BNR Economic Review, Volume 21(2).

Demand for cash in Rwanda: Developments and prospects

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December, 2024

Abstract

Payment systems worldwide have undergone significant mutations, characterized by substantial uptake in digital payments, which are expected to decrease the demand for cash. The use of digital payment means has equally increased in Rwanda amid ongoing developments in digital payment technologies and various policy initiatives to promote the use of cashless means of payment. Nevertheless, cash in circulation continued to grow and play a significant role in consumer payments. This study aimed to analyze the drivers of cash demand in Rwanda and, specifically, the impact of digital payments. Results from different ARDL models suggest that using cashless means of payment, notably mobile payment, negatively affects cash in circulation in Rwanda. Nevertheless, the increase in economic transactions put upward pressure on cash circulation in Rwanda. At the same time, the interest rate proxied by the T-bills rate represents an opportunity cost as its increase reduces cash in circulation. Regarding other payment innovations, while banking agents' transactions negatively affect cash in circulation, there is no evidence of any effect from mobile banking, internet banking, POS, ATMs and mobile money cash transactions on cash in circulation in the long run. Therefore, policy initiatives to (i) foster financial access and inclusion, (ii) use of digital means of payments, (iii) reduce the size of the informal economy will help in reducing the cash in circulation and promote the use of cashless means of payment.

Keywords: cash in circulation, cash, demand for banknotes, digital payments

JEL Classification: E41, E42, E58

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1 Introduction

Payment systems worldwide have undergone significant innovations and transformations, notably with the advent of digital means of payment, and these developments are expected to reduce the demand for cash. Nevertheless, except in a few cases, such as Sweden, where demand for physical cash has been gradually declining, demand for cash remains resilient and has been increasing in many economies, including the US and Eurozone (Bagnall et al., 2018). The recent BIS report on payments across developed and emerging countries highlighted that cash in circulation as a percentage of GDP remained higher than the pre-pandemic level despite solid growth in digital payments. However, differences remained across countries, especially in terms of payment habits.

For Rwanda in particular, ongoing developments in the financial sector, especially in digital payment and financial technologies coupled with initiatives to foster the use of digital means, notably the cashless campaign, have led to an increase in the share of payment using electronic means. However, despite the spread of electronic means of payment, the recent FINSCOPE survey (FINSCOPE, 2024) revealed that cash still accounts for a significant share of consumer payments and is intensively used by some segments of the population. The main question is why the use of cash in circulation continues to increase despite the substantial uptake of digital payment instruments.

Understanding why cash has remained resilient despite significant changes in the payment landscape is crucial for policymakers in general and central banks in particular, given that the latter are usually responsible for the management of the currencies and ensuring the seamless functioning of the payment system, in addition to the traditional function of monetary policy.

In Rwanda, while multiple efforts and policy initiatives to promote the use of cashless means of payment have been underway, it is crucial for the National Bank of Rwanda (henceforth, NBR), in charge of the national currency management and payment system, to analyze the drivers of the use of cash vs cashless instruments, for better management of cash issuance and monetary policy and financial stability considerations, among others. This would enable NBR in many ways, including:

- Understanding the drivers of demand for banknotes to ensure better cash management in terms of planning for the production of banknotes/coins, their availability in different denominations, well-functioning payment systems, etc.

- In terms of monetary policy transmission, having a higher share of cash can impede it, especially when it is kept outside the banking system.

- On the financial system's stability, using cash versus cashless would alter the banks' business model, reduce some costs, and open some other income sources in fees on digital payment.

Thus, the main objective of this study is to examine the drivers of overall demand for cash in Rwanda as well as drivers per banknotes denomination. Secondly, this study assesses the effect of the use of digital

means of payments on cash in circulation in Rwanda.

Following recent literature, our study used several Autoregressive distributed lag models (henceforth, ARDL) on overall cash in circulation and cash in circulation per banknotes denomination to analyze the long-run drivers of cash in circulation and Bayesian VAR models to investigate the short-run drivers. The choice of ARDL models was motivated by their ability to accommodate variables with different integration orders and address endogeneity issues while preserving degrees of freedom. Results obtained were somewhat in line with the literature as they suggest that in the long run, the size of the economy proxied by nominal GDP, and T-bills rate affect cash in circulation.

Regarding the effect of cashless transactions and other innovations in payment systems in Rwanda, our results generally indicate that the use of cashless means of payment, notably mobile payments, has led to a decline in cash in circulation. Besides, regarding other innovations, evidence shows that banking agent transactions reduce cash in circulation. However, there was no evidence of any effect of other key innovations, such as ATM and mobile money transactions, on cash in circulation.

The structure of the paper is as follows: the next section outlines the main insights from the literature on demand for cash, especially recent literature on demand for cash amid the ongoing digitalization of payments. Section 3 briefly illustrates key stylized facts on Rwanda's financial and payment systems. Section 4 presents the methodology used, while section 5 discusses the empirical results. Section 6 concludes.

2 Literature Review

Literature on cash demand and consumer cash management (the consumer use of cash vs cashless instruments, cash hoarding) has gained momentum in the last decade amid the need by policymakers to understand why/how much cash holding and usage persists despite innovations in payment and the spread of alternative electronic payment means. It is crucial here to distinguish two main strands in the empirical literature. On one side, demand for cash studies primarily assessed long-term relationships via cointegration analysis, while studies on payment choice (cash vs digital means) mostly opted for logit-type estimation. In this brief review, we focus on the first strand of literature (demand for cash), highlighting different approaches used, variables selected and the key results obtained.

The main objective of most of the studies reviewed is to assess the reason behind the resilience of cash despite the development in digital payments. Nevertheless, other specific objectives depended on the context. For instance, case studies for US or Euro Area countries also sought to analyze hoarding and foreign demand as their currencies are the reserve currencies. Other studies, especially those conducted by central banks' staff, aimed at devising a forecasting framework to address the cash management issue to ensure that the quantity of needed cash for smooth economic transactions is available and in adequate proportion by denomination. In that vein, some authors e.g. (Figueroa & Pedersen, 2019); (Assenmacher, Seitz, & Tenhofen, 2019); (Baldo et al., 2021) went further and looked at drivers per denomination.

The methodologies used also share similarities. For studies where prime objective was to understand structural drivers at the country level, cointegration techniques notably ECM, VECM, and Dynamic OLS

(e.g. (Seitz, Devigne, & de Pastor, 2022); (Miller, 2017); (Bartzsch & Seitz, 2016); (Vale, 2015), etc.) and ARDL models (Baldo et al., 2021); (Awasthy, Misra, & Dhal, 2022), etc.) mainly were adopted. One recent study by

bartzsch2023forecasting went further with structural time series analysis to disentangle trends and cycles using the Kalman filter. Meanwhile, cross countries studies opted for panel analysis such as panel cointegration analysis (e.g. (Reimers, Schneider, & Seitz, 2020) and panel fixed effects (e.g. (Cabezas & Jara, 2021); (Chandrakamal & Kumar, 2023).

As the exercise to identify drivers of demand for cash could be challenging, especially in this rapidly evolving environment, some of these studies (e.g. ((Baldo et al., 2021); (Figueroa & Pedersen, 2019) enriched their analysis with short-time models such as VAR models and other simple autoregressive models.

Regarding variables selected in different studies mentioned above, models always included an indicator of economic activities (e.g. GDP, consumption, retail sales, etc.), an indicator of opportunity costs (different short-term interest rates but primarily deposit interest rates), indicators of regulations involving the use of cash or other alternative means of payment (mainly included as dummy variables), an indicator of shadow economy (e.g. unemployment rates), an indicator of foreign demand (e.g. real effective exchange rate, henceforth REER), indicator of alternative to cash (e.g., availability of digital means of payment such as POS, use of cards, mobile payments, cheques), other banking and payment system indicators (e.g. number of ATMs, bank branches), indicators of financial inclusions, indicators of tax burden, regulatory environment, security, convenience, demography, etc.

