (2010) showed evidence of this nexus by estimating the correlation between e-money and changes in the velocity of money arising from small but numerous e-money retail transactions. Similarly, Khan and Gill (2013) found evidence of change in velocity of money in Pakistan with the resultant implications for economic growth, inflation, interest rate and ultimately financial development. The effects could be transmitted through asset price, which eventually influence aggregate consumption, investment, and output (Lagos and Zhang, 2019). Their argument is that the degree of the effectiveness of monetary policy on prices is only significant in economies with limits on cashless transactions. The evidence from Lagos and Zhang (2019) led to the conclusion that monetary models without money are inappropriate even in economies with well-developed credit markets.

In terms of risk expsoure, Tobias and Mancini-Griffoli (2021) argue that the risk exposure from e-money encompass operational (including cyber risk), illiquidity, default, market, and foreign exchange rate risk that have potentially undermined monetary stability. Moreover, Tan and Xue (2021) established that rapid development of digital currencies is likely to increase the financial system's vulnerability and pose challenges to the regulatory framework.

Therefore, nexus on the effect of e-money on the economy remains inconclusive, yet there is need for evidence to guide future interactions under various scenarios. This is largely attributed to the fact that e-money will not only affect e-commerce, but also the composition of monetary aggregates and either the direct or indirect conduct of monetary policy (Pan, 2005; Berentsen, 2005; Palley, 2014; Lou and Zhou, 2021; Popovska-Kamnar, 2014). The monetary policy tools are designed to influence aggregate demand through price and quantity-based measures to constrain money supply and credits. The transition to e-money is likely to affect the monetary policy operations and transmission dynamics.

Discussions

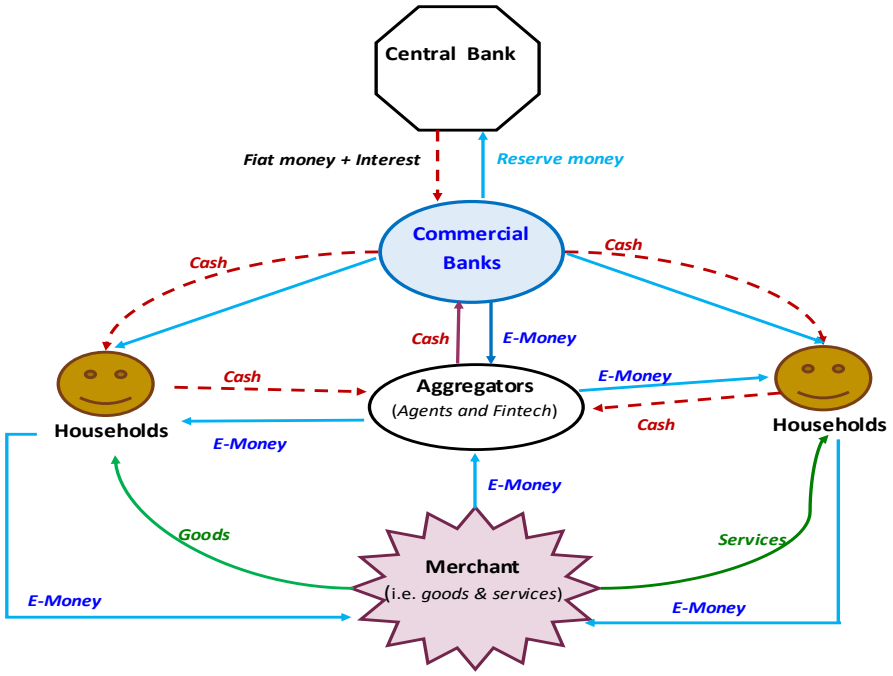
In general, the nexus between e-money, monetary economics and policy remains inconclusive, yet innovations and uptake of digital financial services continue to evolve. A key to the limitation for macro-studies is the focus on description of trends and unavailability of long data series to analyse the cointegrating relationships. The microeconomic research tends to focus on specific e-money services in terms of cost, efficiency, poverty reduction, financial inclusion, inclusive growth, and development. This study leverages the increasing availability of information on e-money creation and transactions to examine its impact on the stability of money demand and the transmission of monetary policy innovations, providing empirical evidence to guide monetary policy decisions

4. Methodology and Data

Conceptual framework for e-money operations

The theoretical foundation for analysis of simultaneous interaction of e-money and cash is illustrated in Figure 4. The framework is structured around the idea that e-money are issued by aggregators whose floats must have equivalent value in the banking institution. This is consistent with mobile money operations in Uganda. The design is intended to restrict the mobile money service providers from money creation.

Figure 4: The conceptual framework for flow e-money and fiat money



Source: *Authors*

The key assumption in Figure 4 is that customers withdraw funds either directly from the bank (i.e., mobile wallet, payment cards, etc.) or in cash and then convert to e-money (e.g., mobile money) for use. In this setting, central bank only manages money supply and interest rates, while the banking institutions provide a platform for intermediation, accessible through either cash or e-money channels. The conceptual framework assumes that customers are at liberty to choose between cash and e-money to ensure stability of the financial system in the modelled economy. The aggregators therefore link these entities through conversion between cash and e-money as well as provision of e-credits.

The conceptual framework and the Quantity Theory of Money (QTM) are employed to empirically quantify the effects of e-money on the stability of money demand function and the transmission of policy shock with e-money penetration. The theoretical foundation is based on the QTM postulated by Friedman (1970). The Quantity Theory of Money (QTM), combined with the Purchasing Power Parity (PPP) theory, has been widely applied to open economy monetary policy and provides insights into the transition to e-

money. The model assumes that real money balance, measured by the quantity of goods and services that a unit of money can purchase in the Fisher equation, postulated by Fisher (1911), specified as:

$$P_t Y_t = M_t^d V_t \quad (1)$$

where the variable P_t denotes the price level, Y_t is aggregate of tradeable goods and services in the economy proxied with the real gross domestic product (GDP), M_t^d represent the money supply available to economic agents at time t, and V_t denotes total velocity of money in circulation. Equation (1) provides the foundation for examining the impact of money supply on prices and income. Friedman's QTM extends this theoretical foundation on the assumption that if velocity of money remains stable, then changes in money supply directly affects real income – such that reduction in money supply translates into reduced effective demand translating into lower inflation. Therefore, in the Quantity Theory of Money (QTM), what matters is the effect of the real quantity of money on price levels, assuming that aggregate supply remains constant as follows:

