How to Cite:
KI, K. K. S. (2026). Does fintech's development affect money demand? Evidence from Uemoa. *International Journal of Economic Perspectives*, *20*(6), 620–640. Retrieved from https://ijeponline.org/index.php/journal/article/view/1328

Does fintech's development affect money demand? Evidence from Uemoa

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***Abstract*---**The aim of this study is to assess the impact of financial technologies on the demand for money in the countries of the West African Economic and Monetary Union over the period 2000–2024. A Vector Error Correction Model was estimated using the modified semi-parametric least squares estimator. The results show that the number of ATMs, debit cards and the use of mobile money have a positive influence on money stock. Furthermore, the coefficient of the error correction term is statistically significant and negative, reflecting an adjustment mechanism towards long-run equilibrium. Consequently, it is imperative that the Central Bank of West African States closely monitors developments in financial technologies and explicitly incorporates indicators of technological innovation into its analytical frameworks. Such an approach enables monetary policy instruments to be adapted to the actual behaviour of economic agents, strengthens monetary stability, and ensures the effectiveness and credibility of monetary policy in a context of digital transformation.

***Keywords*---**Money demand, Payment system, Money supply, Monetary policy
JEL Classification: E41. E42. E51. E52

1. Introduction

The use of financial technologies for transaction settlements is a recent and significant phenomenon in many countries. The rapid expansion of digital payment methods and financial platforms is reducing dependence on conventional monetary instruments. These developments raise questions about the stability of the demand for money, particularly in economies where financial inclusion is progressing rapidly thanks to fintechs (Tule and Oduh, 2016).

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Submitted: 09 March 2026, Revised: 18 April 2026, Accepted: 22 May 2026

The demand for money corresponds to the desire to hold financial assets in the form of cash or bank deposits (Goldfeld and Sichel, 1990). Theories of the demand for money adopt a variety of approaches, both empirical and theoretical. Classical economists have argued that the demand for money is considered stable because it depends primarily on nominal income and an assumed constant velocity of circulation. Keynes (1936) introduced a concept of money demand driven by transactions, precaution and speculation. Within this framework, the stability of money demand is less assured, as the speculative component depends on interest rate expectations, which are subject to fluctuations, particularly in periods of uncertainty or a liquidity trap. Institutional and post-Keynesian theories emphasise the role of financial innovation, deregulation and the sophistication of financial systems. From this perspective, the demand for money is endogenous and potentially unstable (Tobin, 1965). According to Gurley and Shaw (1960), the emergence of new monetary substitutes, resulting from advances in financial technology, can unexpectedly increase the sensitivity of monetary assets to interest rates. Such a change in elasticity in the relationship of the demand for money could weaken the link between monetary aggregates and income, which was initially assumed to be stable.

From an empirical perspective, numerous studies have examined the existence of a potentially stable relationship between money demand and financial innovations using various empirical and econometric techniques (Odularu and Okunrinboye, 2009; Safdar and Khanm, 2013; Mvogo and Avom, 2020). Ghartey (1998) and Kallon (1992) studied the stability of the demand for money in Ghana using the cointegration techniques of Engle and Granger (1987) and Johansen (1988). The results showed that the demand for money in Ghana is stable. Padhan (2011), in his study on India, estimated a money demand function using the error correction model (ECM) approach. The results reveal the existence of a long-run cointegration relationship between real money demand and the selected explanatory variables. In several countries, the results remain mixed regarding the relationship between monetary holdings and various components of financial innovation, as well as their impact on the stability of money demand (Boeschoten, 1998 ; Snellman et al., 2001 ; Drehmann et al., 2002)

Following a number of financial changes, linked to the liberalisation of exchange rates and interest rates during the 1980s and 1990s, the financial sector in the WAEMU economies has seen increased adoption and use of new financial technologies, notably the introduction of cash machines (ATMs), debit cards, the development of electronic banking products and mobile money services. These financial products have enabled the use of electronic payments and serve as close substitutes for cash. In 2020, the number of e-money accounts within the WAEMU stood at 94.23 million, compared with 76.9 million in 2019, representing an increase of 22.43%. On average, nearly 9.71 million transactions were processed daily across all mobile payment platforms in the WAEMU.

Furthermore, the number of ATMs rose from 510,448 to 819,608 by the end of 2020. Each outlet processed an average of 715 transactions, totalling 13.93 million CFA francs. The success of this model is attributed to an extensive network of mobile money service points, which now numbers over 1,071,390, compared to 510,448 in March 2018. This increase in the use of digital platforms

was partly supported at the regulatory level by a notice issued on 1 April 2020 promoting electronic payments, due to the pandemic and the need to limit contact to curb the spread of the disease. Under these circumstances, businesses and households are taking advantage of new opportunities to manage their cash flow.
According to BCEAO data, the money supply stood at around 16% in 2010 and, following various changes, stood at around 28% in 2021. Further changes are thought to have occurred in 1974, 1980 and 1985. Whilst the first two dates refer to the last two oil crises, the year 1985 was mainly marked by financial innovations. These began with the creation of negotiable certificates of deposit, commercial paper and negotiable treasury bills, and gained momentum with the reform of payment systems launched in 1999. The BCEAO aimed to establish efficient and modern payment systems that would facilitate trade, reduce transaction costs and enable the rapid mobilisation of national and regional financial resources. These innovations, which blur the line between monetary and non-monetary assets, ultimately influence the monetary aggregate monitored by the Central Bank, given the transformation of the monetary sphere they bring about (Aglietta et Scialom, 2002). The question that therefore needs to be answered is: does the development of financial technologies affect the demand for money in WAEMU countries? These conclusions will serve as a basis for discussions on the formulation of monetary policies by the issuing institution. As the classical exchange equation indicates, without stable money demand, there will be no predictable link between monetary aggregates and the ultimate objectives of monetary policy. The aim of this article is to assess the effects of financial technological innovations on money demand. We hypothesise that the development of financial technologies has a positive influence on money holdings within the WAEMU.