Looking at empirical evidence on the effect of those main drivers of demand for cash; starting with indicators of economic activities, the results for almost all studies reviewed were in line with the theory. Recall that economic activities were proxied by either consumption or GDP, which positively affects demand for cash. In some cases, there was almost a one-on-one relationship between consumption and demand for cash (e.g. for the case of the UK, (Miller, 2017); (Goodhart, Ashworth, et al., 2020), while for cross-country panel analysis, the coefficient was also positive but relatively lower (e.g. (Seitz, Reimers, & Schneider, 2018).

Similarly, regarding the opportunity cost indicator proxied by interest rates, results were generally in line with the theory, as an increase in interest rate led to reduced cash in circulation in almost all studies. Recalling that most of the studies used deposit interest rates (e.g. (Seitz et al., 2018); (Baldo et al., 2021); (Reimers et al., 2020); (Goodhart et al., 2020) and policy rate (e.g. (Gerst & Wilson, 2011); (Vale, 2015), etc.).

Regarding indicators of financial institutions' reach-out, such as the number of branches and ATMs per population, there is no clear consensus in the theory as there could be two conflicting effects on cash demand. On the one hand, more branches and ATMs could make cash more accessible and reduce the need to hold cash. On the other hand, more access to cash via ATMs could reduce the relative attractiveness of alternative stores-of-value/payment types and thus increase demand for cash ((Gerst & Wilson, 2011).

The case of ATMs is interesting given that they are considered as innovation resulting from the advent of bank cards, and the latter are usually assumed to reduce the use of cash. Miller, (2017) argued that the positive relationship between an increase in demand for cash and the number of ATM per population for the UK might be reflecting the fact that cash stock needed for a larger ATM network outweighs the reduction in

the need for cash by cardholders who can easily access it via ATMs or the fact that ATMs availability can be an incentive for bank cardholders to withdraw. Gerst and Wilson, (2011) also found in the US, more ATMs drive higher demand for cash, and on the relative share of notes of 20 USD used in ATMs, the effect was negative for the share of other notes. Other evidence of a positive relationship between the number of ATMs and demand for cash includes (Seitz et al., 2022) for France, (Rua, 2021) for Euro Area, (Chandrakamal & Kumar, 2023) for a panel of 17 economies, (Cabezas & Jara, 2021) for a panel of 21 developed and emerging economies, etc. Nevertheless, Amromin and Chakravorti, (2007), in a panel of developed countries, found that the number of ATMs led to reduced cash in circulation.

Besides, some evidence suggests that ATM numbers can interact with other key cash demand drivers. For instance, more ATMs could increase interest rate elasticity as they make withdrawing cash easier.

Regarding the number of bank branches, the results are generally mixed. Miller, (2017) found a negative relationship in the UK, while Gerst and Wilson, (2011) for the US and Amromin and Chakravorti, (2007) for a panel of developed countries found that more branches led to higher cash demand across all denominations.

Alternative means of payment, namely cashless payments, were proxied by different indicators depending on the context, sample periods, and data availability, given that innovation in cashless payment has been dynamic over time. One of the proxies used is the number of point-of-sale terminals (henceforth, POS) or transactions done via those POS, which, as expected, led to a decline in cash demand for the case of France (Seitz et al., 2022). Similarly, Reimers et al., (2020) results from a panel study also show that the number of POS terminals and POS transactions negatively affect cash demand.

Another proxy used is the volume of card usage. Seitz et al., (2022) show that it led to lower demand for large and medium denominations in France, while results from (Reimers et al., 2020) also suggest that both the number of card transactions and volume decrease demand for cash in a panel study. The study by Cabezas and Jara, (2021) A panel of 21 developed and emerging economies also highlighted that credit card usage, as well as other technological advances in financial systems (e.g., transacting with financial institutions using phones, using the internet to pay bills, and access to financial institutions), reduced demand for cash.

Another proxy is the volume of payment using mobile phones. Few studies have considered mobile payment, given that this is a recent phenomenon relatively limited to developing financial markets. Although available evidence tends to show that transactions using mobile phones reduce demand for cash, this may not be clear-cut evidence on whether mobile payment increases or decreases demand for cash, given mobile phone transactions are complex and may involve cash or not cash. In fact, mobile phones can allow many cashless transactions such as deposits and withdrawals in banks using the application, payment of bills for many services, internet payment, and some transactions involving cash like withdrawing at mobile money agents. Therefore, results would strongly depend on how authors measure mobile payments. For instance, Kombe, Yabu, Mwita, and Mbiha, (2020) lumped together all payments via mobile phones and found that mobile phone transactions led to reduced demand for all denominations of Tanzanian shilling. Seitz et al., (2022) measured mobile payment as the log value of contactless mobile payment (which is cashless) and found that mobile payment reduces demand for cash but only for small denominations in France. The study by Cabezas and Jara, (2021) on a panel of 21 countries used a percentage of the population using mobile phones to transact with financial institutions and reached the same conclusion.

On indicators of regulations, Baldo et al., (2021) emphasized the role of legal limits on cash transactions in influencing cash circulation in Italy. The reduction of the allowed amount for cash transactions had initially negatively affected cash in circulation, especially during the Covid-19 period. However, the recent reduction had not yet yielded any results. This negative effect was stronger for higher denomination notes, while for the middle denomination, it was the opposite. Besides, legal obligations to accept cards at point of sales contributed to reduced cash circulation in Italy.

On foreign demand, most authors used the REER as a proxy. They considered that local currency appreciation/depreciation would be associated with more/less demand for cash, especially if that demand is for a store of value or for hoarding. Evidence from Seitz et al., (2022) for France, Bartzsch and Seitz, (2016) for Germany and Assenmacher et al., (2019) for Switzerland (especially larger notes denomination) point to that direction as appreciation in drove up demand for cash. Considering that both Euro and Swiss Franc are reserve currencies, these results are consistent with the theory. Nevertheless, some studies, such as Miller, (2017), found that the depreciation had led to more demand for the pound in the UK as foreigners found the pound cheaper.

Regarding evidence on other currencies which are not reserve currencies, results from Kombe et al., (2020) study on demand for the Tanzanian shilling shows that depreciation led to lower demand, which also makes sense considering that the Tanzanian shilling is not a strong reserve currency.

About the shadow economy, different authors argued that the bigger the shadow economy, more demand for cash as due to its anonymity, it does not have much competition as a medium of payment in the shadow economy given its ability to circumvent government regulations and taxation. Indeed, there is empirical evidence on how the shadow economy led to higher demand for cash, including cross-country studies such as Reimers et al., (2020) and country case studies such as Seitz et al., (2022). One exception is the study on Italy (Baldo et al., 2021)., where the effect of the shadow economy on cash balances was quasi-absent.

A closely related factor is the influence of tax burden on cash balances. Cross-country studies (e.g. (Chandrakamal & Kumar, 2023), etc.) pointed out that the higher the tax burden (proxied by the tax to GDP ratio), the higher the demand for cash balance, as people prefer to transact in cash to avoid taxation.

Our study contributes to the literature by examining the drivers of demand for overall cash in circulation and per banknote denomination in both the long and short run in Rwanda, a developing country that recorded significant changes in payment means and payment regulations in recent years coupled with progress in financial inclusion. Similar to recent literature, we use time series models with Rwanda data, considering the reality of the Rwandan economy. The methodology adopted is detailed in the following sections.

3 Stylized facts on Rwanda's payment system

3.1 Cash in circulation vs digital payments

The two figures below depict the evolution of cash in circulation in Rwanda. Cash in circulation has been going up in recent years but at a relatively lower pace than economic activities, as shown by the recent decline in the currency-to-nominal GDP ratio (Figure 1). Figure 2 depicts how the share of cash in circulation in other monetary aggregates has been steadily declining following the ongoing financial sector deepening in Rwanda, among others. This is more obvious in the ratio of cash in circulation to M1.