$$M_t^d = \tau P_t Y_t \quad (2)$$

where $\tau = 1/V$ is the inverse velocity. In equation (2) the amount of money demanded by households is a function of the nominal income ($P_t Y_t$) or simply $M_t^d = f(Y_t, I_t)$ due to the critical role interest rate plays in determination of real money balances under inflation targeting. Equation (2) is applicable to closed economies; however, most economies are open to international trade and capital flows. The model is modified to account for exchange and foreign interest rates that are important in explaining macroeconomic dynamics of Uganda's small open economy. Consequently, equation (2), becomes:

$$\frac{M_t^d}{P_t} = f(Y_t, I_t, S_t, I_t^*) \quad (3)$$

where, Y_t denotes the real income, I_t is the opportunity cost of holding real money balances proxied by the risk-free 91-days annualized treasury bill rates, S_t is the real exchange rate, and I_t^* denotes the foreign interest rates[10]. Equation (3) provides a theoretical basis for evaluation of the effect of e-money

[10] This is on the assumption of no-arbitrage opportunities for entities in small open economy to investment in foreign risk-free debt securities.

on the stability of money demand function. This theoretical underpinning has been implemented in the empirical literature in Friedman (1970) quantity theory, the liquidity preference following Keynes (1936), and the inventory approach of Baumol (1952) and Tobin (1956), which considers transaction costs. Moreover, extensions with the portfolio approach of Tobin (1956), cash-in-advance model of Clower (1967), and shopping time model following Sidrauski (1967) have also been empirically tested.

Empirical approach

Stability of the money demand function

The empirical approach is based on the theoretical construction and econometric estimation of the money demand function with M_t^d as the dependent variables on a set of explained variables in equations (8). Further, the estimated model follows the Baumol and Tobin money demand function augmented with e-money and demographic change[11]. Consider the modified money demand function.

$$ln\left(M_t^d\right) = \alpha_0 + \alpha_1 \ln(Y_t) + \alpha_2 I_t + \alpha_3 \log(S_t) + \alpha_4 I_t^* + \alpha_5 \log(M_t^e) + \alpha_6 \log\left(C_t^d\right) + \alpha_7 \ln(Z_t) + \epsilon_t$$
$$\alpha_1, \alpha_3, \alpha_5, \alpha_6 > 0, and\ \alpha_2, \alpha_4, \alpha_7 < 0 \qquad (4)$$

where M_t^d denotes real money balance computed from monetary aggregates normalized by the GDP deflator. The parameters α_k with $k \in (0, \dots, 8)$ are the coefficients of regressions. The other variables are defined in equation (3) plus M_t^e for real e-money float, C_t^d is currency in circulation, Z_t is the population and ϵ_t is a residual term.

Given the order of integration of the variables, the autoregressive distributed lag (ARDL) approach to cointegration of Pesaran and Shin (1999) and Pesaran, Shin and Smith (2001) are considered the most appropriate method for this cointegration analysis and testing the stability of the estimated model. The ARDL is superior to the univariate Engle and Granger (1987) and the Johansen (1988, 1991) multivariate maximum eigen values and trace statistics for cointegration test approach because it generates plausible results even when the time series is short. Moreover, the ARDL is applicable irrespective of the order of integration as long as the variables are either *I*(0) or *I*(1) but none of

[11] The underlying assumption that population increases aggregate money demand. Such that, even if per capita money holdings remain constant, an increase in population increases transactions demand with the corresponding increase in demand for money. In contrast, e-money adoption facilitates small transactions and therefore lowers the incentive for money.

them has higher order of integration[12]. The ARDL has an internally built mechanism to address the problem of endogeneity since it includes lagged dependent variables among its regressand.

In view of the aforementioned advantages, the regression model in equation (4) is thus formulated into a generalized ARDL model for the dependent variable M_t^d regressed on a set of independent variables $X_{1,t}, X_{2,t}, X_{3,t}, \dots X_{n,t}$ denoted as $ARDL(p_0, p_1, p_2, \dots, p_n)$ such that p_i is the lag order of M_t^d and the others are the lag orders of the independent variables. The equation for $ARDL(p_0, p_1, p_2, \dots, p_n)$ is:

$$m_t^d = \gamma_0 + \sum_{k=1}^{p_0} \alpha_0 m_{t-1}^d + \sum_{k=1}^{p_1} \alpha_1 y_{t-k} + \sum_{k=1}^{p_2} \alpha_2 i_{t-k} + \sum_{k=1}^{p_3} \alpha_3 s_{t-k} + \sum_{k=1}^{p_4} \alpha_4 i_{t-k}^* + \sum_{k=1}^{p_5} \alpha_5 m_{t-k}^e + \sum_{k=1}^{p_6} \alpha_6 c_{t-k}^d + \sum_{k=1}^{p_7} \alpha_7 z_{t-k} + \omega_t \quad (5)$$

Where the lower-case variables $m_t^d, y_t, i_t, s_t, i_t^*, m_t^e, c_t^d \; and \; z_t$ are the log transformation of $M_t^d, Y_t, I_t, S_t, \; I_t^*, M_t^e, C_t^d, and \; Z_t$, respectively. The parameter, ω_t captures the stochastic term.

The estimation of the ARDL model begins with the bound testing procedure to identify the short and long-run cointegrating relationships. The unrestricted error correction model (UECM) of equation (5) is:

$$\Delta m_t^d = \gamma_0 + \sum_{k=1}^{p_0} \alpha_{0,k} \Delta m_{t-1}^d + \sum_{k=1}^{p_1} \alpha_{1,k} \Delta y_{t-k} + \sum_{k=1}^{p_2} \alpha_{2,k} \Delta i_{t-k} + \sum_{k=1}^{p_3} \alpha_{3,k} \Delta s_{t-k} + \sum_{k=1}^{p_4} \alpha_{4,k} \Delta i_{t-k}^* + \sum_{k=1}^{p_5} \alpha_{5,k} \Delta m_{t-k}^e + \sum_{k=1}^{p_6} \alpha_{6,k} \Delta c_{t-k}^d + \sum_{k=1}^{p_7} \alpha_{7,k} \Delta z_{t-k} + \delta_0 m_{t-1}^d + \delta_1 y_{t-1} + \delta_{2,k} i_{t-1} + \delta_3 s_{t-1} + \delta_4 i_{t-1}^* + \delta_5 m_{t-1}^e + \delta_6 c_{t-1}^d + \delta_7 z_{t-1} + \theta ect_{t-1} + \omega_t \quad (6)$$

[12] This implies that the unit root test is only applied to check that none of the variables are of *I*(2) or higher order of integration.

