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Does Digital Finance Change the Stability of Money Demand Function? Evidence from China

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Abstract: Understanding the stability of the money demand function is crucial for determining how money impacts inflation and output, and optimizing monetary policy operations. Our study, using China as a case study, examines the potential effects of digital finance on this stability through cointegration technology. We found that digital finance influences the stability of money demand functions differently across monetary aggregates: it leaves M0 unaltered, doesn't influence the unstable M1, but does disrupt the formerly stable M2. We further investigate how two key services of digital finance - payment and asset management - affect the stability of M0, M1, and M2 demand functions. For payment services, our findings suggest the stability impact on the money demand function follows the order of M0 > M1 > M2. In contrast, for asset management services, the impact is ranked inversely. Consistent with recent studies, our data indicates that employing the Divisia index softens the impact of digital finance on the stability of money demand functions. Moreover, it's essential to monitor the pace of reform and understand how the behaviors of unique economic entities impact the money demand function, while concurrently promoting a deeper reform of interest rate liberalization.

JEL classification: E4, E6, G2

Key words: Digital finance; Money demand function; Stability; Cointegration

1. Introduction

Recent years have seen the rapid growth of digital finance worldwide, transforming many facets of the economy and significantly altering people's demand for real money balances. This change is largely driven by shifts in payment habits and portfolio choices, resulting in potential instability and obscurity in the money demand function. Identifying this function is not just vital for understanding long-term inflation but also forms the bedrock for interpreting money's influence on output and inflation in AD-AS models, and determining the form of money functions in new Keynesian DSGE models. The stability of the money demand function is especially critical for the monetary policies of developing nations. Developed nations have largely transitioned their intermediary monetary policy target from money supply to interest rates since the 1980s, rendering the stability of the money demand function less critical. In contrast, developing nations, whose financial market reforms are ongoing and interest rate transmission mechanisms remain incomplete, depend heavily on a stable money demand function for effective monetary policy, with money supply still a key intermediary target.

If digital finance destabilizes the money demand function, executing effective monetary policy in developing nations becomes challenging. This study focuses on China, a global leader in digital finance, to explore this issue. In this paper, based on the data from January 2013 to December 2020, we establish empirical evidence that digital finance has different effects on the stability of money demand function at different monetary aggregate. Concretely, whether digital financial indicator is included or not, M0 demand function remains stable, while M1 demand function is still unstable. Specifically, after controlling for the digital finance indicator, the M2 demand function shifts from being unstable to stable. Further, we introduce two sub-indicators representing two different services of digital finance - payment service and assets management service - into the money demand function respectively. We find that the impact of payment service on the stability of M0, M1 and M2 demand function decreases gradually, while for the assets management service, the result runs to the opposite. In addition, we find that identifying the impact of digital finance on the stability of money demand function needs to control the structural break brought by institutional reform. Finally, we consider that in China, Divisia monetary aggregate can improve the stability of the money demand function to a certain extent.

This paper contributes to the existing literature on the impact of financial innovation on the stability of the money demand function in terms of research methodology. First, we depart from the usual time division method used in previous studies (Miyao, 1996; Haug, 2006; Hafer and Kutan, 2013; Adil et al., 2020), and instead employ a simultaneous section stability comparison method to discern the effects of financial innovation on the money demand function. Second, our research distinguishes itself from recent literature that utilizes cointegration techniques to identify the stability of the money demand function (De La Fuente et al., 2020; Chowdhury and Karim, 2020; Zhao, 2017; Serletis et al., 2014). We propose a new approach for evaluating the impact of digital finance on the stability of the money demand function. This method, following Wooldridge's argument (Wooldridge, 2015, pp.581-582), compares the changes in the cointegration relationship among money demand, income, and interest rate before and after the inclusion of digital finance indicators. Third, to assure the robustness of our findings, we construct both a single-equation cointegrating regression model and a system VAR-based cointegration model. Furthermore, in the single-equation cointegrating regression, we eschew the ordinary least squares estimation (SOLS) method, instead employing the Fully Modified OLS (FMOLS) (Phillips and Hansen, 1990), Canonical Cointegrating Regression (CCR) (Park, 1992), and Dynamic OLS (DOLS) (Saikkonen, 1992; Stock and Watson, 1993) to avoid the influence of dynamic correlation of stochastic vectors on the results. Fourth, our cointegration testing involves not only the Engle-Granger (E-G) cointegration test as in De La Fuente et al. (2020), but also Hansen's instability test (Hansen, 1992) to verify the robustness of the E-G cointegration test.

Additionally, this paper contributes to the research on the impact of financial innovation on the stability of the money demand function in developing countries. Earlier studies primarily held that financial innovation led to the instability of money demand functions (Milbourne and Moore, 1986; Goldfeld and Sichel, 1990; Miyao, 1996; Glennon and Lane, 1996), largely focusing on developed economies. However, with financial innovation extending to developing nations, recent research has begun to evaluate its impact on their money demand functions, revealing stability variations at differing levels of money supply (Tule and Oduh, 2017; Dunne and Kasekende, 2018; Nnyanzi, 2018; Adil et al., 2020). Notably, Adil et al. (2020) demonstrated that the inclusion of financial innovation variables stabilized India's M1 and M3 money demand functions. In contrast, Liao and Tapsoba (2014) used the M3/M2 ratio as a proxy for China's financial innovation and inferred the absence of a stable money demand due to swift financial innovation and liberalization. Despite these insights, these studies failed to dissect why financial innovation impacts money demand stability differently at various levels. While Jin (2018) argued that the rise of mobile payments and e-commerce rendered China's M1 money demand function more stable than M2, our study goes further. Using a financial functionality perspective, we incorporate two digital finance sub-indicators into the money demand function, enabling us to precisely identify their distinct impacts on money demand stability and the mechanisms behind them.

Finally, the paper also contributes to the literature on the stability of money demand function from the perspective of institutional change in developing countries. Not only have we summarized the patterns of influence that digital finance has on the money demand function at different levels of monetary aggregates, but we've also paid particular attention to how the institutional changes in developing countries like China impact the relationship between digital finance and the stability of the money demand function. While existing studies suggest that institutional changes are a significant factor affecting the stability of the money demand function in developing countries (Chen et al., 2021; Boucekkine et al., 2021; Adil et al., 2020; Folarin and Asongu, 2019), our research differs by focusing on the influence of regulatory reforms targeting financial innovation on the role digital finance plays in the stability of the money demand function. We've found that identifying the impact of digital finance on the stability of the money demand function requires the exclusion of structural breaks caused by these institutional changes.

The paper is organized as follows. Section 2 illustrates the reality of digital finance development in China and proposes three basic hypotheses. Section 3 describes the selected variables and the data used to test the theoretical hypotheses, and discusses the cointegration test approach that we used. Section 4 provides the empirical test results of the hypotheses and additional test results. Section 5 presents the robustness test results obtained by substituting key variables and using the Johanson cointegration test. Section 6 summarizes the findings and draws conclusions.

2. The digital finance development in China and the basic hypotheses

2.1 Development status and characteristics of digital finance in China

As financial structures evolve naturally with a country's financial development, China's financial system has been dramatically reshaped by the swift expansion of digital finance in recent years (Hua and Huang, 2021; Huang and Huang, 2018). The pace and scale of this transformation are astonishing and unprecedented. As per statistics from the China Internet Network Information Center, China's internet wealth management user base hit 530 million in 2020—41% of the national population and equivalent to 7% of the global population. With digital payments nearing 250 trillion yuan, China has become the world's largest digital payment market. The Digital Financial Inclusion Index by Peking University reveals a rapid growth trend in six major indicators: mobile payment, insurance, monetary funds, credit services, investment, and credit under digital finance (see Fig.1). Specifically, mobile payment transactions increased by 169.3 billion yuan from 2011 to 2020, expanding the market size by threefold. Additionally, the transaction size of Yu'e Bao, one of China's largest monetary funds, rose from 185.4 billion yuan in 2013 to 1258.5 billion yuan in 2020—an increase of 6.8 times. In structural terms, mobile payment transactions in 2020 were 13 times larger than commercial bank credit card transactions, and Yu'e Bao alone accounted for 4.6% of the total asset management scale of commercial banks (see Fig.2).

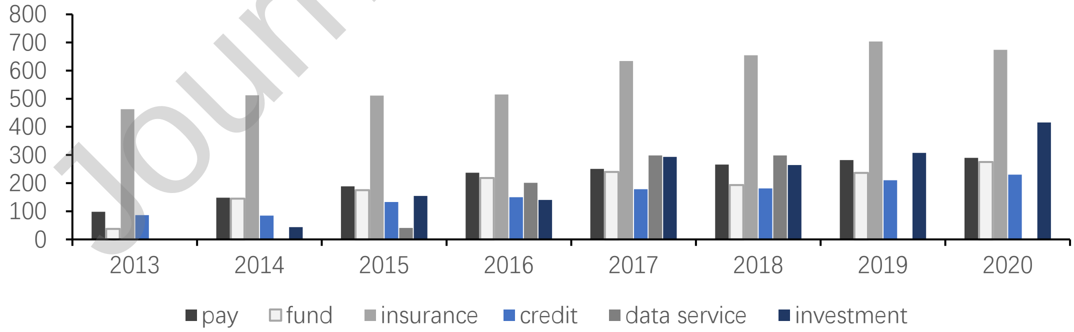

Fig.1. Digital finance Index trends based on functional differentiation

Source: The Peking University Digital Financial Inclusion Index of China

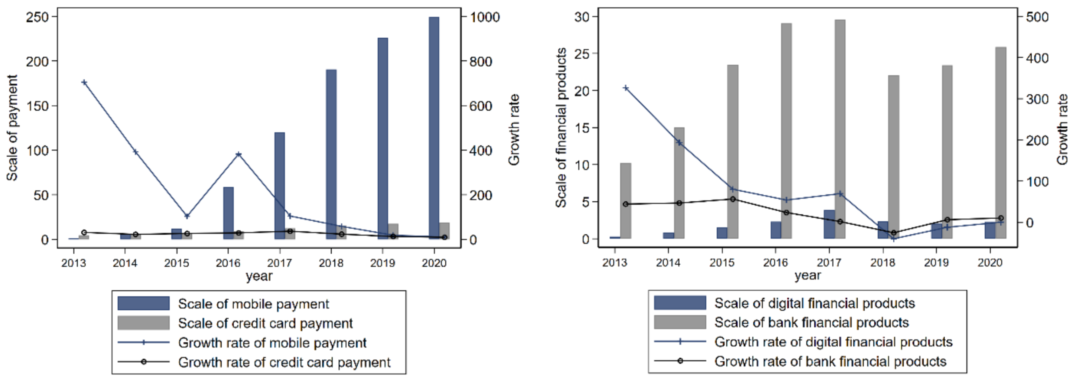

Fig.2. Development trend of digital finance and traditional finance

Source：Wind Database

Compared with previous financial innovations, digital finance has the following two different characteristics. First, it is not only the business innovation of traditional financial institutions or the emergence of new financial intermediaries, but also an alternative to traditional banking business by fintech companies and digital platforms [1](Boot et al., 2021; Goldstein et al., 2019). Previous financial innovations such as credit cards were financial instruments developed by banks to facilitate their own payment, but due to the need to open up a deposit and the inconvenience of carrying, these tools are not commonly used in developing countries such as China[2]. Relatively speaking, mobile payment services provided by fintech companies have become the most important payment options in China due to the full popularity of mobile phones. In fact, with the exception of the elderly, few people in China use alternative payment methods. This will change the demand for currency and the velocity of money flows[3]. At the same time, fintech companies and digital platforms also provide services such as peer-to-peer lending (online lending) (Boot et al., 2021), which allows businesses, especially SMEs (small and medium-sized enterprises), to reduce their own cash holdings, thereby changing the demand for money. Second, the use of information technology has broken the financial market segmentation caused by China's system and expanded the options for asset selection in people's portfolio optimization.

Due to stringent financial regulation, financial instrument innovation is typically not allowed in China. The market seriously lacks various derivative financial instruments to offer investors risk management choices and the ability to optimize investment portfolios. A significant portion of household savings can only be kept as bank deposits. Digital finance, through monetary funds such as Yu'e Bao, provides people with an alternative to bank savings. This, in turn, impacts the stable demand for money functions.2.2 The impact of digital finance on the stability of money demand in China.

According to the statistical division standards of the People's Bank of China[4], the monetary

[1] This is particularly important for China, where the banking sector remains the main source of funding for businesses. Statistics from People’s Bank of China show that by 2021, bank loans will account for 63.6% of the total financing of the whole society, compared with only 3.9% of the funds from the securities market.

[2] According to Chinese Bank data, the average credit card holdings in Chinese increased from 0.17 in 2008 to 0.39 in 2017, but still lagged far behind the rest of neighboring East Asia, such as Taiwan (1.77 per capita) and South Korea (1.28 per capita).

[3] Usually in the form of demand deposits made by businesses in banks.

[4] Since October 27, 1994, People's Bank of China has defined the statistical scope of China's monetary aggregate Mi (i=0,1,2,3).

aggregate is categorized into three levels—M0, M1, and M2—each representing a different size of liquidity. These are as follows:

$$M0 = Currency\ in\ circulation$$

$$M1 = M0 + Corporate\ demand\ deposits + Deposits\ from\ public\ institutions^{5} + Rural\ deposits^{6} + Personal\ credit\ card\ deposits$$

$$M2 = M1 + Savings\ deposits\ of\ urban\ and\ rural\ residents + Corporate\ Time\ Deposits + Trust\ deposits^{7} + Other\ deposits^{8}$$

While theories of money demand function vary (Keynes, 1936; Tobin, 1956; Miller, 1966; Arrow, 1978; Fleissig et al., 2008; Lucas et al.,2015; Folarin and Asongu, 2019; Berentsen et al., 2018), they generally agree that money demand comprises two elements: transactional money demand, mainly related to income levels and necessary for everyday transactions, and investment money demand, reflecting portfolio optimization choices between money and other financial assets. In China, M0, with the strongest liquidity, primarily satisfies urban household daily trading needs. M1 supplements M0 by catering to the daily operational currency needs of rural households, enterprises, and institutions, like the working capital expenditure of businesses. M2, in addition to incorporating the functions of M1, primarily meets the portfolio requirements of Chinese residents and enterprises, influenced by the yields of other financial assets. For example, residents choose between long-term bank deposits and stock investments, and enterprises decide between long-term bank deposits and trust investments. Thus, in the three-tiered structure of China's money demand, M0 and M1 serve transactional needs, while M2 caters to investment requirements.

Digital finance's impact on the stability of the money demand function operates through two channels: its effects on transactional demand through payment services, and its influence on speculative demand via asset management services. Firstly, from the perspective of payment service, due to the use of mobile payment technology, digital finance has changed the traditional payment methods that people use cash. By linking to demand deposit accounts, household sector[9] can directly take the payment through mobile device in daily expenditure transactions, without the need to hold cash, which greatly reduces the need for cash transactions. Since the proportion of cash in M0, M1 and M2 is different, this means that the development of digital finance may have the greatest impact on the stability of M0 and the least impact on M2.

