Finance Research Letters 85 (2025) 108001

Contents lists available at ScienceDirect

Finance Research Letters

journal homepage: www.elsevier.com/locate/frl

Currency digitalization: The supply, demand, and infrastructure aspects of china's central bank digital currency

Linshan Zeng [a], Martin R. Young [b,*], Wei Hao [b]

[a] School of Qiaoxing Economics and Management, Fujian Polytechnic Normal University, China
[b] School of Accountancy, Economics and Finance, Massey University, New Zealand

ARTICLE INFO

JEL Classification:
E4
G2

Keywords:
Central bank digital currency
e-CNY
Currency digitalization
Digital wallets
Digital payment scenarios
Cash substitution

ABSTRACT

This paper studies how digitalization affects the adoption of China's central bank digital currency (e-CNY). Utilizing provincial-level panel data from 2011 to 2021, we examine the impacts of "Breadth of Digitalization Coverage" and "Digitalization Level" on the supply and demand dynamics of e-CNY. Our findings show that digitalization reduces both the supply and demand of physical currency. This decreasing reliance on physical currency implies that digitalization has paved the way for adopting e-CNY. We further investigate the infrastructural factors that support digitalization progression and e-CNY's implementation. Our results suggest that the transition from physical to digital currency is jointly driven by wallet digitalization (enabled by smartphones) and payment scenario digitalization (supported by e-commerce). Our result findings provide implications to both China and other countries developing CBDC initiatives.

1. Introduction

In recent years, interest in Central Bank Digital Currencies (CBDCs) has surged globally, with 134 countries and regions actively engaged in researching or piloting their own CBDCs.[1] CBDCs are regarded as secure digital alternatives with potential to reduce cash transactions (Ma et al., 2023) and improve monetary policy effectiveness (Corbet et al., 2024). By integrating into existing financial systems, CBDCs may serve as a novel governance mechanism that affects cash dynamics (Zhang and Chan, 2025). However, the existing literature largely relies on the theoretical models of CBDCs (Allen et al., 2022; Wang, 2023; Xu, 2022), with limited empirical evidence available due to the challenges of obtaining data, as most CBDC projects remain in the research or pilot phase. This lack of empirical analysis leaves significant gaps in understanding the practical implications of CBDCs.

In this paper, we aim to bridge the gap by investigating how digitalization development promotes CBDCs and identifying the infrastructural forces that support digitalization progression and facilitate CBDCs implementation. China provides a unique setting for this research question for several reasons. First, China has advanced digital infrastructure and widespread digital payment adoption.[2] Its well-developed mobile payment system, dominated by Alipay and WeChat Payment, has established a strong framework for e-CNY's implementation (Allen et al., 2022). Second, China is among the first major economies to launch a CBDC pilot, with significant progress being made in recent years. Since initiating CBDC research in 2014, China has progressively expanded e-CNY trials to 26

* Corresponding author.
E-mail address: m.young@massey.ac.nz (M.R. Young).

[1] Source: Atlantic council. (2024). Central bank digital currencies status. https://cbdctracker.org/.

[2] According to "Overall Operation of the Payment System in 2022" released by the People's Bank of China, by the end of 2022, the scale of mobile payment users in China reached approximately 904 million, accounting for 86.5% of the total number of internet users.

https://doi.org/10.1016/j.frl.2025.108001
Received 17 April 2025; Received in revised form 18 July 2025; Accepted 18 July 2025
Available online 19 July 2025

regions across 17 provinces and cities, with total transactions reaching 7 trillion RMB by June 2024. Third, since the rise of e-commerce and Alipay in 2014, physical cash usage has dropped significantly (Ma et al., 2023), along with a notable decline in the M0 to M1 ratio.[3] This trend supports our hypothesis that digitalization development has reduced both the supply and demand of cash in circulation, consistent with monetary substitution theory. As digital payments become more accessible and efficient, individuals and firms are expected to move away from cash (Beckmann et al., 2024; Zhang and Chan, 2025).

To examine how digitalization affects the supply and demand of e-CNY and the infrastructural factors driving its development in China, we use panel data from 31 provinces covering a period of 2011–2021. As e-CNY remains in the trial stage, direct empirical data is unavailable. To circumvent this data constraint, we use data on physical CNY as an inverse indicator for e-CNY. Given that e-CNY is designed to substitute for cash in circulation (Li and Huang, 2021), our findings should provide meaningful inferences about the e-CNY. Our results show that digitalization, measured by digitalization coverage and level, reduces both the supply and demand of physical cash, suggesting a potential shift towards e-CNY. Further analyses show that different infrastructure prerequisites are required for different aspects of digitalization: smartphones are important for expanding its breadth, while e-commerce is essential for expanding its depth.