Equation (6) depicts the ARDL model that accounts for both the short-run and long-run dynamics. The first part with parameters α_{nk} represents the short-run model while the second with parameters, $\delta_{n,j}$ denotes the long-run multiplier of the long-run model. The operator Δ denotes the first difference of each variable, the parameter θ denotes the coefficient of the error correction term or speed of adjustment, and ω_t is the stochastic error term. The null and alternative hypothesis for testing the cointegrating relationships is given by:

$H_0: \delta_{0,j} = \delta_{1,j} = \delta_{2,j} = \delta_{3,j} = \delta_{4,j} = \delta_{5,j} = \delta_{6,j} = \delta_{7,j} = 0$ (i.e., absence of cointegration)

$H_a: \delta_{0,j} \neq \delta_{1,j} \neq \delta_{2,j} \neq \delta_{3,j} \neq \delta_{4,j} \neq \delta_{5,j} \neq \delta_{6,j} \neq \delta_{7,j} \neq 0$ (i.e., presence of cointegration) (7)

The test for stability of the money demand function is crucial for assessing the implication of e-money adoption. Once the presence or absence of cointegration among the variables is established the stability of the estimated ARDL model is checked with the Wald test, Ramsey's RESET test, the Lagrange Multiplier test and Cumulative Sum of Recursive Residuals (CUSUM) test. The empirical literature also uses the Cumulative Sum of Squares Recursive Residuals (CUSUMSQ) or a combination of both CUSUM and CUSUMSQ to investigate the presence of serial correlation, heteroscedasticity, and the stability of the residuals from estimation. This study employs both the CUMSUM and the CUMSUMSQ plots as well as the Ramsey reset diagnostic test.

Transmission of monetary policy

Uganda's current inflation targeting monetary policy framework uses the policy interest rates or CBR as the main instrument for monetary policy. Changes in the interest rates in response to inflation expectations are considered monetary policy shock that affect aggregate demand and investment decisions in the economy. This section examines the transmission of monetary policy shocks with e-money using vector autoregressive model (VAR) to generate the impulse response function, and variance decomposition. The generalized VAR(p) model follows Lutkepohl (2005), as follows:

$$y_t = \boldsymbol{A}\boldsymbol{Y}_{t-1} + \boldsymbol{B}_o x_t + \boldsymbol{u}_t \qquad (8)$$

Where the variables y_t is a $(k \times 1)$ vector of endogenous variables, $\boldsymbol{Y}_t$ is the $(Kp \times 1)$ matrix of independent variables, and x_t is an $(M \times 1)$ vector of exogenous variables. The parameters $\boldsymbol{A}$ is a $(K \times Kp)$ matrix of coefficients on the lagged endogenous variable and $\boldsymbol{B}_o$ is a $(K \times M)$ matrix of coefficients on

exogenous variables. $\boldsymbol{u}_t$ is the $(k \times 1)$ vector of stochastic white noise innovations. The impulse responses to policy innovations and decomposition of variance are based on VAR(p) estimates for equation (8).

Data

The ARDL and VAR models are estimated with data covering the period 2009Q2 - 2022Q4, which represents 56-time dimension for each variable. The series covers the period with e-money usage in Uganda following the introduction of mobile money and wholesale payment methods. The variables used in the estimation are: C_t^d, which denotes the currency in circulation; Y_t is the income or quarterly real GDP[13]; and I_t is the policy interest rates based on the annualized 91 days treasury bill rates. Since the model is augmented, the variable m_t^e denotes the stock of e-money in the economy[14], S_t is the exchange rate, I_t^* denotes the US dollar federal fund rate, and Z_t represent the population. The datasets were obtained from the Bank of Uganda, Uganda Bureau of Statistics (UBOS), St. Louis Fed, and the World Bank's World Development Indicators (WDI). The detailed description for each variable is provided in Appendix 1.

5. Findings

Empirical results and interpretation

The summary statistics in Table 1, indicates that all the variables exhibit low variance except, policy interest rates and e-money. The high volatility of e-money is attributed to its exponential growth since, 2009Q1. The plot of these 9 variables at level are illustrated in Appendix 2, which indicate that apart from the two interest rates, all other variables exhibit positive trend.

[13] If the aggregate consumption from the GDP series is available, they would have provided a more appropriate variable since it directly feeds into the money demand of economic agents. The unavailability of disaggregated consumption series for Uganda has limited this study to use GDP estimated by expenditure approach, which provides a good approximation.

[14] The stock of e-money in the economy comprises of the cumulative value of mobile money and other e-money floats issued by the mobile network operators and financial institutions.

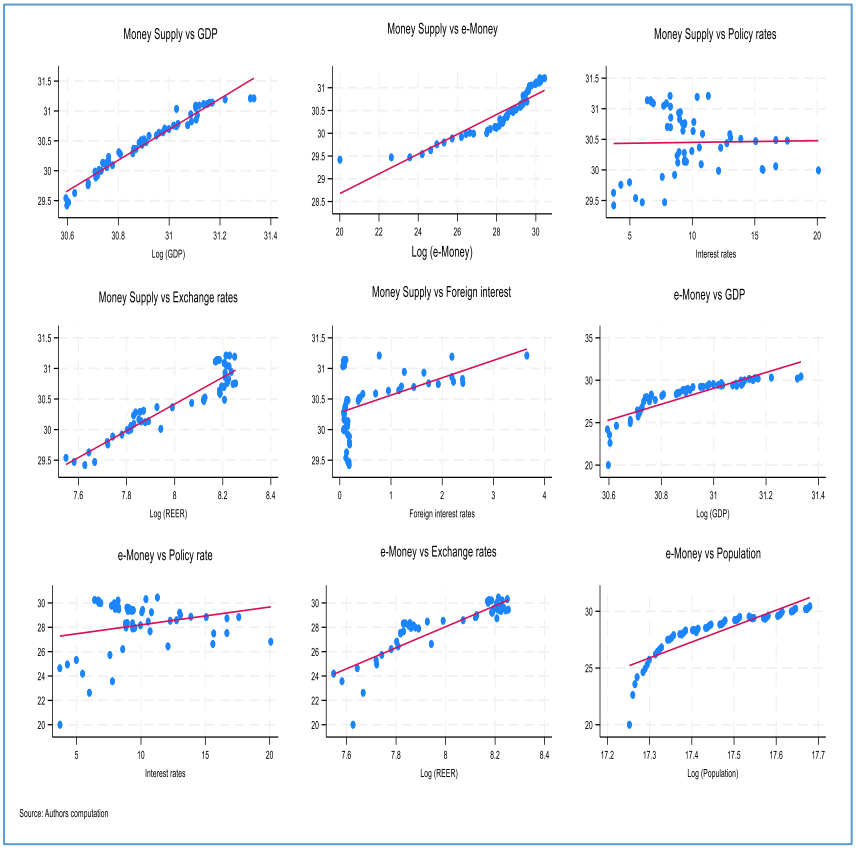
Table 1: Summary statistics (variables after log transformation)