Secondly, from the perspective of asset management service, as mentioned earlier, in China, the main role of digital financial development is to weaken China's financial repression problem

[5] In China, public institutions accept government leadership and take the form of legal entities of organizations or institutions. Deposits of public institutions refer to the funds deposited by Chinese state organs, organizations and institutions in banks for use.

[6] Rural deposits are the deposits of township enterprises, collectives, individual peasant households and rural credit cooperatives in banks, and are mainly composed of three parts, one part of which is the deposit of township enterprises, part of which is the deposit of rural collectives and individual peasant households in the bank, and the other part of which is the interbank deposit of rural credit cooperatives in the bank.

[7] Trust deposits include entrusted loan deposits, entrusted investment deposits, unit trust deposits, charitable fund trust deposits, labor insurance fund trust deposits, and individual special trust deposits. Compared with general bank deposits, trust deposits have the characteristics of longer deposit period, larger amount, higher interest rate, certain restrictions on use, and inability to withdraw principal at will.

[8] Other deposits refer to all claims against monetary institutions, other financial institutions and government organizations represented by certificates of deposits, except for currency and transferable deposits, including deposits in savings banks, small shares, notice deposits and pay-as-you-go deposits.

[9] According to the Law of the People's Republic of China on Commercial Banks, which was amended in October 2015, inter-enterprise payments must be completed through commercial bank transfers, and enterprises and public institutions may independently choose the business premises of a commercial bank to open a basic account for daily transfer settlement and cash receipt and payment, and no institution could open an account in the name of an individual to store the funds.

through the innovation of financial products. Through financial innovation outside the system, such as new wealth management products Yu'e Bao issued by Alibaba, digital finance provides a new choice of financial instruments with higher yield levels for the wealth management of the household sector, which will obviously affect people's speculative demand for money. Since the savings deposits (time deposits) of the household sector in banks are only counted in M2, and savings deposits reflect people's monetary investment needs, with the development of digital finance, people will make new portfolio optimization decisions between digital financial wealth management products and bank savings deposits, which is likely to affect the stability of M2.

Moreover, unlike in most developed countries, Chinese banks offer some interest on M1 (though significantly less than savings deposits), suggesting that the emergence of digital financial wealth management products could also impact demand deposit holdings, even if its effect on M2 is minimal. This indicates that, contrary to its payment services, digital finance's asset management services could incrementally affect the stability of M0, M1, and M2. From these analyses, we propose the following hypotheses.

H1. There is heterogeneity in the influence of digital finance on money demand functions for different measures of money.

H2. The payment service of digital finance has a decreasing impact on the stability of money demand function for M0, M1 and M2.

H3. The assets management service of digital finance has an increasing impact on the stability of money demand function for M0, M1 and M2.

3.Methodology:data, variables and empirical approaches

3.1. Data description

To test the hypotheses mentioned earlier, we employ 96 monthly observations from China between 2013[10] and 2020. The empirical data are collected from various sources. We use PKU_DFIIC[11] (The Peking University Digital Financial Inclusion Index of China) as an indicator to measure the degree of digital finance development. This index has been widely used and cited in academic journals (Guo et al., 2020; Zhang et al., 2019; Zhao et al., 2020; Pan et al., 2021; Han et al., 2021; Li et al., 2020). We also choose the sub-indicators of the payment business and money fund business in the digital finance index as proxy variables to measure the facilitate payment function and the portfolio optimization function, respectively. For money demand, we use the three monetary aggregates M0, M1, and M2, as designated by the People's Bank of China, to measure the real aggregate stock of money demand. Considering the money demand function and China's unique situation, we use the logarithm of real GDP as the income variable and choose the one-month Shanghai Interbank Offered Market Rate (SHIBOR) as the interest rate variable. Given that China's current one-year deposit rate is set by the central bank and hasn't been adjusted since October 2015, it struggles to reflect asset return changes. As SHIBOR is more market-oriented and fluctuates similarly to the bank deposit interest rate (Zuo and Park 2011; Jin 2018), it is a more suitable proxy variable for interest rates[12]. The macro data used in our analysis are obtained from the Wind

[10] Our analysis starts from 2013, since Yu 'ebao, China's largest online financial product, was launched in June 2013, which year is also considered to be the first year of Internet financial management in China.
[11] Considering the characteristics of our sample data and the suitability of various methods, we have employed the quadratic interpolation technique to upgrade the low-frequency data.
[12] We also choose permanent income as the proxy variable of income, and Yu 'ebao interest rate and Treasury bond yield as the proxy variable of interest rate for robustness test. See the robustness test for relevant test results.

Database, which uses raw data from the People's Bank of China, the National Bureau of Statistics, and the Shanghai Interbank Offered Market. Detailed definitions of the key variables are presented in Table 1.

Table 1
Variable definitions and descriptive statistics(N=96)

Variable	Definition	Mean	Median	Std.Dev	Min	Max
DF	Digital Finance Index	256.38	254.67	65.01	157.17	347.24
DPM	Payment Index of digital finance	220.05	243.81	64.69	98.03	290.02
DPF	Portfolio Index of digital finance	189.9	205.55	69.48	37.21	274.9
Ln(M0)	Ln (real aggregate of M0)	11.26	11.27	0.25	10.87	11.73
Ln(M1)	Ln (real aggregate of M1)	13.0	13.07	0.24	12.6	13.35
Ln(M2)	Ln (real aggregate of M2)	14.23	14.26	0.23	13.81	14.6
Ln(gdp）	Ln (real GDP)	11.01	11.03	0.32	10.28	11.71
Rtf	One-month SHIBOR	3.54	3.12	1.08	1.32	7.04

Notes: This table shows the summary Statistics and definitions for main variables used in empirical analyses. The other variables' summary Statistics and definitions are presented in Appendix A.

Considering that China, being in a transition period, often undergoes structural changes caused by institutional reform (Jin, 2018), which can lead to the data generation process of variables showing the characteristics of structural breaks. Therefore, following Perron (1989), Perron and Vogelsang (1992), Zivot and Andrews (1992), and others, we test the stationarity of variables using a variety of methods both with and without structural breaks. First, we perform unit root tests for all series using the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests (Dickey and Fuller, 1981; Phillips and Perrorn, 1988). The PP test is based on nonparametric test methods, which, compared to the ADF test, offer more robust construction of the t-statistic. As shown in Table 2, the results from the PP tests, performed on the first difference, unambiguously indicate that each series is I(1) at a 1% significance level, while the results from the ADF test show that all series are I(1) above a 10% significance level.

Table 2
Unit-root tests

Variable		Levels		First Difference		Multiple Breakpoint tests	
		ADF	PP	ADF	PP	IO	AO
DF	Intercept	-0.61	-0.50	-2.97**	-10.35***	-3.44	-3.70*
	Trend&Int	-3.28	-3.13	-3.60**	-10.29***	-3.46	-3.98*
DPM	Intercept	-2.19	-1.74	-2.58*	-10.21***	-3.42	-3.49*
	Trend&Int	-2.24	-1.68	-3.07**	-10.72***	-3.47	-3.96*
DPF	Intercept	-1.87	-1.87	-9.88***	-9.89***	-9.91***	-9.91***
	Trend&Int	-2.25	-2.25	-9.91***	-9.93***	-12.4***	-10.17***
Ln(M0)	Intercept	3.32	0.09	-13.58***	-25.63***	-12.15***	-8.83***
	Trend&Int	-1.73	-3.14	-14.98***	-22.11***	-12.02***	-12.02***
Ln(M1)	Intercept	-0.78	-0.41	-13.26***	-13.51***	-3.47*	-13.62***
	Trend&Int	-2.04	-1.75	-13.20***	-13.53***	-7.29***	-13.85***
Ln(M2)	Intercept	-3.17	-1.77	-3.29**	-11.54***	-3.78*	-12.20***

	Trend&Int	-1.85	-2.18	-3.60***	-11.81***	-3.82	-12.24***
Ln(gdp)	Intercept	-0.49	-2.55	-3.59***	-14.66***	-3.43	-3.54*
	Trend&Int	-0.36	-3.48	-3.60***	-14.51***	-3.71	-3.88**
Rtf	Intercept	-2.22	-1.38	-9.77***	-9.85***	-10.15***	-10.31***

Notes: ADF and PP are, respectively, the Augmented Dicky-Fuller and Phillips-Perron test for the null hypothesis that the series are nonstationary. Except for Rtf, other time series are considered to contain trend items. IO and AO are, respectively, tests proposed by Perron (1989), and Intercept denotes for allowing structural breaks in intercept trend and Trend&Int allows for structural breaks in both intercept and trend terms[13]. To save space, this table presents the unit-root test results of main variables, the other variables' unit-root test results present in Appendix B. Significance levels at 10%, 5% and 1% levels are denoted by *, **, ***, respectively. To save space, the other variables' unit-root test results are presented in Appendix B.

As a developing country, China's economic structure has changed much faster than that of developed countries, so similar to Zuo and Park (2011), we use innovation oulier (IO) test and additive oulier (AO) test to test the unit root hypothesis under possible structural breaks. Both tests treat structural break exogenously determined, and in these tests, one can also consider possible structural breaks in intercept and trend terms. However, there are differences between the two methods, IO test assumes that the occurrence of mutation is a gradual process and followed the same normal distribution as innovations, while AO test assumes that the occurrence of breaks is immediate. Based on the announcement of People's Bank of China, the method of data compiling in money aggregate statistics had improved since 2017, the item of money market funds, which was treated as deposit of money funds, is now treated as the total of money market fund units held by the non-deposit taking financial institutions, household sectors and non-financial companies. It is reasonable to assume that, based on the rapid expansion of digital wealth management scale, the People's Bank of China's policy abrupt change may lead to acception of the null hypothesis that the sequence is nonstationary. Therefore, we designed January 2017 as a known one-time break to test whether structural breaks occurred in relevant variables (Perron,1989). The results are shown in columns 5 and 6 of Table 2, we observe that AO test rejects null hypothesis above 10% significant level. If we use IO test, the significance of some variables was reduced. However, in combination with these four unit root tests, the hypothesis of the existence of unit root is mostly rejected, hence we conclude that all variables are integrated of order one I (1). Therefore, we can test whether there is a cointegration relationship between some of these variables.

3.2 The model

The stability of the money demand function refers to the existence and recognizability of the long-term equilibrium between money demand, income, and interest rates. These three variables in the money demand function are all I(1). The key idea of this method is that the co-integration relationship essentially represents an irregular trend of several I(1) variables. These variables cancel each other out in the long run, presenting a regular I(0) process. This idea is crucial for evaluating the impact of digital finance on the money demand function. Since digital finance may change the trend of currency, output and interest rate variables, we can judge whether digital finance affects the existence of the co-integration relationship by comparing the trend offset of these variables before and after removing the influence of digital finance. Concretely, depend on the ideas from

[13] Both the AO tests and IO tests, when the break date from the data is estimated, the distributional results required that there be no trend break under the null hypothesis (Vogelsang & Perron,1998; Kim& Perron,2009).

Wooldridge (Wooldridge, 2015, P582), by comparing the changes of cointegration relationship among money demand, income and interest rate before and after including digital finance indicator, we can identify the impact of digital finance on the stability of money demand function.

Specifically, referring to Bae et al. (2006), Chen et al. (2021), and Bahmani-Oskooee and Bohl (2000), we set the following single-equation cointegration test and system cointegration model.

Single-equation cointegration model：

$$\ln(\mathrm{M_i})_t = \mathrm{X^T}\beta + (\mathrm{D_{1t}}^{\mathrm{T}}, \mathrm{DF_t})\gamma_1 + \mathrm{u_{1t}} \quad (1)$$

$$\mathrm{X_t} = \delta_{21}{}^{\mathrm{T}}\begin{pmatrix}\mathrm{D_{1t}}\\ \mathrm{DF_t}\end{pmatrix} + \delta_{22}{}^{\mathrm{T}}\mathrm{D_{2t}} + \varepsilon_{2t} \quad (2)$$

System cointegration model：

$$\Delta Y_t = \Pi Y_{t-1} + \sum_{i=1}^{p}\Gamma_i \Delta Y_{t-i} + B(z_t, DF_t) + \varepsilon_t \quad (3)$$

Where t represents indexes over time， $\beta, \gamma_1, \delta_{21}, \delta_{22}, \Pi, \Gamma, B$ are vectors of parameter. Ln (Mi) is the logarithm of the demand for money, M_i denotes M0, M1, M2 and Divisia Index[14]. X is a vector of factors that affect the money demand function, include Ln(gdp)，Rtf et al., D1 and D2 are trend vectors with p1 and p2 dimensions, respectively. $Y = (\ln(M_i), X^T)^T$, Z denotes other stationary variables that needs to be controlled. $\Delta\varepsilon_{2t} = u_{2t}$, u_{1t} and u_{2t} are stationary and ergodic with zero mean, but u_{1t} and u_{2t} are likely to be contemporaneous or long-term related. Let $u_t = (u_{1t}, u_{2t})^T$ and

$$\Sigma = E(u_t u_t^{'}) = \begin{bmatrix}\sigma_{11} & \sigma_{12}\\ \sigma_{21} & \sigma_{22}\end{bmatrix}, \Lambda = \sum_{j=0}^{+\infty} E(u_t u_{t-1}^{'}) = \begin{bmatrix}\lambda_{11} & \lambda_{12}\\ \lambda_{21} & \lambda_{22}\end{bmatrix},$$

$$\Omega = \sum_{j=-\infty}^{+\infty} E(u_t u_{t-1}^{'}) = \begin{bmatrix}\omega_{11} & \varpi_{12}\\ \omega_{21} & \omega_{22}\end{bmatrix}$$

Regarding the test of whether digital finance affects the stability of the money demand function, we have expanded upon the method used by Fuente et al. (2020) and Serletis and Gogas (2014). The basic idea is as follows. Firstly, the principle of the existence of cointegration relations is based on there being a linear relationship with I(1) variables, and that the linear combination of these I(1) variables is stationary. In other words, under the influence of this linear relationship (long-run equilibrium in economic theories), the parameters of the cointegrating vector must be configured to purge the trend from the linear combination. As a result, this linear combination regularly returns to the mean. We expect that because it affects the demand for transactions and speculation, digital finance (*DF*) will affect the fluctuation regular pattern of money demand *Ln (Mi)*. Since digital finance operates outside the conventional financial system, it will inevitably alter the patterns of fluctuation in financial market interest rates *(Rtf)*. Consequently, this can also affect the pattern of output changes (*Ln (Mi)*) by influencing investment and consumption decisions. Secondly, we incorporate *DF* into Eqs. (1) and (2) to account for its impact on the fluctuations of *Ln (Mi)* and *X*. If we don't do this, its influence will not be correctly isolated. Therefore, by comparing whether there is a cointegration relationship between *Ln (Mi)*, *Ln(gdp)* and *Rtf* in these two cases, the influence of *DF* on the stability of the money demand function can be judged. Thirdly, in a similar vein, we can infer the effect of digital finance on the money demand function. This is achieved by testing for the existence of a cointegration relationship between *Ln (Mi)*, *Ln(gdp)*, and *Rtf*, both including and excluding *DF* in Eq. (3).