We contribute to the literature by providing the novel empirical evidence on CBDC implementation from China. While previous literature has recognized the role of third-party payment platforms and digital payments in reducing cash usage (Cheng, 2023; Tronnier and Qiu, 2024), our study provides empirical evidence on how digitalization development paves the way for implementing e-CNY. In addition, we shed light on the roles of digital wallets and digital payment scenarios in enabling the transition from physical to digital currency. Specifically, smartphone penetration facilitates the digitalization of wallets, enabling individuals to store and access e-CNY. The rise of e-commerce accelerates the digitalization of payment scenarios by offering concrete use cases for e-CNY in everyday transactions. These components of digital infrastructure serve as critical preconditions for e-CNY's adoption. Finally, our findings provide practical implications for economies with different institutional structures. In countries with advanced electronic payment systems, such as China, CBDCs constitute a natural progression of monetary digitalization. In contrast, economies with less developed infrastructure may leapfrog directly from cash to CBDCs. In both cases, the success of CBDC adoption depends on the extent to which the digital infrastructure can support enduring behavioral shifts away from physical cash.

2. Research design

2.1. Data and sample

In this study, we investigate how digitalization affects the development and implementation of e-CNY from both supply and demand perspectives. Since e-CNY remains in the pilot stage, direct data is not available. Therefore, we employ the supply and demand of physical cash as inverse indicators for the demand and supply of e-CNY. Given that e-CNY is intended to replace money in circulation, the analyses conducted using these inverse indicators should provide meaningful inferences to e-CNY.

We conduct a provincial-level analysis using a sample of 31 Chinese provinces from 2011 to 2021. To control for unobserved time-varying factors and province-specific time-invariant characteristics, we include both year and province fixed effects in the regression models.

2.2. Variables construction

2.2.1. Measurement of e-CNY supply

Based on Cohen (2001), M0—comprising banknotes and coins directly issued by state authorities—serves as an indicator for assessing changes in physical currency supply. We use M0, the most liquid form of currency, as the realized supply of physical currency, following the approach of Berger and Bouwman (2013). Based on the monetary substitution theory, a decline in physical currency supply implies an increase in e-CNY supply. Since M0 data is only available at the national level, we estimate the provincial-level M0 aggregates using national M0 time series data and provincial bank branch distribution data in each year. Given that bank branches serve as key centers for the distribution and recycling of banknotes, we assume that M0 is allocated across provinces in proportion to their respective market share of bank branches.[4] Based on this assumption, we estimate provincial M0 as national M0 multiplied by each province's bank branch market share for a given year. Subsequently, we calculate the M0-to-GDP ratio to proxy physical currency supply, which in turn infers a reverse projection of e-CNY supply. This ratio is calculated by dividing the estimated M0 of each province in each year by its corresponding provincial GDP.

[3] See figure 1 in Appendix A.

[4] We acknowledge the potential limitation of estimating provincial-level M0 and cash withdrawals using market shares of bank branches, as regional variations in bank branches numbers may be driven by banking activities unrelated to cash business. To alleviate this concern, we collected cross-sectional data on the distribution of ATMs across 31 provinces in China on May 1, 2022, by scraping publicly available map data using Python (historical ATM distribution data from 2011 to 2021 were unavailable). Since ATMs are mainly used by retail customers for physical cash withdrawals and deposits, we believe that the variations in ATM numbers across provinces can more accurately reflect the variations in cash reliance. We found that the provincial-level ATM distribution in 2022 is highly consistent with the distribution of bank branches in the same year. To ensure robustness, we repeated the scraping process in June 2025 and observed the same consistency. This lends credibility to our approach of proportionally estimating provincial-level cash supply and demand based on the respective market share of bank branches.

2.2.2. Measurement of e-CNY demand

The demand for CBDC will be influenced by trends in the usage of physical cash (Khiaonarong and Humphrey, 2019). In the absence of a direct measurement for e-CNY, we use physical currency cash withdrawals as a proxy for physical cash demand, serving as an inverse predictor of e-CNY demand. Given that changes of bank branches and ATMs reflect cash demand (Ueda, 2024), we estimate provincial cash withdrawals by applying a method similar to our M0 estimation, i.e. using national cash withdrawal data and the market share of bank branches in each province to estimate the provincial cash withdrawal data. We use the ratio of cash withdrawals to GDP (*CashWithdrawal/GDP*) as a measure of physical cash demand in each province in our main regression analysis. We argue that the lower the ratio, the lower the demand for physical cash, and hence the higher demand for e-CNY.