Variable	Obs	Mean	Std. Dev.	Min	Max
Money supply (M3)	56	30.45	0.506	29.42	31.211
Income (GDP)	56	30.906	0.192	30.594	31.333
Interest rates (INT)	56	9.8	3.484	3.696	20.091
E-money (eMy)	56	28.172	2.128	20.007	30.448
Currency in circulation (CiC)	56	28.687	0.464	27.85	29.482
Exchange rates (FX)	56	8.015	0.216	7.548	8.253
Foreign interest (rUS)	56	0.602	0.833	0.06	3.653
Population (POP)	56	17.462	0.13	17.252	17.68

Source: *Authors' computations*

In terms of pairwise correlation between the variables at level, estimates indicate a strong positive correlation among all variables, except interest rates as shown in Figure 5. This is consistent with the consensus in the literature that the level of income positively affects money supply but is negatively related to interest rates increase. Moreover, the findings suggest that there exists a strong positive correlation between money supply and currency in circulation. The latter imply that there is weak substitutability between e-money and physical cash usage. An assessment with e-money growth shows weak, positive, and significant correlation with policy interest rates, as summarized in Appendix 3. This contrasts with monetary theory, which postulate that interest rates have an inverse relationship with money supply. The correlation between monetary supply, e-money and the other variables are mixed. This requires in-depth investigation with the ARDL estimation of the money demand functions under various scenarios.

Figure 5: Correlation between e-money and key variables



As discussed in the methodology, the ARDL approach to bounds testing is applicable regardless of the order of integration of the regressors. Therefore prior to econometric estimation, it is necessary to conduct unit root test to ensure that the variables are either I(0) or *I*(1)) but not *I*(2) and above, which invalidate the ARDL procedure. This study employed Augmented Dickey-Fuller (ADF) unit root test with intercept only on log-transformed variable to check for stationarity and determine the order of integration of the variables. The Philips-Perron (PP) test is employed to check consistency of the ARDL procedure. Results from ADF and PP in Appendix 4 reveal that all the variables are *I*(1), except the two interest rates that are *I*(0). Since the variables have different orders of integration, the ARDL approach of Pesaran, Shin and Smith (2001) are considered the most appropriate method to examine the cointegrating relationship between the variables of interests in the money demand function and its stability.

The choice of appropriate lag-length based on Akaike Information Criterion (AIC) indicate that the maximum lag order is 2 to save on the degree of freedom (*see*, Appendix 5). Estimate of equation (6) with the ordinary least squares (OLS) approach shows that the money demand function is well fitted in signs and significance. The next step involves identification of the cointegrating relationship and test for the stability with and without e-money.

Results of the ARDL bounds test confirm the presence of long-run cointegrating relationships in the money demand function as in Table 2, which indicate that with 54 timeseries and 7 regressors the estimated F-statistics for the two models are greater than the upper critical bounds at 5% levels of significance[15]. This implies the presence of cointegrating relationship among these variables.

Table 2: Bounds test results for cointegration.

Null Hypothesis: No long-run relationship exists among the variables in the model

	Critical Bound values: k=7 and n=54	
	Money supply (M3)	
	***I*(0)**	***I*(1)**
10%	2.03	3.13
5%	2.32	3.50
1%	2.96	4.26
F-Statistics	4.233	

Source: *Authors' computations*

The presence of the cointegrating relationship implies that there is need to estimate the long-run and short-run coefficients for the money demand functions. Estimates of the long run in Table 3 indicate that real output produces the expected sign and is significant at 5%, which suggest that a unit increase in money supply leads to 0.94% rise in output. This low-income elasticity of demand is an indication of low money demand for transactions that may imply transition to e-money. The coefficient of the policy interest rate produces the expected signs and is significant at 5%. Similarly, the exchange rate coefficient is positive and significant at 5%, which indicates that a unit increase in exchange rate increases the demand for broad money by 0.54%.

[15] Two time series are removed from the variables because of the lag adjustment.

Table 3: Long-run coefficient estimates of the money demand function.

Variables	Coefficient	Std Error	t- Statistics	P-values
Income (GDP)	0.9396	0.3597	2.61	0.018**
Interest rates (INT)	-0.0137	0.0062	-2.22	0.039**
e-Money (eMy)	0.0076	0.0180	0.42	0.677
Exchange rate (FX)	0.5356	0.2457	2.18	0.043**
Foreign interest (rUS)	-0.0450	0.0125	-3.61	0.002***

Source: *Authors' computations*

The positive coefficient is suggestive of the wealth effect, which implies that a depreciation (appreciation) of the local (foreign) currency uses more local currency to attract foreign currency per unit. If the increase in local currency translates into increased disposable income, then the local currency demand by households increases and the exchange rate coefficient becomes positive. The coefficient on the foreign interest rates suggests substitutability between the local unit and high yielding foreign assets. The size of the coefficient and levels of significance suggest that influence of globalization on Uganda's economy is large due to the level of openness. The coefficient on e-money and currency in circulation are both positive as expected but are not statistically significant.