[14] Divisia index is used for robustness test, and the setting of relevant variables and test results are shown in the robustness test section.

Unlike Fuente et al. (2020) who used ordinary least squares estimation (SOLS) for regression of single-equation cointegration models, we opted to use Fully Modified OLS (FMOLS) (Phillips and Hansen,1990), Canonical Cointegrating Regression (CCR) (Park, 1992), and Dynamic OLS (DOLS) (Saikkonen ,1992; Stock and Watson, 1993) to estimate Eq. (1). Because, although the estimators of β are still consistent using the SOLS directly on Eq. (1), according to Hansen (1992). The dynamic timing correlation between u_{1t} and u_{2t} (represented by λ_{12} and ω_{12}) results in an estimate of the β biased and follows a non-Gaussian distribution.

According to Hansen (1992), the dynamic temporal correlation between u_{1t} and u_{2t} (reflected by λ_{12} and ω_{12}) results in an estimate of the β biased and follows a non-Gaussian distribution, although the estimator of β is still consistent by using SOLS directly for Eq. (1). While this could be problematic for small samples and inference, our objective is merely to infer the economic relationship between *Ln(Mi), Ln(gdp),* and *Rtf* using the estimated cointegration coefficient β. Therefore, this issue does not impact our ability to draw accurate conclusions. In addition, we not only use E-G cointegration test (Fuente et al., 2020) to test the cointegration relationship between *Ln (Mi), Ln(gdp)* and *Rtf*, but also use the instability test (Hansen, 1992) in order to enhance the robustness of the results. In contrast to the E-G cointegration test, which is based on the unit root test for the residuals of Eq. (1), the instability test method holds that the coefficient of Eq. (1) is unstable under the hypothesis of no cointegration, so the existence of a cointegration relationship can be inferred by testing the stability of the coefficient of Eq. (1).

4.Empirical evidence

4.1. Test of hypothesis 1

Hypothesis 1 focuses on the overall impact of digital finance on China's money demand function. Our strategy is to test whether there is a cointegration relationship among different measures of money demand (*Ln(M0), Ln(M1), Ln(M2)*), income (*ln(gdp)*) and interest rates (*Rtf*), in both cases where Eqs. (1)-(2) include and exclude the total indicator of *DF.* Table 3A-3C report the coefficient estimation results using FMOLS, DOLS and CCR, while the E-G t-statistic and Lc statistic reports the stationary test results of the residuals of Eq. (1). Columns 1-3 correspond to the estimated results of the benchmark model that excludes the *DF* variable, while columns 4-6 report the results of the extended model that includes the *DF* variable. Additionally, Table 3A-3C demonstrate that for the estimation results in the same column, the stationarity test results of the E-G t-statistic and Lc statistic are consistent. This consistency serves as a strong robustness check of our findings, and therefore, we believe that the likelihood of confounding factors materially biasing our estimates is small.

The results indicate that digital finance has varying impacts on the stability of the money demand function, depending on the specific measure of money used. The stationarity of the residuals of Eq. (1) also varies significantly based on whether or not the digital finance variable (*DF*) is included. Table 3A shows the result of cointegrate test for M0, columns 1-3 show that the result of E-G t-statistics (0.0055) and Lc statistics (0.1247,0.1636,0.1762) reject the null hypothesis at the 5% confidence level. When we include the digital finance variable (*DF*), as shown in columns 4-6, the residuals remain stable, and we reject the null hypothesis of the existence of unit roots at the 1% level. This means that *DF* does not affect the stability of M0 demand function. Contrarily, for the M1 cointegration test result in Table 3B, no cointegration relationship is observed among the variables of the money demand function, regardless of whether *DF* is included or excluded. This shows that M1 money demand function is always unstable. Similarly, as indicated by the results in Table 3C, when we analyze the effect of digital finance on the stability of the M2 demand function, we find an uncoordinated vector for M2, irrespective of whether *DF* is included or not.

For the above confusing results, our explanations are as follows. First, it is a wonder that the M0 money demand function has remained stable even as the payment service of digital finance has had a huge impact on cash holdings. We consider that because cash and mobile payment represent two different payment technologies, which correspond to different levels of desirable demand for M0. Specifically, compared with cash, choosing mobile payment for payment will save more costs, so people will gradually replace cash holding with mobile payment until retrieve to a new equilibrium. For instance, it is usually the elderly who prefer to use cash, so the demand for M0 will attain a new equilibrium after other people choose to use mobile payment. In addition, we can also find some other interesting results, for example, according to the FMOLS method estimation results in Table 3A, when excluding or including *DF*, the cointegration coefficient vectors of Eq. (1) are $(1, -0.1637, 0.018)^T$ and $(1, -0.1705, 0.0046)^T$, respectively. The former absolute values of the long-term elasticity of output are decreased than the latter, but the elasticity of interest rate is obviously increased, indicating that if we control the influence of digital finance in the economy system, the sensitivity of M0 to both income and interest rates will change significantly.

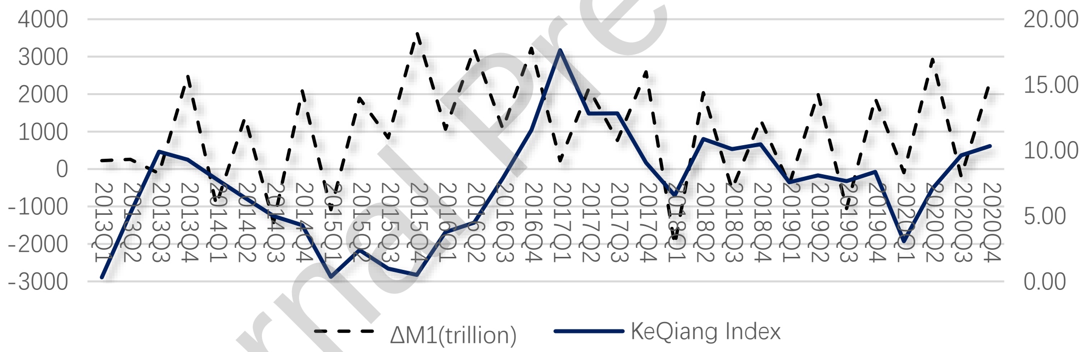

Fig.3. Trends of M1 and KeQiang Index[15]

Source：Wind Database

Secondly, why is the M1 money demand function unstable? We believe that this instability stems from the fact that an important component of M1 is the demand deposits of enterprises. These deposits can fluctuate dramatically in response to economic fluctuations, which are inherently irregular, according to the theory of economic fluctuations (Blanchard, 2017). Additionally, in China, while interest payments on demand deposits can satisfy the speculative money demand of some individuals (Handa, 2013), demand deposits primarily serve transactional purposes. Therefore, during economic boom phases, when business transactions are frequent, the demand for demand deposits by enterprises rises rapidly. However, during economic downturns, enterprises tend to

[15] Keqiang Index, an economic fluctuation indicator created by the Economist, a famous British political and economic magazine, to evaluate the GDP growth of China, and named after Premier Li Keqiang of The State Council. The Li keqiang index is a combination of three economic indicators: industrial electricity consumption, rail freight volume and balance of medium - and long-term bank loans. The formula of Li keqiang index is as follows: Keqiang index = growth rate of industrial electricity consumption ×40% + growth rate of balance of medium and long term loans ×35% + growth rate of railway freight volume ×25% The weight division is based on a simple regression analysis result of the fitting model of the growth rate of the three and GDP.

prefer long-term deposits. This leads to a lack of a stable money demand function, as illustrated in Fig.3.

Finally, how do we explain the instability of the M2 demand function? We believe this instability is due to certain institutional changes within China's financial regulatory regime [16]. In fact, China issued new asset regulations in March 2018. This new policy alters the relative return levels of monetary assets compared to non-monetary financial assets, thus influencing people's speculative demand. In other words, it could change the trend of money demand, potentially affecting the cointegration relationship among *Ln(M2)*, *Ln(gdp)* and *Rtf*. To account for these changes, we define a dummy variable (*Dum*), where *Dum=1* corresponds to the period after March 2018. We then introduce it into *D1* of Eq. (1) and Eq. (2) to mitigate the effect of Internet regulatory events on the trend of M2 money demand.

Table 3A
Cointegration test of Single Equations (M0)

Variable	Ln(M0)			Ln(M0)		
	FMOLS	DOLS	CCR	FMOLS	DOLS	CCR
DF				0.001***	0.001***	0.001***
				(15.0126)	(9.4500)	(12.4263)
Ln(gdp)	0.1637***	0.1850***	0.1636***	0.1705***	0.1964**	0.1807**
	(4.5519)	(4.4557)	(4.4270)	(3.5412)	(2.3016)	(2.9035)
Rtf	-0.018**	-0.0149**	-0.017**	-0.0046*	-0.0041*	-0.0046*
	(-2.4590)	(-2.0617)	(-2.1878)	(-1.7737)	(-1.7738)	(-1.7936)
Constant	3.6274***	3.5149***	3.6296	5.0826***	5.1629***	5.066***
Lc statistic	0.1247	0.1636	0.1762	0.1639	0.1381	0.1198
E-G t-statistic	0.0055	0.0055	0.0055	0.0001	0.0001	0.0001
Observations	96	96	96	96	96	96
R2_adj	0.2395	0.6430	0.2457	0.8460	0.8849	0.8457

Table 3B
Cointegration test of Single Equations (M1)

Variable	Ln(M1)			Ln(M1)		
DF				0.0012***	0.0011***	0.0012***
				(11.4737)	(7.0405)	(10.5802)
Ln(gdp)	0.6768***	0.755***	0.6770***	0.6207***	0.6080***	0.6314***
	(9.3234)	(9.9124)	(9.1631)	(4.9500)	(3.8451)	(4.3991)
Rtf	-0.0225**	-0.0152*	-0.0212**	-0.0029	-0.0022	-0.0032
	(-2.4479)	(-1.7678)	(-2.177)	(-0.5686)	(-0.3655)	(-0.6014)
Constant	2.4881***	2.0896***	2.4825	4.2581***	3.8803***	4.2098***
Lc statistic	0.0788	0.0510	0.0469	0.0455	0.0212	0.0219
E-G t-statistic	0.947	0.947	0.947	0.5089	0.5089	0.5089
Observations	96	96	96	96	96	96
R2_adj	0.6722	0.8639	0.6738	0.9508	0.9552	0.9502

[16] Since the rapid development of Digital finance in China, the central Bank and other regulatory authorities have issued a series of management measures and policy schemes to regulate the development of digital finance industry concerning about monopoly, fraud and other problems. Especially in March 2018, the regulatory authorities issued *the Notice on Strengthening the Rectification and Acceptance of Asset management Business through the Internet*, which eliminated the public issuance and sale of asset management products relying on the Internet. Since then, the number of P2P platforms, which mainly operate Internet financial asset management business, has declined sharply in China, and by November 2020, they have completely disappeared.

Table 3C
Cointegration test of Single Equations (M2)

Variable	Ln(M2)			Ln(M2)		
DF				0.0012***	0.0012***	0.0012***
				(26.2618)	(18.0351)	(24.6722)
Ln(gdp)	0.5819***	0.6283***	0.5805***	0.6590***	0.6523***	0.6231***
	(8.9381)	(9.4323)	(8.7861)	(8.0322)	(9.5728)	(8.3213)
Rtf	-0.0331***	-0.0278***	-0.0322***	-0.0074***	-0.0093***	-0.0073***
	(-4.0206)	(-3.7009)	(-3.7029)	(-3.2765)	(-3.6994)	(-3.1416)
Constant	3.5159***	3.2766***	3.5198	5.3141***	5.1835***	5.2956***
Lc statistic	0.0703	0.061	0.0238	0.0237	0.0201	0.0121
E-G t-statistic	0.8601	0.8601	0.8601	0.4632	0.4632	0.021
Observations	96	96	96	96	96	96
R2_adj	0.6768	0.8753	0.6791	0.988	0.9904	0.9878

Notes: The dependent variable is Ln(M0), Ln(M1) and Ln(M2) respectively, and the regression model applied are FMOLS, DOLS and CCR. T-values are reported in parentheses and *, **, *** denote statistical levels of 10%, 5% and 1% respectively. The presented results of Lc statistics and t-statistics in the table is P-value.Lc statistic is outlined by Hansen(1992), which arise from the theory of Lagrange Multiplier tests for parameter instability, the null hypothesis is cointegration exist. Conversely, the null hypothesis of the Engle-Granger t-statistic is no cointegration.

Table 4 reports the results of extending the benchmark model by including *Dum*. We can observe that, the cointegration test results (see column 4 - 6) of M2 demand function including *DF* variables change significantly (compared with Table 3C) after the addition of *dum*. Both Lc statistics (0.5621,0.4593,0.2117) and E-G t-statistics (0.0042) support the inference of the existence of cointegration relationship between three variables (*Ln(M2)*, *Ln(gdp)*, *Rtf*) at 95% confidence, which is consistent with the inference of hypothesis 1. But when *DF* excluded, compared with the former result (see Table 3C), the result does not apparently change (see column 1-3), and the M2 money demand function remains unstable. Based on the above analysis, we can conclude that digital finance contributes to the instability of the M2 money demand function, thus supporting the corollary of Hypothesis 1. This outcome also indicates that in the process of developing digital finance, it is necessary to improve financial market regulatory systems. Additionally, attention should be paid to the impact of policy changes on people's demand for money in order to prevent money demand from experiencing structural breaks.

Table 4
The Cointegration test for M2 (with the effect of supervision)

Variable	Ln(M2)			Ln(M2)		
	FMOLS	DOLS	CCR	FMOLS	DOLS	CCR
DF				0.0013***	0.0013***	0.0013***
				(26.1053)	(20.0366)	(24.0516)
Dum	-0.0491**	-0.0393**	-0.0511**	0.0172***	0.0159***	0.0167***
	(-2.4219)	(-2.2372)	(-2.5696)	(2.9499)	(2.9496)	(2.8858)
Ln(gdp)	0.4412***	0.5239***	0.4426***	0.4631***	0.5557***	0.4679***
	(6.3847)	(6.5805)	(6.2170)	(6.3339)	(5.5852)	(6.4751)
Rtf	-0.0276***	-0.0242***	-0.0263***	-0.0075***	-0.0092***	-0.0075***
	(-3.4435)	(-3.0017)	(-3.0966)	(-3.9173)	(-4.3966)	(-3.7688)

Constant	4.1994***	3.7876***	4.1897***	5.2584***	5.1324***	5.2384***
Lc statistic	0.0455	0.0319	0.0226	0.5621	0.4593	0.2117
E-G t-statistic	0.6267	0.6267	0.6267	0.0042	0.0042	0.0042
Observations	96	96	96	96	96	96
R2_adj	0.7689	0.8919	0.7699	0.9904	0.9925	0.9902

Notes: The dependent variable is Ln(M2) only, and the regression model applied are FMOLS, DOLS and CCR. T-values are reported in parentheses and *, **, *** denote statistical levels of 10%, 5% and 1% respectively. The presented results of Lc statistics and t-statistics in the table is P-value. Lc statistic is outlined by Hansen(1992), which arise from the theory of Lagrange Multiplier tests for parameter instability, the null hypothesis is cointegration exist. Conversely, the null hypothesis of the Engle-Granger t-statistic is no cointegration.