2.2.3. Measurement of digitalization development

The evolving digitalization is captured by the Digital Financial Inclusion Index (PKU-DFIIC) developed by Peking University. We employ two sub-indices of PKU-DFIIC, namely "Breadth of Coverage" and "Level of Digitalization" to measure digitalization from two different dimensions.

We employ *Digitalization_Coverage* to capture the breadth of digitalization. This measure highlights the interoperability between traditional banking and digital payment platforms (e.g. Alipay). *Digitalization_Level* assesses the convenience and affordability of digital financial services across dimensions such as “Mobility”, “Affordability”, “Credit”, and “Convenience” .[5]

2.3. Model specification

To examine the influence of digitalization on the demand and supply of e-CNY, we employ the following regression models [1–2].

$$MS_{it} = \alpha_{it} + \alpha_1 DIndex_{it} + \alpha_2 Control_{it} + \mu_i + \delta_t + \varepsilon_{it} \quad (1)$$

$$MD_{it} = \beta_{it} + \beta_1 DIndex_{it} + \beta_2 Control_{it} + \mu_i + \delta_t + \varepsilon_{it} \quad (2)$$

Where MS_{it} denotes physical currency supply in province i in year t. MD_{it} denotes physical currency demand in province i in year t. $DIndex_{it}$ captures digitalization, encompassing both the digitalization coverage index and digitalization level index. $Control_{it}$ represents a set of control variables, including $Population_{i,t}$, $GDPG_{i,t}$, $OADR_{i,t}$, $Education_{i,t}$, and $CPI_{i,t}$. Following Barro and Lee (2013), we calculate the education indicator using a weighted average method.[6] μ_i and δ_t are province fixed effect and year fixed effect, respectively.

To further investigate the factors contributing to digitalization development, we employ model [3] to assess the determinants of digitalization coverage and level. Specifically, we test whether *Mobile_Phone* penetration and *E-commerce* activity serve as the foundational drivers for digitalization progression.

$$DIndex_{it} = \gamma_{it} + \gamma_1 FI_{it} + \gamma_2 Control_{it} + \mu_i + \delta_t + \varepsilon_{it} \quad (3)$$

Where FI_{it} represents foundational drivers including $Mobile\_Phone_{i,t}$ and $E\text{-}commerce_{i,t}$. Same set of control variables is included in this model.

3. Empirical analysis

3.1. Descriptive statistics

We begin our analysis by reporting the summary statistics for the variables used in Table 1. The mean values of supply and demand of physical cash are 0.108 and 1.016, and their ranges are 0.016–0.255 and 0.055–2.768 respectively. The mean value of *Digitalization_Level* is 3.008, with a standard deviation of 1.169, while *Digitalization_Coverage* has a mean value of 2.116 and a standard deviation of 1.039. These results demonstrate sufficient regional and temporal variations for regression analysis. *Mobile_Phone* penetration rate shows a mean value of 1.006 and a standard deviation of 0.248. *E-commerce* activity also varies considerably across provinces, with a mean value of 1.089 and a standard deviation of 1.925.[7]

3.2. The impact of digitalization development on e-CNY supply

Table 2, Columns (1) and (3), report the contemporaneous impact of digitalization at time t on the supply of physical currency. Both *Digitalization_Coverage* and *Digitalization_Level* exhibit negative and significant coefficients (−0.066 and −0.044), confirming that higher digitalization reduces physical currency supply. This suggests that as digital payment adoption increases, reliance on cash

[5] We provide detailed descriptions of the indicators in Appendix B.

[6] The formula is given as follows: Education = [(No schooling population * 1 year) + (Primary school population * 6 years) + (Junior high school population * 9 years) + (Senior high school population * 12 years) + (Undergraduate population * 16 years) + (Master population * 19 years)] / Total population.

[7] To test if our main regression models experience multicollinearity problem, we estimated the pairwise correlation of explanatory variables and report the results in Appendix E. VIF tests are also conducted but results are not reported due to limited space. The tests show that all explanatory variables have VIF values do not exceed 5, further confirming the validity of our regression models.

Table 1
Descriptive statistics.