Despite the rapid growth of financial technologies, the empirical literature remains relatively limited regarding their effects on monetary holdings in the WAEMU, a region characterised by the rapid expansion of mobile money and a banking sector still in transition. Existing studies mainly analyse the impact of financial innovations on inequality, financial inclusion and economic growth (Soro and Senou, 2023 ; Senou et al., 2019 ; Awa and Khadre, 2025), whilst the question of the stability of the money demand function in the face of the digitisation of payments remains insufficiently explored. Furthermore, studies on money demand in the WAEMU generally focus on traditional determinants such as income, interest rates and inflation (Canac et al., 2009), without explicitly incorporating variables related to fintechs such as mobile money services, payment cards or ATMs. There therefore remains an analytical gap regarding the role of fintechs on monetary holdings within the WAEMU, which this research aims to fill by providing up-to-date empirical data for the recent period (2000–2024), marked by a significant digital transformation of the financial sector. It thus follows on from recent work highlighting the need to adapt monetary analysis to the changes brought about by financial digitalisation (Pakhnenko et al., 2021).

The rest of the article is organised as follows. The second section reviews the theoretical and empirical literature. The third section outlines the methodology. The fourth section presents the results and examines the effects of payment technologies on the demand for money. The final section concludes the article and sets out the implications for economic policy.

2. Review of the literature on the determinants and stability of the demand for money

2.1. Review of the theoretical literature

We review the classical, Keynesian and monetarist theories of the money demand function. The classical approach, often associated with economists such as David Hume and Jean-Baptiste Say, is based on the idea that the demand for money is primarily determined by the level of transactions in the economy. In the long run, the money demand function is considered stable as it is linked to real variables such as GDP. The basic framework is the quantity theory of money (QTM). QTM posits that money demand depends on the number of transactions. Fisher (2006) is the economist most closely associated with this theory. The author begins his analysis with an accounting identity that allows him to establish that, for an economy, the value of transactions is equal to the number of transactions carried out multiplied by the average price of transactions, and that the value of purchases is equal to the quantity of money in circulation multiplied by the number of times it changes hands during the same period. The main objective of this formulation is to show that the price level is determined by the volume of the money supply. Applied to the money market, Fisher's theory has made it possible to interpret its components in terms of the equilibrium between the supply and demand for money. Consequently, the demand for money depends on the number of transactions.

TQM was developed by the Cambridge school on the basis of the same assumptions, but the interpretations differ somewhat. Unlike Fisher (2006), who focuses on determining the money supply compatible with the general price level, Cambridge economists believe that two properties of money encourage people to hold it: money used as a medium of exchange and money as a store of value. For an individual, the level of wealth and the level of income over a short period evolve in a stable proportion. These preliminary theories were further developed by Keynes (1936). The demand for money was no longer limited to transactions but extended to the financial sectors. Initially, Keynes (1936) identified three motives for which people demand money, namely the transaction motive, the precautionary motive and the speculative motive.

The transaction motive describes the need to hold cash to bridge the gap between expected regular income and expenditure. Keynesians suggest that individuals also hold cash to meet unforeseen expenses, such as unexpected bills, known as the precautionary motive for holding money. Both the transaction and precautionary motives depend on the level of income. The final motive for holding money identified by Keynes is the speculative motive. Individuals demand money if they expect the market value of other assets to fall. The speculative motive for holding money therefore stems from the desire to maximise wealth and depends on the interest rate. This gives interest rates an important role in modelling money holding (Serletis, 2007 ; Sriram, 1999). The lower the interest rate, the more agents anticipate a future rise, and the more they seek to hold money rather than bonds. This sensitivity of money holding to expectations of changes in interest rates or returns on alternative assets implies that the demand for money can fluctuate significantly depending on agents' expectations, making it potentially unstable.

In response to Keynes' approach, monetarism, Friedman (1959) developed a stable money demand function based on permanent income, interest rates and the wealth of economic agents (net worth). Permanent income is linked to wealth by the interest rate. It follows that wealth is equal to permanent income discounted at the interest rate. An increase in the interest rate reduces the value of wealth and the demand for money. It is the wealth effect that establishes a positive relationship between wealth and the demand for money. Thus, when wealth declines, the demand for money also declines. Similarly, when the general price level changes, the demand for real cash undergoes proportional changes. Consequently, in Friedman's theory, the demand for money is linearly homogeneous with respect to wealth and price. Since permanent variables are not observable, it is impossible to evaluate them quantitatively. Friedman (1959) therefore proposes replacing them with expected variables.

Based on this stable relationship between income and the demand for money, monetarists believe that monetary instability can only arise from the money supply side. Consequently, any discretionary intervention in the money supply would simply disrupt this stable relationship, leading to instability and, consequently, disrupting the smooth functioning of the economy. Hence the monetary policy recommendation that the money supply should grow at a constant rate to meet the predictable demand for money holdings. However, at the turn of the 1980s, the unsatisfactory results of monetary targeting policies gave rise to a relatively extensive body of literature on the instability of the money demand function in a context marked by financial innovation and changing regulatory practices, in particular financial liberalisation programmes.