4.2. Test of hypothesis 2 and 3

As explained in the previous section, we believe that different services of digital finance has important correlation with the cointegration among the variables of money demand function for each measure of money. In this part, we will replace *DF* with two different functional indicators of digital finance (*DPM* and *DPF*) in the system of Eqs. (1)-(2).

For the M0 aggregate, the results in Table 5A demonstrate that, regardless of the estimation method used, the E-G t-statistic indicates that the residual sequence of Eq. (1) rejects the null hypothesis of instability, while the Lc statistic accepts the null hypothesis of stability. Although the estimated cointegration coefficient vectors are different, the cointegration relationship of these three variables (*Ln(M2), Ln(gdp)* and *Rtf*) exist under any estimation method. Therefore, the stability of M0 money demand function does not change with different indicators (*DPM* or *DPF)*. This demonstrates that, while the equilibrium of the money demand function has shifted, neither digital finance indicator has affected the stability of the M0 money demand function. Specifically, taking the FMOLS method as an example, compare Table 3A with Table 5A, we find that when the *DF* variable is replaced with *DFM*, the cointegration vector coefficient changes from $(1,-0.1705,0.0046)^T$ to $(1,-0.1704,0.0054)^T$, which is just slightly higher than the former, indicating that *DF* impact the demand for M0 by payment services mainly. However, when replaced with *DFP* variables, the cointegration vector coefficient of the M0 money demand function becomes $(1,-0.1619,0.0171)^T$, closely matching the vector coefficient $(1,-0.1637,0.018)^T$ that excludes *DF* variables, as shown in Table 3A. Therefore, these estimates also confirm that asset management services do not have a pronounced impact on the M0 demand function.

Next, the Lc and E-G t-statistics shown in columns 1-6 of Table 5B reveal that there is no cointegration among the variables (*Ln(M1)*, *Ln(gdp)*, *Rtf, DPM* or *DPF*), regardless of whether *DPM* or *DPF* is included. As explained by Hypothesis 1, this result may be attributed to the fact that demand deposits, a major component of M1, are primarily influenced by economic fluctuations. Furthermore, when the *DPM* variable is included, the p-value of the E-G t-statistic for the M1 demand function is 0.6641, and all Lc statistics are below 0.1. However, when the *DPF* variable is included, the p-value is 0.8096. This suggests that while neither digital finance indicator can alter the instability of the M1 demand function, the impact of payment service (*DPM*) on M1 is still stronger than that of the asset management service (*DPF*).

Table 5A
Cointegration test about different function of DF (M0)

Variable	Ln(M0)	Ln(M0)

	FMOLS	DOLS	CCR	FMOLS	DOLS	CCR
DPM	0.0009***	0.0008***	0.0009***			
	(7.3865)	(4.9829)	(5.9881)			
DPF				0.0001***	0.0001**	0.0001***
				(4.1793)	(3.3794)	(4.0257)
Ln(gdp）	0.1704**	0.1855**	0.1665**	0.1619**	0.1737**	0.1712**
	(2.0783)	(2.1492)	(2.0541)	(2.0562)	(2.3846)	(2.1111)
Rtf	-0.0054*	-0.0051*	-0.0055*	-0.0171*	-0.0145*	-0.0168*
	(-1.7373)	(-1.7567)	(-1.7559)	(-1.7613)	(-1.7625)	(-1.7537)
Constant	4.7696***	4.6876***	4.7025***	4.2097***	3.9665***	4.1528***
Lc statistic	0.1082	0.1073	0.1023	0.1076	0.1045	0.1032
E-G t-statistic	0.0124	0.0124	0.0124	0.0292	0.0292	0.0292
Observations	96	96	96	96	96	96
R2_adj	0.7482	0.7974	0.7436	0.5882	0.7327	0.5814

Table 5B
Cointegration test about different function of DF (M1)

Variable	Ln(M1)			Ln(M1)		
DPM	0.0013***	0.0012***	0.0012***			
	(12.2307)	(8.7517)	(11.2046)			
DPF				0.0007***	0.0005***	0.0006***
				(4.4645)	(3.6969)	(4.1966)
Ln(gdp）	0.2583***	0.3366***	0.2740***	0.771***	0.6062***	0.6991***
	(6.3121)	(5.3480)	(5.6522)	(7.2912)	(7.9890)	(6.9763)
Rtf	-0.0085*	-0.0092*	-0.0089*	-0.0019	-0.0005	-0.0008
	(-1.7083)	(-1.7005)	(-1.7084)	(-0.2218)	(-0.0587)	(-0.0928)
Constant	4.0964***	3.7433***	4.0252***	3.2388***	2.6390***	3.1353***
Lc statistic	0.0907	0.0121	0.0244	0.0290	0.0890	0.0330
E-G t-statistic	0.6641	0.6641	0.6641	0.8096	0.8096	0.8096
Observations	96	96	96	96	96	96
R2_adj	0.9516	0.9632	0.9502	0.8385	0.9068	0.8324

Table 5C
Cointegration test about different function of DF (M2)

Variable	Ln(M2)			Ln(M2)		
DPM	0.0012***	0.0010***	0.0011***			
	11.8378	7.5545	10.8862			
DPF				0.0007***	0.0006***	0.0007***
				(5.4949)	(4.4507)	(5.2474)
Ln(gdp）	0.1901***	0.2564***	0.2057***	0.3725***	0.4767***	0.3889***
	(4.8956)	(3.9550)	(4.5185)	(6.7709)	(7.4178)	(6.5339)
Rtf	-0.0047	-0.0062	-0.0045	-0.0120	-0.0118	-0.0112
	(-0.9975)	(-1.1089)	(-0.9199)	(-1.6368)	(-1.6606)	(-1.4668)
Constant	5.0294***	4.7467	4.9594***	4.3072***	3.8367***	4.2299***
Lc statistic	0.0077	0.0052	0.0031	0.0061	0.0067	0.0021
E-G t-statistic	0.9635	0.9635	0.9635	0.8886	0.8886	0.8886
Observations	96	96	96	96	96	96
R2_adj	0.9568	0.9620	0.9552	0.8709	0.9249	0.8665

Notes: Notes: The dependent variable is Ln(M2), and the regression model applied are FMOLS, DOLS and CCR. T-values are reported in parentheses and *, **, *** denote statistical levels of 10%, 5% and 1% respectively. The presented results of Lc statistics and t-statistics in the table is P-value. Lc statistic is outlined by Hansen(1992), which arise from the theory of Lagrange Multiplier tests for parameter instability, the null hypothesis is cointegration exist. Conversely, the null hypothesis of the Engle-Granger t-statistic is no cointegration.

Lastly, the results shown in Table 5C demonstrate that regardless of whether the indicator is *DPM* or *DPF*, no cointegration exists as evidenced by the Lc statistic and E-G t-statistic. Based on the analyses of the results shown in Table 3C, the instability of M2, which primarily comprises time deposits designed to meet people's speculative needs, may be associated with changes in China's financial asset regulatory regime. Consequently, we introduce a dummy variable (*Dum*) to account for the impact of Internet regulatory events. The results show that, for *DPM*, compared with the former result (see column1-3 in Table 5C), the result does not apparently change (see column 1-3 in Table 13 Appendix C). However, when the dummy variables are included for *DFP* (see column 4-6 in Table 3 Appendix C), the M2 demand function becomes stable. This result indicates that *DPF* mostly contributes to the instability of the M2 money demand function (as concluded in Hypothesis 1), while *DPM* has minimal impact.

Based on the above analysis, it can be concluded that the effects of digital financial substitution variables on different indicators of monetary demand vary. From *Ln(M0)*, *Ln(M1)* to *Ln(M2)*, excluding the impact of the 2018 digital financial asset management regulatory event, the degree of influence of payment services (*DPM)* on the stability of the money demand function decreases, while conversely, the degree of influence of asset management services *(DPF*) increases. This is largely in line with the inferences from Hypothesis 2 and Hypothesis 3. These results also suggest that policymakers need to pay special attention to the development of digital finance, especially as the rapid growth of financial wealth management products driven by digital finance may disrupt the stability of the money demand function.

4.3 Additional tests

One potential problem with the above study of the stability of money demand function is that the statistics of money demand use the conventional simple-sum monetary aggregate (see Fig.4. and Fig.5). Barnett (1980, 1982) argues that this monetary measurement method implicitly assumes that all components of assets are perfect substitutes for each other, ignoring the liquidity differences that exist between different assets. Thus, Anderson et al. (1997a, 1997b) produced a Divisia monetary aggregate. Compared with the simple-sum measurement, the Divisia monetary aggregate takes into account the difference in liquidity and interest rates of different levels of monetary assets, and calculates the total amount of money based on the proportion of liquidity service expenses provided by each monetary asset to the total expenditure. Several studies (Barnett et al., 2022; Bissoondeeal et al., 2019; Belongia and Ireland, 2015; Hendrickson, 2014) have found that when the Divisia Index is used to measure Money Demand, an equilibrium relationship between money, income, and interest rates in the money demand function is observed. In light of this, we will employ the Chinese Divisia Indexes, as calculated by Barnett and Tang (2016), to delve deeper into the influence of digital finance on the stability of the money demand function. It's important to note that, unlike the Divisia Indexes used in advanced economies, the benchmark interest rate employed by the Divisia Index in China is the one-month bank lending rate. However, since this rate has been fixed since 2015, China's Divisia Indexes is comparatively less sensitive in measuring changes in the interest rates of assets.

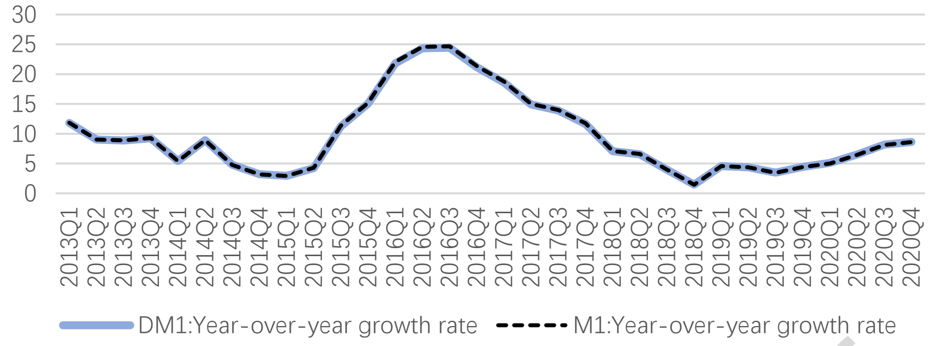

Fig.4. A comparison of the growth rates of two monetary aggregates（M1）

Source：Wind Database

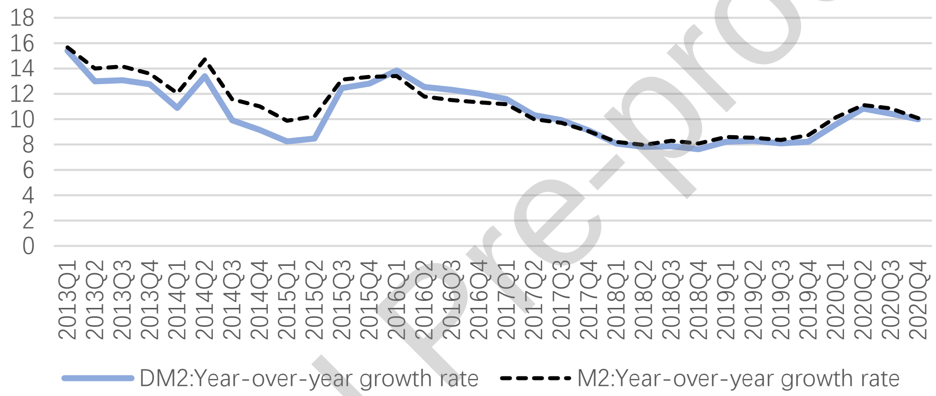

Fig.5. A comparison of the growth rates of two monetary aggregates（M2）

Source：Wind Database

Overall, we can find that, consistent with recent studies (Jin, 2018; Barnett and Tang, 2016), this does improve the stability of money demand function when using Divisia Indexes to measure monetary aggregate. First, it can be seen from the E-G t-statistics and Lc statistics cointegration test results of the Divisia M0 (*DM0*) demand function in Table 6A, which are basically consistent with the M0 cointegration test results in Table 3A, and the *DM0* demand function remains stable regardless of whether *DF* is added or not. Second, the results of Table 6B on Divisia M1 (*DM1*) show that although there is still no cointegration relationship between the three variables of *DM1*, *Ln(gdp)* and *Rtf* in various cases, comparing Tables 6B and 3B, it can be found that the P-value of Lc statistic in Table 6B increases significantly, and the P-value of E-G t-statistic decreases significantly, indicating a significant increase in the likelihood of cointegration. Third, from Table 6C we found that the test results of *DM2* and *Ln(M2)* were inconsistent. Compared with Table 3C and Table 6C, money demand function measured by M2 is unstable excluded *DF*, but the currency demand function measured by Divisia M2 (*DM2*) is stable; while included *DF*, the currency demand function measured by *DM2* remains stable, which shows that the stability of M2 demand function measured by the Divisia index is better than that measured by the simple-sum aggregate. And that stability hasn't changed with digital finance. In addition, we also found that compared to column 1-4 in Table 6C, column 4 Table 3C contains *DF* and *Ln(gdp)* without *DF*, the normalized coefficients for *Rtf* are (0.5819, -0.0331) and (0.6590, -0.0074), the former long-term income elasticity is 4.73 lower than the latter, and the long-term interest rate elasticity is 67.5%, which also shows that the money demand function measured by the Divisia index is less affected by *DF* compared to simple-sum M2. Finally, we further replace *DF* with *DPM* and *DFP* to verify the stability of the *DM2* requirement functions. As Table 7 shows, the stability of the *DM2* demand function has increased relative to Table 5C in both *DFM* and *DFP*, which is consistent with the results of *DF*.

However, we also observe that our findings were somewhat different from those of existing studies. According to Belongia and Ireland (2015) study of the effects of macro monetary policy in the United States using the Divisia Index, the income elasticity and interest rate elasticity of Divisia M2 were significant at level 1 from 2000 to 2013. Barnett et al. (2022) Analysis of the Demand Stability of the Divisia aggregate in the European Union, India, Brazil, Poland and the United Kingdom shows that from 2000 to 2018, the Divisia M3 demand function in these countries showed significant stability, and the income elasticity and interest rate elasticity were almost both significant at M1 level. However, compared to the estimates presented in Table 6C, the income elasticity and interest rate elasticity of China's Divisia M2 are only significant at the 10% level.