Variables	Observation	Mean	Standard deviation	Minimum	Maximum
MS_M0	341	0.108	0.041	0.016	0.255
MD_CashWithdrawal	341	1.016	0.537	0.055	2.768
Digitalization_Coverage	341	2.116	1.039	0.020	4.334
Digitalization_Level	341	3.008	1.169	0.076	4.622
Mobile_Phone	341	1.006	0.248	0.520	1.890
E-commerce	279	1.089	1.925	0.0221	14.271
Population	341	3.525	0.842	1.128	4.843
GDPG	341	0.099	0.052	−0.053	0.267
OADR	341	10.695	2.774	4.824	18.800
Education	341	9.166	1.121	4.220	12.680
CPI	341	4.628	0.012	4.606	4.667

This table provides the descriptive statistics for the variables used in the study. The sample includes 31 provinces in China from 2011 to 2021. Comprehensive definitions of the variables are detailed in Appendix D.

declines immediately. We further examine how digitalization at current time *t* predicts future supply of physical currency at time $t + 1$ and present the results in Columns (2) and (4). We find that the impact of *Digitalization_Coverage* and *Digitalization_Level* on money supply weakens or disappears at time $t + 1$. The temporal dynamics revealed in the results highlight the short-lived impact of digitalization on physical currency supply. These findings are not unexpected, as the long-term supply of physical currency is ultimately determined by central bank policy rather than market-driven digital adoption.

3.3. The impact of digitalization development on e-CNY demand

The results in Table 3 show that increasing digitalization significantly reduces physical cash usage, measured by *CashWithdrawal/GDP*. As shown in Columns (1) and (3), both *Digitalization_Coverage* and *Digitalization_Level* reduce the immediate demand for physical cash, with a stronger effect associated with *Digitalization_Coverage*. In Columns (2) and (4), we use a one-period forward measure to assess digitalization's impact on money demand. The results indicate that both variables remain statistically significant at time $t + 1$, with *Digitalization_Coverage* consistently exerting a stronger effect. Since *Digitalization_Coverage* captures the extent of reliance on electronic payment platforms (e.g. Alipay), our results highlight the prominent role of advanced payment technologies in accelerating the transition away from physical cash. With digitalization progression (e.g. mobile phones and electronic payment platforms), the process of holding and using physical cash has become relatively less efficient, making e-CNY a more attractive alternative.

The results for control variables are generally consistent with those in Table 2. *OADR* remains positively associated with cash demand, reflecting greater reliance on physical cash among older demographics. Additionally, we find that *Population* negatively affects currency demand. As electronic payments become more cost-efficient in regions with larger populations, the shift from cash to digital payments becomes more pronounced.

3.4. Infrastructure analysis for CNY digitalization

In our previous analyses, we have demonstrated that digitalization significantly reduces the reliance on physical currency from both supply and demand perspectives. These findings suggest that digitalization can play a prominent role in promoting e-CNY as a replacement for physical cash in circulation. We next investigate the key factors contributing to the digitalization progression in China, with results reported in Tables 4 and 5. Panel A of Table 4 reveals a positive association between *Mobile_Phone* usage and *Digitalization_Coverage*, indicating that widespread smartphone penetration significantly enhances digital access across provinces. This effect persists when the forward measure of *Digitalization_Coverage* is used at time $t + 1$. Panel B indicates that while *E-commerce* shows some association with *Digitalization_Coverage,* the relationship is not statistically significant.

In Panel A of Table 5, we find that *E-commerce* significantly enhances *Digitalization_Level*, indicating that e-commerce development boosts the digitalization capability. This impact remains significant in subsequent period ($t + 1$). However, *Mobile_Phone* appears to have no significant effect on *Digitalization_Level* as shown in Panel B. These findings suggest that different infrastructure prerequisites are required for different aspects of digitalization: mobile phone penetration is essential for expanding its breadth, while a well-developed e-commerce environment plays a key role in improving its depth and sophistication.

3.5. Granger causality test

To strengthen our causal claims, we test the Granger causality relationship between digitalization indicators (measured by *Digitalization_Coverage* and *Digitalization_Level*) and supply and demand of physical cash. The results, reported in Table 6, show that both dimensions of digitalization Granger-cause reductions in physical cash supply and demand at the 1 % significance level, with coefficients statistically significant at the 1 % level. These results support our main hypothesis that digitalization precedes the substitution away from physical cash.

Table 2
The influence of digitalization development on e-CNY supply.