The pioneering work of Gurley et Shaw (1979) highlights that the emergence of new interest-bearing monetary substitutes, resulting from changes in the financial system, can significantly increase the sensitivity of monetary assets to interest rate fluctuations. Such an adjustment in the elasticity of money demand is likely to alter the assumed stable relationship between monetary aggregates and the ultimate objectives of monetary policy. If the hypothesis put forward by Gurley et Shaw (1979) is empirically verified, it raises important questions regarding the effectiveness of monetary policy and calls into question the relevance of monetary targets as a central instrument of monetary policy. Furthermore, in the model developed by Baumol (1952) and Tobin (1956), when economic agents decide on the frequency and, by extension, the amount of their cash holdings, consumers take two factors into account: the cost incurred per withdrawal and foregone interest. This means that innovations such as ATM transactions and cashless payments are likely to affect the optimal level of cash holdings. This point is highlighted in the following section.

2.2. Review of the empirical literature

In order to better understand the impact of financial innovations on the stability of money demand, the empirical literature employs a variety of methodological approaches. These include structural break tests, such as the Chow test, CUSUM and CUSUMSQ tests, as well as dynamic econometric approaches, such as error correction models (ECMs) and autoregressive distributed lag (ARDL) models. Among the findings are those of Nagayasu (2011) in Japan. The author seeks to determine whether innovations in the financial sector, measured by the number of cash dispensers, have had a significant impact on the demand for money. The results indicate that the number of ATMs has a negative effect on the demand for money. Furthermore, the stability of the money demand function is assessed using recursive tests based on residual analysis, which lead to the conclusion that the estimated relationship is stable.

Safdar and Khan (2013) show that the number of cash machines and credit cards has a negative effect on the demand for cash in Pakistan. They also show that the expansion of new financial instruments leads to monetary imbalances that significantly widen the output gap in the economy. According to Safdar and Khan (2013), monetary control thus becomes possible by curbing the expansion of ATMs. Kampusü (2011) estimated the effect of financial innovation on the demand for money in Turkey from 2002 to 2010 using monthly time-series data. He used a distributed polynomial model (DPM) and a moving vector error correction model (MVEC) to estimate the demand for money. Based on the number of ATMs and credit cards, he found a negative effect on the demand for money. Furthermore, the coefficient of the error correction term is statistically significant and of the expected sign, indicating an adjustment towards long-run equilibrium and suggesting stability in the money demand function over the period studied. Previously, Rinaldi (2001) had studied the effect of ATMs on the demand for cash in Belgium. Using an error correction model applied to annual data covering the period 1960–1999, he found that ATMs had a significant negative effect on the demand for money. Furthermore, the error correction term exhibits a statistically significant coefficient consistent with theoretical expectations, reflecting a mechanism of adjustment towards long-run equilibrium and confirming the stability of the money demand function over the period under consideration.

In Uganda, Nakamya (2014) uses an error correction model to assess the effect of the number of ATMs and the volume of electronic transfers on the demand for cash. Aggregated monthly data from June 2003 to March 2011 were used, and a Johansen-Juselius cointegration approach was applied. The study concludes that the number of ATMs and the volume of electronic transfers have positive and significant effects on money holdings. Furthermore, the application of recursive tests allows for an assessment of the stability of the money demand function and leads to a stable relationship in the estimated model. Subsequently, Mvogo and Avom (2020) explore this issue. The author analyses the effect of the number of ATMs and mobile money on the demand for money using panel data covering sub-Saharan African countries over the period 1990–2014. The author shows that mobile money has a positive and significant influence on the demand for money, both in the narrow sense (M1) and in the broad sense (M2). As for the number of ATMs, it has a positive and significant influence on the demand for money in the narrow sense (M1) and no significant influence on the demand for money in the broad sense (M2). Furthermore, the statistical significance and the expected negative sign of the error correction term coefficient indicate a gradual return to long-run equilibrium, suggesting a stable relationship between the demand for money and the analysis horizon.

Kasekende (2016), using the ARDL approach over the period 2000–2014, shows that mobile money has proved to be an important variable in determining the demand for money in Kenya, with a positive relationship between mobile money and the demand for money. The coefficient of the error correction term, which is significant and consistent with theory, highlights an adjustment towards long-run equilibrium and attests to the stability of money demand over the period studied. The results are similar to those obtained by Alomari et al., (2019) The study uses the ordinary least squares (OLS) regression model to analyse data from 13 commercial banks in Jordan over the period 2011–2016. The results reveal that GDP growth and the increase in the number of Visa cards held by each bank have a positive and significant effect on the demand for money. Conversely, the demand for money is negatively correlated with the increase in the number of credit cards.

Recently, in the Nigerian context, Tule and Oduh (2016), using an error correction model on monthly time series covering the period 2009–2015, argue that the value of transactions on electronic platforms will have a positive influence on the demand for money. The stability of the money demand function induced by electronic platforms is tested using a recursive residual plot. Electronic platforms did not affect the stability of the money demand function, with the exception of the period in December 2011, which corresponds to fundamental changes in the payment system during that period. Mujuri et al., (2018) studied the effect of mobile money (M-PESA) and ATMs on money demand in Kenya. Using an error correction model, the authors indicate that between 2008 and 2016, ATMs had a positive influence on the demand for cash. Finally, the error correction term is statistically significant and has the expected sign, reflecting the existence of an adjustment process towards a long-run equilibrium and indicating stability in the money demand function over the period analysed. The volume of mobile money transactions, on the other hand, has a negative effect on the demand for money.

This literature review shows that most research has been conducted using internal financial technology formats from the perspective of digital currency and electronic payments, such as debit cards and ATM networks. The conclusions of this article are of a more general nature. It analyses the simultaneous effect of these payment technologies, revealing the fundamental law governing this influence and ensuring consistency across studies. Previous arguments put forward by (Pakhnenko et al., 2021) suggest that constant innovations in digital finance and technology, and at different stages of their development, necessitate the study of simultaneous effects.