The reasons for the aforementioned differences may lie in the unique aspects of monetary demand in China. In the statistical analysis of China's monetary demand, apart from households and private enterprises, a significant proportion includes state-owned enterprises and institutions, which are integral to China's governmental economic structure. Their behaviors related to monetary demand exhibit certain distinct characteristics. For instance, they tend to exhibit a lower sensitivity to interest rates, which markedly influences speculative demand for money. More specifically, for these entities, their optimal decision-making information set for monetary demand might not only encompass income and interest rates, but may also involve other elements such as government administrative orders. These factors could potentially affect the stability of the monetary demand function to a certain extent. Therefore, in the process of determining the supply of money, reference should not only be made to the total demand for money as measured by the Divisia index, but also the distinct behavior of governmental economic entities in their demand for money. This consideration is necessary to enhance the effectiveness of monetary policy.

Table 6A
Cointegration test for Divisia M0

Variable	DM0			DM0		
	FMOLS	DOLS	CCR	FMOLS	DOLS	CCR
DF				1.1829***	1.2040***	1.1753***
				(12.4597)	(8.9882)	(11.5773)
Ln(gdp)	298.7429***	315.8719***	298.8417***	244.8548***	278.5281***	240.3321***
	(4.2912)	(4.0229)	(4.1725)	(3.9583)	(3.5728)	(3.9951)
Rtf	-21.6782**	-18.1421**	-20.4414**	-20.6778**	-18.6874**	-19.6544**
	(-2.4649)	(-2.0945)	(-2.1843)	(-2.3899)	(-2.2315)	(-2.2683)
Constant	-840.9287***	-933.3838***	-845.4189**	883.7499***	1047.0130***	864.2319***
Lc statistic	0.1134	0.1591	0.1532	0.1299	0.1234	0.1048
E-G t-statistic	0.0049	0.0049	0.0049	0.0002	0.0002	0.0002
Observations	96	96	96	96	96	96
R2_adj	0.2180	0.6204	0.2229	0.8259	0.8708	0.8256

Table 6B
Cointegration test for Divisia M1

Variable	DM1			DM1		
DF				2.6854***	2.4217***	2.6522***
				(13.7086)	(8.7615)	(12.6107)
Ln(gdp)	1466.4480***	1638.7350***	1467.6750***	1472.1801***	1644.3539***	1495.5067***
	(9.5023)	(10.2568)	(9.3395)	(8.7795)	(10.5005)	(9.1161)
Rtf	-44.8969**	-28.6523	-41.9120*	-10.6545	-10.0237	-11.2991
	(-2.3029)	(-1.5906)	(-2.0287)	(-1.1376)	(-0.9294)	(-1.1659)
Constant	-5862.7500***	-6741.8160***	-5878.3980***	-2008.1300***	-2758.6680***	-2113.0180***
Lc statistic	0.0298	0.0219	0.0866	0.0912	0.0872	0.0523
E-G t-statistic	0.8756	0.8756	0.8756	0.2584	0.2584	0.2584
Observations	96	96	96	96	96	96
R2_adj	0.6739	0.8674	0.6754	0.9614	0.9668	0.9608

Table 6C
Cointegration test for Divisia M2

Variable	DM2			DM2		
DF				3.3622***	3.2535***	3.3445***
				20.8603	(13.7234)	(19.3212)
Ln(gdp)	1224.9290*	1297.8700*	1278.112*	1329.2433*	1361.9436**	1340.8714*
	(1.7108)	(1.7148)	(1.7115)	(1.9079)	(1.9473)	(1.9036)
Rtf	-83.9488*	-69.6744*	-80.74156*	-75.4731**	-62.7142**	-71.3298**
	(-1.8290)	(-1.8246)	(-1.7911)	(-2.1781)	(-2.1149)	(-1.9086)
Constant	-6006.6480***	-6642.8630***	-6032.341***	-1175.3620***	-1291.6040**	0.9822***
Lc statistic	0.1231	0.1393	0.1507	0.1123	0.1232	0.1385
E-G t-statistic	0.0847	0.0847	0.0847	0.0799	0.0799	0.0799
Observations	96	96	96	96	96	96
R2_adj	0.6706	0.8569	0.6719	0.9823	0.9833	0.9822

Notes: The dependent variable is DM0, DM1 and DM2 respectively, and the regression model applied are FMOLS, DOLS and CCR. T-values are reported in parentheses and *, **, *** denote statistical levels of 10%, 5% and 1% respectively. The presented results of Lc statistics and t-statistics in the table is P-value. L c statistic is outlined by Hansen (1992), which arise from the theory of Lagrange Multiplier tests for parameter instability, the null hypothesis is cointegration exist. Conversely, the null hypothesis of the Engle-Granger t-statistic is no cointegration.

Table 7
Cointegration test about different function of DF (Divisia M2)

Variable	DM2			DM2		
	FMOLS	DOLS	CCR	FMOLS	DOLS	CCR
DPM	2.7075***	2.3445***	2.6151***			
	(7.0388)	(4.3686)	(6.3992)			
DPF				1.5244***	1.1841***	1.4698***
				(3.7716)	(2.8053)	(3.5766)
Ln(gdp)	647.0247***	847.0023***	707.7737***	1106.8040***	1373.6420***	1157.972***
	(4.2202)	(3.3035)	(3.9417)	(6.2719)	(6.3020)	(6.0378)
Rtf	-27.7728	-20.1701	-26.9127	-37.9559*	-35.5086*	-35.0850*
	(-0.9484)	(-0.9189)	(-0.8708)	(-1.8136)	(-1.7713)	(-1.8286)
Constant	-2414.475***	-3280.027***	-2686.559***	-4229.707***	-5445.369***	-4472.855***
Lc statistic	0.0498	0.0532	0.0901	0.1146	0.1219	0.1721
E-G t-statistic	0.9887	0.9887	0.9887	0.0238	0.0238	0.0238

Observations	96	96	96	96	96	96
R2_adj	0.9091	0.9196	0.9057	0.8227	0.8878	0.8171

Notes:The dependent variable is DM2, and the regression model applied are FMOLS, DOLS and CCR. T-values are reported in parentheses and *, **, *** denote statistical levels of 10%, 5% and 1% respectively. The presented results of Lc statistics and t-statistics in the table is P-value. L c statistic is outlined by Hansen (1992), which arise from the theory of Lagrange Multiplier tests for parameter instability, the null hypothesis is cointegration exist. Conversely, the null hypothesis of the Engle-Granger t-statistic is no cointegration.

4.4 Robustness checks

4.4.1 Alternative Income

According to Friedman's theory (1956) of money demand, money demand depends on permanent income and interest rates. In terms of empirical evidence, Hansen (2013) also proposed in summarizing the problem of selecting the income variable of the money demand function, when the monetary demand regression equation includes permanent income and current income, the monetary demand function caused by permanent income is more stable. Therefore, we take Friedman's adaptive expectation method to obtain permanent income (*Ln(inc)*) by using the Koyck transformation of the geometric distributed lag function, then replace it with the income variable *Ln(gdp)* to perform a cointegration test. Table 8A-8C is the test results for hypothesis 1 and the test result for hypotheses 2 and 3 presented in Table 4A-4C Appendix D, all the result shown on both tables indicate that the results remain robust.

Table 8A
Robustness check: Cointegration test of alternative income variables for hypothesis 1(M0)

Variable	Ln(M0)			Ln(M0)		
	FMOLS	DOLS	CCR	FMOLS	DOLS	CCR
DF				0.0001*	0.0002*	0.0001*
				(1.7631)	(1.7691)	(1.7732)
Ln(inc)	0.6279***	0.5310***	0.6430***	0.6593***	0.5455*	0.6737***
	(17.3303)	(15.3753)	(17.0979)	(3.6165)	(1.9748)	(3.6014)
Rtf	-0.0029**	-0.0025**	-0.0025**	-0.0038*	-0.0026*	-0.0036*
	(-2.0118)	(-2.2355)	(-2.2418)	(-1.916)	(-1.9607)	(-1.8948)
Constant	1.8704***	1.8979***	1.8907***	2.1888***	2.6085**	2.1373***
Lc statistic	0.2811	0.2921	0.1922	0.1338	0.2865	0.1152
E-G t-statistic	0.0002	0.0002	0.0002	0.0003	0.0003	0.0003
Observations	96	96	96	96	96	96
R2_adj	0.8218	0.8829	0.8211	0.8243	0.8825	0.8238

Table 8B
Robustness check: Cointegration test of alternative income variables for hypothesis 1(M1)

Variable	Ln(M1)			Ln(M1)		
DF				0.0013***	0.0002	0.0013***
				(3.2251)	(0.3797)	(3.1253)
Ln(inc)	0.4220***	0.7111***	0.2224***	0.2443	1.2119**	0.2531
	(15.0266)	(15.0743)	(15.0768)	(0.6962)	(2.2742)	(0.7048)
Rtf	-0.0055	-0.0058	-0.0058	-0.0027	-0.0020	-0.0026
	(-0.2300)	(-0.2751)	(-0.2683)	(-0.4364)	(-0.2921)	(-0.4103)
Constant	0.0488	0.0912	0.0467	4.3338***	0.8149	4.3023***

Lc statistic	0.0120	0.0238	0.0497	0.0076	0.0078	0.0032
E-G t-statistic	0.9510	0.9510	0.9510	0.2055	0.2055	0.2055
Observations	96	96	96	96	96	96
R2_adj	0.8780	0.9366	0.8778	0.9171	0.9362	0.9170

Table 8C
Robustness check: Cointegration test of alternative income variables for hypothesis 1(M2)

Variable	Ln(M2)			Ln(M2)		
DF				0.0014***	0.0008***	0.0014***
				(7.1157)	(3.2836)	(7.1157)
Ln(inc)	0.2771***	0.2476***	0.2766***	0.6234*	0.5168**	0.671*
	(21.6198)	(27.3580)	(21.7213)	(1.8046)	(2.2851)	(1.8046)
Rtf	-0.0092**	-0.0099***	-0.0091**	-0.0074***	-0.0094***	-0.0076**
	(-2.6014)	(-3.0631)	(-2.1959)	(-2.6014)	(-3.3080)	(-2.6014)
Constant	1.1929***	1.3119***	1.1947***	5.6159***	3.9678***	5.5908***
Lc statistic	0.0213	0.0388	0.0768	0.0309	0.0234	0.0495
E-G t-statistic	0.9190	0.9190	0.9190	0.1084	0.1084	0.1084
Observations	96	96	96	96	96	96
R2_adj	0.9392	0.9808	0.9392	0.9780	0.9856	0.9780

Notes: The dependent variable is Ln(M0), Ln(M1) and Ln(M2) respectively, and the regression model applied are FMOLS, DOLS and CCR. T-values are reported in parentheses and *, **, *** denote statistical levels of 10%, 5% and 1% respectively. The presented results of Lc statistics and t-statistics in the table is P-value.Lc statistic is outlined by Hansen(1992), which arise from the theory of Lagrange Multiplier tests for parameter instability, the null hypothesis is cointegration exist. Conversely, the null hypothesis of the Engle-Granger t-statistic is no cointegration.

4.4.2 Alternative Interest rate

In the baseline results, we use one-month SHIBOR(*Rtf*) as the interest rate variable of money demand function. In this subsection, we use two alternative variables, monthly yield on the one-year Treasury (*Rbd*), an indicator of bond market benchmark interest rate, and Monthly yield of Yu 'ebao money fund (*Rdf*), an indicator of digital financial products interest rate, to measure the interest rate of money demand function. Both of these indicators have the characteristics of high degree of interest rate marketization and are widely accepted by micro market sector. The results of cointegration test by *Rbd* are presented in Tables 9A-9C and Tables 5A-5C Appendix E (the results of cointegration tests using *Rdf* are shown in the Tables 6A-6C Appendix F and Tables 7A-7C Appendix G), both of which are consistent with the results of Table 3A-3C and Tables 5A-5C, confirm that the baseline results are robust with alternative variables of the interest rate.

Table 9A
Robustness check: Cointegration test of alternative interest rate variables for hypothesis 1(M0)

Variable	Ln(M0)			Ln(M0)		
	FMOLS	DOLS	CCR	FMOLS	DOLS	CCR
DF				0.0010***	0.0010***	0.0010***
				(13.0136)	(9.0637)	(11.6557)
Ln(gdp)	0.3202***	0.3342***	0.3140***	0.3312***	0.3492*	0.3538***
	(6.2090)	(6.4164)	(6.2338)	(3.4290)	(1.9360)	(2.7124)
Rbd	-0.0243**	-0.0218**	-0.0243**	-0.0204**	-0.0208**	-0.0214**
	(-2.0551)	(-2.0843)	(-2.0551)	(-2.6246)	(-2.1232)	(-2.0758)

Constant	3.3626***	3.2895***	3.3926***	5.1016***	5.0988***	5.0694***
Lc statistic	0.1231	0.1289	0.1532	0.1201	0.1323	0.1123
E-G t-statistic	0.0037	0.0037	0.0037	0.0011	0.0011	0.0011
Observations	96	96	96	96	96	96
R2_adj	0.2118	0.6481	0.2205	0.8413	0.8806	0.8405

Table 9B
Robustness check: Cointegration test of alternative interest rate variables for hypothesis 1(M1)

Variable	Ln(M1)			Ln(M1)		
DF				0.0012***	0.0011***	0.0012***
				(12.3095)	(7.4785)	(10.9745)
Ln(gdp)	0.5557***	0.5064***	0.5480***	0.6079***	0.6918***	0.6165***
	(11.3866)	(12.7009)	(11.5383)	(4.7321)	(3.6762)	(4.1441)
Rbd	-0.0253	-0.0194	-0.0255*	-0.0065	-0.0051	-0.0064
	(-1.6521)	(-1.5186)	(-1.6793)	(-0.8288)	(-0.5896)	(-0.8294)
Constant	2.1036***	1.8457***	2.1414***	4.3076***	3.9454***	4.2708***
Lc statistic	0.0208	0.0234	0.0798	0.0334	0.0211	0.0342
E-G t-statistic	0.9389	0.9389	0.9389	0.5385	0.5385	0.5385
Observations	96	96	96	96	96	96
R2_adj	0.6391	0.8561	0.6435	0.9520	0.9563	0.9517

Table 9C
Robustness check: Cointegration test of alternative interest rate variables for hypothesis 1(M2)

Variable	Ln(M2)			Ln(M2)		
DF				0.0013***	0.0012***	0.0013***
				(26.5324)	(17.4312)	(23.9276)
Ln(gdp)	0.5904***	0.5219***	0.5823***	0.6302***	0.5730***	0.6364***
	(11.3130)	(12.6166)	(11.4714)	(6.2489)	(4.7624)	(5.5249)
Rbd	-0.0419***	-0.0372***	-0.0424***	-0.0094**	-0.0111***	-0.0094**
	(-2.9708)	(-3.2338)	(-3.0381)	(-2.5300)	(-2.8252)	(-2.5616)
Constant	2.9997***	2.8371***	3.0403***	5.2544***	5.0768***	5.2274***
Lc statistic	0.0277	0.0321	0.0155	0.0123	0.0341	0.0092
E-G t-statistic	0.8546	0.8546	0.8546	0.1318	0.1318	0.1318
Observations	96	96	96	96	96	96
R2_adj	0.6305	0.8622	0.6356	0.9870	0.9889	0.9868

Notes: The dependent variable is Ln(M0), Ln(M1) and Ln(M2) respectively, and the regression model applied are FMOLS, DOLS and CCR. T-values are reported in parentheses and *, **, *** denote statistical levels of 10%, 5% and 1% respectively. The presented results of Lc statistics and t-statistics in the table is P-value.Lc statistic is outlined by Hansen(1992), which arise from the theory of Lagrange Multiplier tests for parameter instability, the null hypothesis is cointegration exist. Conversely, the null hypothesis of the Engle-Granger t-statistic is no cointegration.