Variables	*MS_M0* (1)	*F.MS_M0* (2)	*MS_M0* (3)	*F.MS_M0* (4)
Digitalization_Coverage	−0.066***	−0.045**		
	(−3.673)	(−2.286)		
Digitalization_Level			−0.044**	−0.029
			(−2.194)	(−1.482)
Population	−0.008	−0.047	−0.023	−0.079**
	(−0.220)	(−1.166)	(−0.628)	(−2.070)
GDPG	0.012	0.004	0.011	0.012
	(0.378)	(0.106)	(0.336)	(0.317)
OADR	0.003**	0.002	0.004***	0.002*
	(2.543)	(1.558)	(3.317)	(1.835)
Education	0.005	−0.004	0.004	−0.005
	(1.017)	(−0.821)	(0.862)	(−0.888)
CPI	0.030	−0.116	0.090	−0.090
	(0.136)	(−0.505)	(0.397)	(−0.389)
Constant	−0.101	0.858	−0.291	0.835
	(−0.096)	(0.795)	(−0.271)	(0.763)
Observations	341	310	341	310
Adj. R-squared	0.868	0.873	0.864	0.871
Province FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

This table presents the baseline result of the impact of digitalization coverage and digitalization level on physical currency supply. Columns (1) and (3) show the results of the current period. Columns (2) and (4) present the regression for physical currency supply in $t + 1$ period. *t*-statistics are presented in parentheses, where *, **, and *** denote significance at the 10 %, 5 %, and 1 % levels, respectively.

Table 3
The influence of digitalization development on e-CNY demand.

Variables	*MD_ CashWithdrawal* (1)	*F.MD_ CashWithdrawal* (2)	*MD_ CashWithdrawal* (3)	*F.MD_ CashWithdrawal* (4)
Digitalization_Coverage	−0.625**	−0.869***		
	(−2.173)	(−2.790)		
Digitalization_Level			−0.013**	−0.010*
			(−2.183)	(−1.689)
Population	−0.038	−0.065	−0.053	−0.081*
	(−0.132)	(−0.427)	(−0.335)	(−1.896)
GDPG	−0.551	−0.879**	−0.384	−0.769**
	(−1.512)	(−2.174)	(−1.135)	(−2.130)
OADR	0.073***	0.051**	0.056***	0.031
	(3.696)	(2.556)	(2.739)	(1.531)
Education	0.025	−0.173**	0.037	−0.161**
	(0.305)	(−2.146)	(0.451)	(−2.030)
CPI	3.464	5.682	2.565	4.921
	(0.968)	(1.586)	(0.721)	(1.399)
Constant	−24.467	−32.081*	−17.536	−24.937
	(−1.453)	(−1.895)	(−1.044)	(−1.498)
Observations	341	310	341	310
Adj. R-squared	0.806	0.815	0.809	0.822
Province FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes

This table presents the baseline result of the impact of the digitalization coverage and digitalization level on physical currency demand. Columns (1) and (3) show the results of the current period. Columns (2) and (4) present the regressions for paper currency demand in $t + 1$ period. *t*-statistics are presented in parentheses, where *, **, and *** denote significance at the 10 %, 5 %, and 1 % levels, respectively.

4. Conclusion

Building on the existing theoretical frameworks on CBDCs, this paper provides empirical evidence that digitalization, measured by its coverage and level, significantly reduces individuals' reliance on physical cash, indicating a strong shift toward e-CNY. Smartphone infrastructure broadens digitalization coverage, while e-commerce growth enhances the depth of digitalization. Together, these developments position e-CNY as a more attractive alternative to physical currency, reinforcing the inverse relationship between the two. We also find that demographic factors influence this transition: provinces with larger populations support e-CNY adoption by spreading infrastructure costs, whereas aging populations tend to retain a preference for cash.

Our results offer several implications. First, the digitalization of physical wallets and payment scenarios, enabled by widespread

Table 4
The influence of infrastructure on digitalization coverage.

Panel A. Mobile phone		
Variables	*Digitalization_Coverage*	*F. Digitalization_Coverage*
	(1)	(2)
Mobile_Phone	0.227***	0.205***
	(5.052)	(4.372)
Population	0.833***	0.893***
	(7.401)	(7.747)
GDPG	−0.077	−0.198*
	(−0.751)	(−1.736)
OADR	−0.008**	−0.006
	(−1.993)	(−1.582)
Education	0.007	−0.008
	(0.433)	(−0.524)
CPI	−0.335	−0.228
	(−0.482)	(−0.324)
Constant	−1.159	−1.249
	(−0.354)	(−0.376)
Observations	341	310
Adj. R-squared	0.998	0.998
Province FE	Yes	Yes
Year FE	Yes	Yes
Panel B. E-commerce		
Variables	*Digitalization_Coverage*	*F. Digitalization_Coverage*
	(1)	(2)
E-commerce	−0.001	−0.002
	(−0.165)	(−0.352)
Population	1.041***	1.042***
	(7.232)	(6.801)
GDPG	−0.114	−0.251*
	(−1.041)	(−1.948)
OADR	0.002	0.003
	(0.375)	(0.591)
Education	−0.002	−0.006
	(−0.113)	(−0.350)
CPI	0.222	−0.168
	(0.305)	(−0.220)
Constant	−3.462	−1.125
	(−1.012)	(−0.312)
Observations	279	248
Adj. R-squared	0.997	0.996
Province FE	Yes	Yes
Year FE	Yes	Yes