3. Methodological approach

3.1. Empirical analyses

To analyse the relationship between the development of financial technologies and the stability of the demand for money, we formulate the equation based on the Baumol and Tobin (1956) model. The demand for physical money is primarily determined by income levels, interest rates and the cost of withdrawals. In theory, financial innovations can improve the efficiency of the banking sector by reducing transaction costs (Kasekende and Dunne, 2016). To capture the impact of financial innovation on the demand for money, we incorporate several indicators representing the development of financial technologies in payment systems, namely mobile money, the number of ATMs and the number of bank cards. To these traditional determinants, we add other macroeconomic variables likely to influence money-holding behaviour, notably the inflation rate, gross domestic product and the exchange rate. The empirical equation of the model is as follows:

$$\mathrm{Enc}_{i,t} = \alpha_0 + \alpha_1 \mathrm{Pib}_{i,t} + \alpha_2 \mathrm{Int}_{i,t} + \alpha_3 \mathrm{Ter}_{i,t} + \alpha_4 \mathrm{Inf}_{i,t} + \alpha_5 \mathrm{Fint}_{i,t} + \theta_{i,t} \quad (1)$$

With i=1,2,……,7 and t=1,2,…..,25. $\mathrm{Enc}_{i,t}$ is the actual cash flow, $\theta_{i,t}$ is the error term, $\mathrm{Pib}_{i,t}$ is the Gross Domestic Product, $\mathrm{Int}_{i,t}$ is the interest rate, $\mathrm{Fint}_{i,t}$ is a financial technology indicator, $\mathrm{Ter}_{i,t}$ is the exchange rate, and $\mathrm{Inf}_{i,t}$ is the inflation rate. α_0, α_1, α_2, α_3, α_4, and α_5 are parameters to be estimated. In terms of sign, the theory predicts a positive relationship between income and money demand. However, studies differ on the size of the coefficients. The quantity theory of money predicts that the income coefficient is approximately 1, the Baumol-Tobin model predicts that it is 0.5, while Friedman's (1959) model assumes an elasticity greater than 1, that of 'luxury money'. Interest rates and the level of inflation are often used to capture the opportunity cost of holding money and should have a negative sign. While most studies arrive at this result, the magnitude of the coefficient varies, but is generally less than one, as indicated by the Baumol-Tobin model, which assumes that the coefficient is negative and equal to 0.5. The expected sign of the exchange rate coefficient is ambiguous, as it depends on whether wealth effects or substitution effects are more important. For example, if there is evidence of a wealth effect, the sign of the exchange rate is positive, implying that a depreciation of the exchange rate leads to an increase in wealth (Dobson and Ramlogan, 2001). However, if the sign of the exchange rate is negative, the demand for currency should decrease due to the substitutability of the domestic currency for foreign currency or bonds, as holding foreign currency is more profitable (Sriram, 2001)

3.2 Description of variables and data sources

Our sample comprises eight UEMOA countries over the period 2000–2024. These are Benin, Burkina Faso, Mali, Niger, Côte d'Ivoire, Senegal, Guinea-Bissau and Togo. The data include M2 (deflated by the implicit GDP deflator), income, interest rates, inflation rates, exchange rates and various measures of financial technology. M2 is defined as the sum of currency in circulation and demand deposits other than those held by the central government. Income is represented by gross domestic product, and the nominal exchange rate is measured as the average local currency per dollar. The inflation rate is measured using the Consumer Price Index (CPI), which reflects the average change in the prices of goods and services consumed. Three indicators of financial technology were taken into account: the first is mobile money, measured by the number of active mobile money accounts; the second is the number of ATMs; and finally, the third is the number of bank cards. Monetary aggregates, the GDP deflator, GDP, interest rates, exchange rates and inflation rates are sourced from the World Bank's World Development Indicators (WDI) database. Data on payment technologies were extracted from the International Monetary Fund's Financial Access Survey (FAS) database. For some countries, missing data were adjusted using the moving average method.

3.3 Descriptive statistics

The descriptive statistics for the main variables used in this study highlight the macroeconomic and monetary dynamics within the WAEMU countries. Table 1 presents the mean, standard deviation, and minimum and maximum values for all the variables included in our models. Monetary holdings, measured in logarithms, have a mean of 23.563 with a standard deviation of 0.929. Values range from 21.284 to 25.857, suggesting significant differences in the availability of liquidity across countries. GDP, measured in logarithms, has a mean of 29.607 and a standard deviation of 0.687. Values range from 28.371 to 31.443. The interest rate, with a mean of 2.647%, shows considerable variability, as indicated by its standard deviation of 2.994. Observations range from -6.427% to 7.578%. The average exchange rate is 560.990 with a standard deviation of 74.204. The values range from 446 to 732.397. The inflation rate averages 2.708%, with a standard deviation of 2.966. The values range from -8.165% to 12.485%. For mobile money, the mean is 14.927, with a standard deviation of 1.305. The extreme values range from 12.024 to 17.087. The number of ATMs, measured on a logarithmic scale, has a mean of 5.885 and a standard deviation of 0.426. The values range from 4.844 to 6.608. The bank card measure has a mean of 13.267 and a low standard deviation of 0.806, with values ranging from 11.544 to 14.945.