Figure 1: Currency in circulation level and ratio to GDP

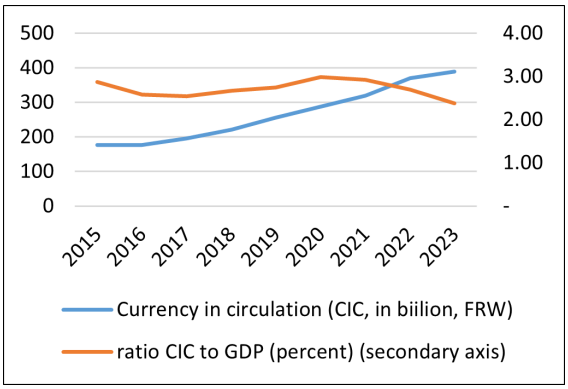
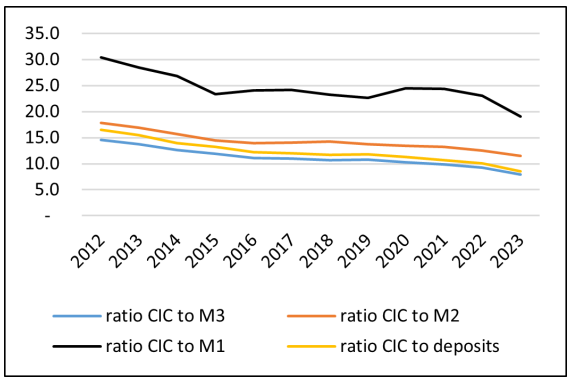


Figure 2: Ratio of CIC to monetary aggregates



Source: Authors' computation using data from NBR

Figures 3 and 4 portray the evolution per banknote denomination and how the growth in the number of 5000 and 2000 banknotes has relatively stagnated since the beginning of 2023. The latter represents, by far, the largest share of unfit banknotes and banknotes deposited by banks at BNR, as shown in Figure 4.

Figure 3: Number of banknotes per denomination

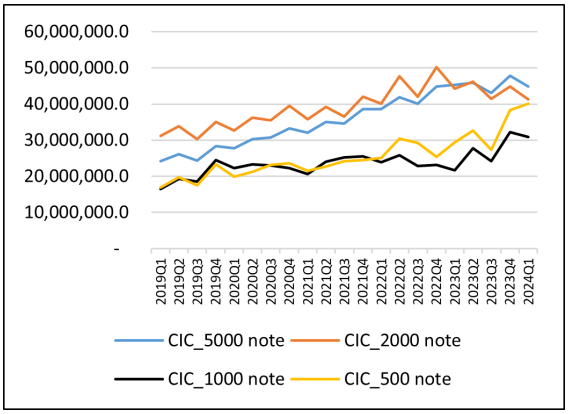
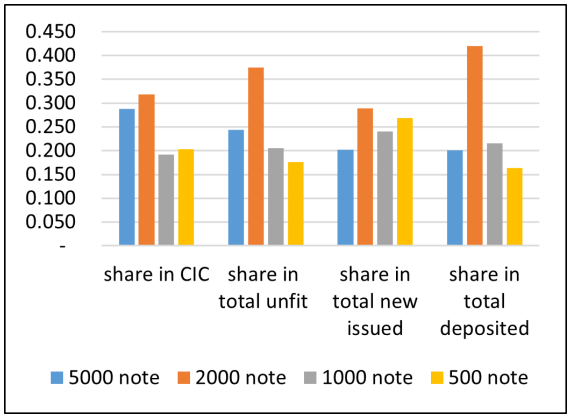


Figure 4: Average share per denomination (2020 - 2023)



Source: Authors' computation using data from NBR

Meanwhile, the uptake of digital means of payment continues to grow faster, as shown in Figures 5 and 6, with one exception, namely the POS transactions. In the last decade, several policy initiatives, regulations and campaigns have been undertaken to modernize the payment system, foster financial inclusion and promote digital payment. One notable recent initiative was the interoperability between financial institutions and mobile money operators, and since its launch, the volume of transactions has steadily increased.

Figure 5: Uptake of digital payments

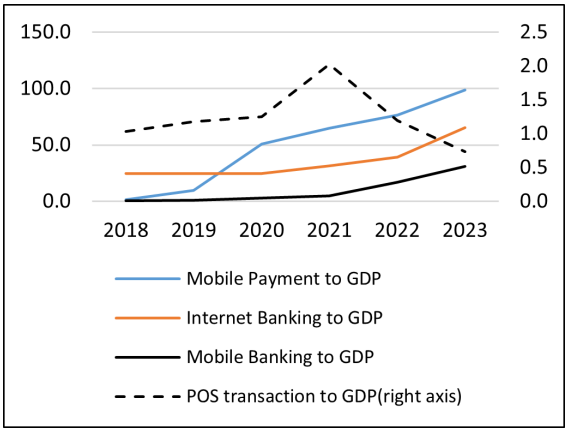
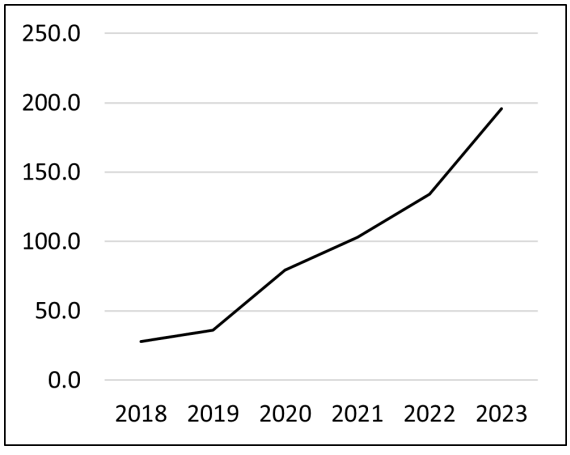


Figure 6: Total cashless transactions to GDP

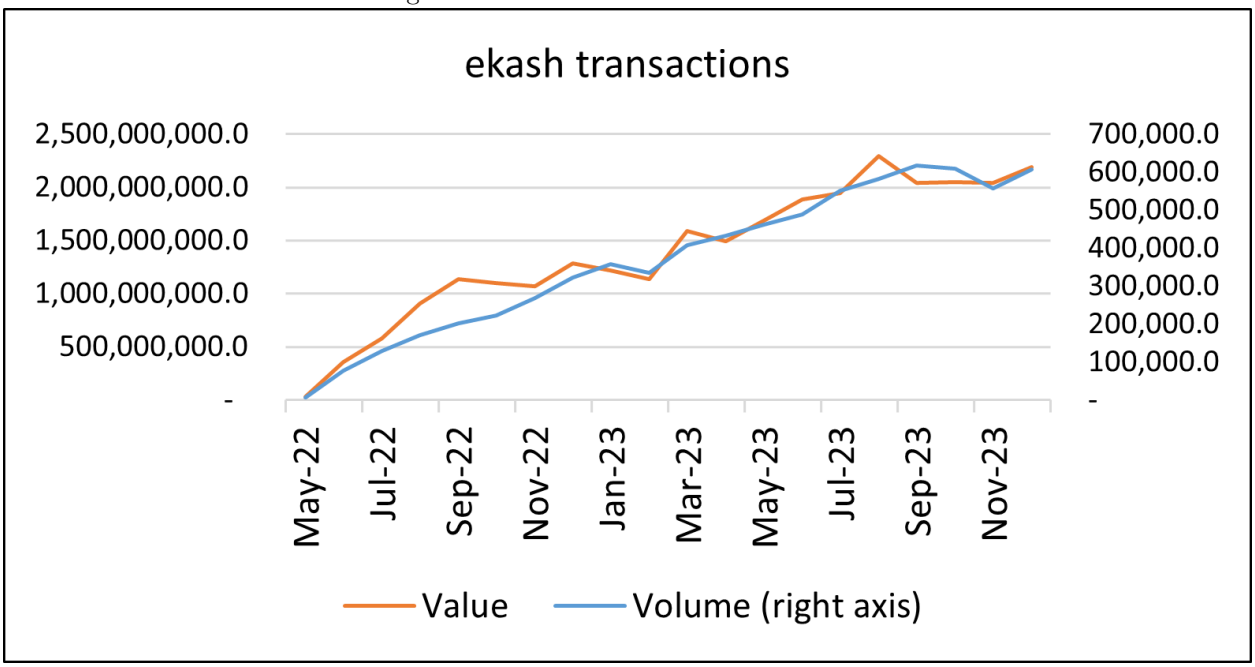


Source: Authors' computation using data from NBR

3.2 Recent policy initiatives and regulatory environment.

Interoperability between financial institutions and mobile money operators is among recent policy initiatives, regulations and campaigns undertaken to modernize the payment system, foster financial inclusion and promote digital payment. Since its launch, the volume of transactions has steadily increased, as shown in Figure 7 below.