This table presents the results of the influence of infrastructure on digitalization coverage. Panel A reports the impact of the mobile phone penetration rate on digitalization coverage. Panel B reports the impact of e-commerce on digitalization coverage. In both Panel A and Panel B, Column (1) shows the result of the current period. Column (2) presents the regression for digitalization coverage in $t + 1$ period. *t*-statistics are presented in parentheses, where *, **, and *** denote significance at the 10 %, 5 %, and 1 % levels, respectively.

smartphone adoption and the rise of e-commerce, has created the necessary preconditions for currency digitalization. Second, from a policy perspective, China's e-CNY initiative has benefited from a uniquely centralized institutional environment, where strong top-down policy coordination has enabled the rapid digital infrastructure deployment. This sets China apart from more liberal or market-oriented economies. Although our findings are rooted in China's context, the underlying mechanisms provide valuable insights for CBDC adoption in other institutional settings. For future research, several topics merit exploration as more public data becomes available. These include how CBDCs may reshape the macro-financial system through intensified deposit competition and banking disintermediation risks (Agur et al., 2022; Fernández-Villaverde et al., 2021), potential threats to financial stability (Brunnermeier and Niepelt, 2019; Heitmann et al., 2025), and enhanced central banks' control over monetary policy (Raskin and Yermack, 2018). Furthermore, subsequent studies could explore the global implications of CBDC design choices, especially their impacts on cross-border settlements and international monetary cooperation. Overall, our results suggest that the digitalization of CNY is both conditional and inevitable, though overcoming developmental challenges will take time.

Table 5
The influence of infrastructure on digitalization level.

Panel A. E-commerce		
Variables	(1) *Digitalization_Level*	(2) *F. Digitalization_Level*
E-commerce	0.082***	0.097***
	(5.960)	(5.362)
Population	1.355**	2.062***
	(2.457)	(3.418)
GDPG	−0.764*	−0.213
	(−1.825)	(−0.419)
OADR	0.044**	0.067***
	(2.527)	(3.544)
Education	−0.129**	−0.028
	(−2.006)	(−0.402)
CPI	1.582	2.791
	(0.569)	(0.929)
Constant	−8.905	−17.977
	(−0.680)	(−1.266)
Observations	279	248
Adj. R-squared	0.931	0.900
Province FE	Yes	Yes
Year FE	Yes	Yes
Panel B. Mobile Phone		
Variables	(1) *Digitalization_Level*	(2) *F. Digitalization_Level*
Mobile_Phone	−0.213	−0.157
	(−1.211)	(−0.843)
Population	1.607***	1.643***
	(3.654)	(3.583)
GDPG	−0.630	−0.313
	(−1.563)	(−0.690)
OADR	0.085***	0.100***
	(5.659)	(6.389)
Education	−0.058	0.073
	(−0.933)	(1.153)
CPI	4.378	3.045
	(1.609)	(1.089)
Constant	−25.484**	−19.921
	(−1.990)	(−1.509)
Observations	341	310
Adj. R-squared	0.976	0.961
Province FE	Yes	Yes
Year FE	Yes	Yes

This table presents the impact of the e-commerce on digitalization level. Panel A focuses on e-commerce, while Panel B analyzes mobile phone usage. In both panels, Column (1) shows current-period result, and Column (2) shows the impact on in digitalization level in $t + 1$ period. *t*-statistics are presented in parentheses, where *, **, and *** denote significance at the 10 %, 5 %, and 1 % levels, respectively.

Table 6
Granger causality test of related variables.

