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Money Demand Stability with Endogenous Structural Breaks and the Role of Payment System Innovation in Indonesia[1]

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Abstract

This study examines the stability of the demand for money function in Indonesia using quarterly data from 2007 to 2021, employing Gregory-Hansen's (1996) cointegration test and Hendry's general-to-specific approaches. The cointegration and error correction models show a causal relationship between money demand and its conventional determinants and payment system innovation. Considering the central bank policy that part of economic reforms captured by the structural break in the cointegration test and the stability test results of the short-run analysis, we confirm the stable narrow money and currency demand and its dynamics in Indonesia. The Gregory and Hansen test found a cointegrating relationship between money demand variables, with a structural break in 2011Q2, which refers to the central bank's new minimum reserve policy. The paper advises that the central bank should comprehensively understand how technological advancement in the payment system affects money demand and how prior central bank policy may induce a structural break to maintain the optimality of future monetary policy.

Keywords: Money demand, payment system, technology innovation, structural break, monetary policy.
JEL Classifications: E41, E42, E52, E58

INTRODUCTION

Payment instruments are an essential catalyst in the daily interactions of economic participants, such as households, businesses, retailers, and governments, particularly in the modern economy. According to Bank Indonesia (2019), a payment instrument is defined as a device or a set of operations that allows transferring or receiving funds from payer to payee. Due to technological innovation in payment systems, people can now pay for transactions using various alternative instruments, including paper-based payment, card payment, or more advanced digital payment instruments, in addition to traditional banknotes and coins. These payment instruments may also act as a store of value in addition to their traditional functions as a medium of exchange and a means of payment. Consequently, the use of noncash payment methods becomes paramount.

[1] The article is part of a PhD thesis of the author at the University of Birmingham

Many scholars claim that altering payment methods from cash to noncash would benefit the economy by boosting the consumption rate and economic growth (Luo et al., 2022) and initiating efficiency in the economy (Ilyés & Varga, 2016). This favorable effect of card, electronic, and mobile payments on the economy occurs in advanced countries and developing nations, as evidenced by Oyelami et al. (2020) and Wong et al. (2020). However, some potential drawbacks may arise, such as weakening the ability of the central bank to control the money supply (Tule & Oduh, 2017) or other monetary aggregates (Åberg et al., 2021; Brodo D & Levin T, 2017) and subside the seigniorage income (Camera, 2017); Additionally, households may face risks such as increased societal vulnerability and technological failures, as noted by de Almeida et al. (2018) and Atzei et al. (2017).

In recent decades, the ubiquity of mobile telecommunications, internet connectivity, and payment system innovation in Indonesia has resulted in a drastic shift in the country's payment patterns, which may influence the consumer habits and economic activities of the populace. According to Aristiyowati & Falianty (2019), card payment instruments have a favorable effect on the velocity of money and a negative effect on the demand for cash and narrow money. This finding is corroborated by Igamo & Falianty (2018), who concludes that electronic money has favorable long-term impacts on consumption.

Macroeconomic theory suggests that stable money demand is essential for central banks to implement monetary policy since it ensures that shifts in monetary aggregates caused by a policy will have predictable impacts on economic growth and price stability. According to Leong et al. (2021) and Kurniawan et al. (2022), there is a stable relationship between narrow money demand and income regardless of the ongoing financial reforms and innovation in Indonesia, particularly after the financial crises in the late 1990s.

Motivated by previous empirical studies, we aim to examine the dynamic interaction between money demand and its conventional drivers, namely interest rate and income, with the inclusion of payment instruments innovation and structural break. This research will focus on Indonesia, a G20 developing middle-income country with the world's fourth-largest population, using quarterly data from 2007Q1 through 2021Q4.

In addition, many policies enacted by the central bank and the government, along with a crisis and other unforeseen occurrences, may induce a structural break in the economy, as illustrated by Karavias et al. (2023) and Mody & Nedeljkovic (2024). According to Lagarde (2023), it is necessary for policymakers to comprehend the cause and existence of the structural break in the economy to evaluate their policies and enhance their projections.

The Gregory & Hansen (1996a) cointegration approach with structural break is used to help determine the presence of cointegration among the variables while capturing the possible structural break endogenously. The GH test is then followed by an error correction model to estimate the coefficients of the short-run and long-run explanatory variables of the demand for narrow money and currency demand equations, namely income, interest rate, and payment instrument innovation. Finally, we analyze the parameter stability of the money demand equation in the short-term using the CUSUMSQ stability test.

The remaining sections of this work are structured as follows. The next section provides the relevant works of literature and some of the measures that may

affect the demand for money, and section three presents the methodology. Section four outlines the data and model specification, and the empirical results are presented in section five. Finally, the concluding remarks are presented in section six.

LITERATURE REVIEW

Modelling the influence of payment instrument innovation on money demand in relation to the quantity theory for money has become popular in practice and applied in many studies. This section presents a literature overview on money demand, the role of financial innovation in the economy, and measures that may influence money demand.

Theoretical Review

John Maynard Keynes theorized that money demand is affected by transaction motive and precaution motive based on income level and speculative motives that consider the current interest rate (r) and the wealth level. This concept influenced many later theories, such as those developed by Friedman (1970), who pointed out that the opportunity cost of retaining cash consists of the potential gain from owning bonds, stocks, and other interest-bearing assets. Therefore, a higher return on other assets will cause a decrease in the demand for money because of the principle of diminishing marginal rate of substitution between money and other assets. Fender (2012) provides a detailed explanation of the idea that, traditionally, money demand has been driven by interest rate and income, which can be expressed as follows:

$$\frac{M_t}{P_t} = L(y_t, R_t) \quad (1)$$

Where M_t/P_t is the real money demand of the household during period *t*, *y* is the household's consumption during period *t*, and R is the interest rate of some asset.
However, does money demand still matter? Instability in the relationship between nominal income and broad money, as noted by Whelan (2021), makes it challenging for the central bank to control the money base. In addition, according to Fender (2012), giving the central bank a responsibility to maximize societal welfare was doubtful, and determining how to quantify the central bank's success was a further concern.

Many countries widely regarded the Inflation Targeting Framework (ITF) as the "state of the art formula" for monetary policy (Gillitzer & Simon, 2015), and in Indonesia, the ITF has been successfully performed since it was first implemented in mid-2005 (Juhro & Goeltom, 2015). However, ITF has a potential shortcoming that should be considered. Gonçalves & Salles (2008), for instance, are of the opinion that there are no compelling arguments to consider the idea of money growth playing a significant role in the central bank, and many scholars also support the idea of avoiding theoretical and practical ignorance of "money" in monetary policy discourse, see Kahn & Benolkin (2007).

Issing (2011) argued that monetary policy applying ITF based only on interest rate targeting as a medium objective could be suboptimal. In addition, according to Mishkin (2010), the development of money and credit are critical components of a medium-term objective to be examined by monetary authorities as

it is crucial to forecast financial imbalances in the long term. Hence, the stability of the demand for money is still essential for the central bank to achieve a credible monetary policy.

Differences in empirical background explain why the Federal Reserve and the European Central Bank view money and monetary policy differently, as Kahn & Benolkin (2007) pointed out. Compared to the United States, money growth in the Euro area is more highly connected to inflation over the medium and long term and is viewed as a more accurate inflation forecast. In this regard, Issing (2011) explained that the ECB's strategy is distinct from that of other central banks due to the central bank's view of money as a crucial element. Consequently, it is essential to comprehend the linkages between money demand and its traditional variables, such as income, interest rate, and other factors, such as technological advancement, from the standpoint of the quantity theory of money.

