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THE EFFECT OF FINANCIAL INNOVATION ON THE STABILITY OF MONEY DEMAND: EVIDENCE FROM SUB-SAHARAN AFRICA

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Abstract

Since 2007, several Sub-Saharan African countries are witness to the development of mobile money (MM), which transforms the supply of financial services. This paper examines whether these mobile money affect money demand function in sub-Saharan African economies using ARDL model in panel. Our results obtained from the cointegration technique of (PESARAN and SHIN, 1999) confirm that a long-term relationship exists between M2 and its determinants: GDP, inflation, credit interest rate and inflation. In fact, our results show that mobile money influences positively and significantly the demand for money in both the strict and the broad sense. Also, the number of automatic tellers machines (ATMs) influences positively but not significantlythe demand for money in the broad sense. Therefore, the monetary authorities must integrate the transactions realized through the mobile currency and the expansion of the ATMs in the definition of the function of demand of money and for effective policy actions aimed at stabilizing economies.

Jel codes: C22, E41, E52, G21.

Keywords: Money Demand Function, ARDL in Panel, Sub - Saharan Africa, Mobile Money, ATMs.

INTRODUCTION

The quest for stability and efficiency in the payment system, in order to guarantee sustainable economic growth, is fundamental for Central Banks in all economies. The payment system provides the means for settling commercial transactions and other economic activities. It is vital for financial intermediation, enabling the transfer of liquidity between economic agents. A well-functioning paymentsystem not only ensures better use of scarce resources, but also eliminates systemicrisks. This importance of the payment system justifies the constant changes it undergoeson the part of both monetary authorities and banking and non-banking financial institutions, which, through increased competition and technological innovation, develop new payment instruments to meet the expectations of economic agents.

In Sub-Saharan Africa, this trend towards transformation of the payment system and means of payment has increased following the financial liberalization of the last decade. 30. The impact has been evident in the way financial services are delivered to customers. A range of financial innovation has developed, which can be defined as the introduction of new financial instruments (mobile payment or mobile money, bank cards, ATMs) on the one hand, and on the other, changes in the structure and depth of financial markets, in the role of financial institutions, the methods by which financial services are provided and the introduction of products and procedures in the wake of deregulation (NDIRANGU and NYAMONGO, 2015).

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Traditional distribution methods for financial services have given way to new distribution technologies, including electronic banking products, ATMs and bank cards. Similarly, the development of mobile communication networks and access to cell phones by all populations, both urban and rural, has y revolutionized the provision of financial services. The latter, known as mobile money, have enabled the development offinancial services to meet the needs of unbanked populations. Available data show that in sub-Saharan Africa, 135 million people have a mobile money account, i.e. around 21.9% of the active population. Transactions reached $19.2 billion in 2017, up 14.3%on 2016. This evolution of the payment system and means of payment has enabled a considerable improvement in its efficiency, and better management and circulation of liquidity between economic agents.

In the field of monetary economics, the impact of the emergence and use of e- money on the conduct of monetary policy has rapidly become an object of study. Theoretical work on the demand for money argues that heavy use of e-money destabilizes the demand for money (WEIL et al., 2012; DRITSAKIS, 2011; MISATI et al., 2010). At Indeed, electronic money (financial innovation) makes the environment in which the central bank operates more complex, thereby limiting the way in which the economy reacts to monetary policy and reducing the reliability of monetary aggregates on which monetary policy decisions are based. In line with this, the growing use of e-money has revived empirical work on the determinants and stability of money demand around the world (NAMPEWO and OPOLOT, 2016; HYE, 2009; TAYLOR, 2007; MILBOURNE, 1986). In Africa, with the wave of financial innovations several studies using various methodologies, periods and variables of financial innovation, have been conducted on the effect of financial innovation and the stability of money demand in several countries, but the results of this research still remain mixed in terms of the direction of the relationship between money demand and financial innovation and its impact on the stability of money demand (NAMPEWO and OPOLOT, 2016; NDIRANGU and NYAMONGO, 2015). The majority of these studies are focused on a single country; no study, to our knowledge, has specifically integrated the development of mobile money on the scale of all African countries. Our study aims to fill this gap.