Table 4: Short-run Coefficient estimates of the money demand function (M3)

ARDL(4,4,4,4,4,3,4) regression *Sample: 2010q1 - 2022q4*

Variables	Coefficient	Standard Error	t-Statistics	P-values
Δ_3 Money supply (M3)	-0.4617	0.1452	-3.18	0.005***
Δ_1 Income (GDP)	-0.4797	0.1709	-2.81	0.012**
Δ Income (GDP)	-0.2953	0.1356	-2.18	0.043**
Δ_1 Interest rate (INT)	0.0077	0.0019	4.11	0.001***
Δ_2 Interest rate (INT)	0.0078	0.0015	5.25	0.000***
Δ e-Money (eMy)	-0.0733	0.0188	-3.91	0.001***
Δ_3 e-Money (eMy)	-0.0383	0.0092	-4.15	0.001***

ARDL(4,4,4,4,4,3,4) regression				*Sample: 2010q1 - 2022q4*
Variables	**Coefficient**	**Standard Error**	**t-Statistics**	**P-values**
Δ_3 Currency in circulation (CiC)	-0.2692	0.1207	-2.23	0.039**
Δ_1 Foreign exchange rate (FX)	-0.1560	0.0709	-2.20	0.041**
Δ Foreign exchange rate (FX)	-0.2021	0.1002	-2.02	0.059*
Δ_2 Foreign exchange rate (FX)	-0.2365	0.0874	-2.71	0.014**
Δ_2 Foreign interest rate (rUS)	-0.0434	0.0160	-2.71	0.014**
Δ_3 Foreign interest rate (rUS)	-0.0402	0.0120	-3.34	0.004***
Cnstant	-8.5583	3.6539	-2.34	0.031**
ECT(-1)	-0.6620	0.3200	-2.07	0.053*
R-squared	0.9691			
Adjusted R-squared	0.9123			
Log likelihood	193.0336			

Source: *Authors' computations*

The stability of the estimated money demand function is checked using a set of diagnostic tests conducted, presented in Table 5. The result shows that the model passes the Durbin-Watson test for autocorrelation but fails on the serial correlation and heteroskedasticity. However, the Ramsey reset test confirms stability of the model.

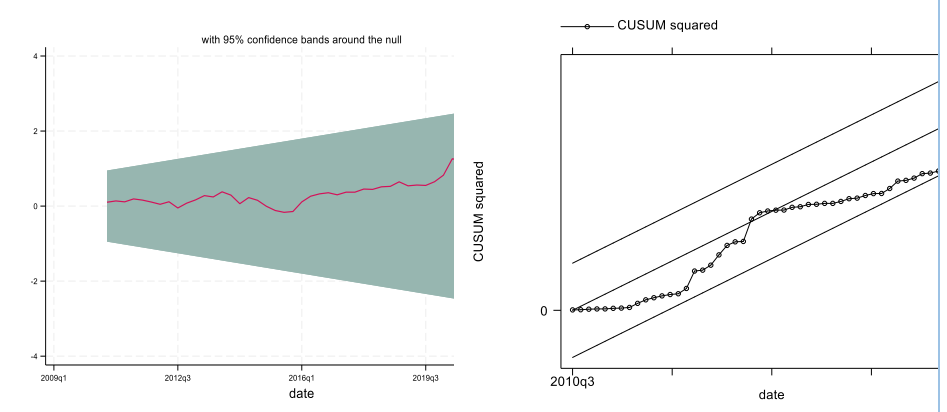
Table 5: Short-run coefficient estimates of the money demand function

Diagnostic test type		**Dependent: M3**	
		Test-stat	**P-value**
Autocorrelation	Durbin–Watson	2.251287	-ve
Serial corelation	Breusch–Godfrey	3.003	0.0831
heteroskedasticity	Breusch–Pagan	3.02	0.0825
Stability	Ramsey RESET	0.04	0.9898

Source: *Authors' computations*

The stability of the parameters of the money demand function and money multiplier is important for assessing the efficacy of monetary policy. Previous studies have employed the CUSUM and the CUSUMSQ or a combination to assess the stability of the estimated money demand functions. The plot of both CUSUM and CUSUMSQ in Figure 6 reveal that the statistics lies within the critical bounds, which suggest that the estimated money demand function model is stable.

Figure 6: Plot of CUSUM and CUSUMSQ for the estimated model



Source: *Author's computation*

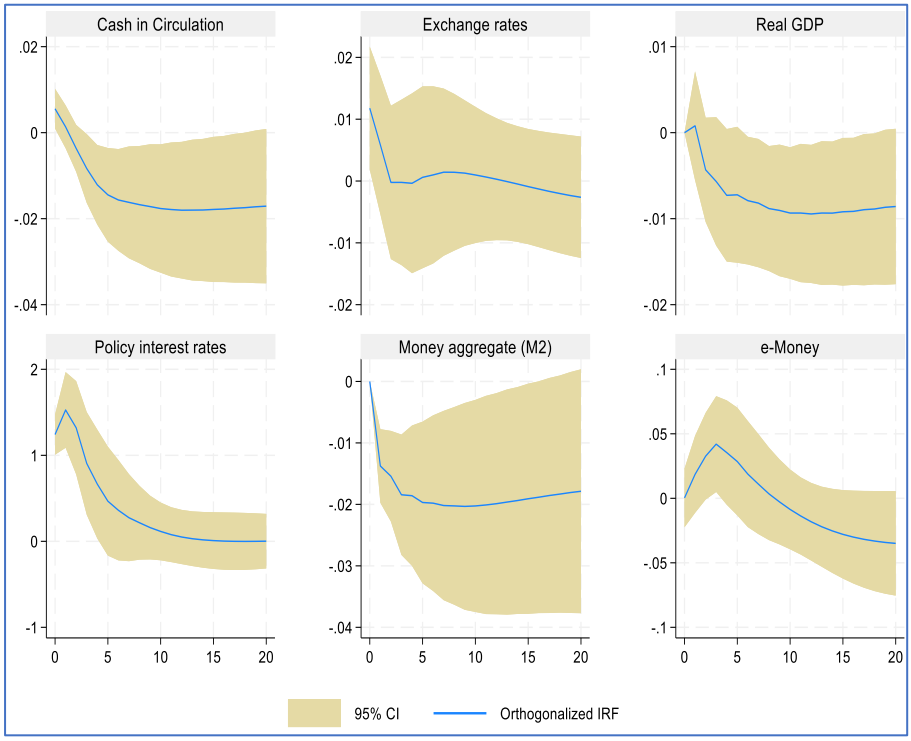
The estimated money demand function shows the presence of the long and short run relationship between variables and that the model is stable even when e-money is included. It is important to note however, that there are some changes created by the transition to e-money, which could have implications on the economy and monetary policy transmissions.