Understanding the role of technological advancement in the payment system, which promotes noncash payment instruments, on the money demand can be evaluated using the shopping time model initially introduced by Saving (1977). In this study, money is an asset held only for transaction purposes and assumed in a closed economy. The shopping-time model allows us to evaluate the role of technological advancement in payment instruments that would substitute traditional money functions. The shopping-time model allows us to evaluate the role of technological advancement in payment instruments that would substitute traditional money functions; for example, see Dias (2001). In a close economy, consider a hypothetical household tries to maximize their expected welfare at time t from the utility function over an infinite period:

$$U(c_t, l_t) + \sum_{j=1}^{\infty} \beta^j E_t\left[U\left(c_{t+j}, l_{t+j}\right)\right] \quad (2)$$

where c_t is the household's consumption during period *t*, l_t is the leisure of the household, β^j is the constant discount factor that is positive but smaller than 1, and E_t denotes the expectation conditional on information at time *t*. At time *t*, it is assumed that the household is concerned about their consumption of goods and leisure not only in the present but also in future periods. They know the current values of all relevant variables when making decisions.

According to the shopping time model, the more time (and energy) spent on shopping, the less time is available for leisure. The relationship can be expressed in terms of a function, ψ, as follows:

$$l_t = \psi(s_t, m_t) \quad (3)$$

where s_t is the transaction cost, $0 < s < 1$ at period *t*, that accommodates financial innovation such as digital money that allows noncash transactions and $m_t = M_t/P_t$, is the real money holding. So that the lower the transaction cost, s_t, the more transactions can be carried out with the same amount of money held, m_t. The household is then moderated by a budget constraint. The household receives real income in the amount y_t, which this amount is unaffected by their choices, then divides his wealth between money and bonds.

Let M_t and B_t be the nominal money balances and the nominal quantity of bonds purchased by the household in period *t* (which expire in *t* + 1) at the interest rate R_t. That is, the household begins period t with assets in the amount M_{t-1} and B_{t-1}.

For period t, the household budget constraint is written as follows:

$$P_t\, y + \, M_{t-1} + \, (1 + R_t)\, B_{t-1} = \, P_t c_t + \, M_t + \, B_t \qquad (4)$$

where P_t is the price index at time *t*, M_t is the nominal holding of money, and B_t is the nominal holding of bonds. The model can be solved by equating, over time, the utility of consumption and leisure with respect to money holding and interest rate. Refer to Appendix B for the detailed derivation.

Using Lagrangian expression, after simplification and solving for λ_t, we find

$$m_t = \left[1 + \frac{1}{R_t}\right] \frac{a \propto c_t}{1 - \propto - a \propto c_t / s_t} \qquad (5)$$

The above result shows a positive sign of positive partial derivative w.r.t c_t, negative partial w.r.t R_t and s_t, that demonstrates payment instrument innovation exerts influence in increasing overall money demand due to a reduction in the cost of the transaction. Based on this result, the general form of money demand function that accommodates payment instrument innovation may be written as follows:

$$m_t = L(c_t, R_t, s_t) \qquad (6)$$

This equation shows that consumption positively influences the demand for money, while the interest rate and financial innovation have a negative impact on money held by households. Advancements in financial products reduce transaction costs, which finally increases the opportunity for overall money demand usage. In addition, traditional money (notes and coins) will be substituted by other forms of money that allow for a noncash transaction. This finding is confirmed by Kombe et al. (2020), who pointed out, based on Baumol and Tobin's framework, that the advancement of technology in the payment system negatively impacts the demand for currency.

Empirical Literature

Research on money demand and related topics in developed and developing countries, including Indonesia, has been the subject of several empirical studies. Studies conducted on the topic of money demand in Indonesia have made use of various variables, econometric approaches, and tests. The cointegration relationship between money and real output in Indonesia was identified for both the narrow (M1) and broad (M2) definitions of money (Melati & Kurniawan, 2023). This result on the cointegration relationship is consistent with the findings of Mahatir et al. (2020) and Lubis et al. (2019) concerning currency demand and its determinants. A possible structural break also exists in the long-run relationship of the money demand function (real narrow money and real broad money), as suggested by

Roussel et al. (2021). Some empirical studies conducted in other countries have also corroborated these findings in the Indonesian case. For instance, the stability of money demand and its equilibrium relationship with interest rates and income are validated using data from the United States (Kia, 2024) and South Asia (Nepal & Paija, 2020).

Numerous research studies have demonstrated that financial innovation substantially influences the demand for money. Dunne & Kasekende (2018) found that financial innovation adversely impacts money demand (MD), a finding supported by Mlambo & Msosa (2020). Aliha & Said (2017) examined 215 nations and found that financial innovation adversely affected money demand (MD) in both the long and short term, corroborating the results of Adil et al. (2020) in their study focused on India. Conversely, whereas financial innovation is defined as real domestic credit to the private sector per capita, financial development exerts a positive influence on money demand (Ahad, 2017).

Moreover, some scholars have indicated that the use of electronic payment methods will diminish cash transactions, with the substitution impact being more pronounced for lower values in retail transactions (Cabezas & Jara, 2021; Wisniewski et al., 2021). In contrast, Bech et al. (2018) suggested that the role of currency will persist in many countries, including developed ones, and will only be partially replaced by electronic payment instruments or cards in the near future. This observation aligns with the conclusions of Kombe et al. (2020), which indicate that many individuals continue to retain cash as a store of value and for precautionary reasons. This phenomenon is underpinned by comparatively low and stable inflation, which reduces the cost of storing cash and may be instigated by the crisis (Wisniewski et al., 2021). The limited availability of cashless payment options offered by merchants also contributes to the continued reliance on cash, even in developed regions like the euro area (Meyer & Teppa, 2023). The behavior of opting to adopt payment instruments remained unchanged: "First, decide the share of cash, then other payment instrument alternatives are the rest." This finding corroborates research on Hungarian customers who are not yet prepared to completely embrace electronic payments, as they still encounter challenges in relinquishing cash transactions (Pintér et al., 2022).

Additionally, Tee & Ong (2016) suggested that policies aimed at enhancing economic growth through the promotion of noncash payments should not be seen as short-term objectives, as the impact of noncash payment usage on economic growth will only become significant over an extended period. Electronic money as a payment instrument has a positive impact on consumption in the long term (Igamo & Falianty, 2018).