It should be noted that the study of the determinants of money demand and its stability has important monetary policy implications. Indeed, the stability of money demand is a fundamental element of central bank strategy. The ability to stabilize(regulate) the economy in the short term depends on it. It is therefore important to have empirical results on the long-term relationship between money demand and financial innovation for a set of countries. Such results will form the basis for discussions on policies to promote the development of financial innovation, given that it is a key factor in fostering financial inclusion in countries with a high level of financial exclusion. It therefore makes sense to determine the relationship between money demand and financial innovation, considering mobile money as the most developed form in sub- Saharan Africa. Based on recent theoretical and empirical developments, the aim of this article isto assess the effect of mobile money on the money demand function in sub-Saharan African countries. According to the economic literature, the provision of financialservices by cell phone

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(mobile money) induces specific gains, theoretically symbolized by an increase in the efficiency of the payment system and financial inclusion. Through mobile money, the increased efficiency of the payment system offers a payment methodthat facilitates the transition to electronic payments, even for small-value purchases. Financial inclusion, on the other hand, reduces poverty and simulates shared prosperity.

In this article, we evaluate the effect of mobile money on money demand over the period 1990-2014. The reference to this period is dictated by the availability of data for all countries in the sample. The estimation of this effect and of the traditional determinants of the money demand function is based on a panel autoregressive lag model (ARDL) developed by (PESARAN and SHIN., 1999). This model highlights the traditional determinants (GDP, inflation, interest rates). In addition, it enables us to specifically test the effect of the existence of mobile money (in the absence of data) in each of the economies. This is achieved by introducing a dummy variable that takes the value 1 if mobile money exists in the economy and 0 otherwise. The originality of this paper lies in the use of an advanced econometric technique. Indeed, the panel ARDL model has the advantage of simultaneously obtaining the short-run and long-run equations, and of taking heterogeneity into account, unlike the traditional panel; it iswell suited to co-integration analysis in the case of limited sample sizes, whereas Johansen's co-integration technique requires a larger sample size to achieve reliability. Also, this model can be used even in the case of stationary series of the same or mixed order, level I (0) or I (1).

Finally, while other co-integration techniques generally requirethe regressors to have the same lag period, the ARDL model incorporates a different, optimal lag period, thereby resolving the potential problem of endogeneity between variables. For the estimation itself, we first perform the usual panel unit root tests (IM, PESARAN and SHIN, 2003; LEVIN, LIN and CHU, 2002; CHOI, 2001; HADRI,2000; BREITUNG, 2000) on the based on the assumption of inter-individual independence. Following this stationarity analysis, we calculate the Mean Group (MG), Pool Mean Group (PMG) and Dynamic Fixed Effect (DFE) estimators. The Hausman test enables us to select the most efficient estimator among the three. The remainder of the paper is organized as follows. The second section presents the literature review on the relationship between money demand and financial innovation for developing countries. The third section describes the data used in the estimation. The fourth section presents the econometric model and outlines the empirical results. The final section suggests some policy implications and concludes thepaper.

I. LITERATURE REVIEW

As soon as the first financial innovations appeared, the literature began to debatetheir implications for the conduct of monetary policy. Indeed, with the development of payment instruments competing with base money and tending to replace it, central bank money is no longer a relevant operational target, nor a judicious channel for transmittingcentral bankers' policy impulses (WOODFORD, 2000). In this respect, the transformation of the payments system and means of payment, notably the emergenceof electronic money,

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has given rise to a lively theoretical debate in the literature on its impact on the conduct of monetary policy. On the one hand, some authors argue that the increasing use of electronic money can make it difficult to control and measure the monetary base (FRIEDMAN, 1999; KOBRIN, 1997). In this logic, financial innovation destabilizes the demand for money by inducing a variation in the velocity of money circulation, thereby limiting the determination of the interest rate (GORMEZ and BUDD, 2004; BECK, 2002; FREEDMAN, 2000; WOODFORD, 2000). Similarly, the high dependence on new financial products reduces the extent to which monetaryimpulses are transmitted via changes in the cost of capital, in the sense that newproducts encourage the formation of financial bubbles, rendering the Central Bank's monetary policy impulses ineffective (MARIO, 2007; OOI SANG, 2005). On the other hand, the other strand of the literature maintains that fears about the future of monetary policy in terms of its effectiveness are exaggerated (FREEDMAN, 2000; GOODHART, 2000). Indeed, for these authors, although the use of electronic money is increasing, the Central Bank will continue to monitor the issuance of this new form of money through the obligation to set aside reserves on each unit of electronic money issued, in order to limit the disconnection between the Central Bank and the quantity of money in circulation. In addition, this high level of usage will enhance the trickle-down effect of the interest rate in the transmission of monetary policy, by implying that current and anticipated variations in the interest rate are rapidly transmitted to financial asset prices, and thus influence the long-term interest rate and, consequently, consumption andinvestment (MISHRA and PRADHAH, 2008). This debate shows that the impact of financial innovation can affect both the transmission channels of monetary policy and the stability of demand. As a result, it has led to a number of empirical studies to test theoretical speculations against the facts. However, we will concentrate more on workin developing countries.