Turning to the implications of e-money on the transmission of policy, we estimate the VAR model in equation (8) and generate the impulse responses to a shock. Monetary economics suggests that a unit increase in the policy rate leads to a decline in the money supply as credit conditions tighten, thereby reducing output. The impulse responses in Figure 7 indicate that a unit monetary policy innovation causes e-money to fall below zero and begins to decline only after 10 quarters and the impact remains persistent. This irregular response is likely to expand as e-money usage increases and could adversely affect monetary policy transmissions. The irregular response could be attributed to the willingness of Fintech to undercut rates on digital credits in the short run to expand their market share. These competitive behaviors could be balanced with the regulation of FinTechs. Digital credits availability is likely to affect the speed and distribution of the effect of monetary policy shock. This

could render policy ineffective in a situation with large structural liquidity that makes it possible for intermediaries to provide credits at rates not aligned to the policy rates. There could, however, be efficiency gains arising from the ease of identification, rating, competitive pricing, and access to credits.

A unit monetary policy shock leads to appreciation of exchange rates, which suggest portfolio arising from relative interest rates. However, the effect of the monetary shock on exchange rate dissipates after 2.5 quarters probably on account of the level of integration with the global financial system – that facilitate agents to exploit any arbitrage opportunities.

Figure 7: Impulse response to a unit (1%) monetary policy shock



Source: *Authors' computations*

The transition to e-money is likely to affect the transmission of monetary policy. This is an evolving area that require continuous investigations as more data points become available. E-money will continue to affect the monetary economics and the conducts of policy in the coming years, but any adverse impacts can be managed if research continues to provide empirical evidence.

6. Conclusions

This study examines the economics of e-money and its implication on monetary policy dynamics using time series techniques on quarterly data from Uganda over the period 2009Q1-2022Q4. First it empirically estimates and checks the stability of the money demand function with e-money in an estimated ARDL model. The bounds test for cointegration test established long-run relationship among the variables and the test for stability based on the CUSUM and CUSUMSQ plots showed that the estimated model is stable. However, the estimates show low-income elasticity of money demand in contrast to theory, which suggests the transition from cash-based to e-money has been slow. In other words, the low-income elasticity of money demand signals that e-money has penetrated the economy, even though the informal economy remains large. This suggests improved level of inclusion that could facilitate the transmission of monetary policy to real economic activities through its impact on aggregate demand. Similarly, exchange rate was found to have a positive and statistically significant relationship with money supply signifying the impact of Uganda's openness.

In addition, to examine the implications of e-money on the transmission of monetary policy, we estimated a simple VAR model using the same quarterly data and computed the impulse response function to an interest rate shock. The findings indicate that e-money initially increases following an increase in the policy rates before gradually declining in contrast to the other monetary aggregates. This could be due to inefficiency and bad competitive behaviours in the digital segment of the credit market creating higher rigidities to upward interest adjustments.

In general, the empirical results reveal the transition to e-money will affect the monetary economics and is likely to affect the efficiency of monetary policy transmission. The low-income elasticity of 0.9, confirms the impact of the switch from cash to e-money but there is need to incentivize agents to adopt and remain in e-money ecosystem.

Policy implications

- Given the short-term distortive effect of e-money, and the gains from the long-term benefits of e-money, policy should target close regulation and monitoring of the e-money ecosystem to dampen and mitigate the distortive effects on the economy in the short run.
- There is need to invest in the production of quality statistics on e-money to facilitate quantitative research in this area, which may require revision

in the legal and regulatory framework to guide stakeholders involved with e-money.

- There is need for policy makers and financial institutions to take into consideration social norms and understand the nature of society of the intended beneficiaries for appropriate interventions.

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8. Appendices

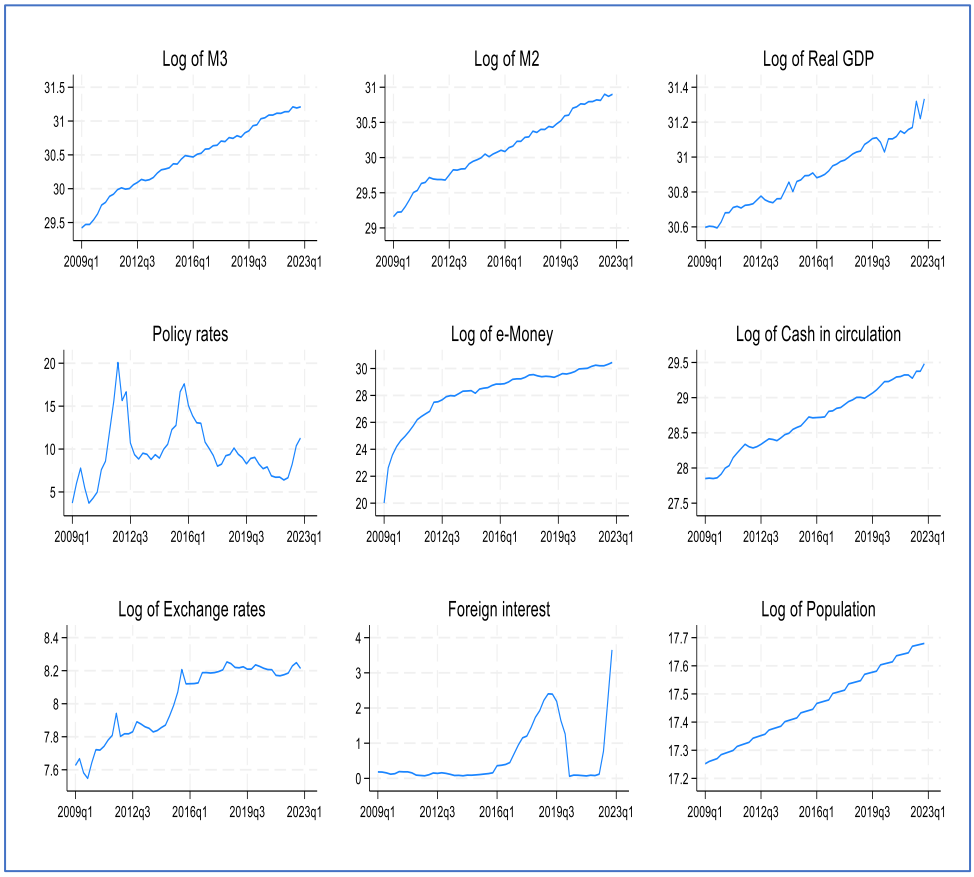
Appendix 1: Description of the variables