Some of the Measures Adopted that May Impact the Money Demand

The Central Bank of Indonesia and the government have actively promoted less-cash payment methods, such as electronic money, card payment, and mobile payment, to boost the economy's efficiency, particularly during the COVID-19 pandemic. Since the adoption of inflation targeting in Indonesia in January 2005, the central bank and the government have announced several policies that are part of economic reform and regarded as significant milestones that may affect the demand for money in Indonesia, such as:

a. Electronic currency regulation. Electronic money, or e-money, is another form of cash whose monetary value is stored electronically on cards, devices, or servers (Dobler et al., 2021). Electronic money has been circulating in Indonesia since 2007, but the Central Bank of Indonesia (Bank Indonesia) first regulated it in April 2009[2]. Banks and nonbanks licensed by BI can issue electronic money and will be supervised occasionally. E-money is separated into two types: registered e-money, which requires customer identity data, and unregistered e-money, with a minimum quantity that can be maintained.
b. Tightening of the reserve requirement. In March 2011, Bank Indonesia implemented a new policy that increased the minimum statutory reserves (giro wajib minimum, GWM) for conventional banks dealing in foreign-denominated currencies[3]. Reserve requirements for foreign currency funds increased from 1% in 2010 to 5% in March 2011 and 8% in June 2011. The minimum reserve requirement for Rupiah remains the same for both primary and secondary reserves. The reserve requirement shortfall is subject to a penalty rate, calculated in Rupiah at the central bank's middle rate on the day of violation.
c. National initiatives of less-cash movements. Bank Indonesia officially launched "The National Non-Cas Movement" (GNNT) in August 2014, aimed to build awareness and promote noncash payment instruments among the public, businesses, and government institutions. Gradually fostering a less cash society will reduce the cost of money printing and distribution and provide a more effective and accountable transaction in the economy.
d. Changing the manner of transactions at toll gates from cash to noncash. In September 2017, the Ministry of Public Works and Public Housing launched Regulation No. 16/PRT/M/2017 on Noncash Toll Transactions on Toll Roads, which was effectively implemented in October 2017 to limit car users in paying tolls in cash. This regulation aims to increase the efficiency of transactions at tollgates previously separated by various card issuers (Joewono et al., 2017).
e. Substituting a noncash instrument for the cash payment of social support or subsidy. In July 2017, the government released Presidential Regulation No. 63/2017 on Cashless Social Assistance Distribution to promote financial inclusion and improve efficiency, transparency, and accountability in distributing financial support to low-income citizens (kartu keluarga sejahtera, KKS). After the new regulation, KKS recipients are now linked to a bank account and receive government social support electronically.
f. The implementation of QRIS (quick response code Indonesian standard). In late 2019, Bank Indonesia launched a national standard for a quick response in the payment system called the QRIS. It aims to promote interoperability and enhance efficiency by allowing consumers to transfer funds to their counterparts who use different payment services (Bank Indonesia, 2020). QRIS enables contactless payment among server-based e-money or digital wallets and mobile banking users.
g. The Covid-19 epidemic. Since the World Health Organization proclaimed COVID-19 a global pandemic in March 2020, it has had a significant impact

[2] Bank Indonesia Regulation No. 11/12/2009 concerning Electronic Money.
[3] Bank Indonesia Regulation No. 13/10/PBI/2011 on Reserve Requirement in Rupiah and Foreign Currencies for Conventional Commercial Banks.

on lives, livelihoods, and the global economy. In March 2020, it was confirmed that the virus had spread to Indonesia.

In this study, the technological advancement of payment instruments (PSINV) is represented by the usage of retail payment instruments, namely electronic money, ATM/Debit card, and credit card payments relative to cash holding. Referring to the literature mentioned above, some researchers have examined the determinants of money demand using various methodologies in developed or emerging countries; however, there are few studies on the stability of money demand related to payment system advancements and structural breaks resulting from central bank policies, particularly in Indonesia.

METHODOLOGY

Each variable is subjected to the Augmented Dickey-Fuller (ADF) and Phillip-Perron's (PP) unit root tests to guarantee the stationarity and integration order of the series, before proceeding with any further econometric analysis. Then, to account for the possibility of a structural break, a residual-based test for cointegration developed by Gregory & Hansen (1996a), which permits a structural break among the observed variables, is undertaken in the second phase. This cointegration test presents three distinct models to account for the structural break in the alternative cointegrating relationship. Given the observed data is Y_t and X_t, where Y_t is a scalar variable, X_t is a vector of explanatory variables. The standard model of cointegration with no structural change is defined as follows:

$$Y_t = \mu_1 + \alpha X_t + \varepsilon_t \quad (7)$$

where the dependent variable Y_t and the explanatory variables X_t are supposed to be I (1) and the error ε_t term is I (0).

Considering the parameters μ and α as time-invariant, Gregory & Hansen (1996a) defined the structural break as a shifting of a new 'long-run' relationship from cointegration that was held in the previous period, with the timing of the shift as unknown. The general structural change considered in Gregory & Hansen (1996b) is a general structure change that permits changes to the intercept μ and/or the slope α, but not to the trend β. Then, the structural change will be reflected in changes in the intercept (α) and/or changes in slopes (β). The following definition of a structural dummy variable is employed to represent the structural change:

$$D_{tb} = \begin{cases} 0, & if\ t \leq [Tb] \\ 1, & if\ t > [Tb] \end{cases}$$

The unknown parameter $b \in (0,1)$ serves as the change point, while [ ] denotes the integer part. The three models of Gregory and Hansen's (1996) break testing (GH) adhere to the structural change pattern as outlined below:

The first model, GH-1, is the level shift (C) model, defined as:

$$Y_t = \mu_1 + \mu_2 D_t + \alpha X_t + \varepsilon_t \quad (8)$$

This basic model from Gregory & Hansen (1996a) describes a shift in the level of the cointegrating relationship, represented by a shift in the intercept while

holding the slope coefficients fixed. Parameter μ_1 measures the intercept before the break in T_b and μ_2 the shift that occurred after the break.

The second model, GH-2, is the level shift with trend (C/T) model:

$$Y_t = \mu_1 + \mu_2 D_t + \beta t + \alpha X_t + \varepsilon_t \quad (9)$$

where β is the coefficient of the time trend term, t.

The third model, GH-3, is the intercept and slope shifts (C/S) model or regime shift:

$$Y_t = \mu_1 + \mu_2 D_t + \alpha X_t + \delta X_t D_t + \varepsilon_t \quad (10)$$

Where δ measure the change in the cointegrating vector after the regime shift.

As an extension to these three models, Gregory & Hansen (1996b) introduced a fourth model in which both the regime and trend shifts are permitted, denoted as C/S/T. Due to software limitations, we have not employed the fourth Gregory-Hansen model to test for the presence of cointegration.

$$Y_t = \mu_1 + \mu_2 D_t + \beta t + \alpha X_t + \delta X_t D_t + \varepsilon_t \quad (11)$$

All the GH models are residual-based tests that use ADF test statistics to examine the null hypothesis of no cointegration compared to the alternative hypothesis of cointegration in the presence of a possible break in various models of C, C/T, C/S and C/S/T. The cointegration breakpoint is determined by the minimal value of the t-statistic.

If evidence of cointegration with structural breaks is present, we adopt an adequate error correction model. Then, we apply the London School of Economics (LSE)/Hendry's general-to-specific approach (GETS) to develop a parsimonious short-run regression model, see Hendry et al. (2005). In the final step, the Cumulative Sum of Squares (CUSUMQ) of the recursive residuals test is used to assess the stability of the model parameters of the short-run equations.

DATA DESCRIPTION AND MODEL SPECIFICATION

In this section, we show a brief description of both the analyzed variables and model specifications.

The Data

The study uses quarterly data covering the period of the first quarter of 2007 to the fourth quarter of 2021 due to e-money data only being available since that year. Data are gathered from the Indonesian Financial Statistics of Bank Indonesia and the Indonesian Bureau of Statistics, which is available at https://www.bi.go.id/id/statistik/ekonomi-keuangan/spip/Pages/SPIP-Mei-2022.aspx.

Table 1. Summary of the Variable Included in the Study

Variable	Mean	Median	Maximum	Minimum	Std. Dev.	Obs.
LRCOB	8.12	8.13	8.66	7.47	0.29	60
LRM1	9.01	9.02	9.67	8.41	0.30	60
LRCONS	4.71	4.66	5.15	4.40	0.21	60
IR	6.30	6.50	11.02	3.50	1.64	60
PSINV	0.37	0.39	0.56	0.20	0.09	60

Note: Variables were transformed into natural logarithm form except for variable interest rate and payment instrument innovation in percentage units.