4.4.3 The Johansen cointegration test

In addition to the single-equation model, based on the VAR system, the Johansen system framework test (Johansen, 1988, 1991; Johansen and Juselius, 1990) provides another system co-integration test technique. Different from the single-equation model, Johansen test is not based on the stationarity test of regression residual, but on the test of eigenvalues or traces of VAR system, and can judge the number of co-integration relations. Here, we use this technology to test the stability of the money demand function. The test results for hypothesis 1 are shown in Table 10 , and Table 8 Appendix H is the test result for hypothesis 2 and 3. The results show that in almost all cases, the cointegration relationship of *Ln(Mi),Ln(gdp)* and *Rtf* is consistent with the results of the previous single equation model. Moreover, if there is a cointegration relationship, the test results support that there is only one cointegration relationship.

Table 10

Robustness check: The Johansen cointegration test for hypothesis 1

		λ-Max test	Critical value			Trace test	Critical values	
Null hypotheses	Alternative hypotheses	t-statistics	95%	90%	Alternative hypotheses	t-statistics	90%	95%
Test A: M0 demand function								
Cointegrating vector:Ln(M0),Ln(gdp),Rtf								
r=0	r=1	32.4309**	23.4408	25.8232	r≥1	50.5155**	39.7553	42.9152
r≤1	r=2	10.5716	17.2341	19.3870	r≥2	18.0845	23.3423	25.8721
r≤2	r=3	7.5129	10.6663	12.5179	r=3	7.5129	10.6664	12.5178
Cointegrating vector:Ln(M0),Ln(gdp),Rtf,DF								
r=0	r=1	36.1169**	23.4408	25.8232	r≥1	74.1065**	39.7553	42.9152
r≤1	r=2	16.4533	17.2341	19.3870	r≥2	22.9896	23.3423	25.8721
r≤2	r=3	9.5363	10.6663	12.5179	r≥3	9.5363	10.6664	12.5178
Test B: M1 demand function								
Cointegrating vector:Ln(M1),Ln(gdp),Rtf								
r=0	r=1	22.6896	23.4408	25.8232	r≥1	37.2482	39.7553	42.9152
r≤1	r=2	15.5501	17.2341	19.3870	r≥2	22.5587	23.3423	25.8721
r≤2	r=3	4.0086	10.6663	12.5179	r=3	4.0086	10.6664	12.5178
Cointegrating vector:Ln(M1),Ln(gdp),Rtf,DF								
r=0	r=1	23.2865	23.4408	25.8232	r≥1	38.7430	39.7553	42.9152
r≤1	r=2	16.6577	17.2341	19.3870	r≥2	23.2565	23.3423	25.8721
r≤2	r=3	2.7988	10.6663	12.5179	r≥3	2.7988	10.6664	12.5178
Test C: M2 demand function								
Cointegrating vector:Ln(M2),Ln(gdp),Rtf								
r=0	r=1	20.4019	23.4408	25.8232	r≥1	36.1554	39.7553	42.9152
r≤1	r=2	13.8922	17.2341	19.3870	r≥2	18.7535	23.3423	25.8721
r≤2	r=3	4.8613	10.6663	12.5179	r=3	4.8613	10.6664	12.5178
Cointegrating vector:Ln(M2),Ln(gdp),Rtf,DF								
r=0	r=1	22.3963	23.4408	25.8232	r≥1	38.5331	39.7553	42.9152
r≤1	r=2	16.7124	17.2341	19.3870	r≥2	21.8365	23.3423	25.8721
r≤2	r=3	3.1239	10.6663	12.5179	r≥3	3.1239	10.6664	12.5178

Notes: * denotes rejection of the null hypothesis of "no-cointegration" at the 0.1 level; ** denotes rejection of the null hypothesis at the 0.05 level. The result from both test statistics (**λ**-Max and the trace) consistently suggest no evidence for cointegrating (long-run) money demand relationships among real money demand (both LnM1 and LnM2), Ln(gdp), Rtf, DF (included or excluded), while there is a cointegration vector existed for LnM0 demand function, among LnM0, Ln(gdp), Rtf, DF (included or excluded).

4.4.4 Tests for major developing countries

Our findings indicate that the advancement of digital finance may lead to instability in the money demand function. However, can this conclusion be generalized to developing countries in general? We know that changes in institutional or policy structures are likely to be another key factor causing instability in the money demand function in developing countries, and the economic structures and systems differ among various countries. So ,we would like to examine whether the differences in the economic structures and systems of various countries might make our conclusions less robust. To explore this, we conducted empirical testing on the BRICS countries, where digital finance is growing rapidly (Kabakova et al.,2016; Pinochet et al.,2019; Tan et al.,2020; Emara and Zhang, 2021), the cointegration test results are shown in Table 11, while variable definitions, unit root test results and descriptive statistics for each country are detailed in Appendix I of Tables 9A-9B.

The results (see Table 11) revealed that without discounting the impact of digital finance, none of the BRICS countries exhibits a stable money demand function. However, after controlling for the influence of digital finance, the stability of the money demand function in each country has seen a significant increase, yet only Russia and India maintain a stable function, which is consistent with Katircioglu et al.(2022), Adil et al.(2020) and Korhonen and Mehrotra (2017).. Considering the reality of the political and economic environment in each of the BRICS countries, we believe the occurrence of these results is closely related to policy changes in these countries - a conclusion supported by existing literature (Hossain and Arwatchanakarn, 2020;Adil et al.,2022; Shagi and Tochkov, 2022). This result implies that for developing countries, it is crucial not only to pay attention to the impact of technological progress on the stability of the money demand function but also to consider how domestic policy or institutional changes disturb this stability.

Table 11
Cointegration tests of money demand functions for four countries (M2)

Variable	Ln(M2)			Ln(M2)		
	FMOLS	DOLS	CCR	FMOLS	DOLS	CCR
Russia						
DF				0.3851*	0.3974*	0.3742*
				(0.0697)	(0.0755)	(0.0729)
Ln(gdp)	0.5681	0.7236	0.5333	0.5033*	0.6557*	0.4821**
	(1.4944)	(1.1588)	(1.584)	(1.903)	(1.8442)	(2.0043)
Rtf	-0.0219***	-0.0222***	-0.0219***	-0.0199***	-0.0212***	-0.02***
	(-6.4222)	(-5.6470)	(-6.4544)	(-5.5126)	(-5.1166)	(-5.5553)
Constant	10.1847***	11.3218***	9.9293***	9.5109***	10.6291***	9.3609***
Lc statistic	0.0031	0.0027	0.0041	0.2463	0.3212	0.2918
E-G t-statistic	0.5631	0.5630	0.5630	0.0848	0.0849	0.0877
Observations	96	96	96	96	96	96
R2_adj	0.5415	0.5548	0.5429	0.5575	0.5584	0.5579
Brazil						
DF				1.0431***	1.4315***	1.1003***
				(3.3228)	(4.2725)	(3.1137)
Ln(gdp)	1.0445***	1.0218***	1.0443***	1.2354***	1.3182***	1.2493***
	(9.2389)	(7.1236)	(9.2704)	(12.0494)	(10.2647)	(11.1198)
Rtf	-0.0727***	-0.0742***	-0.0728***	-0.0177	-0.0084	-0.015
	(-3.6084)	(-3.3376)	(-3.5537)	(-0.8382)	(-0.37)	(-0.6409)
Constant	0.0882***	0.2202***	0.0894***	-1.391***	-2.0003***	-1.4913**
Lc statistic	0.0342	0.0274	0.0328	0.0320	0.0343	0.0310
E-G t-statistic	0.7888	0.7888	0.7888	0.2351	0.2352	0.2352
Observations	96	96	96	96	96	96
R2_adj	0.866	0.8714	0.866	0.8929	0.92492	0.8924
India						
DF				11.4975***	12.6702***	11.5773***
				(3.0022)	(2.6766)	(2.9639)
Ln(gdp)	0.5372***	0.5327***	0.5375***	0.8625***	0.9034***	0.8646***
	(3.6119)	(3.1216)	(0.1481)	(5.2952)	(4.5614)	(5.2758)
Rtf	-1.1529***	-1.1507***	-1.1539***	-1.2775***	-1.2831***	-1.2806***
	(-4.5761)	(-4.0291)	(0.2525)	(-5.5955)	(-5.2820)	(-5.5826)

Constant	6.9792***	7.0355***	6.9767***	-7.9973	-9.6169	-8.0972
Lc statistic	0.0013	0.0021	0.0042	0.1974	0.1884	0.1925
E-G t-statistic	0.2622	0.2622	0.2622	0.0711	0.0712	0.0712
Observations	96	96	96	96	96	96
R2_adj	0.8867	0.8898	0.8867	0.9046	0.9270	0.9055
South Africa						
DF				-0.9526	-1.4549	-0.9382
				(-0.8121)	(-0.8626)	(-0.7396)
Ln(gdp）	0.2153*	0.2011	0.2159*	0.3530	0.4143	0.3518
	(1.8879)	(1.3979)	(1.8762)	(1.6285)	(1.4416)	(1.5444)
Rtf	-0.0762*	-0.0535	-0.0769	-0.0720	-0.0446	-0.0725
	(-1.6620)	(-0.8681)	(-1.5906)	(-1.6344)	(-0.7212)	(-1.5645)
Constant	10.1880***	10.2791***	10.1840***	9.3757***	9.0034***	9.3796***
Lc statistic	0.0032	0.0041	0.0037	0.0730	0.0733	0.0739
E-G t-statistic	0.3514	0.3514	0.3514	0.1779	0.1779	0.1779
Observations	96	96	96	96	96	96
R2_adj	0.299	0.446	0.297	0.414	0.699	0.413

Notes: The dependent variable is Ln(M0), Ln(M1) and Ln(M2) respectively, and the regression model applied are FMOLS, DOLS and CCR. T-values are reported in parentheses and *, **, *** denote statistical levels of 10%, 5% and 1% respectively. The presented results of Lc statistics and t-statistics in the table is P-value.Lc statistic is outlined by Hansen(1992), which arise from the theory of Lagrange Multiplier tests for parameter instability, the null hypothesis is cointegration exist. Conversely, the null hypothesis of the Engle-Granger t-statistic is no cointegration.

5.Conclusion

In this study, we explore the significant impact of rapidly developing digital finance on the stability of money demand function, an issue critical for choosing appropriate intermediary targets of monetary policy and enhancing its effectiveness in developing countries. Utilizing China as our case study due to its leading growth in digital finance, we establish empirical evidence of digital finance's influence, and its two services, on the stability of money demand function across various measures of monetary aggregates. Our dataset spans from January 2013 to December 2020, capturing significant technological and economic changes.

The results show that there is heterogeneity in the effect of digital finance on the stability of money demand function for different measures of monetary aggregate. First, different from the previous literatures drawing conclusion on the instability of M0 demand function in developing countries, we find that although digital finance changes people's payment habits, it only changes people's desired money demand, while the M0 demand function is still stable and identifiable. Second, the M1 money demand function remains unstable. We consider that this is mainly because M1 demand is closely related to the economic activity of enterprises in China, as the economic activity of enterprises is greatly affected by macroeconomic fluctuations, the impact of digital finance on its stability is relatively weak. Third, after excluding the effect of institutional change factors, we come to the conclusion that digital finance is an essential ingredient affecting the stability of M2 demand function. The main reason is that the assets management service of digital finance affects people's speculative money demand. More specifically, we find that the impact of payment service on the stability of money demand function decreases with the rise of monetary aggregate measures, while assets management service runs to the opposite. Furthermore, consistent with the previous research, after adopting Divisia index, the stability of money demand function in China has improved in all cases, although the range is relatively small.

While this study primarily focuses on China, the methods and conclusions drawn are broadly applicable and provide valuable insights for the study of money demand functions in other developing countries. On the one hand, different from the previous literatures which study the impact of financial innovation on the stability of money demand function by comparing the effects in different periods (Haug, 2006; Cuthbertson, 1991; Hafer and Jansen, 1991; Coenen and Vega, 2001), we regard digital finance as a factor that may change the trend of concerned variables and introduce it into cointegration equation. When financial innovation metrics are available, this technology can more effectively evaluate the impact of digital finance on the stability of money demand function.

On the other hand, our research also has the following policy implications for developing countries. Firstly, enhancing the stability of the money demand function can be achieved by using the Divisia index to measure the monetary aggregate. Secondly, as financial innovation leads to an increase in financial products, policymakers should be mindful of its potential impact on the stability of money demand. While improving the regulatory system for these products is necessary, the pace of reform should also be carefully managed to avoid exacerbating speculative demand and causing structural disruptions in money demand trends. Finally, for developing countries, it's essential to promote financial market reforms to ensure a smooth transmission of monetary policy via interest rate channels, so as to enhance the effectiveness of price-based monetary policy, particularly in scenarios when financial innovation lead to instability in the monetary demand function.

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Appendix

Appendix A:

Table1

Variable definitions and descriptive statistics(N=96)

Varibable	Definition	Mean	Median	Std.Dev	Min	Max
DM0	Divisia M0	505.61	507.38	67.99	401.79	693.19
DM1	Divisia M1	972.02	1019.81	220.66	636.91	1339.89
DM2	Divisia M2	1206.64	1217.47	265.09	787.00	1686.51
Ln(inc)	Ln (Permanent income)	3.93	3.93	0.07	3.80	4.04
Rbd	Ln (One-month Treasury yields)	2.84	2.75	0.59	1.26	4.08
Rdf	Ln (Monthly yield of Yu 'e Bao)	3.43	3.49	1.15	1.39	6.58

Appendix B:

Table 2

Unit-root test

Variable		Levels		First Difference		Multiple Breakpoint tests	
		ADF	PP	ADF	PP	IO	AO
DM0	Intercept	1.46	-2.04	-8.56***	-19.68***	-10.77***	-12.32***
	Trend&Int	-2.19	-3.45	-9.53***	-20.15***	-11.90***	-12.20***
DM1	Intercept	-0.01	0.27	-1.481	-13.08***	-13.61***	-13.97***
	Trend&Int	-1.79	-2.25	-1.483	-13.02***	-13.49***	-14.50***
DM2	Intercept	3.45	3.41	5.75	-15.56***	-3.79**	-3.77**
	Trend&Int	-1.09	-3.43	-1.09	-16.46***	-3.81**	-3.97**
Ln(inc)	Intercept	-1.73	-0.57	-3.08**	-10.62***	-3.76**	-3.99**
	Trend&Int	-1.06	-2.71	-4.22**	-10.36***	-4.26**	-4.07**
Rbd	Intercept	-2.43	-2.10	-7.45***	-7.38***	-8.26***	-7.94***
Rdf	Intercept	-3.22	-1.38	-9.77***	-9.85***	-10.20***	-11.10***

Notes: ADF and PP are, respectively, the Augmented Dicky-Fuller and Phillips-Perron test for the null hypothesis that the series are nonstationary. Except for Rbd and Rdf, other time series are considered to contain trend items. IO and AO are, respectively, tests proposed by Perron (1989), and Intercept denotes for allowing structural breaks in intercept trends and Trend&Int allows for structural breaks in both intercept and trend terms. To save space, this table presents the unit root test results of main variables, the other variables' unit-root test results present in Appendix B. Significance levels at 10%, 5% and 1% levels are denoted by *, **, ***, respectively.