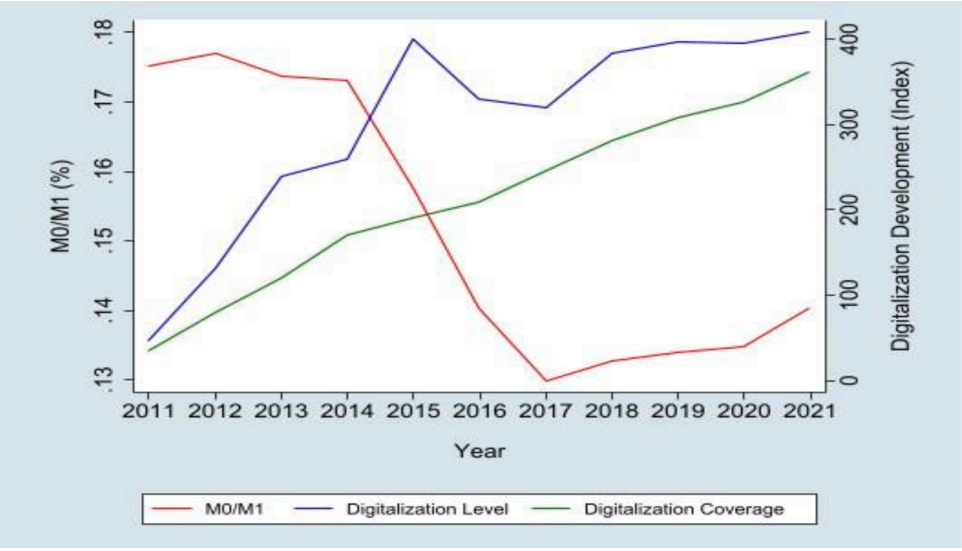
Preorder	Postorder	Coef.	HPJ Wald test	P-value HPJ	BIC
Digitalization_Coverage	MS_M0	−0.007*** (0.001)	25.391	0.000	−2141.260
Digitalization_Level	MS_M0	−0.008** (0.001)	31.095	0.036	−2145.349
Digitalization_Coverage	MD_CashWithdrawal	−0.176*** (0.022)	61.528	0.000	−824.465
Digitalization_Level	MD_CashWithdrawal	−0.110*** (0.012)	78.739	0.000	−801.767

This table shows the results of Granger non-causality tests between the preorder and postorder variables. The null hypotheses that the preorder variables do not Granger-cause the postorder variables are all rejected at the 1 % level of significance. This suggests that digitalization dynamics causes changes in cash-related metrics, supporting our baseline proposition. Values in parentheses are the standard errors. ***$p < 0.01$, **$p < 0.05$, and * $p < 0.1$.

CRediT authorship contribution statement

Linshan Zeng: Writing – original draft, Visualization, Software, Resources, Methodology, Investigation, Formal analysis, Data curation. **Martin R. Young:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Wei Hao:** Writing – review & editing, Supervision, Project administration, Conceptualization.

Appendix A. Relationship between digitalization development and physical currency



This figure illustrates the inverse relationship between China's digitalization development—measured by digitalization coverage and level—and the proportion of physical cash, as indicated by the declining M0/M1 ratio. The Digital Financial Inclusion Index, calculated as national averages across 31 provinces by Peking University, represents digitalization progress.

Appendix B. Indicators of digitalization coverage and digitalization level[8]

Level 1 Dimension	Level 2 Dimension	Indicators' Construction
Digitalization Coverage(Breadth of Coverage)	Account coverage rate	Number of Alipay accounts owned by per 10,000 people
		Proportion of Alipay users who have bank cards bound to their Alipay accounts
		Average number of bank cards bound to each Alipay account
Digitalization Level(Level of Digitalization)	Mobility	Proportion of number of mobile payments
		Proportion of total amount of mobile payments
	Affordability	Average loan interest rate for small and micro businesses
		Average loan interest rate for individuals
	Credit	Proportion of number of Ant Check Later payments
		Proportion of total amount Ant Check Later payments
		Proportion of number of "Zhima Credit as deposit" cases
		Proportion of total amount of "Zhima Credit as deposit"
	Convenience	Proportion of number of QR code payments by users
		Proportion of the total amount/average amount of QR code payments by users

This table provides detailed descriptions of the indicators used to measure the breadth and depth of digitalization, as constructed by the Institute of Digital Finance, Peking University. The *Digitalization Coverage* dimension reflects the extent to which digital financial services, represented by Alipay usage, have penetrated the population. It includes indicators such as the number of Alipay accounts per 10,000 people, the proportion of users who have linked bank cards, and the average number of bank cards linked per account. The *Digitalization Level* dimension evaluates the depth and quality of digital financial usage across four aspects: Mobility, Affordability, Credit, and Convenience. These indicators jointly capture the level of digital financial development in China. (Source: Institute of Digital Finance, Peking University).