As described in the previous section, variables used in this research to investigate the determinants of money demand in Indonesia comprise as follows: M1 is narrow money, COB is total cash outside the bank or currency demand, CONS is consumption, IR is an interest rate (bank rate), and PSINV is payment instrument innovation which refers to the value of the transaction of card payment and digital payment divided by cash outside the bank. The descriptive statistics of the data included in this study are shown in Table 1.

Empirical Model Specification and Description of the Variables

Based on classic money demand theories and empirical models, the purpose of this study is to investigate the dynamic link between the demand for money, namely narrow money *(M1)* and currency demand *(COB)*, with its traditional determinants (income, interest rate, and price), and payment instrument innovation, following Pramono et al. (2006)who modified the basic money demand model for Indonesia to enable the assessment of payment instrument innovation role. The functional form with respective money stocks is as follows:

$$\frac{M}{P} = f(RCONS, IR, PSINV) \quad (12)$$

where *M* is money demand, *RCONS* is real consumption, *P* is a consumer price index, *IR* is the nominal interest rate (bank rate), and *PSINV* is payment system innovation. Components in equation (8) were transformed into a natural log, except for interest rate and the ratio of payment instruments innovation, which are expressed in two models as follows:

Specification (1): $LRM1_t = \alpha + \beta_1 LRCONS_t + \beta_2 IR_t + \beta_3 PSINV_t + \varepsilon_t$ (13)
Specification (2): $LRCOB_t = \alpha + \beta_1 LRCONS_t + \beta_2 IR_t + \beta_3 PSINV_t + \varepsilon_t$ (14)

Dependent variables in specifications (1) and (2) are defined as follows: *LRM1* is the natural logarithm of real narrow money (M1) deflated by the natural logarithm of the CPI, lrcob is the natural logarithm of cash outside the bank subtracted by the natural logarithm of the CPI. Both specifications have the independent variables of real consumption *(LRCONS)*, interest rate *(IR)*, and payment instruments innovation *(PSINV)*, and ε_t is the error term in the model.

EMPIRICAL RESULT

The macroeconomic time series data is often not stationary; hence, the regression based on nonstationary data might produce spurious and meaningless economic results (Enders, 2015). In the first stage, the characteristics of the data were tested using the unit root test. This test is employed to observe the stationarity conditions of the data. The unit root testing methods used in this study are Augmented Dickey-Fuller (ADF) and Phillips-Perron Test. The result of unit root tests is shown in Table 2 below.

Table 2. Result of Unit Root Test

Variable	ADF Test		Phillips-Perron Test	
	Level	1st Difference[4]	Level	1st Difference
LRM1	1.065 (4)	-2.680* (3)	0.453	-13.947***
LRCOB	-0.264 (4)	-3.839*** (3)	-1.384	-25.289***
LRCONS	-2.035 (4)	-2.953** (3)	-1.730	-15.515***
IR	-1.899 (1)	-5.131*** (0)	-1.656	-4.758***
PSINV	-2.389 (0)	-9.255*** (0)	-2.059	-10.781***

Notes: (i) Entries in ***, **, * represent significance at 1%, 5% and 10% level, respectively. (ii) ADF test for variables at the level and 1st differences are in constant

Based on visual evaluation at the level of the series and the result of the Augmented Dickey-Fuller test and Phillips-Perron Test, the unit root test result indicates that the observed variables are stationary at the first difference. Therefore, we can also conclude that all variables are stationary on degrees integration one or I(1), and no variables were I(2).

Cointegration test

Following the result of the stationarity test that the variables follow the same order of integration and are stationary at the first difference or I (1), we can conduct a cointegration test to determine whether cointegration exists. From equation (12), we estimate the long-run equation of money demand functions for both specifications (1) and (2) without the structural break and conduct the Engle & Granger (2015) residual test to examine the existence of cointegration in the proposed model that Table 3 reports.

Table 3. Estimation Result for Money Demand Function without Structural Break

Independent Variables	Dependent Variables	
	lrm1	lrcob
C	14.478***	13.479***
	(22.929)	(19.796)
LRCONS	-1.060***	-1.059896***
	(-8.949)	(-8.300)
IR	-0.058***	-0.043***
	(-5.504)	(-3.749)
PSINV	-0.414	-0.358
	(-0.818)	(-0.655)

[4] All variables also stationary in the 1st difference for ADF test with intercept and trend, no variables were I(2).

Table 4. Unit Root Test on the Residual of Equation (13) and (14)

Dependent variables	Lrm1	Lrcob
Augmented Dickey-Fuller test statistic	-1.804	- 2.780
Test critical values:		
1% level		-3.557
5% level		-2.917

*MacKinnon (1996) one-sided p-values.

All parameters of both equations are statistically significant at the 1% level, except payment instrument innovation. The unit root test on the residuals from equations (13) and (14) in Table 4 indicates that there is no evidence of a cointegration relationship among the variables, and the signs of some of the dependent variables were different from economic theory and most empirical studies. This condition could result from a structural break that might exist in the cointegration relationship between the variables.

Considering this, we will use the Gregory & Hansen (1996a) test for cointegration with an uncertain break date to determine the potential breakpoint, as previously explained in Section 3. Specifications (1) and (2) are then applied to the three GH equations with a structural break to examine the cointegration relationship of the money demand function in Indonesia. The implied specifications of the three alternatives of Gregory and Hansen's structural break models for the narrow money demand equation (13) are as follows:

$$LRM1 = \mu_1 + \mu_2 D_{tb} + \alpha_1 LRCONS_t + \alpha_2 IR_t + \alpha_3 PSINV_t + \varepsilon_t \quad (15)$$

$$LRM1 = \mu_1 + \mu_2 D_{tb} + \beta_1 t + \alpha_1 LRCONS_t + \alpha_2 IR_t + \alpha_3 PSINV_t + \varepsilon_t \quad (16)$$

$$LRM1 = \mu_1 + \mu_2 D_{tb} + \alpha_1 LRCONS_t + \delta_1 D_{tb} LRCONS_t + \alpha_2 IR_t + \delta_2 D_{tb} IR_t + \alpha_3 PSINV_t + \delta_3 D_{tb} PSINV_t + \varepsilon_t \quad (17)$$

Specification (2) is then applied to the three GH equations containing a structural break to examine the stability of the demand function of currency demand in Indonesia. The following are the implied three alternative models of Gregory and Hansen specifications from equation (14):

$$LRCOB = \mu_1 + \mu_2 D_{tb} + \alpha_1 LRCONS_t + \alpha_2 IR_t + \alpha_3 PSINV_t + \varepsilon_t \quad (18)$$

$$LRCOB = \mu_1 + \mu_2 D_{tb} + \beta_1 t + \alpha_1 LRCONS_t + \alpha_2 IR_t + \alpha_3 PSINV_t + \varepsilon_t \quad (19)$$

$$LRCOB = \mu_1 + \mu_2 D_{tb} + \alpha_1 LRCONS_t + \delta_1 D_{tb} LRCONS_t + \alpha_2 IR_t + \delta_2 D_{tb} IR_t + \alpha_3 PSINV_t + \delta_3 D_{tb} PSINV_t + \varepsilon_t \quad (20)$$

Table 5 shows the outcomes of the residual-based test on the null hypothesis of no cointegration of Gregory and Hansen (1996) for the 1(1) series in the presence of a structural break for specifications (1) and (2) with different break dates for all three GH models. The Gregory and Hansen cointegration test revealed a long-term relationship between the variables of the demand for narrow money function or specification (1) with several possible break dates. The break dates suggested by the three models of the GH test are 2017Q2, 2011Q2, and 2013Q1, with the recommended breakpoint occurring in 2011Q2, assuming level and slope shifts (GH-2). Similar GH test outcomes were seen for the currency demand equation or specification (2), with alternative breakpoints at 2017Q3, 2011Q2, and 2013Q1,

and the occurrence of a structural break in the series at 2011Q2 is recommended based on the assumption of level and slope shifts (GH-2).