Appendix C:

Table 3

The Cointegration test for M2 includes two indicators of DF (with the effect of supervision)

Variable	Ln(M2)			Ln(M2)		
	FMOLS	DOLS	CCR	FMOLS	DOLS	CCR
DPM	0.0011***	0.0010***	0.0011***			
	(14.9907)	(9.9517)	(13.7985)			
DPF				0.0008***	0.0007***	0.0008***
				(12.5811)	(9.3388)	(11.9318)
Dum	-0.0380***	-0.0363***	-0.0379***	-0.0745***	-0.0648***	-0.0736***
	(-4.6432)	(-4.2337)	(-4.6919)	(-8.5204)	(-7.0888)	(-8.3468)

Ln(gdp)	0.1240***	0.1650***	0.1316***	0.1732**	0.2597***	0.1848***
	(4.2926)	(3.1104)	(3.8161)	(5.4320)	(5.3388)	(5.0377)
Rtf	-0.0014	-0.0031	-0.0013	-0.0009**	-0.0012**	-0.0012**
	(-0.3993)	(-0.7446)	(-0.3627)	(-2.2352)	(-2.2657)	(-2.2888)
Constant	5.3696***	5.1986***	5.3359***	5.2369***	4.8448***	5.1827***
Lc statistic	0.0422	0.0637	0.0821	0.1451	0.1321	0.1191
E-G t-statistic	0.1584	0.1584	0.1584	0.0066	0.0066	0.0066
Observations	96	96	96	96	96	96
R2_adj	0.9761	0.9772	0.9758	0.9608	0.9695	0.9599

Notes: The dependent variable is Ln(M2), the regression model applied are FMOLS, DOLS and CCR. T-values are reported in parentheses and *, **, *** denote statistical levels of 10%, 5% and 1% respectively. The presented results of Lc statistics and t-statistics in the table is P-value.Lc statistic is outlined by Hansen(1992), which arise from the theory of Lagrange Multiplier tests for parameter instability, the null hypothesis is cointegration exist. Conversely, the null hypothesis of the Engle-Granger t-statistic is no cointegration.

Appendix D:

Table 4A

Robustness check: Cointegration test of alternative income variables for hypothesis 2 and 3(M0)

Variable	**Ln(M0)**			**Ln(M0)**		
	FMOLS	DOLS	CCR	FMOLS	DOLS	CCR
DPM	0.0002**	0.0002**	0.0002**			
	(1.9353)	(1.9256)	(1.9373)			
DPF				0.0001*	0.0001*	0.0001*
				(1.7871)	(1.7879)	(1.7855)
Ln(inc)	0.8671***	0.8496***	0.8703***	0.7111***	0.6746***	0.7122***
	(7.3735)	(6.9613)	(7.2473)	(9.0178)	(10.0404)	(8.9644)
Rbd	-0.0024**	-0.0037**	-0.0023**	-0.0008*	-0.0012*	-0.0008*
	(-1.9725)	(-1.9719)	(-1.9639)	(-1.7988)	(-1.7911)	(-1.8003)
Constant	1.4651***	1.5295***	1.4525***	2.0264***	2.1624***	2.0224***
Lc statistic	0.1763	0.1741	0.1701	0.2881	0.2879	0.2021
E-G t-statistic	0.0001	0.0001	0.0001	0.0012	0.0012	0.0012
Observations	96	96	96	96	96	96
R2_adj	0.8120	0.8841	0.8121	0.8155	0.8823	0.8155

Table 4B

Robustness check: Cointegration test of alternative income variables for hypothesis 2 and 3(M1)

Variable	**Ln(M1)**			**Ln(M1)**		
DPM	0.0009***	0.0007***	0.0009***			
	(4.0866)	(3.0881)	(4.0790)			
DPF				0.0001	0.0001	0.0001
				(0.8343)	(0.5875)	(0.8414)
Ln(inc)	0.6661***	0.8541***	0.6735***	1.3122***	1.3738***	1.3128***
	(3.5340)	(4.3650)	(3.5287)	(9.4320)	(11.4740)	(9.4186)
Rbd	-0.0184**	-0.0167**	-0.0184**	-0.0130	-0.0117	-0.0130
	(-2.2736)	(-2.1746)	(-2.3194)	(-1.2768)	(-1.2722)	(-1.2950)
Constant	2.7680***	2.0810***	2.7404***	0.4213	0.1951	0.4189
Lc statistic	0.0245	0.0231	0.0172	0.0319	0.0451	0.0283
E-G t-statistic	0.6215	0.6215	0.6215	0.9103	0.9103	0.9103
Observations	96	96	96	96	96	96

R2_adj	0.9251	0.9562	0.9249	0.8881	0.9437	0.8880

Table 4C
Robustness check: Cointegration test of alternative income variables for hypothesis 2 and 3 (M2)

Variable	**Ln(M2)**			**Ln(M2)**		
DPM	0.0005***	0.0003**	0.0005***			
	(3.0331)	(2.1823)	(3.1721)			
DPF				0.0002*	0.0001*	0.0002*
				1.8539	(1.9340)	(1.9113)
Ln(inc)	0.8830***	1.0604***	0.8784***	1.1707***	1.2172***	1.1690***
	(6.0161)	(8.6858)	(6.0353)	(12.6414)	(19.6153)	(12.7038)
Rbd	-0.0030	-0.0060	-0.0027	-0.0037	-0.0062	-0.0036
	(-0.4807)	(-1.2546)	(-0.4389)	-0.5412	(-1.2943)	(-0.5359)
Constant	0.0005***	1.9601***	2.6148***	1.5509***	1.3883***	1.5566***
Lc statistic	0.0021	0.0023	0.0021	0.0239	0.0321	0.0120
E-G t-statistic	0.9979	0.9979	0.9979	0.6764	0.6764	0.6764
Observations	96	96	96	96	96	96
R2_adj	0.9542	0.9808	0.9543	0.9428	0.9801	0.9428

Notes:The dependent variable is Ln(M0),Ln(M1) and Ln(M2) respectively, and the regression model applied are FMOLS, DOLS and CCR. T-values are reported in parentheses and *, **, *** denote statistical levels of 10%, 5% and 1% respectively. The presented results of Lc statistics and t-statistics in the table is P-value.Lc statistic is outlined by Hansen(1992), which arise from the theory of Lagrange Multiplier tests for parameter instability, the null hypothesis is cointegration exist. Conversely, the null hypothesis of the Engle-Granger t-statistic is no cointegration.

Appendix E:

Table 5A
Robustness check: Cointegration test of alternative interest rate variables (Rbd) for hypothesis 2 and 3(M0)

Variable	Ln(M0)			Ln(M0)		
	FMOLS	DOLS	CCR	FMOLS	DOLS	CCR
DPM	0.0008***	0.0008***	0.0008***			
	(7.2871)	(4.8252)	(6.4038)			
DPF				0.0005***	0.0004***	0.0005***
				(4.2223)	(3.4792)	(3.8679)
Ln(gdp)	0.0330*	0.0029*	0.0137*	0.1175**	0.1775***	0.1320**
	(1.6899)	(1.8362)	(1.8451)	(2.2271)	(2.7349)	(2.3397)
Rbd	-0.0015*	-0.0002*	-0.0012*	-0.0047*	-0.0056*	-0.0047*
	(-1.8611)	(-1.8760)	(-1.8754)	(-1.7760)	(-1.7949)	(-1.7892)
Constant	4.7909***	4.6392	4.7071***	4.1781***	3.9090***	4.1143***
Lc statistic	0.1301	0.1342	0.1282	0.1231	0.1213	0.1311
E-G t-statistic	0.0120	0.0120	0.0120	0.0291	0.0291	0.0291
Observations	96	96	96	96	96	96
R2_adj	0.7430	0.7945	0.7361	0.5866	0.7403	0.5746

Table 5B
Robustness check: Cointegration test of alternative interest rate variables (Rbd) for hypothesis 2 and 3(M1)

	Ln(M1)			Ln(M1)		
DPM	0.0013***	0.0012***	0.0012***			
	(13.2077)	(9.1035)	(11.6979)			
DPF				0.0007***	0.0006***	0.0007***

				(4.8305)	(4.0213)	(4.3623)
Ln(gdp)	0.2344***	0.3065***	0.2466***	0.4791***	0.6023***	0.5016***
	(5.8463)	(4.7580)	(5.1304)	(7.4450)	(8.2313)	(7.1253)
Rbd	-0.0145*	-0.0132*	-0.0141*	-0.0025	-0.0017	-0.0020
	(-1.9185)	(-1.7193)	(-1.8890)	(-0.1858)	(-0.1471)	(-0.1454)
Constant	4.1991***	3.8824***	4.1469***	3.2103***	2.6529***	3.1124***
Lc statistic	0.0023	0.0039	0.0076	0.0026	0.0045	0.0034
E-G t-statistic	0.5689	0.5689	0.5689	0.8930	0.8930	0.8930
Observations	96	96	96	96	96	96
R2_adj	0.9547	0.9640	0.9539	0.8385	0.9066	0.8318

Table 5C
Robustness check: Cointegration test of alternative interest rate variables (Rbd) for hypothesis 2 and 3(M2)

Variable	Ln(M2)			Ln(M2)		
DPM	0.0012***	0.0011***	0.0011***			
	(12.5526)	(8.0322)	(10.8946)			
DPF				0.0007***	0.0006***	0.0007
				(5.9790)	(5.0915)	(5.4719)
Ln(gdp)	0.1956***	0.2661***	0.1995***	0.3986***	0.5060***	0.4186
	(4.9542)	(3.9978)	(4.3205)	(7.3141)	(8.2795)	(7.0724)
Rbd	-0.0049	-0.0075	-0.0036	-0.0132	-0.0149	-0.0137
	(-0.6656)	(-0.9495)	(-0.6873)	(-1.1380)	(-1.5043)	(-1.2034)
Constant	4.9949***	4.6940***	4.9834***	4.1703***	3.6907***	4.0833
Lc statistic	0.0076	0.0075	0.0045	0.0024	0.0025	0.0047
E-G t-statistic	0.9648	0.9648	0.9611	0.7153	0.7153	0.7153
Observations	96	96	96	96	96	96
R2_adj	0.9561	0.9615	0.9580	0.8657	0.9253	0.8595

Notes: The dependent variable is Ln(M0), Ln (M1) and Ln(M2) respectively, and the regression model applied are FMOLS, DOLS and CCR. T-values are reported in parentheses and *, **, *** denote statistical levels of 10%, 5% and 1% respectively. The presented results of Lc statistics and t-statistics in the table is P-value.Lc statistic is outlined by Hansen(1992), which arise from the theory of Lagrange Multiplier tests for parameter instability, the null hypothesis is cointegration exist. Conversely, the null hypothesis of the Engle-Granger t-statistic is no cointegration.

Appendix F:

Table 6A
Robustness check: Cointegration test of alternative interest rate variables (Rdf) for hypothesis 1(M0)

Variable	Ln(M0)			Ln(M0)		
	FMOLS	DOLS	CCR	FMOLS	DOLS	CCR
DF				0.001***	0.001***	0.001***
				(15.0126)	(11.7163)	(14.5595)
Ln(gdp)	0.2060***	0.2366***	0.2132***	0.1243***	0.1632***	0.1244***
	(3.1145)	(3.2671)	(3.1057)	(4.6068)	(3.4810)	(3.9461)
Rdf	-0.0199**	-0.0177**	-0.0186**	-0.0020*	-0.0028*	-0.0018*
	(-2.5461)	(-2.4387)	(-2.2987)	(-1.9043)	(-1.9133)	(-1.9585)
Constant	3.9079***	3.7544***	3.8692***	5.1735***	5.3501***	5.1727***
Lc statistic	0.2286	0.2212	0.2381	0.2521	0.2336	0.2323
E-G t-statistic	0.0142	0.0142	0.0142	0.0001	0.0001	0.0001
R2_adj	0.3168	0.6469	0.3129	0.8401	0.9141	0.8403

Table 6B

Robustness check: Cointegration test of alternative interest rate variables (Rdf) for hypothesis 1(M1)

Variable	Ln(M1)			Ln(M1)		
DF				0.0012***	0.0011***	0.0012***
				(11.2271)	(7.4699)	(10.7350)
Ln(gdp)	0.6310***	0.7357***	0.6393***	0.2179***	0.3044***	0.2266***
	(7.3017)	(8.4846)	(7.2020)	(4.7800)	(3.8387)	(4.2702)
Rdf	-0.0214**	-0.0143	-0.0200*	-0.0015	-0.0018	-0.0018
	(-2.0955)	(-1.6465)	(-1.8986)	(-0.2652)	(-0.2984)	(-0.3249)
Constant	2.7005***	2.1769***	2.6562***	4.2799***	3.8982***	4.2400***
Lc statistic	0.0222	0.0323	0.0628	0.0295	0.0453	0.0445
E-G t-statistic	0.9439	0.9439	0.9439	0.5447	0.5447	0.5447
R2_adj	0.6907	0.8571	0.6881	0.9505	0.9563	0.9501

Table 6C

Robustness check: Cointegration test of alternative interest rate variables (Rdf) for hypothesis 1(M2)

Variable	Ln(M2)			Ln(M2)		
DF				0.0012***	0.0012***	0.0012***
				(26.8232)	(18.9405)	(25.7835)
Ln(gdp)	0.1220***	0.1935***	0.1286***	0.1019***	0.1258***	0.1058***
	(6.5453)	(7.4297)	(6.4808)	(5.2552)	(3.7087)	(4.7064)
Rdf	-0.0318***	-0.0262***	-0.031***	-0.0086***	-0.0088***	-0.0084***
	(-3.3658)	(-3.2720)	(-3.1763)	(-3.6276)	(-3.5049)	(-3.5510)
Constant	3.7928***	3.4329***	3.7578***	5.4002***	5.2998***	5.3823***
Lc statistic	0.0253	0.0231	0.0711	0.0821	0.0819	0.0859
E-G t-statistic	0.8253	0.8253	0.8253	0.4371	0.4371	0.4371
R2_adj	0.7014	0.8606	0.6993	0.9897	0.9904	0.9896

Notes: The dependent variable is Ln(M0), Ln(M1) and Ln(M2) respectively, and the regression model applied are FMOLS, DOLS and CCR. T-values are reported in parentheses and *, **, *** denote statistical levels of 10%, 5% and 1% respectively, Lc statistic is outlined by Hansen (1992), which arise from the theory of Lagrange Multiplier tests for parameter instability, the null hypothesis is cointegration exist. But the null hypothesis of the Engle-Granger t-statistic is no cointegration. The presented results of Lc statistics and t-statistics in the table is P-value.