Figure 7: Evolution of e-kash transactions



Source: Authors' computation using data from NBR

4 Methodology

We refer to the methodologies used by other studies on examining the drivers of demand for cash per denomination (e.g. (Bartzsch & Seitz, 2016); (Miller, 2017); (Assenmacher et al., 2019); (Figueroa & Pedersen, 2019); (Baldo et al., 2021) and (Seitz et al., 2022) for the Euro in Germany, the GB Pound, the Swiss Franc, the Peso, the Euro in Italy, and the Euro in France, respectively), and will assess overall demand for cash in both the long and short run and demand for cash per each denomination.

This study uses different time series modelling approaches, compares the relative importance of key drivers, and assesses the role of digital means of payments. Thus, we analyze long-run relationships using the ARDL framework and short-run relationships using Bayesian VAR models.

4.1 Key macroeconomic variables selected

The choice of variables referred to recent literature on drivers of demand for cash while also considering local realities; it is crucial to consider the ongoing development in the payment landscape, notably the use of cashless means, to analyze the demand for cash in Rwanda. Nevertheless, given that some of those ongoing developments are relatively recent and time series models usually require many observations, it is necessary to use high-frequency data, i.e. monthly data, to ensure enough degree of freedom during estimation.

Starting with the dependent variables, we first use the overall stock of cash in circulation to analyze its drivers. Secondly, we group cash in circulation into three categories based on denomination, namely large, medium, and small denominations.

Independent variables were selected based on the literature and realities of the Rwandan economy. They include measures of economic transactions in the economy, the opportunity cost of holding cash, alternatives to cash (cashless means of payment), banking sector outreach, banking sector lending and the size of the informal economy. Data on tax burden and regulatory environment were not available.

Regarding the measure of economic transactions, most of the previous studies (e.g. (Bartzsch & Seitz, 2016); (Miller, 2017); (Baldo et al., 2021) and (Seitz et al., 2018)) opted for either consumption or GDP or both as a proxy of economic transactions. As these two variables are not available on a monthly basis, we use the nominal composite index of economic activities (henceforth, nominal CIEA) as it is a good proxy of GDP and is compiled by the National Bank of Rwanda and available at a monthly frequency. It combines various high-frequency macroeconomic variables such as turnovers from different sectors, exports, imports, cement production, electricity production, etc.

Besides, we use data on quarterly nominal GDP from the national account statistics, which are transformed into monthly frequency, using the change observed in the NCIEA as a reference in interpolation into monthly series.

Regarding the opportunity costs of holding cash, the deposit interest and T-bills rates are the most used indicators in the studies reviewed. Given that both rates are strongly correlated in Rwanda, we opt for the T-bills interest rate, as the T-bills rate reflects better the opportunity cost of holding cash in Rwanda than

the deposit rate as some big depositors have market power on the deposit market. Their weights influence the movement in the weighted deposit rate.

On the indicator of alternative payments (digital means of payment) in Rwanda. The payment ecosystem is rapidly evolving, and many instruments and solutions are currently on the market. Although the NBR has been monitoring these developments and collecting data from commercial banks, mobile network operators and fintech companies, it is not straightforward to capture how overall cashless payments have been evolving at a higher frequency because including all variables in the model without long historical series would lead to a degree of freedom issues. Some studies reviewed would include one or several indicators (e.g. volume of card payments, volume of POS transactions, volume of mobile payment) depending on the realities of the economy under study. Thus, we examine the effect of these digital payments by lumping together all cashless instruments (mobile money payments, mobile banking, internet banking, and POS transactions) under one indicator. Secondly, we delve into details and include each cashless instrument in the model.

While in the past literature, most studies measured the use of cashless with transactions volume, we considered the realities of Rwanda, where the quick uptake and diversity of users led to the volume and value of transactions increasing at different paces on a monthly basis. Thus, we opted to measure all these new digital means as the volume-to-value ratio to better capture the usage intensity. This is important in the Rwandan context as some of these digital means have progressively been adopted by the population, and the change in volume without considering value would only portray one side of the story.

Given that the financial sector in Rwanda is still developing and not as deep as in the developed countries, the degree of banking sector outreach can also influence the agents' demand for different forms of money. Therefore, we consider the other three additional indicators, which are also digital innovations but are not considered cashless because their use involves direct manipulation of cash. One of the indicators usually included in this type of study is the number of ATMs per population and the number of bank branches. However, as this number is relatively stagnant, considering that we are using monthly data, we opted for the ratio of volume to value of ATM transactions and the ratio of banks' agents' transactions. Besides, we also include the ratio of volume to value of mobile money transactions involving cash manipulation to distinguish them from those which do not involve cash, which are included in cashless indicators mentioned in the previous paragraph.

In addition, as Rwanda is a small open economy, with transactions with the rest of the world, we include the nominal exchange rate depreciation in independent variables.

We also consider the estimate of the informal economy, calculated by the National Institute of Statistics of Rwanda, as this usually involves cash transactions, and its size can affect demand for cash.

Lastly, we include the credit-to-deposit ratio as a proxy for cash/funds leakage from the banking system. In fact, according to some commercial banks' staff in charge of managing banknotes, their need for banknotes can be seasonal and concomitant with periods of higher government spending and higher bank lending as some borrowers immediately withdraw cash when their account is credited after loans are granted. If this is used to settle payments and the beneficiaries deposit in their accounts in other banks, the ratio of outstanding loans to deposits will remain relatively stable. Otherwise, if the ratio increases, it will imply a higher need by banks for physical cash to serve the need for customers to withdraw.

Due to data availability on different banknote denominations and various indicators of digital payment (mobile banking, internet banking, mobile money, etc.), our sample period ran from January 2019 to December 2023.

4.2 Estimated models

Considering that the objective of this study is two-fold, namely analyzing the drivers of overall demand for cash and per denomination and examining the role of digital means of payment, our approach analyzes both the short-run and long-run relationships between cash in circulation and the independent variables listed above. Identifying long-run drivers of demand for cash and the role of ongoing uptake in digital means of payment is key for understanding future demand for banknotes and essential for managing banknotes printing and cash cycle.

To analyze drivers of demand for cash in Rwanda, starting with the long run, following recent studies on demand for cash and the fact that our selected variables have different orders of integration, we estimated single long run equations model for overall cash in circulation and per denomination using ARDL. ARDL helps estimate long-run relationships and can deal with small sample bias, endogeneity bias, and variables integrated at different levels. The latter can be an issue in the time-series models. A number of other studies ((Baldo et al., 2021); (Awasthy et al., 2022), etc.)) also used ARDL. Specifically, Awasthy et al., (2022) highlighted the advantage of ARDL over other models, such as VAR, especially in addressing endogeneity issues while preserving degrees of freedom and accommodating variables integrated at different orders.

As our sample period is not very long (from January 2019 to December 2023), we could not include all variables in one model due to issues with the degree of freedom. Thus, we opted for estimating different ARDL models, starting with a baseline model and progressively adding additional variables to assess the drivers of overall cash in circulation as in Awasthy et al., (2022) and, in the second phase, to analyze the drivers per banknotes denomination.

The baseline model is as follows:

$$\begin{aligned}\log c_t = \beta_0 + \beta_1 \log c_{t-1} + \beta_2 \log \text{GDP}_t + \beta_3 \text{tbills rate}_t \\ + \beta_4 \log \text{exchange rate}_t + \beta_5 \log \text{credit ratio}_t \\ + \beta_6 \log \text{informal econ}_t + \beta_7 \log \text{Cashless}_t + \varepsilon_t\end{aligned} \tag{1}$$

With c_t as cash in circulation at time t, as GDP_t nominal GDP alternatively nominal CIEA at time t, tbills rate_t as the weighted average interest rate on T-bills at time t, exchange rate_t as FRW exchange rate versus the US dollar at time t, credit ratio_t as the ratio of outstanding loans to outstanding deposits in the banking sector at time t, informal econ_tas the measure of the informal economy and Cashless_t as the ratio of total volume to total value of cashless transactions at time t.