Table 5. Gregory -Hanson Cointegration Test Result for Money Demand

Money Aggregates	Model	ADF	Breakpoint	5% CV	Existence of Cointegration
LRM1	GH-1	-3.96	2017q2	-5.28	NO
	GH-2	-6.33***	2011q2	-5.57	YES
	GH-3	-4.55	2013q1	-6.00	NO
LRCOB	GH-1	-4.84	2017q2	-5.28	NO
	GH-2	-6.74***	2011q2	-5.57	YES
	GH-3	-4.84	2013q1	-6.00	NO

This finding suggests that long-run cointegration is formed under the assumption of level and slope shifts (GH-2), with all the estimates being statistically significant, valid based on the data, and consistent with the theory. Table 5 of the GH-2 cointegration test findings suggest the existence of a long-run relationship between real money demand (narrow money and currency demand), real income, interest rate, and payment instrument innovation, as the null hypothesis is rejected at the 1% significance level.

According to Pesaran & Timmermann (2004), ignoring structural break exposes the estimator to risks of inefficiency, resulting in biased inferences. Based on the GH test result that a structural break occurs 2011: Q2, the dummy variable is formed with indicator function = 0 for periods 2007: Q1 to 2011: Q1 and the indicator function = 1 for periods 2011: Q2 and forward. Table 6 displays the estimation results of the implied Gregory and Hansen (C/T) equation (21). The structural break in 2011: Q2 corresponds to the year the central bank implemented the new regulation regarding reserve requirements, particularly in March 2011, which was applied in stages.

This study follows Roussel et al. (2021), who found a structural break in the money demand function, and Åberg et al. (2021), who found that a change in reserve requirement policy by the central bank may be responsible for the changing of banks' behavior of maintaining excess liquidity for precautionary purposes. The impact of this quantitative strategy of the central bank on money demand can also be explained by its effect on liquidity and credit channels; for example, see Warjiyo & Juhro (2022).

Cointegrating equation and error correction estimates

The structural break identified to occur in 2011: Q2 reflects the impact of the central bank's new regulation that increased the minimum statutory reserves, particularly for deposits in foreign currency. This regulation was effectively implemented in two stages, in March 2011 and June 2011, corresponding to the central bank's policy to halt the influx of capital and moderate the appreciation of the exchange rate, thereby neutralizing its impact on domestic liquidity, see Warjiyo (2017). As part of the policy mix approach, this reserve requirement policy was linked to a loan-to-funding ratio (LFR) policy to anticipate procyclicality in liquidity with the ultimate goal of promoting stable GDP growth and inflation. Consequently, the reserve requirement policy successfully boosted the credit rate, which subsequently had an expansionary effect on the demand for money.

Real consumption (LRCONS) estimates are correctly signed and statistically significant at the 1 percent level in both the narrow money demand and currency demand equation. In contrast, interest rate (IR) parameter estimates are statistically significant only for the narrow money demand equation. The GH-2 cointegration estimates presented in Table 6 indicate that the income elasticity is less than unity with a positive and statistically significant in affecting real money demand, both the narrow money demand and currency demand, indicating that real money demand is inelastic with respect to consumption. The result indicates the argument that money is essential and more sensitive to changes in consumption than changes in the interest rate. These findings follow Pramono et al. (2006) and Huntington et al. (2019).

Table 6. Long Run Parameters for Demand for Money Functions with Intercept and Regime Shifts (GH2)

Independent Variables	Money Aggregates	
	LRM1	LRCOB
C	6.568***	5.719***
	(11.622)	(7.085)
LRCONS	0.419***	0.393**
	(3.971)	(2.606)
IR	-0.015***	-0.001
	(-2.749)	(-0.099)
PSINV	-0.450**	-0.419
	(-2.075)	(-1.353)
trend	0.020***	0.019***
	(14.874)	(10.022)
dum_11Q2	0.104***	0.120***
	(5.421)	(4.393)
Adjusted R2	0.983	0.963
Serial Correlation LM Test	2.613	2.486

Source: Author's computations. Note: ***, **, and * denotes significance at the 10%, 5% and 1%, respectively, t-statistics are in parenthesis.

As anticipated, our study indicates that the interest rate (IR) has a negative and statistically significant relationship with long-term real narrow money demand, which may reflect the opportunity cost of holding money over the long term and imply that money and financial assets are substitutes. This finding is consistent with the findings of Kia (2024) and by economic rationale. On the other hand, it was discovered that interest rates have no long-term effect on the amount of currency demand.

In the long term, the advancement of payment instruments (PSINV) significantly and negatively impacts the narrow money demand. Our study confirms the findings of Adil et al. (2020) and Mlambo & Msosa (2020) but contradicts the findings of Ahad (2017). This result is consistent with expectations, given that the innovation of payment instruments was closely tied to technological advancements that substituted the function of conventional money and facilitated economic transactions.

However, some studies, such as Adil et al. (2020) and Hammad Naeem et al. (2023), found that financial innovation might have a positive or negative sign, depending on whether it was an institutional and technological advancement

(negative sign) or increasing monetization of the economy and financial deepening (a positive sign). In the case of specification (2), we discovered that the advancement of payment instruments does not have a long-term impact on the amount of cash in circulation.

The time trend and dummy break date have positive and significant coefficients for specifications (1) and (2). Further evidence indicates that the endogenous change was a level shift with a time trend; as suggested by the selection of the GH-2 equation, a statistically significant and positive upward trend over time indicates an increase in real money demand. This finding is consistent with the findings of Adil et al. (2020).

Table 7. Short Run Parameters for Demand for Money Functions with Intercept and Regime Shifts (GH2)

Independent Variables	Money Aggregates	
	LRM1	**LRCOB**
C	0.035***	0.0303***
	(10.268)	(7.702)
D(LRM1(-1))	-0.355***	
	(-4.561)	
D(LRM1(-6))	-0.355***	
	(-5.585)	
D(LRCOB(-1))		-0.157**
		(-2.493)
D(LRCOB(-3))		-0.181***
		(-3.32)
D(LRCONS)	0.427***	0.534***
	(7.898)	(6.323)
D(IR(-1))	-0.021***	0.015**
	(-3.974)	(2.090)
D(IR(-6))	-0.012**	-0.017**
	(-2.385)	(-2.514)
D(PSINV)	-0.383***	-0.570***
	(-2.954)	(-2.995)
D(PSINV(-2))	-0.502***	
	(-3.611)	
D(PSINV(-6))	-1.014***	
	(-6.984)	
ECT_RM1_GH2(-1)	-0.406***	
	(-3.570)	
ECT_RCOB_GH2(-1)		-0.770***
		(-6.620)
Adjusted R2	0.867041	0.887239
Serial Correlation LM Test	4.142153	1.880107

Source: Author's computations. Note: ***, **, and * denotes significance at the 10%, 5% and 1%, respectively, t-statistics are in parenthesis.