Appendix G:

Table 7A

Robustness check: Cointegration test of alternative interest rate variables (Rdf) for hypothesis 2 and 3(M0)

Variable	Ln(M0)			Ln(M0)		
	FMOLS	DOLS	CCR	FMOLS	DOLS	CCR
DPM	0.0008***	0.0008***	0.0008***			
	(7.2427)	(5.3912)	(6.9812)			
DPF				0.0005***	0.0005***	0.0005***
				(4.0579)	(3.5715)	(4.0009)
Ln(gdp)	0.0387**	0.0351*	0.0268*	0.0944*	0.1343*	0.1073*
	(1.9463)	(1.8652)	(1.8100)	(1.8043)	(1.8897)	(1.8139)
Rdf	-0.0002***	-0.0007**	-0.0004**	-0.0045*	-0.0042*	-0.0032*
	(-2.8389)	(-2.2156)	(-2.1598)	(-1.8847)	(-1.8609)	(-1.7167)
Constant	4.8214***	4.8108***	4.7653***	4.2901***	4.1080***	4.2257***
Lc statistic	0.5641	0.5311	0.4351	0.3345	0.4129	0.3149

E-G t-statistic	0.0124	0.0124	0.0124	0.0311	0.0311	0.0311
R2_adj	0.7431	0.8186	0.7406	0.5971	0.7460	0.5904

Table 7B
Robustness check: Cointegration test of alternative interest rate variables (Rdf) for hypothesis 2 and 3(M1)

Variable	Ln(M1)			Ln(M1)		
DPM	0.0013***	0.0011***	0.0012***			
	(11.7831)	(9.1070)	(11.2136)			
DPF				0.0007***	0.0006***	0.0007***
				(4.4248)	(4.0081)	(4.2720)
Ln(gdp)	0.2724***	0.3581***	0.2872***	0.4796***	0.6085***	0.5000***
	(6.4215)	(5.7638)	(5.8323)	(6.8091)	(7.7270)	(6.5922)
Rdf	-0.0092	-0.0093*	-0.0096*	-0.0004	-0.6085	-0.0016
	(-1.6470)	(-1.7427)	(-1.7165)	(-0.0435)	(-0.2934)	(-0.1655)
Constant	4.0266***	3.6448***	3.9593***	3.2147***	2.6166***	3.1170***
Lc statistic	0.0823	0.0891	0.082	0.0231	0.0317	0.0283
E-G t-statistic	0.7003	0.7003	0.7003	0.9096	0.9096	0.9096
R2_adj	0.9509	0.9640	0.9496	0.8384	0.9064	0.8329

Table 7C
Robustness check: Cointegration test of alternative interest rate variables (Rdf) for hypothesis 2 and 3(M2)

Variable	Ln(M2)			Ln(M2)		
DPM	0.0012***	0.0011***	0.0011***			
	(11.4475)	(8.1170)	(10.8946)			
DPF				0.0007***	0.0006***	0.0007***
				(5.4259)	(4.8150)	(5.2727)
Ln(gdp)	0.1847***	0.2446***	0.1995***	0.3593***	0.4600***	0.3747***
	(4.6018)	(3.7987)	(4.3205)	(6.0364)	(6.6872)	(5.9109)
Rdf	-0.0040	-0.0044	-0.0036	-0.0097	-0.0086	-0.0089
	(-0.7637)	(-0.8047)	(-0.6873)	(-1.1799)	(-1.1812)	(-1.0751)
Constant	5.0512***	4.7892***	4.9834***	4.3566***	3.8944***	4.2831***
Lc statistic	0.0773	0.0731	0.0789	0.0988	0.0921	0.0801
E-G t-statistic	0.9611	0.9611	0.9611	0.6991	0.6991	0.6991
R2_adj	0.9571	0.9616	0.9556	0.8731	0.9212	0.8690

Notes: The dependent variable is Ln(M0), Ln(M1) and Ln(M2) respectively, and the regression model applied are FMOLS, DOLS and CCR. T-values are reported in parentheses and *, **, *** denote statistical levels of 10%, 5% and 1% respectively. The presented results of Lc statistics and t-statistics in the table is P-value. Lc statistic is outlined by Hansen (1992), which arise from the theory of Lagrange Multiplier tests for parameter instability, the null hypothesis is cointegration exist. But the null hypothesis of the Engle-Granger t-statistic is no cointegration.

Appendix H:

Table 8
Robustness check: The Johansen cointegration test for hypothesis 2 and 3

		λ-Max test	Critical value			Trace test	Critical values	
Null hypotheses	Alternative hypotheses	t-statistics	95%	90%	Alternative hypotheses	t-statistics	90%	95%
Test A: M0 demand function								
Cointegrating vector: Ln(M0), Ln(gdp), Rtf, DPM								
r=0	r=1	36.5139**	23.4408	25.8232	r≥1	63.7991**	39.7553	42.9152
r≤1	r=2	19.7419	17.2341	19.3870	r≥2	22.2853	23.3423	25.8721
r≤2	r=3	7.54339	10.6663	12.5179	r≥3	7.5434	10.6664	12.5178
Cointegrating vector:								

Ln(M0), Ln(gdp), Rtf, DPF								
r=0	r=1	34.2339**	23.4408	25.8232	r≥1	57.2021**	39.7553	42.9152
r≤1	r=2	15.3825	17.2341	19.3870	r≥2	22.9682	23.3423	25.8721
r≤2	r=3	7.5857	10.6663	12.5179	r≥3	7.5857	10.6664	12.5178
Test B: M1 demand function								
Cointegrating vector: Ln(M1), Ln(gdp), Rtf, DPM								
r=0	r=1	22.0551	23.4408	25.8232	r≥1	35.4559	39.7553	42.9152
r≤1	r=2	16.9238	17.2341	19.3870	r≥2	23.2007	23.3423	25.8721
r≤2	r=3	6.4770	10.6663	12.5179	r≥3	6.4770	10.6664	12.5178
Cointegrating vector: Ln(M1), Ln (gdp), Rtf,DPF								
r=0	r=1	23.2232	23.4408	25.8232	r≥1	36.1440	39.7553	42.9152
r≤1	r=2	15.3870	17.2341	19.3870	r≥2	22.3830	23.3423	25.8721
r≤2	r=3	8.5179	10.6663	12.5179	r≥3	4.8127	10.6664	12.5178
Test C: M2 demand function								
Cointegrating vector: Ln(M2), Ln(gdp), Rtf, DPM								
r=0	r=1	19.4711	23.4408	25.8232	r≥1	33.8026	39.7553	42.9152
r≤1	r=2	15.077	17.2341	19.3870	r≥2	22.3316	23.3423	25.8721
r≤2	r=3	5.2546	10.6663	12.5179	r≥3	5.2546	10.6664	12.5178
Cointegrating vector: Ln(M2), Ln(gdp), Rtf, DPF								
r=0	r=1	22.6290	23.4408	25.8232	r≥1	38.7676	39.7553	42.9152
r≤1	r=2	15.3493	17.2341	19.3870	r≥2	20.1386	23.3423	25.8721
r≤2	r=3	4.7893	10.6663	12.5179	r≥3	4.7893	10.6664	12.5178

Notes: Notes: * denotes rejection of the null hypothesis of "no-cointegration" at the 0.1 level; ** denotes rejection of the null hypothesis at the 0.05 level. The result from both test statistics (λ-Max and the trace) consistently suggest no evidence for cointegrating (long-run) money demand relationships among real money demand (both LnM1 and LnM2), Ln (gdp), Rtf, DPM or DPF, while there is a cointegration vector existed for LnM0 demand function respectively, among LnM0, Ln(gdp), Rtf, DPM or DPF.

Appendix I:

Given the absence of direct metrics to measure digital finance progress for the four BRICS countries, we sought to establish a comparative basis for our investigation. In this effort, we incorporated global database information and adopted a commonly used approach in existing literature (Malik and Aslan, 2010; Liao and Tapsoba,2014; Dunne and Kasekende,2018; Nnyanzi, 2018), utilizing the M1/M2 ratio as a proxy for digital finance. We also selected monthly data from the period of 2013 to 2020 as our sample range for evaluation.

Table 9A
Variable definitions and descriptive statistics of four developing countries

Russia						
Variable	Definition	Mean	Median	Std.Dev	Min	Max
DF	M1/M2	0.47	0.47	0.02	0.45	0.54
Ln(M2)	Ln (real aggregate of M2)	5.84	5.85	0.08	5.65	5.98
Ln(gdp)	Ln (real GDP)	7.3	7.3	0.03	7.24	7.36
Rtf	Inter-Bank Offered Rate	9.22	8.32	3.1	4.23	21.91
Brazil						
Variable	Definition	Mean	Median	Std.Dev	Min	Max
DF	M1/M2	0.33	0.33	0.02	0.31	0.38
Ln(M2)	Ln (real aggregate of M2)	6.02	6	0.07	5.9	6.22
Ln(gdp)	Ln (real GDP)	5.73	5.73	0.05	5.6	5.84

Variable	Definition	Mean	Median	Std.Dev	Min	Max
Rtf	Inter-Bank Offered Rate	0.71	0.72	0.29	0.15	1.22

India

Variable	Definition	Mean	Median	Std.Dev	Min	Max
DF	M1/M2	0.97	0.97	0.01	0.96	0.98
Ln(M2)	Ln (real aggregate of M2)	12.73	12.71	0.26	12.31	13.22
Ln(gdp)	Ln (real GDP)	11.95	11.96	0.22	11.55	12.30
Rtf	Inter-Bank Offered Rate	0.57	0.56	0.13	0.35	0.75

South Africa

Variable	Definition	Mean	Median	Std.Dev	Min	Max
DF	M1/M2	0.59	0.60	0.03	0.54	0.63
Ln(M2)	Ln (real aggregate of M2)	12.18	12.19	0.09	11.93	12.38
Ln(gdp)	Ln (real GDP)	9.97	9.98	0.14	9.69	10.19
Rtf	Inter-Bank Offered Rate	1.99	2.13	0.34	1.17	2.33

Notes: This table shows the summary Statistics and definitions for main variables used in empirical analyses. The other variables' summary Statistics and definitions are presented in Appendix A.

Table 9B
Unit-root test for four countries' variables

Russia

Variable		Levels		First Difference		Multiple Breakpoint tests	
		ADF	PP	ADF	PP	IO	AO
DF	Intercept	-1.83	-1.82	-9.78***	-9.78***	-2.56	-2.63
	Trend&Int	-0.58	-0.35	-10.10***	-10.09***	-3.46	-3.47
Ln(M2)	Intercept	-1.7	-1.77	-8.08***	-8.12***	-2.23	-2.25
	Trend&Int	-1.57	-1.57	-8.12***	-8.16***	-4.89	-4.79
Ln(gdp)	Intercept	-0.72	-1.02	-3.54***	-4.08***	-3.37	-6.88***
	Trend&Int	-1.53	-1.24	-2.22*	-4.03**	-3.49	-7.15***
Rtf	Intercept	-1.8	-1.9	-8.02***	-7.95***	-2.56	-2.55

Brazil

Variable		Levels		First Difference		Multiple Breakpoint tests	
		ADF	PP	ADF	PP	IO	AO
DF	Intercept	-2.01	-1.55	-0.46	-12.42***	-3.95	-4.02
	Trend&Int	-1.09	-1.86	-1.98*	-14.53***	-5.12*	-4.67
Ln(M2)	Intercept	-1.7	1.79	-2.17**	-10.48***	-2.83	-3.28
	Trend&Int	0.34	0.41	-1.51	-10.43***	-3.22	-1.52
Ln(gdp)	Intercept	-1.53	-1.13	-7.5***	-20.98***	-2.83	-3.28
	Trend&Int	-2.8	-2.38	-7.57***	-21.44***	-7.25***	-9.06
Rtf	Intercept	-0.01	-0.26	-4.5***	-15.73***	-3.62	-2.38

India

Variable		Levels		First Difference		Multiple Breakpoint tests	
		ADF	PP	ADF	PP	IO	AO
DF	Intercept	-1.33	-1.19	-8.06***	-8.17***	-7.66***	-3.17
	Trend&Int	-2.21	-2.61	-8.02***	-8.12***	-8.90***	-3.85
Ln(M2)	Intercept	-0.38	-0.02	-7.48***	-8.90***	-3.08	-3.04

	Trend&Int	-1.11	-2.24	-7.49***	-8.97***	-5.88***	-5.38***
Ln(gdp)	Intercept	-0.97	-0.78	-6.87***	-10.34***	-3.08	-2.06
	Trend&Int	-3.35*	-3.45*	-7.06***	-10.26***	-10.86***	-4.52
Rtf	Intercept	-0.37	-0.31	-9.94***	-9.95***	-2.11	-1.79

South Africa

Variable		Levels		First Difference		Multiple Breakpoint tests	
		ADF	PP	ADF	PP	IO	AO
DF	Intercept	-1.29	-1.59	-9.88***	-16.91***	-5.32***	-5.38***
	Trend&Int	-2.24	-2.08	-9.83***	-16.74***	-6.35***	-6.26***
Ln(M2)	Intercept	-2.09	-2.09	-10.89***	-10.88***	-3.17	-3.22
	Trend&Int	-2.41	-2.41	-10.98***	-10.97***	-3.16	-3.22
Ln(gdp)	Intercept	-1.31	-1.16	-9.96***	-10.62***	-3.05	-2.44
	Trend&Int	-2.69	-2.83	-9.91***	-10.95***	-7.50***	-4.32
Rtf	Intercept	-0.15	-0.59	-3.73***	-9.80***	-3.75	-2.25

Notes: ADF and PP are, respectively, the Augmented Dicky-Fuller and Phillips-Perron test for the null hypothesis that the series are nonstationary. Except for Rbd and Rdf, other time series are considered to contain trend items. IO and AO are, respectively, tests proposed by Perron (1989), and Intercept denotes for allowing structural breaks in intercept trends and Trend&Int allows for structural breaks in both intercept and trend terms. To save space, this table presents the unit root test results of main variables, the other variables' unit-root test results present in Appendix B. Significance levels at 10%, 5% and 1% levels are denoted by *, **, ***, respectively.

Declaration of Interest Statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.