Secondly, we expand the cashless indicator to include details on cashless instruments namely. $\text{internet banking}_t$, mobile banking_t, POS transaction_t, mobile payment_t, as the ratio of transactions volume to value at time t of internet banking transactions, mobile banking transactions, POS transactions and mobile money cashless transactions, respectively, in the following model 2 as follows:

$$\begin{aligned}\log c_t = \beta_0 &+ \beta_1 \log c_{t-1} + \beta_2 \log \text{GDP}_t + \beta_3 \text{tbills rate}_t \\ &+ \beta_4 \log \text{exchange rate}_t + \beta_5 \log \text{credit ratio}_t \\ &+ \beta_6 \log \text{informal econ}_t + \beta_7 \log \text{internet banking}_t \\ &+ \beta_8 \log \text{mobile banking}_t + \beta_9 \log \text{POS transactions}_t \\ &+ \beta_{10} \log \text{mobile payment}_t + \varepsilon_t\end{aligned} \tag{2}$$

In the model 3 below, we expand to include other indicators of innovations in payments as follows:

$$\begin{aligned}\log c_t = \beta_0 &+ \beta_1 \log c_{t-1} + \beta_2 \log \text{GDP}_t + \beta_3 \text{tbills rate}_t \\ &+ \beta_4 \log \text{exchange rate}_t + \beta_5 \log \text{credit ratio}_t \\ &+ \beta_6 \log \text{informal econ}_t + \beta_7 \log \text{Cashless}_t \\ &+ \beta_8 \log \text{ATM}_t + \beta_9 \log \text{bank agents}_t \\ &+ \beta_{10} \log \text{mobile money cash}_t + \varepsilon_t\end{aligned} \tag{3}$$

With ATM_t as ratio of volume to value of ATM transactions at time t, bank agents_t as ratio of volume to value of transactions of bank agents at time t, and mobile money_t, as ratio of volume to value of mobile money cash in and cash out transactions at time t.

Each of these three models outlined above is also estimated per banknotes denomination, namely for 5000 FRW banknote, 2000 FRW banknote and 1000 FRW and 500 FRW banknotes lumped together under the label "small banknotes".

Considering that we are using macro variables, which are usually endogenous, we also estimate simple VAR models to assess main drivers in the short run and complement the analysis of drivers. As VAR models may imply more lags and lead to the degree of freedom issues, we first include those variables of model 1 and progressively add selected variables based on their importance (the size of the transactions).

5 Empirical results

5.1 Stationarity Analysis

We used the Augmented Dickey-Fuller test to assess the stationarity of all variables selected in our models. As illustrated in Table 1 below, there are different levels of integration. As usually expected for macroeconomic variables, most of the series are integrated into order one. Two are stationary in the level, while one is integrated at order 2.

As the appropriate model to deal with variables at different level of integration is the ARDL, the next sections discuss the results from different models estimated, focusing on long run relationships between the cash in circulation and selected macro variables.

Table 1: Results of ADF unit root tests

Variable	In Levels		In First Difference		Conclusion
	t-statistic	Prob.	t-statistic	Prob.	
Log cash in circulation	-1.09	0.71	-4.72	0.00	Integrated of order 1
Log loan to deposit ratio	-1.73	0.41	-11.30	0.00	Integrated of order 1
Log 5000 banknotes denomination	-0.91	0.78	-9.09	0.00	Integrated of order 1
Log 2000 banknotes denomination	-1.88	0.34	-9.48	0.00	Integrated of order 1
Log small banknotes denomination	-3.20	0.03			Stationary
Log exchange rate FRW to USD	2.95	1.00	-0.86	0.79	Integrated of order 2
Log informal GDP	-0.65	0.85	-9.48	0.00	Integrated of order 1
Log nominal GDP	0.19	0.97	-9.83	0.00	Integrated of order 1
Log ATM transactions	-3.39	0.06			Stationary
Log of bank agents' transactions	-4.74	0.00			Stationary
Log of total cashless transactions	-1.88	0.33	-6.25	0.00	Integrated of order 1
Log of internet banking transactions	-3.45	0.00			Stationary
Log of mobile banking transactions	-4.44	0.00			Stationary
Log of mobile money transactions	-1.86	0.34	-6.28	0.00	Integrated of order 1
Log of mobile money cash transactions	-1.32	0.61	-7.56	0.00	Integrated of order 1
Log of POS transactions	-0.89	0.78	-8.10	0.00	Integrated of order 1
T-bills rate	-1.11	0.71	-6.37	0.00	Integrated of order 1

Source: Authors' calculations

5.2 Longrun analysis

5.2.1 Drivers of total cash in circulation

In line with our research objective, namely, to examine the drivers of cash in circulation and the effect of digital means of payment in Rwanda, our models explained in the methodology, included traditional macro drivers of cash in circulation along with indicators of recent modernization in the payment system, which were expected to reduce the use of physical cash going forward.

Regarding the diagnostics, the results are generally satisfactory. The initial lag length for dependent and regressors was set at 2 but allowed the automatic selection of lags based on Akaike criterion. A long-run relationship was found in all estimations, and other diagnostic tests, namely the Breusch-Godfrey Serial Correlation LM Test, ARCH test for Heteroskedasticity and Jarque Berra test for normality, were satisfactory. The only exception is the normality tests on the models of small banknote denominations.

Regarding the results for each model. Table 2 below shows all the three models explained in the methodology, and for each model, we alternatively proxied economic activities by nominal GDP and nominal CIEA.

The results generally align with recent literature as the main drivers of cash in circulation are economic activities (proxied by nominal GDP and CIEA), opportunity costs (proxied by T-bills rate), and the use of cashless means of payment. In fact, an increase in nominal GDP or CIEA leads to higher demand for cash while the increase in T-bills rate led to a reduction in demand for cash in circulation, as expected. Regarding the effect of digital means of payment, results indicate that the uptake of cashless means of payment has led to a reduction in cash in circulation, driven mainly by its main component, mobile payment. The effects of other cashless instruments (POS, mobile banking, and Internet banking) were not statistically different from zero.

Regarding other variables included in the models (loan-to-deposit ratio, exchange rate depreciation and the measure of informal economy), their coefficients are not statistically significant.

Table 2: Long-run relationships from different ARDL models estimation

Variable	Model 1	Model 2	Model 3	Model 4	Model 5
Dependent Variable	Log of CIC				
Log of nominal GDP	0.822***		0.967***		0.574**
Log of nominal CIEA		0.780***		0.694***	0.537***
Log of loan-to-deposit ratio	0.032	-0.192*	0.082	-0.146	0.185
T-bills rate	-0.038*	-0.043**	-0.03	-0.028	-0.065***
Δ Log of FRW exchange rate	-0.205	-0.288	0.214	-0.907	6.013**
Log of informal nominal GDP	-0.041	0.002	0.036	0.027	-0.142
Log of cashless payments	-0.149***	-0.083***			-0.128*
Log of internet banking transactions			0.021	-0.024	
Log of mobile banking transactions			0.054	-0.025	
Log of mobile payments transactions			-0.126**	-0.064**	
Log of POS transactions			0.109*	0.048	
Log of ATM transactions				-0.275	-0.098
Log of banking agents' transactions				-0.172***	-0.100***
Log of mobile money cash transactions				0.26	0.043
Breusch-Godfrey Serial Correlation LM Test:					
F statistic	0.057	0.422	1.096	0.97	0.046
Probability	0.945	0.659	0.345	0.388	0.956
Heteroskedasticity Test: ARCH					
F statistic	0.226	0.006	0.034	0.098	0.033
Probability	0.637	0.937	0.854	0.755	0.856
Normality Test					
Jarque-Bera	2.1	0.361	2	0.45	0.183
Probability	0.349	0.834	0.366	0.798	0.912

Source: Authors' calculations

As illustrated in table 2 above, we also assessed the effect of other recent modernization in the payment system in Rwanda, which are not entirely cashless as they can involve the use of cash but have the potential to alter the demand for cash as their availability implies higher outreach of banking/payment services and can affect the need to hold precautionary cash. These include ATMs transactions, banking agents' transactions and mobile money cash in and cash out transactions.