Although there are studies looking at the effect of financial innovation on monetary policy transmission mechanisms (WEIL et al., 2012; MISATI et al., 2010), most of the empirical literature focuses on the effect of financial innovation on money demand, insofar as it is a shock with permanent effects on money demand analogous to productivity shocks in production functions (ARRAU and DE GREGORIO, 1993). As aresult, these studies, using different methodologies, produce contradictory results depending on the study context and the financial innovation indicator selected. To this end, (NDIRANGU and NYAMONGO, 2015) investigate whether the waves of financialinnovation that occurred in Kenya, notably the emergence of M-Pesa, impacted the long-term stability of money demand there. Their results show that the strong expansionof financial innovation has not caused a structural break in the long-term relationship of money demand. The latter therefore remains stable and well cointegrated with its main determinants. In the same vein, (WEIL et al., 2012) analyze the implications of innovations in the financial sector for the conduct of monetary policy. Their resultsshow that although the velocity of e-money circulation is increasing over time, it remains low compared to the velocity of other monetary components. This indicates that households are more inclined to use e-money as a means of transaction, to the detriment of other monetary assets. They also show that, despite t h e observed instability of the money demand function after 2007, the monetary policy implications of e-money are minimal, due to the fact that mobile money

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transactions are still less important than other monetary aggregates. However, they show that such a result may change if the system continues to evolve towards simple money transfers between individuals. A similarstudy was conducted by (SICHEI and KAMAU, 2012), in which they show that financial innovation captured by the number of ATMs has no effect on money demand. However, they highlight the instability of money demand after the introduction of M- pesa in 2007. In Tanzania, (MACHA, 2013) studies the impact of innovation on the conduct of monetary policy, focusing on the stability of money demand. His results show that the instability of money demand observed coincides with the introduction of e-money. He concludes that e-money has an impact on the demand for money and therefore on the velocity of money.

In Pakistan, (MALIK and ASLAM, 2010) find that innovation positively determines money demand, but not significantly. For these authors, innovation affects the interest rate, as their results show that the latter is highly elastic to variations in financial innovation. Similarly, for (SAFDAR and KHAN, 2014) financial innovation measured by the number of ATMs and the number of credit cards negatively determine money demand. In their view, monetary control is only possible by controlling the expansion of ATMs. They also show that this expansion of new financial instruments induces a monetary imbalance that considerably accentuates the output gap in the Pakistani economy. Furthermore, (SABWAR et al., 2013) show that financial innovation, captured by the ratio of broad money supply to non-bank money, positively determines the demand for broad money. They thus show that the role of financial innovation in explaining the demand for money in Pakistan, guarantees all the attention that the formulation of monetary policy must pay.

In Malawi, (LUNGU et al., 2012) analyze money demand to show the different implications of monetary policies that may derive from the structural changes thiseconomy has undergone. Their results show that there is a long-term relationship between income, financial innovation and the exchange rate. They show that financial innovation, as measured by financial deepening, positively and significantly determines the demand for money, and therefore recommend that both long-term and short-term policies should be directly linked to financial innovation. (KOVANEN, 2004), examining the determinants of money demand in Zimbabwe, shows that financial innovation, measured by the ratio of money supply to currency in circulation,is not significant in determining money demand.

In Nigeria, (ODULARU, 2010) analyzed whether financial innovations in the financial sector, captured by a dummy variable in structural adjustment programs (SAPs), had a negative and insignificant impact on money demand. Similarly, (ODULARU and OKUNRINBOYE, 2009) conducted a similar study to investigate the effect of financial innovation measured by the financial liberalization index on money demand. Their results show that financial innovation affects money demand negatively and insignificantly. Consequently, the broad money aggregate remains a good indicator for defining monetary policy. In the context of Bangladesh, (SINGH and PANDEY, 2009) analyze the effectof financial innovation captured by various policy changes in the financial systemthrough the introduction of breaks in monetary policy variables on the stability ofmoney demand. Their results show that financial innovation associated with the lending rate positively affects money demand, and that the latter is unstable over the study period.