Table 1: Descriptive statistics for the model variables

Variables	Obs	Mean	Etd-Dev	Min	Max
Cash on hand	175	23.563	0.929	21.285	25.857
GDP	175	29.608	0.688	28.371	31.443
Interest rate	99	2.647	2.994	-6.427	7.578
Exchange rate	175	560.991	74.204	446	732.398
Inflation rate	175	2.708	2.966	-8.165	12.486
Mobile money	99	14.928	1.306	12.024	17.088
ATM	99	5.885	0.427	4.844	6.608
Debit card	99	13.268	0.806	11.544	14.945

Source: author

3.3 Model specification test

3.3.1 Unit root test

There are two categories of unit root tests: first-generation and second-generation tests. First-generation tests are based on the assumption of cross-sectional independence of observations. The second category of tests takes into account the cross-sectional dependence of observations. The results presented in Table 2 indicate that there is a strong presence of cross-sectional dependence. Indeed, the study sample includes different areas of the WAEMU, which is highly interconnected due to internal trade, the mobility of internal exchanges, the movement of people, labour and financial capital flows.

Table 2: Pesaran's dependence test (2004)

Variables	CD	P-Value
Cash on hand	24.892	0.0000
GDP	25.673	0.0000
Interest rate	8.141	0.0000
Exchange rate	25.923	0.0000
Inflation rate	6.658	0.0000
Mobile money	14.949	0.0000
ATM	6.534	0.0000
Debit card	8.765	0.0000

Source: author

Given the results in Table 2, a second-generation test seems more appropriate. The unit root test to be used is the Pesaran (2007) test, also known as the Cross-sectional Im, Pesaran, Shin (CIPS) test. In addition to taking cross-sectional dependence into account, the Pesaran (2007) test also assumes parameter heterogeneity. The values reported in Table 3 are the CIPS test statistics for the variables in our model. The test is performed with and without a linear trend. The test results indicate that none of the variables are integrated of order higher than one. Real cash balances, GDP, interest rates, exchange rates, mobile money transaction volumes, mobile banking transaction volumes, the number of debit cards, the number of ATMs and exchange rates are integrated of order one. We can explore the cointegration relationship between the variables.

Table 3: Unit root test with and without linear trend

Variables	Sans trend		Avec trend		Ordre
	Niveau	Différence	Niveau	Différence	
Cash on hand	-0.6398	-8.3156***	-0.5895	-9.6531***	I(1)
GDP	-2.3997	-6.6210***	-0.9368	-7.2418***	I(1)
Interest rate	-2.5269	-7.0856***	-4.8585	-4.5039***	I(1)
Exchange rate	-4.5535	-5.3289***	-2.6435	-6.8112***	I(1)
Inflation rate	4.3878	-4.5214***	1.1918	-3.1620***	I(1)
Mobile money	-0.4273	-0.6626***	0.5533	-2.8694***	I(1)
ATM	2.5349	-5.1588***	0.2685	-3.1209***	I(1)
Debit card	3.5414	-4.3436***	2.0527	-3.2708***	I(1)

Source: author. *p-value<0,10, **p-value<0,05, ***p-value<0,01.

3.3.2 Cointegration test

Several tests have been developed in the context of panel data, including those proposed by Pedroni (1999, 2004), Kao (1999) and Westerlund (2008). In this study, the cointegration test used is that proposed by Westerlund (2008), which allows the cointegration of variables to be tested in the presence of dependence between observations. The Westerlund (2008) test actually consists of four tests: G_α, G_τ, P_α and P_τ. The first two tests (G_α and G_τ) correspond to group mean tests, and the alternative hypothesis stipulates that at least one unit in the panel has cointegrated variables. The last two (P_α and P_τ) are panel tests, and in this case, the alternative hypothesis indicates that the entire panel is cointegrated. According to Table 4, the non-cointegration hypothesis is rejected in all cases for the Pτ test, with a significance level of 5%. These tests were calculated using the bootstrap method and are robust in the presence of cross-sectional dependence in the series.

Table 4: Westerlund (2008) cointegration test

Statistic	Value	Z-value	P-value	Robust P-value
Gt	-1.486	2.841	0.998	0.054
Ga	-3.027	3.666	0.700	0.080
Pt	-3.587	2.298	0.989	0.037
Pa	-3.195	2.280	0.989	0.040

Source: author

3.3.3 Estimation method

According to the unit root results, the variables are I (1) and in a cointegration relationship. Equation (1) can be rewritten with an error correction formula (MVCE):

$$\mathrm{D.Enc}_{i,t} = \delta_0 \mathrm{ECM}_{t-1} + \sum_{z=1}^{p} \delta_{1i}\,\mathrm{D.PIB}_t + \sum_{z=1}^{p} \delta_{2i}\,\mathrm{D.Int}_t + \sum_{i=1}^{p} \delta_{3i}\,\mathrm{D.Ter}_t + \sum_{i=1}^{p} \delta_{4i}\,\mathrm{D.Inf}_t + \sum_{i=1}^{p} \delta_{5i}\,\mathrm{D.Fint}_t + v_t \quad (2)$$

v_t is the error term. ECM_{t-1} is the error correction term, δ_0 measures the speed of adjustment of any short-term deviation towards long-term equilibrium. It is also expected to be negative and statistically significant if there is an adjustment to equilibrium. The biases encountered in the asymptotic distribution of OLS estimators of cointegrated vectors in the time series context are more acute for non-stationary panel configurations. Appropriate techniques must therefore be used to obtain efficient estimators, in particular the semi-parametric modified least squares estimator (FMLOS). Pedroni's FMOLS estimator (1996) corrects for the effects of endogenous variables and also takes into account heterogeneity in the cointegration relationship. Monte Carlo simulations show that the FMLOS estimator is particularly suitable in situations where the individual dimension N is smaller than the time dimension. Given the structure of our database (N=7, T=25), the FMOLS estimator is particularly appropriate.