While evidence shows that the volume of ATM and mobile money cash transactions have no statistically significant effect on cash in circulation, banking agents have instead led to a reduction in cash in circulation in Rwanda (see last two columns in Table 2 above).

5.2.2 Drivers of cash in circulation per banknote denomination

We deepened our analysis by considering different banknote denominations to assess whether there could be notable differences in their main drivers. We grouped bank notes into three categories: the volume of 5000 banknotes in circulation, the volume of 2000 FRW banknotes in circulation, and, lastly, the 1000 FRW and 500 FRW banknotes into a category labelled small denomination.

The results from models per banknotes denominations are, at a larger extent, similar to the previous model, which lumped together all cash in circulation in Rwanda, especially on the effect of economic activities (nominal GDP), opportunity costs (T-bills rate) and usage of cashless means of payment for 5000 FRW banknotes and 2000 FRW banknotes. Meanwhile, results from the model for small denominations portray some differences. Nevertheless, these results must be cautiously taken as sometimes the type of banknotes put into circulation by the central or commercial banks are not necessarily the ones desired by economic agents and thus may not fully reflect the demand.

In summary, nominal GDP positively affects cash in circulation in almost all models per banknote denomination, and the effect is relatively more substantial for smaller denominations. For the T-bills rate, although the results are mixed, the statistically significant coefficients are for bigger banknotes (5000 and 2000) and have a negative sign as expected, indicating that it is indeed an opportunity cost for holding cash.

Regarding other macroeconomic variables, the effect of the loan-to-deposit ratio and the size of the informal economy are mixed. For the loan-to-deposit ratio, the coefficient is statistically significant in only two models (for 5000 and 2000 banknotes), and the sign is positive as it is expected that an increase in bank lending led to higher cash in circulation. For the size of the informal economy, evidence points out the opposite effect on 5000 banknotes versus 2000 banknotes. The impact on 5000 banknotes is positive but not statistically significant. In comparison, it is the opposite for 2000 banknotes, suggesting that an increase in the size of the informal economy led to lowering 2000 banknotes in circulation. The effect on smaller banknotes is absent.

Regarding the impact of cashless means, results indicate that the increase in cashless usage, especially mobile payment, has led to a decline in the circulation of 5000 banknotes (see table 3 below). Besides, similar to previous results on the model of overall cash in circulation, banks agents' transactions exert downward pressures on cash in circulation across banknote denominations, while the effect of ATM transactions is only on 5000 banknotes, where the former leads to a decline in the circulation of 5000 banknotes.

Another result worth highlighting is mobile money cash transactions' strong and positive effect on demand for small banknote denominations. This could be explained by the fact that these transactions involve cash manipulation.

Table 3: Long-run relationships from different ARDL models estimation for different banknotes denomination (Models 1 and 2)

	Model 1			Model 2		
Dependent variable	Log of 5000 denom.	Log of 2000 denom.	Log of small denom.	Log of 5000 denom.	Log of 2000 denom.	Log of small denom.
Log of nominal GDP	0.757***	1.313***	1.742***	0.973***	1.368***	2.267***
Log of loan-to-deposit ratio	0.050	0.264	-0.430	0.116	0.489*	-0.429
T-bills rate	-0.033	-0.09***	0.034	-0.023	-0.123**	0.096
Δ log of FRW exchange rate	-2.480	5.155	-14.647	-1.229	11.120*	-21.440
Log of informal real GDP	0.204	-0.60***	-0.831	0.339*	-0.44**	-0.902
Log of cashless payments	-0.165***	-0.13***	-0.34***			
Log of internet banking transactions				0.029	0.037	0.208
Log of mobile banking transactions				0.097	0.031	0.081
Log of mobile payments transactions				-0.142**	-0.102	-0.223
Log of POS transactions				0.150**	0.065	0.317
Breusch-Godfrey Serial Correlation LM Test:						
F statistic	0.405	0.076	0.121	1.004	0.024	0.279
Probability	0.670	0.927	0.887	0.376	0.977	0.758
Heteroskedasticity Test: ARCH						
F statistic	0.000	1.003	0.017	1.028	0.320	0.053
Probability	0.995	0.321	0.898	0.315	0.574	0.820
Normality test						
Jarque Bera	2.420	4.110	55.210	0.328	3.950	39.400
Probability	0.297	0.127	0.000	0.193	0.138	0.000

Source: Authors' calculations

Table 4: Long-run relationships from different ARDL models estimation for different banknotes denomination (Model 3)

	Model 3		
Dependent variable	Log of 5000 denom.	Log of 2000 denom.	Log of small denom.
Log of nominal GDP	0.097	0.896***	1.968*
Log of loan-to-deposit ratio	0.148	0.405*	1.391
T-bills rate	-0.06**	-0.117***	-0.021
Δ log of FRW exchange rate	4.138	10.887**	19.698
Log of informal real GDP	0.275	-0.470**	-0.551
Log of cashless payments	-0.065	-0.124	-1.481***
Log of ATM transactions	-0.511**	-0.159	0.527
Log of banking agents' transactions	-0.22***	-0.172**	-0.627*
Log of mobile money cash transactions	0.254	0.250	3.130*
Breusch-Godfrey Serial Correlation LM Test:			
F statistic	0.500	0.027	0.579
Probability	0.610	0.973	0.566
Heteroskedasticity Test: ARCH			
F statistic	0.270	0.754	0.001
Probability	0.606	0.389	0.979
Normality test			
Jarque Bera	0.363	3.021	0.753
Probability	0.833	0.220	0.686

Source: Authors' calculations

5.3 Short-run analysis

Although the main focus of the study is to analyze long-run drivers of cash in circulation, we also looked at short-run relationships as they can shed some light. We run different model specifications on the short-run analysis using the Bayesian VAR framework which is more appropriate than traditional VAR in addressing small sample issues. As in the previous case, we initially estimated the baseline model with traditional macroeconomic drivers and total cashless transactions. In the second model specification, we added mobile money transactions because they constitute the larger bulk of cashless transactions. Lastly, we individually considered ATM transactions, agents banking transactions, and mobile money cash transactions, but we also included the total volume of cashless transactions as a control. Similar to the long-run analysis discussed above, we included all these innovations (total cashless transactions, mobile money transactions, ATM transactions, bank agents' transactions, mobile money cash transactions) as a ratio of volume to value.

In summary, short-run results mimic to a larger extent the long-run relationships discussed above, except for the effect of change in nominal GDP as it is less evident in the short run. The main drivers of cash in circulation in the short-run are the loan-to-deposit ratio and the size of the informal economy, as their increase led to higher cash in circulation. The influence of nominal GDP is slightly positive but not statistically significant. The proxy of opportunity costs, namely T-bills rate, is negatively associated with cash in circulation after some lags, in line with the literature.

Regarding the role of payment innovations, the results generally align with the long-run analysis as they show that an increase in cashless transactions reduces cash in circulation in Rwanda (see impulse response functions on different BVAR in the annexes).

Regarding other innovations, the increase in banking agents and ATM transactions also reduces cash in circulation (see impulse response functions on different BVAR in the annexes). This is an important insight considering that both bank agents' operations and ATM operations usually involve cash. Meanwhile, the effect of mobile money cash transaction volume is not statistically different from zero. More details are shown in the impulse response function in the annexes.

5.4 Discussion of results

There were two main issues in our different models' estimation. First, the sample period was not long enough to include all control variables considering that either ARDL or VAR models involve lags in dependent and regressors, which is an additional challenge. Thus, we opted for different models, progressively adding variables. Secondly, we could not obtain some key indicators that could be useful for this study, especially in the context of Rwanda. These are indicator of tax avoidance/evasion (considering that some businesses limit their use of new payment tools to avoid that their records to be easily tracked by the revenue authority) and secondly the indicator of cost of using the new digital payment means, which could be a key driver in their adoption. Nevertheless, with available data, we managed to get insights on the drivers of cash in circulation in Rwanda.