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In South Korea, (CHO and MILES, 2007) found a downward trend in velocity, which was attributed to the monetization of the economy. For these authors, velocity should be expected to increase over time as the payment system evolves or cashmanagement improves.

Table 1: Summary of studies in developing countries

Authors	Study period	Methodology used	Innovation measurement financial	Results
NAMPEWO and OPOLOT (2016)	2000Q1 - 2013Q4	ARDL	Ratio broad money supply (M2) tonarrow money supply (M1) Time deposit ratio on total deposits.	Financial innovation has both negative and positive short-term and long-term effects. Long term. However, the speed of money circulation remainsstable.
NDIRANGU and NYAMONGO (2015)	1998Q1 - 2013Q3	ARDL	Money supply ratio In circulation term deposits	Financial innovation negatively affects M2 and M3 in both the long and short term, but does not destabilizes.
WEIL and al. (2012)	2000Q1 - 2011Q4	Univariate analysis	Velocity from currency	The velocity of money increases over time, but with weak policy implications. However, the demand for money unstable after 2007.
SICHEI and KAMAU (2012)	1997Q4 - 2011Q2	VAR	Number automated teller machines machines	Financial innovation has no significant effect on the demand for money, but the latter becomes unstable after 2007, the year of the introduction of money. electronics.
MALIK and ASLAM (2010)		ARDL	Ratio broadmoney supply (M2)to narrow moneysupply (M1)	Financial innovation positively affects and the demand for short-termmoney and positively and and the relationship betweenlong term.
LUNGU et al (2012)	1985-2010	Technique co integration by Johansen and Juselius	Financial deepening (monetary base on GDP)	Financial innovation positively determines the demand for money.
ODULARU (2010)	1980-2010	Technique cointegration Engle and Granger	Variable dummy tapping Structural AdjustmentPrograms	Financial innovation has a negative and insignificant impact on the demand for money.
ODULARU and OKUNRIBOYE(2009)	1980-2008	Technique cointegration Engle and Granger	Index of financial liberalization developed by Abiad and Modid (2005)	Financial innovation has a negative and insignificant impact on the demand for money.

Source: authors

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From this literature review, it emerges that these studies generally focus on a particular country in Sub-Saharan Africa, and also fail to integrate several measures of financial innovation in order to highlight which has a greater effect on the stability of money demand. This study attempts to fill this gap by taking into account several indicators of financial innovation, notably those linked to the transformation of meansof payment on the one hand, and to the complexity of circumscribing financial innovation to one indicator on the other. On the other hand, it will make a comparison between several African countries south of the Sahara.

II. THE DATA

We consider annual data covering the period 1990-2014 from a sample of 13 Sub-Saharan African countries: Angola, Benin, Cameroon, Congo, Ivory Coast, Gabon, Ghana, Kenya, Senegal, Rwanda, Tanzania, Uganda and Zambia. These countries were selected on the basis of available data, in order to have a cylindrical panel. Sub-Saharan Africa was chosen for two reasons. Firstly, this region of the world is the most innovative in terms of financial innovation, especially mobile money. Secondly, we wanted to highlight, based on the literature, the various mobile money options in these economies, given that they belong to several monetary unions.

PIB represents national income in nominal terms (in local currency units). It is obtained from the sum of the gross value added of all resident producers in eachcountry. M1 includes currency outside banks plus sight deposits in commercial banks.

$M2$ includes $M1$ plus quasi money, which includes savings and time deposits. $M2$ also includes residents' deposits in foreign currencies. $Indice\ des\ prix\ la\ consommation$ (IPC) represents the level of inflation in the economy, i.e. changesin the cost of goods and services. i.e. variations in the cost of a basket of goods and services purchased by the average consumer with the 2010 base year 100. *The interest rate* is represented by the lending rate. It has been chosen on the basis of data availability for all panel items*. Financial innovation* is decomposed into two, thefirst measure relates to the number of ATMs in each country collected on the basis ofthe 2015 International Financial Services and, the second measure refers to the existence of mobile money in the economy. It is a binary variable that takes the value 1 if it is possible to carry out financial transactions via the cell phone and 0 otherwise. With the exception of the second measure of financial innovation, all other variables have been logarithmized.