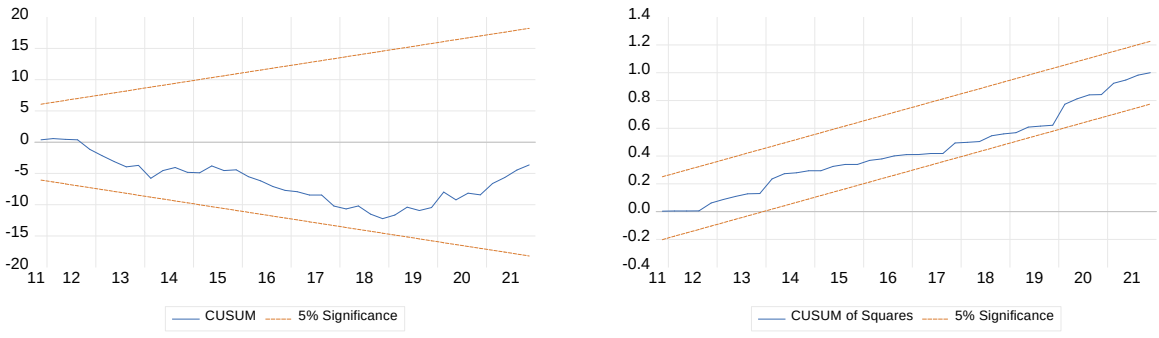
Based on the selected GH-2 model, we estimate an error correction model with the suggested optimal lag length of 6 based on the Lag Length Selection using Information Criteria presented in Appendix A. Table 7 demonstrates the outcome of a parsimonious short-run regression model derived from the Hendry's general-to-specific technique (GETS), for detail, see Hendry et al. (2005). The short-run

regression results show that in addition to real consumption, policy rates, payment instrument innovation, and previous values of real money demand are all robust determinants of the demand for money.

Table 7 demonstrates that a rise in the use of cards and digital payment compared to cash usage decreases the demand for money for both the narrow money and currency demand, which may also indicate a rise in the efficiency of transaction costs. This finding implies that the monetary authority should support the innovation of payment instruments and encourage economic agents to adopt them widely all over the country. The error correction term coefficient for specification (1) is negative (-0.406) and highly significant, implying that real narrow money demand is cointegrated into its determinants in the pre- and post-reserve requirement new regulation periods. The ECM estimate in the specification (1) indicates that approximately 40.6% of the disequilibrium in real narrow money demand caused by shocks in the previous period will return to the long-run equilibrium within one quarter. Furthermore, the error correction term coefficient for specification (2) is negative (-0.770) and very significant, implying that real currency demand is cointegrated with its determinants, considering the structural break that may result from the central bank's new reserve requirement policy. The currency demand adjustment speed is higher than the narrow money demand.

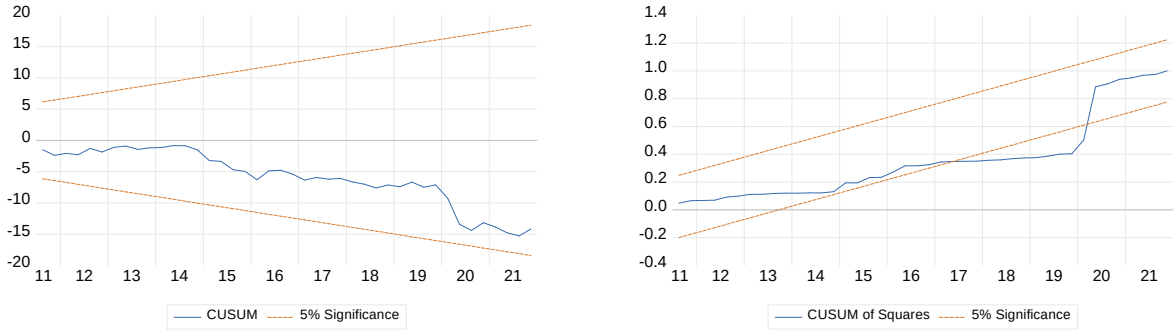
Parameter stability test

We then use Brown et al. (1975) CUSUM and CUSUMSQ tests to determine if Indonesia's short-run money demand function, as reported in Table 7, is stable during the observed period. The parameter is considered unstable if the recursive residual of the expected money demand equation lies outside the two critical lines. The CUSUM and CUSUMSQ test results of the short-run equation confirm the stability of the money demand equation for both Specification (1) and Specification (2), as evidenced by the fact that the recursive residual of the estimated currency demand equation lies within the critical bounds of 5 percent significance level, as depicted in Figures 1 and 2.



a) CUSUM Test result b) CUSUMQ Test result

Figure 1. Stability Test for Short-Run Narrow Money Demand (CUSUM and CUSUMSQ Tests)



a) CUSUM Test result b) CUSUMQ Test result

Figure 2. Stability Test for Short-Run Currency Demand (CUSUM and CUSUMSQ Tests)

CONCLUSION

This study analyzes the impact of technological advancements in the retail payment system on the demand for money and their implications for Indonesian monetary policy. The CUSUM and CUSUMSQ tests give evidence for a stable demand function in Indonesia both before and after the new reserve requirement policy was introduced since the recursive residual plots of the demand for narrow money demand and the currency demand are within the 5% critical lines. The findings of our study indicate that real money demand is cointegrated with real consumption, policy rate, and payment instrument innovation, with a suggested break in 2011: Q2 under the assumption of intercept and trend shift (C/T). The identified break date corresponds to the release of a new policy regarding the minimum statutory reserves of foreign deposits and a loan-to-funding ratio (LFR) by the central bank in 2011 to limit the influx of capital and neutralize its effect on domestic liquidity.

The results of the cointegration equation and error correction models indicate a causal relationship between real money demand, specifically narrow money and currency demand, its traditional determinants (income and interest rate), and the technological advancement of the payment instrument. This study validates the shopping-time model of money demand theory, which posits that the demand for money is impacted not only by its traditional drivers but also by the advancement of payment technology. The error correction term (ECT) coefficient of one period lag revealed that approximately 40.6 percent of the narrow money demand equation (M1) disequilibrium is rectified after one quarter. In comparison, the ECT of the currency demand equation (COB) is expected to correct around 77.0 percent of the disequilibrium after one quarter.

In conclusion, the long-run and short-run estimates of the narrow money demand and currency demand equations shown in this analysis are novel for the subject area in Indonesia; they highlight the dynamic interaction among the variables under consideration and capture the structural break that reflects the influence of central bank policy. This result implicitly addresses worries over the prospect of a central bank policy weakening due to technological advancements in the payment system.

Although the ITF has been in place since 2006, considering the Indonesia Payment System Blueprint 2025 initiated by the central bank and the rapid

development of payment system innovation, the central bank must have a comprehensive understanding of how technological advancements in the payment system affect money demand and other monetary aggregates. As a result, our analysis suggests that central banks should monitor and anticipate the effects of payment system advancement on monetary aggregates to maintain the effectiveness of the monetary policy and consider the payment system in its policy mix framework.

Finally, we propose expanding future research on the payment system to include policy impact analysis based on primary data and examining how people respond to central bank policies. In addition, it would be advantageous to apply more contemporary techniques, such as a machine learning approach encompassing both structured and unstructured data, to examine policy-related issues in more depth.