Looking at the main variables included in the model, the main issue is notably the measurement of different digital payment means currently used in Rwanda. While in recent studies, some were usually measured

as transaction volume, we opted for an alternative measure: the ratio of volume to value of transactions. This is because some of these digital means are new on the market and the volume increase may include existing and new users. Deflating it with value would represent a relatively more accurate picture.

The results presented in the previous section were generally consistent across different specifications, but there were also some exceptions. Regarding the effect of economic transactions, nominal GDP positively impacted cash in circulation. Alternatively, the nominal composite index of economic activities always had a positive relationship with cash in circulation. It is usually expected that expansion in economic activities involves an increase in demand for cash in circulation, as our results and past studies show (e.g.(Miller, 2017); (Goodhart et al., 2020); (Seitz et al., 2018), etc.) have generally found this positive relationship.

More importantly, the coefficients of either nominal GDP or nominal CIEA are lower than one, implying that cash in circulation expands at a slower pace than economic activities in Rwanda. Nevertheless, smaller notes increase faster than economic activities in most specifications. This may be linked to Rwanda's ongoing improvement in financial inclusion, primarily involving the lower-income population who usually transact with small transactions.

There is no evidence of the effect of the loan-to-deposit ratio and the size of the informal economy on cash in circulation in the long run. However, the analysis by banknote denomination provides some evidence. However, in the short-run, the size of the informal economy exerts a more substantial and positive influence on cash in circulation. At the same time, the effect of the loan-to-deposit ratio is also positive but less protracted. Obviously, how these two variables will evolve in the future is critical to how demand for cash in circulation evolves. It is important here to recall the importance of financial inclusion and ease of access to financial services in reducing the size of the informal economy and the leakages from the banking sector proxied by loan-to-deposit ratio.

The indicators of ongoing modernization in Rwanda's payment systems were subdivided into two categories. On one side, there are cashless instruments (internet banking, mobile banking, mobile payment, and POS transactions), and on the other side, those that directly involve cash (ATM, banking agents, mobile money cash in and cash out).

Results across different model specifications generally show that increased usage of cashless means of payment puts downward pressure on cash in circulation in both the long and short run. This is well in line with recent literature (e.g. (Seitz et al., 2022) in France, (Cabezas & Jara, 2021) in a panel of 21 countries, etc.). Looking closely at this phenomenon, we can see that it is mainly driven by mobile payment(mobile money cashless transactions), Rwanda's largest component of cashless payment. Kombe et al., (2020) had found that mobile payment reduces cash in circulation in Tanzania, which shares many similarities with Rwanda.

The effect of other components (mobile banking, internet banking, and POS) is not evident. Even though this result is counterintuitive, this can be explained by the fact that the total transactions of these three instruments represent a negligible share (around 0.2%) in terms of volume and value of total cashless transactions. Thus, their adoption is too little to influence cash circulation directly.

One intriguing result is the absence of a negative effect from the use of POS, while literature has been

quasi-unanimous on how POS usage led to a decline in cash demand (e.g.(Seitz et al., 2022); (Reimers et al., 2020), etc.). However, in our case, we proxy POS usage as ratio of volume to value, contrary to other studies that used the number of POS terminals. Our results should also be put into context as the uptake of POS in Rwanda is relatively new and volatile, contrary to other cashless instruments, which depict a sustained upward trend in recent years.

Regarding other digital means involving cash, the results generally show that in the long run, there is no evidence of either usage of ATM or mobile money cash-in and cash-out influence on cash in circulation, while bank agents rather led to a reduction in the latter. Regarding ATM in particular, recent literature had shown that their effect can be either way, as on one side, they imply increased need of cash to feed the ATM network and ensure that customers can easily withdraw at any time, (e.g. (Miller, 2017); (Gerst & Wilson, 2011); (Seitz et al., 2022)), but on the other hand, they can reduce the need to hold a bunch of cash in the pockets as economic agents can easily access it via ATM when needed. Thus, for the case of Rwanda, both effects are likely at play. It is important to recall that ATM use is proxied by transaction volume to value, while in the past literature, the number of ATMs' terminals was mostly used.

Besides, the latter effect is likely more salient for bank agents' transactions, which usually involve cash manipulation. Still, evidence points out that it has reduced cash in circulation.

In the short run, there is evidence that ATMs and bank agents are reducing cash in circulation. These innovations have led to greater proximity and access to banking services, notably withdrawing and depositing and cash transfer, especially for banking agents. This reduces the need to hold more precautionary cash at home or in pockets.

The results for banknotes denomination can also be useful. However, there are some caveats, as holding a category of banknotes does not necessarily imply that that category was the one desired. Nevertheless, some insights are worth discussing. Starting with commonalties, economic activity growth leads to higher circulation of cash across all banknote denominations. Besides, there is evidence across all bank denominations of a reduction in cash in circulation following an increase in the uptake of cashless means of payment. Both of these effects are stronger in small banknote denominations, implying that efforts to promote the use of cashless payments yield results in terms of lower small banknote circulation, but this is offset by the sustained expansion in the Rwandan economy, which continues to push higher the circulation of small banknotes.

Regarding the main differences in drivers per banknote denomination. First, regarding the effect of payment instruments, the negative effect of mobile transfer and ATM transactions is only evident for 5000 banknotes, while it is absent for other denominations. This is mainly at odds with recent literature where most studies (e.g. (Gerst & Wilson, 2011); (Seitz et al., 2022)) for France found that banknotes usually used in ATMs (in Rwanda, it is mostly 5000) increase with the number of ATMs. Nevertheless, in our cases, this difference may be because we used the ATM transactions instead of the ATMs number.

Secondly, as expected, the T-bills rate represents an opportunity cost for larger banknotes (5000 and 2000). These larger banknotes are usually used for hoarding, and a higher return in terms of interest rate disincentivizes this. Assenmacher et al., (2019) had also found that the interest rate elasticity was relatively higher for bigger Swiss Francs banknotes denomination.

Another insight worth discussing is the effect of the loan-to-deposit ratio and the size of the informal economy, which is only evident in the 2000 banknotes. Bank lending significantly increases the demand for 2000 banknotes, probably because the latter is an alternative to the 5000 banknotes as the second biggest banknotes in Rwanda. Meanwhile, it is puzzling why demand for 2000 banknotes is negatively associated with the size of the informal economy.

Generally, the results are in line with the literature. However, different specifications and differences in measuring variables, especially in measuring the use of new payment instruments, could bring a few different results. Overall, digital means of payment, especially mobile payment, exert downward pressure. Nevertheless, as cash in circulation is also positively associated with economic activities, the ongoing expansion of the Rwandan economy implies a higher demand for cash in circulation. The T-bills rate represents an opportunity cost of holding cash in line with the literature, which is crucial for the transmission of economic policies.

6 Conclusion and Recommendation

This study aims to examine the drivers of demand for cash in Rwanda and assess the effect of digital means of payment. Following recent literature on this issue, we estimated several ARDL models with cash in circulation as the dependent variable and, alternatively, different banknote denominations. We used monthly data starting from January 2019 to December 2023.

The results from ARDL models highlighted the main long-run drivers of cash in circulation in Rwanda and were, to a larger extent, in line with the literature on the relationship between cash in circulation and some key macroeconomic variables. On one hand, expansion in economic activities plays a predominant role in driving the observed resilience in cash in circulation in Rwanda, as illustrated by a positive effect of nominal GDP and the nominal CIEA on cash in circulation. On the other hand, results show that the interest rate represents an opportunity cost to hold cash as higher rates led to lower cash in circulation.

Regarding the role of digital means of payment, the results generally indicated that the use of cashless means of payment leads to a reduction of cash in circulation. A deeper analysis, especially on individual components of cashless transactions, shows that mobile money cashless transactions drive this adverse effect. One puzzling result is that the impact of other digital means, namely mobile banking, internet banking and POS was not evident.

Nevertheless, about other digital means that directly involve cash usage (ATM, bank agents, and mobile money cash transactions), only bank agent transactions had a negative effect on cash in circulation, while the effect of ATM and mobile money cash transactions was absent in the long run.