Our sample covers 13 sub-Saharan African countries from 1990 to 2014, with 24 observations per country. In terms of size, our sample is well above those used in previous studies quantifying the effect of financial innovation on money demand. By way of illustration, apart from the study by (WEIL et al., 2012) which investigated the effect of financial innovation in three countries, the other studies focus on a single country. Consequently, to the best of our knowledge, our study appears to be the first in Sub-Saharan Africa to assess the effect of financial innovation o n money demand, covering 13 countries. Before proceeding with the estimation of our model, we will first study stationarity.

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III. THE ECONOMETRIC MODEL

In this section, we propose to test our theoretical result that financial innovation destabilizes the money demand function in sub-Saharan African economies. Given the availability of data, we use panel data techniques to estimate equation (2). As mentioned above, with non-stationary time series, equation (2) needs to be a cointegrated relation, as is usually the case for money demand functions. Consequently, before estimating equation (2), we perform panel unit root tests and tests for the existence of the cointegrating relationship.

3.1 Panel unit root and cointegration tests

Panel unit roots are used to examine the degree of integration between money supply and financial innovation, as well as between money supply and other economic and financial variables. Panel unit root tests are suggested as alternative tests for analyzing the causal relationship between financial innovation and money supply in the panel structure insofar as these tests capture country-specific effects as well as allowing heterogeneity in the direction and magnitude of the parameters. To investigate the existence of unit roots in our series, we use three different panel unit root tests comprising LEVIN, LIN and CHU (LLC); IM, PESARAN and SHIN (IPS);

MADDALA and WU, and CHOI. For each technique, we test for the presence o f the panel unit root using two types of model. The first model contains a constant, while the second incorporates the constant and the trend.

The LLC (2002) test, which is the most widely used, is based on the Augmented DICKEY FULLER (ADF) test and assumes panel homogeneity. The IPS (2003) test is an extension of the LLC (2002) test. This test relaxes the assumption of panel homogeneity by allowing heterogeneity in the autoregressive coefficients for all panel members. However, both tests assume cross-sectional independence between panelmembers. However, to take account of possible correlations between countries in our sample, we have used the tests of MADDALA and WU (1999) and CHOI (2001). In oursample, cross-country dependence is clearly present due to the common membership of certain countries in economic and monetary unions. Thus, the MADDALA and WU (1999) and CHOI (2001) test emerges as superior to the IPS test, being a non-parametrictest based on the Fisher test and relaxing the hypothesis of the unit root process common to all panel members. Furthermore, the result obtained on the basis of this test does not depend on the different lags in the ADF regressions. Table 1 shows the unitroot results under the assumption of independence between panel members. Table 2 presents the results of the unit root test under the hypothesis of dependence between panel members. Analysis of these results shows that the variables gross domestic product and inflation measured by the consumer price index are stationary at level in themodel with individual constancy, while in the model with individual constant and trend, only the variables inflation and money supply are stationary at level. The other variablesare stationary in difference whatever the model considered. In conclusion, as all the variables in our study are stationary, we can explore the cointegration relationship between financial innovation and money supply in the economies of sub-Saharan Africa.

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Table 2: Unit root results assuming independence between panel members

Variables	Individual consistency				Individual consistency and trend		
	Testing unit root	value	Sig.	Conclusion	Value	Sig.	Conclusion
GDP	LLC	-6.00192	0.0000	I(0)	-4.31994	0.0000	I(1)
	IPS	-1.71551	0.0431	I(0)	-6.57878	0.0000	I(1)
IPC	LLC	-8.02000	0.0000	I(0)	-2.77005	0.0028	I(0)
	IPS	-5.51864	0.0000	I(0)	-7.84195	0.0000	I(0)
M2	LLC	-16.3738	0.0000	I(1)	-6.66539	0.0000	I(0)
	IPS	-13.6340	0.0000	I(1)	-8.84963	0.0000	I(0)
M1	LLC	-15.4248	0.0000	I(1)	-13.2553	0.0000	I(1)
	IPS	-13.3215	0.0000	I(1)	-11.0384	0.0000	I(1)
R	LLC	-11.7284	0.0000	I(1)	-9.55098	0.0000	I(1)
	IPS	-10.7708	0.0000	I(1)	-8.85737	0.0000	I(1)
FI	LLC	-12.1198	0.0000	I(1)	-11.2197	0.0000	I(1)
	IPS	-9.42989	0.0000	I(1)	-7.87217	0.0000	I(1)