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REFERENCES

Adil, M. H., Hatekar, N., & Sahoo, P. (2020). The Impact of Financial Innovation on the Money Demand Function: An Empirical Verification in India. *Margin: The Journal of Applied Economic Research*, *14*(1). https://doi.org/10.1177/0973801019886479

Ahad, M. (2017). Financial Development and Money Demand Function: Cointegration, Causality and Variance Decomposition Analysis for Pakistan. *Global Business Review*, *18*(4). https://doi.org/10.1177/0972150917692209

Aliha, S., & Said, S. (2017). Investigating the effect of financial innovations on demand for money on a world scale: A systems GMM panel data approach. *Journal of Global Business and Social Entrepreneurship*, *3*(5), 181–188.

Aristiyowati, E. S., & Falianty, T. A. (2019). Peranan Perkembangan Inovasi Finansial Sistem Pembayaran Dalam Mempengaruhi Permintaan Uang di Indonesia. *EKUITAS (Jurnal Ekonomi Dan Keuangan)*, *2*(3). https://doi.org/10.24034/j25485024.y2018.v2.i3.128

Atzei, N., Bartoletti, M., & Cimoli, T. (2017). A survey of attacks on Ethereum smart contracts (SoK). *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, *10204 LNCS*, 164–186. https://doi.org/10.1007/978-3-662-54455-6_8/FIGURES/1

Bech, M., Ougaard, F., & Picillo, C. (2018). Payments are a-changin' but cash still rules. *BIS Quarterly Review*, *March*.

Brodo D, M., & Levin T, A. (2017). Central bank digital currency and the future of monetary policy - Global Business Outlook. *NATIONAL BUREAU OF ECONOMIC RESEARCH*, *93*(I).

Cabezas, L., & Jara, A. (2021). The demand for cash: stylized facts and substitution by electronic means of payment. In *CEPAL Review N°* (Vol. 135). https://hdl.handle.net/11362/47820

Camera, G. (2017). A Perspective on Electronic Alternatives to Traditional Currencies. *Sveriges Riksbank Economic Review*, *1*.

de Almeida, P., Fazendeiro, P., & Inácio, P. R. M. (2018). Societal risks of the end of physical cash. *Futures*, *104*. https://doi.org/10.1016/j.futures.2018.07.004

Dias, J. (2001). Digital Money: Review of Literature and Simulation of Welfare Improvement of This Technological Advance. *Departement of Economic State University of Maringa, Brazil*, *4*(3).

Dunne, J. P., & Kasekende, E. (2018). Financial Innovation and Money Demand: Evidence from Sub-Saharan Africa. *South African Journal of Economics*, *86*(4). https://doi.org/10.1111/saje.12205

Fender, J. (2012). *Monetary policy*. John Wiley & Sons.

Friedman, M. (1970). A Theoretical Framework for Monetary Analysis. *Journal of Political Economy*, *78*(6). https://doi.org/10.1086/259720

Gillitzer, C., & Simon, J. (2015). Inflation targeting: A victim of its own success. *International Journal of Central Banking*, *11*.

Gonçalves, C. E. S., & Salles, J. M. (2008). Inflation targeting in emerging economies: What do the data say? *Journal of Development Economics*, *85*(1–2). https://doi.org/10.1016/j.jdeveco.2006.07.002

Hendry, D. F., & Mizon, G. E. (2005). Forecasting in the presence of structural breaks and policy regime shifts. In *Identification and Inference for Econometric Models: Essays in Honor of Thomas Rothenberg* (Vol. 9780521844413). https://doi.org/10.1017/CBO9780511614491.021

Ilyés, T., & Varga, L. (2016). Macroeconomic effects of the increase of electronic retail payments – A general equilibrium approach using Hungarian data *. *Financial and Economic Review*, *15*(2).

Issing, M. O. (2011). *Lessons for monetary policy: What should the consensus be?* International Monetary Fund.

Juhro, S. M., & Goeltom, M. S. (2015). Monetary policy regime in Indonesia. In *Macro-Financial Linkages in the Pacific Region*.

Kahn, G. a., & Benolkin, S. (2007). The role of money in monetary policy: why do the Fed and ECB see it so differently? *Economic Review, Q III*.

Karavias, Y., Narayan, P. K., & Westerlund, J. (2023). Structural Breaks in Interactive Effects Panels and the Stock Market Reaction to COVID-19. *Journal of Business and Economic Statistics*, *41*(3). https://doi.org/10.1080/07350015.2022.2053690

Kia, A. (2024). Demand for Money in the United States: Stability and Forward-Looking Tests. *Economies*, *12*(2). https://doi.org/10.3390/economies12020049

Kombe, C. A., Yabu, N., Mwita, D. L., & Mbiha, G. E. (2020). Mobile Phone Payments and Demand for Cash: The Case of Tanzania. *American Journal of Industrial and Business Management*, *10*, 1505–1573. https://doi.org/10.4236/ajibm.2020.108099

Kurniawan, M. L. A., A'yun, I. Q., & Perwithosuci, W. (2022). Money Demand in Indonesia: Does Economic Uncertainty Matter? *Jurnal Ekonomi & Studi Pembangunan*, *23*(2). https://doi.org/10.18196/jesp.v23i2.15876

Leong, C.-M., Puah, C.-H., & May-Jean TANG, M. (2021). Symmetric and Asymmetric Approaches to Money Demand Determination in Indonesia: Is Divisia Money Relevant? *The Journal of Asian Finance, Economics and Business*, *8*(7).

Lubis, A., Alexiou, C., & Nellis, J. G. (2019). Payment system innovations and financial intermediation: the case of Indonesia. *ADBI Working Paper Series., No. 984*.

Luo, S., Sun, Y., & Zhou, R. (2022). Can fintech innovation promote household consumption? Evidence from China family panel studies. *International Review of Financial Analysis*, *82*, 102137. https://doi.org/10.1016/J.IRFA.2022.102137

Mahatir, M. R., Aimon, H., & Sentosa, S. U. (2020). Stability of Money Supply, E-money, Interest Rate, and Inflation in Indonesia. *The Fifth Padang International Conference On Economics Education, Economics, Business and Management, Accounting and Entrepreneurship (PICEEBA-5 2020)*, 92–100.

Melati, I., & Kurniawan, M. L. A. (2023). Money Demand Analysis through Business Cycle in Indonesia. *Ekuilibrium : Jurnal Ilmiah Bidang Ilmu Ekonomi*, *18*(2). https://doi.org/10.24269/ekuilibrium.v18i2.2023.pp203-212

Meyer, J., & Teppa, F. (2023). Euro area consumers' payment behaviour and banking digitalisation. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.4396347

Mishkin, F. S. (2010). Monetary policy flexibility, risk management, and financial disruptions. *Journal of Asian Economics*, *21*(3). https://doi.org/10.1016/j.asieco.2009.07.005

Mlambo, C., & Msosa, S. K. (2020). The effect of financial technology on money demand: Evidence from selected African states. *International Journal of Economics and Business Administration*, *8*(1). https://doi.org/10.35808/ijeba/430

Nepal, R., & Paija, N. (2020). Stability of Money Demand Function in the SAARC Region: A Panel Co-Integration Approach. *Journal of Economic Integration*, *35*(1), 1976–5525. https://doi.org/10.11130/jei.2020.35.1.111