The short-run analysis revealed additional macroeconomic drivers of cash in circulation in Rwanda. While similar to the long run, the use of cashless means of payment, specifically mobile payments and bank agents' transactions, put downward pressures on cash in circulation in the short run; bank lending and the size of the informal economy led to increased cash in circulation.

In short, there is evidence that digitalization in payment systems has lowered cash in circulation in recent years. In contrast, sustained expansion in economic activities observed in the last five years led to more need for cash in circulation. Nevertheless, the prospects are, to some extent, encouraging. First, the coefficient of nominal GDP is less than one, indicating that cash in circulation will grow at a slower pace than economic activities. Secondly, about the main drivers of cash in circulation in the short run, (size of informal economy and the loan-to-deposit ratio), have been trending downward in the last two years and if this trend continues along with more financial inclusion and access and modernization of Rwanda economy, we expect lower demand for cash in the future.

Therefore, the main policy recommendation is to enhance existing initiatives to foster the use of digital means of payments. This adds more efficiency to economic transactions, and a larger uptake would lead to lower demand for cash in the future. Secondly, reinforcing existing policies to promote financial inclusion and increase the size of the formal economy would also contribute to reducing the need for physical cash for transactions.

One of the limitations of this study was the lack of data on tax avoidance/evasion or alternatively the size

of shadow economy as these could be an impediment on using digital means of payment in many businesses in Rwanda. Another one is the lack of data on the cost of using digital means of payment which can also influence their uptake. Lastly, long series availability, especially on digital payment and cash in circulation per banknote denomination, was a challenge, and the sample period was relatively shorter (5 years). This is one avenue for future research.

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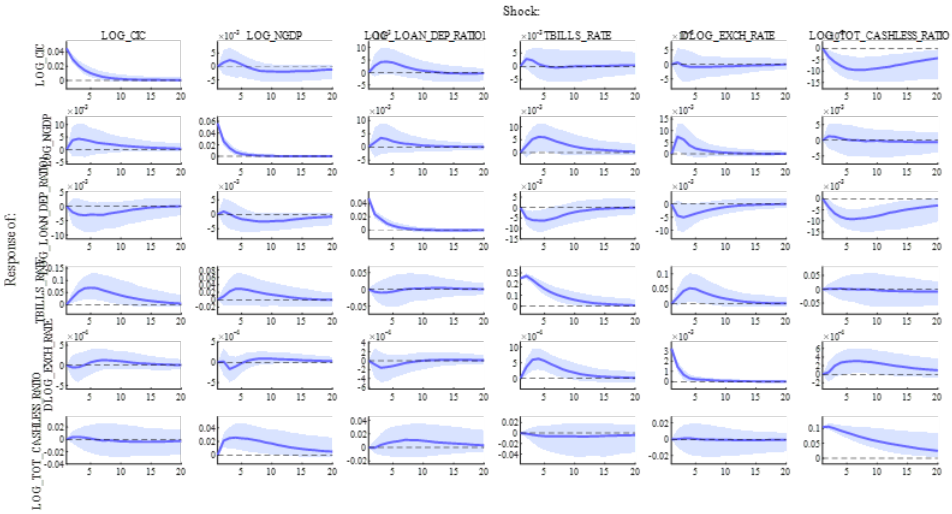
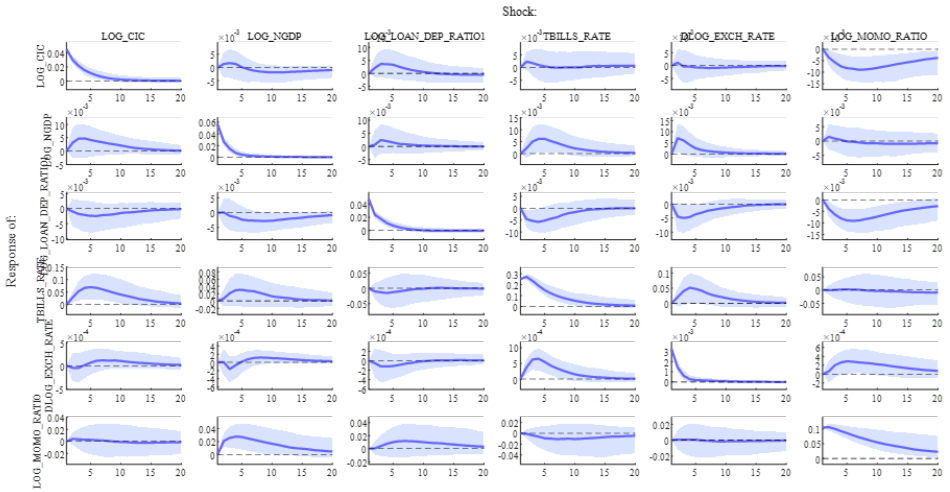
Appendices

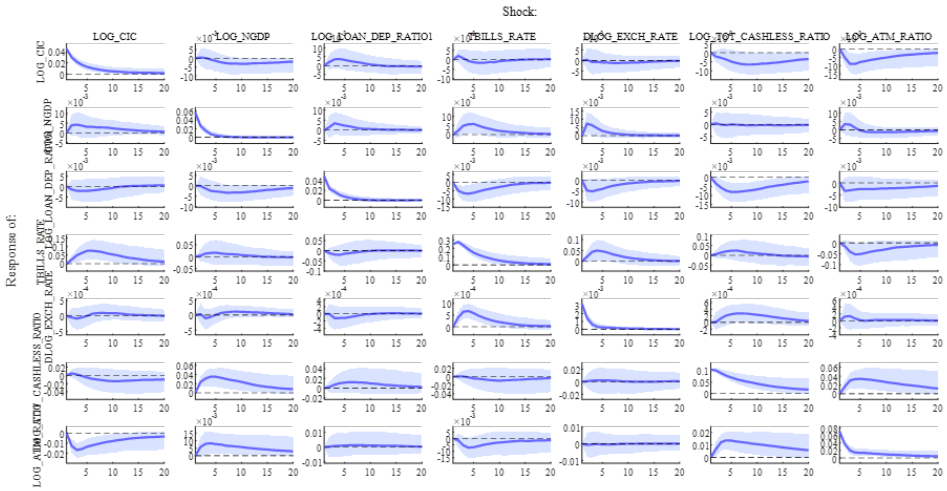
IRF of Bayesian VAR model 1



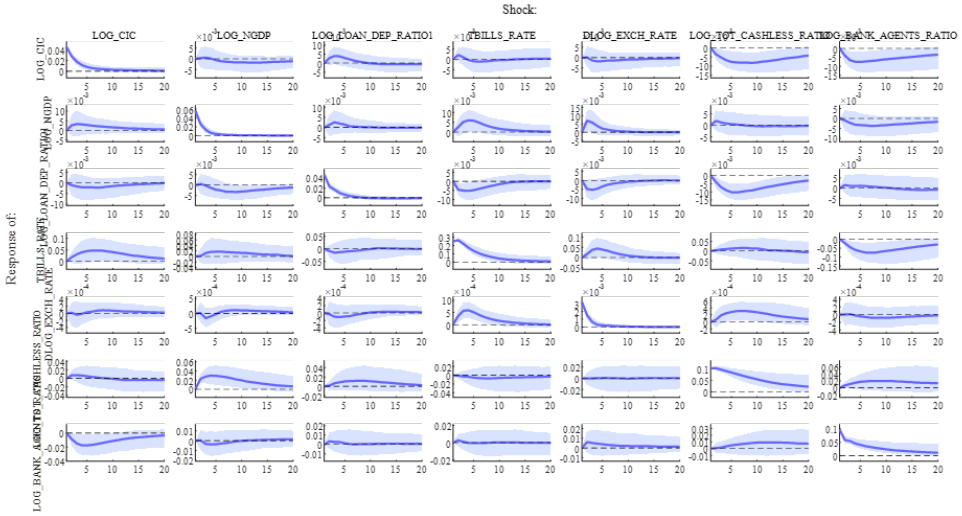
IRF of Bayesian VAR model 2



IRF of Bayesian VAR model 3



IRF of Bayesian VAR model 4



IRF of Bayesian VAR model 5