Source: authors

Table 3: Unit root results assuming dependence between panel members

Variables	Individual consistency				Individual consistency and trend		
	Root testing unitary	value	Sig.	Conclusion	Value	Sig.	Conclusion
GDP	ADF-fisher	43.2207	0.0183	I(0)	113.881	0.0000	I(1)
	PP-Fisher	42.7292	0.0206	I(0)	136.675	0.0000	I(1)
IPC	ADF-fisher	103.009	0.0000	I(0)	123.350	0.0028	I(0)
	PP-Fisher	71.8818	0.0000	I(0)	287.089	0.0000	I(0)
M2	ADF-fisher	294.115	0.0000	I(1)	162.292	0.0000	I(1)
	PP-Fisher	188.765	0.0000	I(1)	309.532	0.0000	I(1)
M1	ADF-fisher	189.518	0.0000	I(1)	145.182	0.0000	I(1)
	PP-Fisher	229.968	0.0000	I(1)	414.222	0.0000	I(1)
R	ADF-fisher	100.718	0.0000	I(1)	133.308	0.0000	I(1)
	PP-Fisher	125.110	0.0000	I(1)	155.178	0.0000	I(1)
FI	ADF-fisher	114.614	0.0000	I(1)	88.3141	0.0000	I(1)
	PP-Fisher	112.651	0.0000	I(1)	86.2912	0.0000	I(1)

Source: Authors

3.2 Panel cointegration estimation

The second stage of our empirical work involves investigating the long-term relationship between financial innovation and money demand. The analysis of the relationship between money demand and financial innovation in developing countries has been the subject of several studies (Table 1). These studies differ according to the measure of financial innovation and the econometric approach adopted. To study the effect of financial innovation on money demand in Kenya over the period 1998-2013, (NDIRANGU and NYAMONGO, 2015) use a staggered lag autoregressive model(ARDL) given that not all their statistical series have the same order of integration.They start from a dynamic specification enabling them to simultaneously distinguish between long-term and short-term effects. (WEIL et al., 2012) also study the stability of money demand following

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the emergence of financial innovations in a sample of three countries between 2000 and 2011, using a univariate analysis. (SICHEI and KAMAU, 2012) use the cointegration technique of (JOHANSEN and JUSELIUS, 1990) in thecase of Kenya over the period 1985-2010. (ODULARU, 2010; ODULARU and OKINBOYE, 2009) focus on Engle and Granger's cointegration technique in the case of Nigeria to highlight the relationship between money demand and financial innovation.

As in the work of (NDIRANGU and NYAMONGO, 2015), the empirical model used here, using an error-correction model on panel data and estimated by means of the cointegration technique developed by (PESARAN et al., 2001), is the staggered lag autoregressive model. This methodology makes it possible to take into account both the short-term and long-term relationships of the variables tested, but in a distinct way. It also offers flexibility in the choice of lagged dynamics and the degree of heteroregeneity between countries. Last but not least, it allows us to estimate variables with different levels of integration (I(1) and I(0)). Seen from this angle, the estimation results are as follows, with a lag a was retained for the monetary aggregate and none for the other variables. T h e cointegrationrelationship is specified by the following equation:

$$m_{it} = \delta_{10i} pib_{it} + \delta_{11i} pib_{it} + \delta_{20i} icp_{it} + \delta_{21i} icp_{it} + \delta_{30i} r_{it} + \delta_{31i} r_{it} + \delta_{40i} fi_{it} + \delta_{41i} fi_{it} + \lambda_i m_{it-1} + \mu_i + \varepsilon_{it} \quad (1)$$

Where is the money aggregate (both money demand in the sense of the explanatory variables are: gross domestic product, credit interest rate, inflation(NAMPEWO and OPOLOT, 2016; NDIRANGU and NYAMONGO, 2015). The explanatory variables are: gross domestic product, lending rate, inflation (NAMPEWO and OPOLOT, 2016; NDIRANGU and NYAMONGO, 2015) and financial innovation. (SICHEI and KAMAU, 2012); δ'_{ij} are the *k* *1 coefficient vectors and μ_i is the effect country-specific.