In addition to the FMOLS method, we use the dynamic ordinary least squares (DOLS) method to verify the robustness of the results obtained. The DOLS estimator is a parametric approach that corrects for endogeneity and autocorrelation between the explanatory variables and the error term by incorporating lagged terms into the explanatory variables. The estimation is performed separately for each financial technology indicator: mobile money, ATMs and debit cards, in order to identify the specific effects of each channel. This approach avoids the biases associated with the use of synthetic indices, limits the problems of multicollinearity between highly correlated indicators, and better isolates the mechanisms by which each technology influences the demand for money.

3.3.4 Selection of the optimal offset length

In econometric analysis, choosing an appropriate lag length is essential. If too many lags are selected, the probability of multicollinearity and forecasting error increases. Furthermore, it also reduces the degree of freedom. Conversely, including an insufficient number of lags leads to poor model specification (Gujarati and Porter, 2009). For these reasons, the selection process is carried out using information criteria such as AIC and SC. The AIC and SC criteria may not always give the same result. In this situation, the principle of parsimony suggests choosing the lowest number of lags (Doucouré, 2015). The results relating to the selection of model lags are presented separately for the base model and then for the specifications incorporating each financial technology indicator in turn. Based on the information criteria, a lag order of one (1) is selected as optimal for all model specifications.

Table 5: Selection of the optimal length of offset for the model variables

Length	Model (1)		Model (2)		Model (3)		Model (4)	
	AIC	SIC	AIC	SIC	AIC	SIC	AIC	SIC
0	5.716	5.875	5.024	5.230	2.106	2.307	4.204	4.399
1	-4.915	-3.958	-13,159	-8.805	-8.309	-7.105	-7.195	-6.026
2	-2.711	-2.958	-6.455	-5.214	-8.413	-6.204	-7.796	-5.652
3	-4.961	-2.411	-6.608	-4.333	-8.567	-5.487	-7.761	-4.642
4	-4.927	1.581	-7.782	-4.472	-8.567	-4.351	-8.447	-4.354

Source: author.

4. Results and discussions

4.1. Basic results

The results of the estimates relating to payment technologies are presented in Table 6. The first set of results, shown in column (1), examines the traditional determinants of money demand, namely income, interest rates, inflation and exchange rates. This specification constitutes the baseline model. The second set of results, presented in column 2, focuses on the number of active mobile money accounts. The third set of results, presented in column 3, takes into account the number of ATMs. The fourth set of results, presented in column 4, takes into account the number of debit cards.

According to the regression results, the coefficient of determination (R^2) in all specifications ranges from 0.856 to 0.895. This means that more than 80% of the variation in cash holdings is explained by payment technologies, interest rates, exchange rates, inflation rates and GDP. The error correction term is negative and statistically significant at the 1% level, indicating an adjustment towards long-run equilibrium and suggesting stability in the money demand function over the period studied. Around 5% of the imbalance is corrected each year, reflecting a relatively slow pace of adjustment in the demand for money. When a macroeconomic or financial shock occurs, economic agents do not immediately adjust their monetary holdings. This reflects significant inertia in money-holding behaviour. These results are comparable to those of Nabiddo (2007), who used quarterly data and obtained an error correction term of -0.09 in Uganda. The data suggest that the monetary authorities in these countries should continue to monitor monetary growth closely, as it remains a priority area of their monetary policy.

The coefficient for mobile money transaction volume is positive and statistically significant at the 1% significance level. This suggests that the development of mobile financial services stimulates demand for money rather than replacing it. This result can be explained by a financial inclusion effect. Mobile money is generally backed by deposits held with commercial banks, which establishes a link between digital financial services and the formal banking system. It thus enables people who were previously excluded from the financial system, particularly due to a lack of access to bank branches, to access financial services more easily. These findings are consistent with those obtained by Kasekende and Dunne (2016) in sub-Saharan Africa. These results differ from those of other studies on financial innovation that use different indicators, such as those by Ndirangu and Nyamongo (2015), who find a negative relationship between financial innovation and the demand for money using the non-bank money/time deposits ratio as an indicator of financial development, and those by Sichei and Kamau (2012), who observe a negative relationship using the number of ATMs. In WAEMU countries, the positive effect of mobile money on the demand for money appears to be far greater than its negative effect. Mobile money is an alternative form of cash (i.e. electronic money) and not necessarily an alternative form of non-cash assets. The coefficient associated with ATMs and the number of debit cards is positive and statistically significant at the 1% level. This suggests that the digitisation of payments facilitates access to liquidity and increases monetary holdings. Failing to take this into account could lead to an erroneous specification of the money demand equation, which could have implications for the monetary policy of WAEMU countries. The results obtained are consistent with those of Mujuri et al., (2018) for Kenya and those obtained by Alomar et al., (2019). However, they contrast with those obtained by Kipsang (2013), who found that ATMs had no impact on cash holdings.

With regard to the traditional determinants of money demand, we note that GDP, regardless of its specific characteristics, is always positively and significantly associated with money demand at the 1% significance level. This is consistent with the quantity theory of money and with a priori predictions. The present study differs from other studies only in the order of magnitude of the coefficients. Some empirical studies arrive at a coefficient of less than 1, such as (Mwega and Killick (1990), whilst others, such as Darrat (1985) ; Adam (1992) ; Sichei and Kamau (2012) and Ndirangu and Nyamongo (2015), estimate that the income elasticity is greater than 1. This has been attributed to various factors, including high monetisation of economies, under-monetisation of economies and underdevelopment of the financial sector, but is sometimes the result of a failure to take into account the effect of financial innovation (Arrau and De Gregorio, 1991).