Oyelami, L. O., Adebiyi, S. O., & Adekunle, B. S. (2020). Electronic payment adoption and consumers' spending growth: empirical evidence from Nigeria. *Future Business Journal*, *6*(1). https://doi.org/10.1186/s43093-020-00022-z

Pintér, Z., Nagy, M. Z., Tóth, K., & Varga, J. (2022). The Struggle between Cash and Electronic Payments. *Economies*, *10*(12). https://doi.org/10.3390/economies10120304

Saving, T. R. (1977). A theory of the money supply with competitive banking. *Journal of Monetary Economics*, *3*(3). https://doi.org/10.1016/0304-3932(77)90023-X

Tule, M. K., & Oduh, M. O. (2017). Financial innovations and the future of monetary policy in Nigeria. *Economics of Innovation and New Technology*, *26*(5). https://doi.org/10.1080/10438599.2016.1229854

Whelan, K. (2021). Central banks and inflation: Where do we stand and how did we get here? *European Journal of Economics and Economic Policies: Intervention*, *18*(3). https://doi.org/10.4337/ejeep.2021.03.06

Wisniewski, T. P., Polasik, M., Kotkowski, R., & Moro, A. (2021). Switching from Cash to Cashless Payments during the COVID-19 Pandemic and Beyond. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3794790

Wong, T. L., Lau, W. Y., & Yip, T. M. (2020). Cashless Payments and Economic Growth: Evidence from Selected OECD Countries. *Journal of Central Banking Theory and Practice*, *9*. https://doi.org/10.2478/jcbtp-2020-0028

Appendix A.

Table A.1. Lag Length Selection Criteria for Specification 1 (real narror money demand)

Lag	LogL	LR	FPE	AIC	SC	HQ
0	275.9004	NA	4.41e-10	-10.1922	-9.5861	-9.9606
1	312.8923	62.3785	1.95e-10	-11.0154	-9.8033*	-10.5522
2	337.0737	36.9834	1.45e-10	-11.3362	-9.5180	-10.6414
3	367.4247	41.6583	8.72e-11	-11.8990	-9.4748	-10.9726
4	387.3174	24.1833	8.19e-11	-12.0517	-9.0213	-10.8937
5	409.4314	23.4148	7.44e-11	-12.2914	-8.6551	-10.9019
6	450.3010	36.8628*	3.50e-11*	-13.2667	-9.0243	-11.6455*
7	469.3474	14.1915	4.34e-11	-13.3862	-8.5377	-11.5334
8	486.5811	10.1374	6.87e-11	-13.4346*	-7.9800	-11.3502

Table A.2. Lag Length Selection Criteria for Specification 2 (real currency demand)

Lag	LogL	LR	FPE	AIC	SC	HQ
0	289.4735	NA	2.59E-10	-10.7245	-10.11839*	-10.4929
1	316.8010	46.0817	1.68E-10	-11.1687	-9.9565	-10.7055
2	333.2531	25.1621	1.69E-10	-11.1864	-9.3682	-10.4916
3	373.1418	54.7491	6.97E-11	-12.1232	-9.6990	-11.1968
4	390.8064	21.4747	7.14E-11	-12.1885	-9.1582	-11.0305
5	401.9401	11.7886	9.99E-11	-11.9977	-8.3613	-10.6081
6	444.1044	38.03050*	4.47e-11*	-13.0237	-8.7813	-11.40254*
7	465.7452	16.1245	5.00E-11	-13.2449	-8.3964	-11.3922
8	485.4810	11.6093	7.17E-11	-13.39141*	-7.9368	-11.3071

Appendix B. Shopping Time Model, Adapted from Dias (2001)

Recall the objective of the household at period t is then to choose the value of consumption c_t, money holding M_t, and bonds B_t in equation (2) and equation (3), subject to the constraint (4). Formulation of a Lagrangian expression, L_t, to maximize the problem can be formulated as follows:

$$L_t = U\left[c_t, \psi\left(s_t, \frac{M_t}{P_t}\right)\right] + \beta U\left[c_{t+j}, \psi\left(s_{t+j}, \frac{M_{t+j}}{P_{t+j}}\right)\right] + \lambda_t\{(1 + R_{t-1})B_{t-1} - [P_t(c_t - y) + (M_t - M_{t-1})] - B_t\} \quad (5)$$

Then we maximize the equation with respect to λ_t, as well as the appointed variables and impose the budget constraint (4) by following the first-order condition

$$\partial L_t / \partial \lambda_t = 0.$$

In obtaining the money demand function, however, we need to find the first order of $\partial L_t / \partial c_t$ and $\partial L_t / \partial M_t$, and set the resulting equations equal to zero.

$$\frac{\partial L_t}{\partial \lambda_t} = U_1[c_t, \psi(s_t + m_t)] + U_2[c_t, \psi(s_t + m_t)]\psi_1(s_t + m_t) - \lambda_t P_t = 0 \quad (6)$$

$$\frac{\partial L_t}{\partial M_t} = \frac{U_2[c_t, \psi(s_t + m_t)]\psi_2(s_t + m_t)}{P_t} - \lambda_t + \lambda_t(1 + R_t)^{-1} = 0 \quad (7)$$

Then by eliminating $\lambda_t P_t$ from equation (6) and (7), we have:

$$U_2[c_t, \psi(s_t + m_t)]\psi_2(s_t + m_t) = [1 - (1 + R_t)^{-1}]\{U_1[c_t, \psi(s_t + m_t)] + U_2[c_t, \psi(s_t + m_t)]\psi_1(s_t + m_t)\} \quad (8)$$

We can assume the welfare function takes a Cobb-Douglas form:

$$U(c_t, l_t) = c_t^{1-\alpha} l_t^{\alpha} \quad (9)$$

And

$$l_t = \psi(s_t, m_t) = s_t^{-a} m_t^{a} \quad (10)$$

where α and a are positive fractions ($0 < \alpha < 1$, $0 < a < 1$). Then the partial derivatives will be

$$U_1 = \frac{\partial U}{\partial c} = (1-\propto)\, c_t^{-\propto}(s_t^{-a} m_t^{a})^{\propto} \quad (11)$$

$$U_2 = \frac{\partial U}{\partial l} = \propto c_t^{1-\propto}(s_t^{-a} m_t^{a})^{\propto - 1} \quad (12)$$

$$\psi_1 = \frac{\partial \psi}{\partial s} = -a\, s_t^{-(a+1)} m_t^{a} \quad (13)$$

$$\psi_2 = \frac{\partial \psi}{\partial m} = a\, s_t^{-a} m_t^{a-1} \tag{14}$$

Using these, we find that equation (8) becomes:

$$\propto c_t^{1-\propto}(s_t^{-a} m_t^{a})^{\propto-1}.a\, s_t^{-a} m_t^{a-1} = \left[\frac{R_t}{1+R_t}\right]\begin{Bmatrix}(1-\propto)\, c_t^{-\propto}(s_t^{-a} m_t^{a})^{\propto} + \\ \propto c_t^{1-\propto}(s_t^{-a} m_t^{a})^{\propto-1}.-a\, s_t^{-(a+1)} m_t^{a}\end{Bmatrix} \tag{15}$$

After simplification and solving for λ_t, we find

$$m_t = \left[1 + \frac{1}{R_t}\right] \frac{a \propto c_t}{1-\propto -a \propto c_t/s_t} \tag{16}$$

The general form of money demand function that accommodates payment instrument innovation can be written as follows:

$$m_t = L(c_t, R_t, s_t) \tag{17}$$