ε_{it} represents the error term, which is white noise. This equation (1) can be rewritten with an error correction formula:

$$\Delta m_{it} = \mu_i + \phi_i (m_{it-1} - \theta_{0i} - \theta_{1i} y_{it} - \theta_{2i} icp_{it} - \theta_{3i} r_{it} - \theta_{4i} fi_{it}) + \delta_{11i} \Delta pib_{it} + \delta_{21i} \Delta icp_{it} + \delta_{31i} \Delta r_{it} + \delta_{41i} \Delta fi_{it} + \varepsilon_{it} \quad (2)$$

To estimate this model, two approaches have been proposed in the literature. Thefirst is group-mean (GM) estimation, which involves estimating the N regressions based on equation (2) separately, and then calculating the estimators as unweighted averagesof the coefficients obtained from the regression for each country. Thus, this approach considers the model with strictly heterogeneous coefficients imposing no country restrictions, and allows country-by-country estimates provided the time horizon is large. The second approach assumes that the long-term coefficients are strictly homogeneous, i.e. that they are the same for all countries in the sample. This PMG-based estimator sets the same long-term restrictions for all countries, but allows short-term coefficients to vary between the different countries in the sample. However, this assumption of homogeneity

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in long-term coefficients is justified by the fact that disparities between individuals in terms of institutional quality and similarities in economic structure can have an impact on short-term dynamics. However, the choice of one approach over another will depend on how restrictions are imposed. Following this logic, if long-term restrictions are exact, MPG estimates will be consistent and efficient, while MG estimates will be consistent but not efficient. Conversely, if long-term restrictions are imposed inappropriately, the PMG estimates will not be consistent, whereas the MG estimates will give consistent estimates of the mean of the long-run coefficients across countries. To ensure that the estimate is consistent and efficient, the Hausman test is applied, as (PESARAN and SMITH, 1999) argue that imposing an invalid restriction on the parameters in dynamic models generally results in an underestimation of the speed of adjustment. In our study, the Hausman test shows that the PMG estimate is the most appropriate, so we introduce a sub-group of long-run homogeneity restrictions. The empirical results are obtained assuming that the residuals are normal, and so the panel likelihood model is obtained as the product of the likelihood of each country. Maximizing this likelihood simultaneously estimates the long-run and adjustment coefficients for each country. The maximum likelihood method enables us to derive, from the long-term coefficients, the short-term coefficients for each country, together with their error variances. Table 4 presents the results of the estimation of long-run coefficients from stacked regressions of the effect of financial innovation on broad money demand in sub-Saharan Africa, with the number of ATMs and the existence or non-existence of mobile money representing the measure of financial innovation.

Table 4: Results of broad money demand regressions on dynamic panel data

Variables	M2			M2		
	PMG	MG	DFE	PMG	MG	DFE
Long-term coefficients						
Gross domestic product	1.144*** (0.000)	1.635*** (0.000)	0.934* (0.0703)	1.222*** (0.013)	1.594* (0.002)	0.813* (0.0250)
Inflation	-0.7025*** (0.000)	-0.2983 (0.320)	-0.2186 (0.0112)	-0.5295*** (0.001)	-0.066 (0.892)	-0.205 (0.166)
Interest rates	0.2166 (0.171)	-0.3886 (0.218)	-1.051*** (0.002)	0.2344 (0.480)	0.591 (0.015)	-1.45*** (0.000)
Financial innovation 1				0.558*** (0.001)	-0.239 (0.667)	1.1*** (0.000)
Financial innovation 2	-0.0056 (0.850)	0.0521 (0.505)	0.222*** (0.000)			
Average correction term error	-0.1795* (0.0211)	-0.4061*** (0.005)	-0.4004*** (0.000)	-0.178* (0.0226)	-0.391*** (0.008)	-0.374*** (0.000)
Hausman test	1.28 (0.8643)	-	2.37 (0.6682)	5.26 (0.2612)	-	4.25 (0.2132)
Comments	312	312	312	312	312	312

Source: authors. Values in brackets represent significance levels at 1%, 5% and 10% respectively (****), (**) and (*).

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This analysis of the effect of financial innovation on money demand focuses on the PMG results, although those obtained with the MG and DFE estimators are useful for comparison purposes. The main results obtained are as follows:

- PMG estimates show that GDP and inflation are significant at 5% and have the expected sign. The credit rate, on the other hand, is positive and insignificant. In the case where financial innovation is captured by the existence of mobilemoney, the latter has a positive and significant influence on the demand for money in the broad sense. The results of the Hausman test confirm that the hypothesis of homogeneity of the long-run coefficients cannot be rejected concerning the relationship between financial innovation and money demand. Conversely, the results show that the effect of financial innovation measured by the number of ATMs has a significant negative effect on money demand. Similarly in this case, the results of the Hausman test confirm that the hypothesisof homogeneity of the long-run coefficients cannot be rejected concerning the relationship between financial innovation and money demand in the broad sense.
- Considering both measures of financial innovation, the estimated meancoefficient for the error-correction term is negative and significant, thus confirming the long-run or equilibrium relationship between broad money demand and its determinants. The magnitude of this speed of adjustment inbroad money demand is so large that ignoring it would introduce biases into the estimation of long-term parameters.