Interest rates and inflation have negative coefficients, in line with monetary theory, suggesting an arbitrage effect linked to the holding of cash. Economic agents choose between holding cash or bonds. The lower the interest rate, the more agents seek to hold cash rather than bonds. The results are therefore consistent with Keynesian theory on speculative demand for money. The coefficient associated with the exchange rate is consistently positive and statistically significant at the 1% level. Studies such as that by Narayan et al., (2009) on South Asian countries and that of Aliha et al., (2019) for Malaysia have highlighted a positive relationship between the exchange rate and the demand for money, whilst other studies, such as those by Kumar and Pradhan (2005) and Ndirangu and Nyamongo (2015) for Kenya, have revealed a negative relationship.

Table 6: Effect of financial technologies on money demand in WAEMU countries

Variables	Model (1)	Model (2)	Model (3)	Model (4)
D.Gross Domestic Product	0.4735*	0.9680***	0.1569***	0.2033***
	(0.2480)	(0.3050)	(0.0180)	(0.0135)
D.Interest rate	-0.0013**	-0.0251***	-0.004**	-0.0069*
	(0.0006)	(0.0080)	(0.0019)	(0.0037)
D.Inflation rate	-0.0030*	-0.0306***	-0.0032*	-0.077***
	(0.0016)	(0.0086)	(0.0017)	(0.0080)
D.Exchange rate	0.1337	-0.0519	0.2722***	0.1852***
	(0.0863)	(0.1180)	(0.0574)	(0.0461)
D.Mobile money		0.0916***		
		(0.0169)		
D.ATM			0.0749**	
			(0.0373)	
D.Debit card				0.0361**
				(0.0170)
ECM (-1)	-0.061***	-0.0497***	-0.0488***	-0.0370***
	(0.0101)	(0.0069)	(0.0105)	(0.0068)
Constante	0.2162	-1.0764***	-1.0874***	-0.8178***
	(0.2376)	(0.1590)	(0.2480)	(0.1547)
Number of Observations	91	91	91	91
Country	7	7	7	7
R-Ajusted	0.895	0.859	0.856	0.892

Source: author. *p-value<0,10, **p-value<0,05, ***p-value<0,01. (.) représente les erreurs standard.

4.2. Robustness tests

In order to verify the stability of our results, we undertake several robustness tests. First, we consider different sets of control variables in our reference formulation, notably the banking penetration rate and the size of the informal sector, and repeat the FMOLS estimation of Phillips and Hansen (1990). Second, we use an alternative dependent variable, namely narrow money (M1), in the benchmark formulation. Third, we use an alternative estimation method, namely canonical cointegrating regression, to take into account the cointegration relationship between the model variables.

4.2.1 Robustness test with additional control variables in our reference formulation

We test the robustness of our results by adding additional control variables to the baseline specification in order to account for other variables that may influence actual cash balances. These additional control variables are the size of the informal sector and the rate of bank penetration. The size of the informal sector reflects a strong preference for liquidity. A larger size could indicate increased demand for liquidity (Hossain, 2004 ; Davis et al., 2013). Indeed, the predominance of cash transactions and the need for liquidity for unregulated activities can lead to an increase in the demand for money. The banking penetration rate is a structural indicator of the degree of financial inclusion. It reflects the proportion of the population with access to traditional banking services. The estimates are presented in Table 7. The results indicate that, following the introduction of additional control variables, the direction and magnitude of the coefficients remain unchanged, as in our baseline model. However, the exchange rate appears statistically significant in all specifications, suggesting a more pronounced role for external factors. Furthermore, the results show positive effects linked to the size of the informal sector on cash holdings. Indeed, those in the informal sector tend to hold larger amounts of cash to facilitate daily transactions, which increases the demand for money. The rate of access to banking services has a negative coefficient in all specifications.

Table 7: Robustness test with additional control variables

Variables	Model (1)	Model (2)	Model (3)	Model (4)
D.Gross Domestic Product	0.7181***	0.9820**	0.2739**	0.1284***
	(0.1481)	(0.4680)	(0.1269)	(0.0267)
D.Interest rate	-0.004*	-0.041***	-0.0320***	-0.0221***
	(0.0024)	(0.0137)	(0.0087)	(0.0058)
D.Inflation rate	-0.009***	-0.013***	-0.0310***	-0.0243***
	(0.0032)	(0.0015)	(0.0088)	(0.0061)
D.Exchange rate	0.1558***	0.6112***	0.4458***	0.3541***
	(0.0481)	(0.2232)	(0.0566)	(0.0355)
D.Informal sector size	0.0493***	0.0269	0.0215	0.0297***
	(0.0110)	(0.0177)	(0.0139)	(0.0083)
D.Banking penetration rate	-0.0002*	-0.0008**	-0.0011***	-0.0009***
	(0.0001)	(0.0003)	(0.0002)	(0.0001)
D.Mobile money		0.1036***		
		(0.0267)		
D.ATM			0.0308*	
			(0.0178)	
D.Debit card				0.0784***
				(0.0123)
ECM (-1)	-0.0053**	-0.0678***	-0.0894***	-0.0607***
	(0.0024)	(0.0123)	(0.0117)	(0.0058)
Constante	0.2029	-1.4894***	-2.0207***	-1.3687***
	(0.1264)	(0.2853)	(0.2735)	(0.1320)
Number of Observations	91	91	91	91
Country	7	7	7	7
R-Ajusted	0.890	0.828	0.817	0.874

Source: author. *p-value<0,10, **p-value<0,05, ***p-value<0,01. (.) représente les erreurs standard.