Variable	Symbol	Description	Data source
Broad money (M3)	M3	M3 is the sum of the stock of M2 and the value of foreign currency deposits with the depository corporations at the end of each quarter in Uganda Shillings (UShs).	Bank of Uganda (BoU)
Broad Money (M2)	M2	M2 is the sum of the stock of M1 (i.e., transferable deposits and currency outside depository corporations) plus other deposits held by the depository corporations at the end of each quarter in Uganda Shillings.	BoU
Real GDP	GDP	Real Gross Domestic Product (GDP) is an estimate of the value of goods and services produced in Uganda within each quarter at constant 2010=100 prices. The quarterly series used for the estimates are seasonally adjusted.	Uganda Bureau of Statistics (UBOS)
Policy interest rates	INT	Measured with the average quarterly 7 days interbank rate. The 7-days interbank rate is closely correlated with the policy interest rates and has more frequency of adjustments as the central bank fine-tune its policy around the target range.	BoU
e-Money	eMy	The total value of e-money at the end of each period is proxied from the balance on customers' accounts (UShs) of the mobile money floats. This does not include uncleared EFC/RTGS transactions or funds held in bank accounts.	BoU
Currency in Circulation	CiC	The stock of currency in circulations is proxied with the with the total value of Currency Outside Depository Corporations from the depository corporation survey.	BoU
Foreign exchange	FX	Foreign exchange rate is the nominal quarterly average rates between the US dollars and the Uganda shillings. It is measured as the number of UShs. per unit US$. The US$ is the main currency to trade between Uganda and the rest of the world and provides a good proxy.	BoU
Foreign interest rates	rUS	The foreign interest rate is based on the United States Federal Reserve bank monthly rates averaged into quarterly series.	St. Louis Fed

Variable	Symbol	Description	Data source
Broad money (M3)	M3	M3 is the sum of the stock of M2 and the value of foreign currency deposits with the depository corporations at the end of each quarter in Uganda Shillings (UShs).	Bank of Uganda (BoU)
Broad Money (M2)	M2	M2 is the sum of the stock of M1 (i.e., transferable deposits and currency outside depository corporations) plus other deposits held by the depository corporations at the end of each quarter in Uganda Shillings.	BoU
Real GDP	GDP	Real Gross Domestic Product (GDP) is an estimate of the value of goods and services produced in Uganda within each quarter at constant 2010=100 prices. The quarterly series used for the estimates are seasonally adjusted.	Uganda Bureau of Statistics (UBOS)
Population	POP	Total population is based on the de facto definition of population, which counts all residents regardless of legal status or citizenship. The values shown are midyear estimates.	World Bank, WDI.

Abbreviations used: US$ – United States dollars and WDI- world development indicators.

Appendix 2: Log of time series variables used at levels.



Source: *Authors' computations*

Appendix 3: Pairwise correlation between the variables

	LM3	LGDP	LINT	LeMy	LCiC	LFX	LrUS	LPOP
LM3	1.0000							
LGDP	0.9756*** (0.0000)	1.0000						
LINT	0.0194** (0.8872)	-0.0392 (0.7741)	1.0000					
LeMy	0.9135*** (0.0000)	0.8438*** (0.0000)	0.2400* (0.0748)	1.0000				
LCiC	0.9972*** (0.0000)	0.9796*** (0.0000)	0.0219 (0.8724)	0.8953*** (0.0000)	1.0000			
LFX	0.9327*** (0.0000)	0.9008*** (0.0000)	0.1607 (0.2368)	0.8752*** (0.0000)	0.9352*** (0.000)	1.0000		

	LM3	LGDP	LINT	LeMy	LCiC	LFX	LrUS	LPOP
LrUS	0.4676*** (0.0003)	0.5722*** (0.0000)	-0.0274 (0.8408)	0.3847*** (0.0034)	0.4912*** (0.0001)	0.5377*** (0.0000)	1.0000	
LPOP	0.9874*** (0.0000)	0.9853*** (0.0000)	-0.0701 (0.6075)	0.8567*** (0.0000)	0.9905*** (0.0000)	0.9117*** (0.0000)	0.5115*** (0.0001)	1.0000

Source: *Authors' computations*

Appendix 4: ADF and PP unit root test for non-stationarity of log-variables (1 lag)

Variables	ADF test statistics		PP test statistics	
	At level	First difference	At level	First difference
LM3	-2.501 (0.1151)	-3.555*** (0.0067)	-2.527 (0.1091)	-8.017*** (0.0000)
LGDP	0.649 (0.9888)	-5.922*** (0.0000)	0.729 (0.9904)	-12.090*** (0.0000)
LINT	-2.576* (0.0981)	-3.729*** (0.0037)	-2.536 (0.1069)	-5.984*** (0.0000)
LeMy	-4.810*** (0.0001)	-5.904*** (0.0000)	-8.610*** (0.0000)	-13.126*** (0.0000)
LCiC	-0.732 (0.8382)	- -4.234*** (0.0006)	-0.584 (0.8746)	-6.401*** (0.0000)
LFX	-1.427 (0.5695)	-5.683*** (0.0000)	-1.579 (0.4943)	-7.650*** (0.0000)
LrUS	-1.474 (0.5464)	-0.587* (0.0873)	-0.340 (0.9197)	-1.248* (0.0652)
LPOP	0.273 (0.9761)	-9.457*** (0.0000)	0.147 (0.9692)	-10.187*** (0.0000)

The null hypothesis is a unit root for both ADF and PP tests. Rejection of the null means that the variable is stationary. The MacKinnon approximate p-value for Z(t) are provided in paratheses. The asterisks ∗∗∗, ∗∗, and ∗ indicate significance at 1%, 5%, and 10%, respectively.