Table 5 presents the results of the estimation of long-run coefficients from stacked regressions of the effect of financial innovation on the demand for money in the strict sense in sub-Saharan Africa. These results are presented both for innovationmeasured through the number of ATMs and through the existence or absence of mobile money. The analysis of these results also focuses on the PMG estimate, and the other estimates are presented for comparison. It shows that:

Table 5: Strict money demand regression results on dynamic panel data

variables	M1			M1		
	PMG	MG	DFE	PMG	MG	DFE
Long-term coefficients						
Gross domestic product	1.334***	0.732*	0.966**	1.373*	1.298*	0.730*
	(0.0000)	(0.0108)	(0.081)	(0.013)	(0.013)	(0.0314)
Inflation	-0.546 *** (0.00462)	-0.554* (0.075)	-0.197** (0.0108)	-0.499*** (0.003)	-0.053 (0.905)	-0.1857* (0.0228)
Interest rates	0.433*** (0.0260)	-0.144** (0.064)	-0.1236*** (0.0000)	0.135 (0.349)	0.1143 (0.707)	-1.655*** (0.000)
Financial innovation 1				0.6554*** (0.001)	0.151 (0.754)	1.13*** (0.001)
Financial innovation 2	0.0642** (0.0419)	0.118 (0.205)	0.223*** (0.000)			
Average correction term error s	-0.193** (0.0189)	-0.520*** (0.000)	-0.402*** (0.000)	-0.1963* (0.0184)	-0.492*** (0.000)	-0.375*** (0.000)
Hausman test	1.86 (0.7617)	-	3.08 (0.5450)	1.86 (0.7617)	-	3.66 (0.4542)
Comments	312	312	312	312	312	312

Source: authors. Values in brackets represent significance levels at 1%, 5% and 10% respectively (****), (**) and (*).

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- PMG estimates show that GDP and inflation are significant at 5% and have the expected sign. The credit rate is positive and significant. In the case where financial innovation is captured by the existence of mobile money, the latter hasa positive and significant influence on the demand for money in the strict sense. The results of the Hausman test confirm that the hypothesis of homogeneity of the long-run coefficients cannot be rejected concerning the relationship between financial innovation and money demand. Similarly, the results show that the effect of financial innovation measured by the number of ATMs also has a positive and significant effect on money demand in the strict sense. The resultsof the Hausman test confirm that the hypothesis of homogeneity of the long-run coefficients cannot be rejected concerning the relationship between financial innovation and money demand in the strict sense.
- Considering both measures of financial innovation, the estimated average coefficient relating to the error-correction term is negative and significant, thus confirming the long-run or equilibrium relationship between money demand in the strict broad sense and its determinants. The magnitude of this adjustment speed in money demand is so large that failure to take it into account would introduce biases into the estimation of long-term parameters.

CONCLUSION

We have analyzed how financial innovation in terms of the number of ATMsand mobile money influences the dynamics of money demand. To do this, we conducted an econometric estimation for African countries south of the Sahara for the period 1990-2014. Our results show that mobile money has a positive and significant influence on money demand in both the narrow and broad senses.

Furthermore, with regard to the number of ATMs, its influence is positive and significant for money demand in thestrict sense, but not significant for money demand in the broad sense. These results are particularly important, as they show that central banks in sub-Saharan Africa today needto integrate the development of innovation into their monetary policy strategy, in order to better enable financial inclusion for those excluded from the traditional banking system.

As a result, it appears that financial innovation plays an important role in determining the money demand function and its fluctuations in sub-Saharan Africa. From a policy point of view, these results suggest that any monetary policy measure seeking to stabilize each of the economies considered, may lead to uncertain results if the effects of financial innovation are not included in the implementation ofthis monetary policy.

The reaction of the money demand of the countries in the sample to financial innovation requires that it be taken into account for the effectiveness of monetary policy. Moreover, the unit elasticity of income is compatible with monetarist theory, according to which the money supply should be allowed to grow at the same rateas output.

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