4.2.2 Robustness test with alternative dependent variable

We use an alternative dependent variable to M1 money stock in our baseline specification. M1 is the dominant component of the money supply in developing countries (Kumar and Rao, 2019). The estimates are presented in Table 8. We observe that the main results remain stable, as in our baseline model. The number of ATMs, the number of debit cards and mobile money remain significant determinants of money demand in WAEMU countries. The traditional determinants of money demand are consistent with theoretical predictions. GDP has a positive effect on money demand, whilst the interest rate and the inflation rate have a negative influence on monetary holdings.

Table 8: Robustness test with alternative dependent variable

Variables	Model (1)	Model (2)	Model (3)	Model (4)
D.Gross Domestic Product	0.0502**	0.0853*	0.1371***	0.8140**
	(0.0234)	(0.0472)	(0.0090)	(0.3961)
D.Interest rate	-0.0110***	-0.0373**	-0.0716***	-0.0449***
	(0.00129)	(0.0155)	(0.0201)	(0.0150)
D.Inflation rate	-0.0460***	-0.0249**	-0.0651***	-0.0420***
	(0.0121)	(0.0125)	(0.0195)	(0.0069)
D.Exchange rate	0.2288	-0.2173	0.6619***	0.5291**
	(0.1910)	(0.2268)	(0.1360)	(0.2692)
D.Mobile money		0.1212***		
		(0.0338)		
D.ATM			0.2946***	
			(0.0878)	
D.debit card				0.1066***
				(0.0107)
ECM (-1)	-0.0242***	-0.0127***	-0.1054**	-0.0856*
	(0.0023)	(0.0015)	(0.0462)	(0.0460)
Constante	0.2679	0.1480	0.9732**	0.6479*
	(0.1954)	(0.1165)	(0.3881)	(0.3522)
Number of Observations	91	91	91	91
Country	7	7	7	7
R-Ajusted	0.866	0.897	0.828	0.818

Source: author. *p-value<0,10, **p-value<0,05, ***p-value<0,01. (.) représente les erreurs standard.

4.2.3 Robustness test with an alternative estimative method

The empirical results obtained using the alternative canonical cointegration regression (CCR) method are presented in Table 9. The coefficient estimates are similar to those obtained using the fully modified ordinary least squares method described above. The results relating to the traditional determinants of money demand are consistent with theoretical predictions. Indeed, GDP has a positive effect on money demand, whilst the interest rate and the inflation rate have a negative effect on cash holdings. Technological innovations, notably mobile money, the development of ATMs and debit cards, have a significant and positive effect on cash holdings.

Table 9: Robustness test with alternative estimation method (Canonical Cointegrating Regression)

Variables	Model (1)	Model (2)	Model (3)	Model (4)
D.Gross Domestic Product	0.4422*	0.9829*	0.1871***	0.2432***
	(0.2276)	(0.5611)	(0.0047)	(0.0321)
D.Interest rate	-0.036***	-0.0257***	-0.04***	-0.093***
	(0.0108)	(0.0026)	(0.0132)	(0.0130)
D.Inflation rate	-0.008***	-0.0311**	-0.045***	-0.0113***
	(0.0092)	(0.0124)	(0.0132)	(0.0014)
D.Exchange rate	0.0976	-0.2263	0.2619***	0.1759**
	(0.1232)	(0.4815)	(0.0970)	(0.0806)
D.Mobile money		0.0871***		
		(0.0225)		
D.ATM			0.0913*	
			(0.0500)	
D.Debit card				0.0438***
				(0.0148)
ECM (-1)	-0.0047**	-0.0498***	-0.0470***	-0.0348***
	(0.0019)	(0.0109)	(0.0138)	(0.0107)
Constante	0.1856	-1.0782***	-1.0438***	-0.7674***
	(0.2337)	(0.2417)	(0.3273)	(0.2396)
Number of Observations	91	91	91	91
Country	7	7	7	7
R-Ajusted	0.811	0.814	0.856	0.876

Source: authors. *p-value<0,10, **p-value<0,05, ***p-value<0,01. (.) représente les erreurs standard.

5. Conclusion and economic policy implications

This article analyses the effect of financial technologies on the demand for money in WAEMU countries over the period 2000–2024. To this end, we have carried out an econometric estimation that takes into account the cointegration relationship between the variables. Based on the empirical results, we have found evidence that various elements of financial technology, such as ATMs, mobile money and debit cards, are determinants of money demand within the WAEMU. Thus, failing to take them into account may lead to specification and forecasting errors in monetary aggregates. The results of this study suggest that financial innovation should be incorporated into the modelling of money demand. With negative and significant cointegration coefficients, the model's results appear to indicate long-term stability in the demand for money within the WAEMU. These findings encourage monetary authorities to explicitly incorporate indicators of technological innovation into their analytical frameworks and to adapt their monetary policy instruments in order to preserve the effectiveness and credibility of monetary policy in a context of increasing digital transformation. This study nevertheless has certain limitations linked, on the one hand, to the difficulty of distinguishing the substitution effects between traditional money and electronic money brought about by the development of financial technologies, and, on the other hand, to the heterogeneity of WAEMU countries in terms of financial inclusion, access to digital technologies and internet penetration, which may lead to differing effects across countries. In any case, these limitations offer opportunities for more in-depth analysis.

Funding: No funding was received for this research.

Compliance with Ethical Standards: This research uses secondary data obtained from World Bank's World Development Indicators (WDI) database and International Monetary Fund's Financial Access Survey (FAS) database. No human participants, personal data, or experimental interventions were involved.

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