Source: *Authors' computations*

Appendix 5.: Optimal Lag-length selection

Sample: 2010q1-2022q4 *Number of obs = 52*

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	219.462				4.1e-14	-8.13314	-8.01805	-7.83295
1	641.086	843.25	64	0.000	4.4e-20	-21.8879	-20.8522	-19.1862
2	736.163	190.15	64	0.000	1.6e-20	-23.0832	-21.1267	-17.98
3	835.252	198.18	64	0.000	6.8e-21	-24.4328	-21.5556	-16.928
4	1035.04	399.58*	64	0.000	1.1e-22*	-29.6554*	-25.8575*	-19.7491*

* optimal lag
Endogenous: LM3 LGDP LINT LeMy LCiC LFX LrUS LPOP
Exogenous: _cons

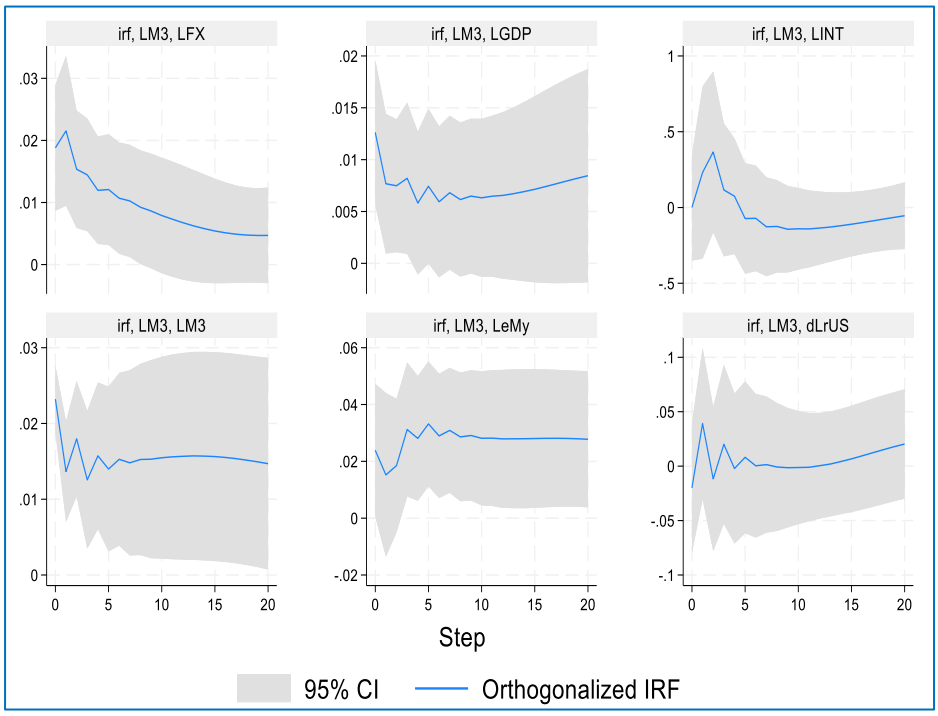
Source: *Authors' computations*

Appendix 6.: OLS estimation of the money demand function

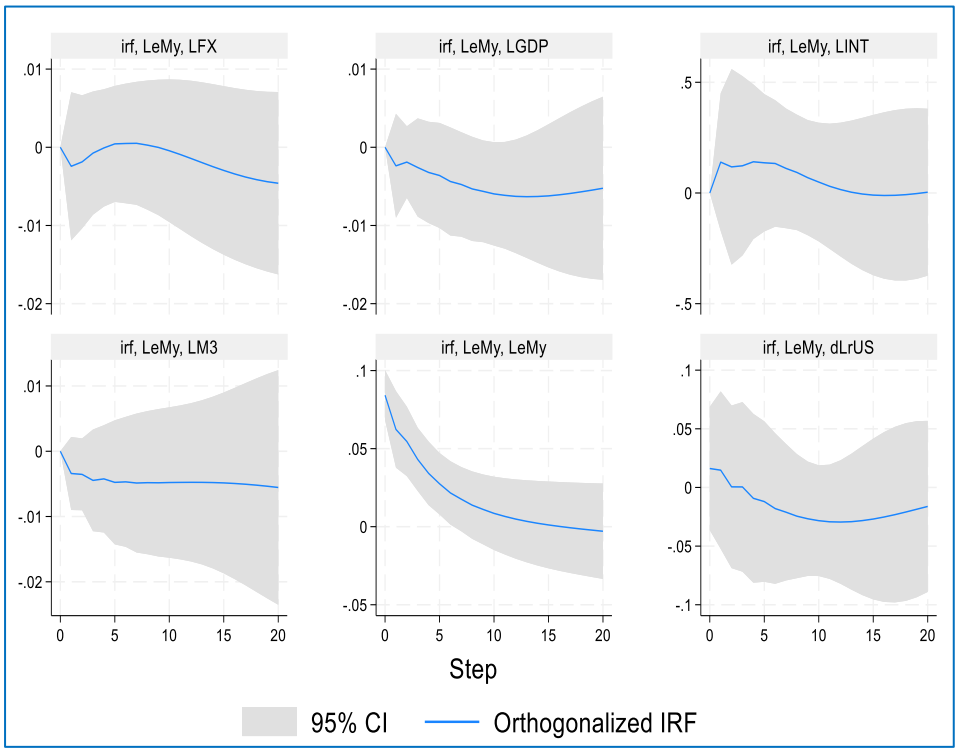
Variables	**Model (1)**	**Model (2)**	**Model (3)**	**Model (4)**	**Model (5)**	**Model (6)**
LGDP	2.571***	2.577***	1.790***	1.513***	1.710***	0.666***
	(0.0787)	(0.0767)	(0.105)	(0.128)	(0.101)	(0.176)
LINT		0.00839*	-0.00549*	-0.00820***	-0.00707***	-0.000723
		(0.00423)	(0.00321)	(0.00305)	(0.00231)	(0.00196)
LeMy			0.0831***	0.0722***	0.0579***	0.0493***
			(0.00979)	(0.00955)	(0.00754)	(0.00571)
LFX				0.372***	0.468***	0.254***
				(0.112)	(0.0859)	(0.0713)
LrUS					-0.0645***	-0.0422***
					(0.0102)	(0.00827)
LPOP						1.934***
						(0.295)
Constant	-49.02***	-49.28***	-27.17***	-21.25***	-27.68***	-27.31***
	(2.433)	(2.373)	(3.034)	(3.302)	(2.688)	(1.983)
Observations	56	56	56	56	56	56
R-squared	0.952	0.955	0.981	0.985	0.991	0.995

Source: *Authors' computations*

Appendix 7: VAR impulse response to a unit (1%) money supply shock



Appendix 8: VAR impulse response to a unit (1%) e-Money shock



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