[8] Ant Financial offers a range of digital financial services including payment solutions, insurance, monetary funds, credit services, investment opportunities, and credit assessment.

Appendix C. Differences among e-CNY, traditional electronic payment, and M0

Items	E-CNY	M0 (Cash)	Electronic Payments
Form	Digital	Physical	Digital
Legal status	Legal tender	Legal tender	Payment instrument without legal tender status
Issuer	Central bank	Central bank	Commercial banks and non-bank payment institutions
Regulation	Central bank	Central bank	Multiple financial authorities
Liability	Liability of central bank	Liability of central bank	Liability of commercial banks or payment service providers
Privacy (Anonymity)	Partial anonymity with conditional traceability	Full anonymity	Limited anonymity, with comprehensive traceability
Accessibility	Universal(requires digital access)	Universal	Requires Bank Account or Credit History
Interest bearing	Generally non-interest-bearing	Non-interest-bearing	Potentially interest-bearing (account-based conditions)
Economic influence	Facilitates the effectiveness of monetary policy transmission	Conventional monetary policy tool	Influences monetary dynamics through spending channels

This table outlines the key differences among e-CNY, M0 (cash), and traditional electronic payments. Both e-CNY and M0 are legal tenders and liabilities of the central bank, while traditional electronic payments are not legal tender and are issued by commercial entities. M0 is physical and fully anonymous, whereas electronic payments are digital, account-based, and offer limited privacy. Importantly, e-CNY, as a central bank digital currency, combines features of both—offering digital legal tender with controlled anonymity and broader accessibility, while also supporting more efficient monetary policy implementation.

Appendix D. Variable definitions

Variables	Definition	Data Source
$MS\_M0_{i,t}$	Physical currency in circulation scaled by GDP, estimated using provincial bank branches data.	National Bureau of Statistics
$MD\_CashWithdrawal_{i,t}$	Cash withdrawal scaled by GDP, estimated using the provincial bank branches data.	People's Bank of China annual reports
$Digitalization\_Coverage_{i,t}$	Breadth of digitalization coverage index.	Peking University Digital Financial Inclusion Index
$Digitalization\_Level_{i,t}$	Digitalization level index.	Peking University Digital Financial Inclusion Index
$Mobile\_Phone_{i,t}$	Mobile phone penetration rate (mobile phones per capita).	National Bureau of Statistics
$E\text{-}commerce_{i,t}$	Per capita e-commerce transaction volume.	National Bureau of Statistics
$GDPG_{i,t}$	GDP growth rate.	National Bureau of Statistics
$Population_{i,t}$	Natural logarithm of population.	National Bureau of Statistics
$Education_{i,t}$	Per capita years of education.	National Bureau of Statistics
$OADR_{i,t}$	Old-age Dependency Ratio, defined as the ratio of individuals aged 65 and over to the total population.	National Bureau of Statistics
$CPI_{i,t}$	Natural logarithm of consumer price index.	National Bureau of Statistics

Appendix E. Pairwise correlation matrix

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) *Digitalization_Coverage*	1								
(2) *Digitalization _Level*	0.870***	1							
(3) *Mobile_Phone*	0.680***	0.461***	1						
(4) *E-commerce*	0.449***	0.271***	0.727***	1					
(5) *Population*	0.065	0.032	−0.069	−0.057	1				
(6) *GDPG*	−0.432***	−0.573***	−0.297***	−0.024	−0.074	1			
(7) *OADR*	0.586***	0.473***	0.321***	0.287***	0.431***	−0.273***	1		
(8) *Education*	0.392***	0.196***	0.619***	0.637***	0.237***	−0.263***	0.455***	1	
(9) *CPI*	−0.603***	−0.721***	−0.289***	−0.036	−0.058	0.485***	−0.322***	−0.147***	1

This table presents the correlation matrix for the variables in the analysis. *, **, and *** indicate significance at the 10 %, 5 %, and 1 % levels, respectively.

Data availability

Data will be made available on request.

Reference

Agur, I., Ari, A., Dell'Ariccia, G., 2022. Designing central bank digital currencies. J. Monet Econ. 125, 62–79.
Allen, F., Gu, X., Jagtiani, J., 2022. Fintech, cryptocurrencies, and CBDC: financial structural transformation in China. J. Int. Money Finance 124, 102625.
Barro, R.J., Lee, J.W., 2013. A new data set of educational attainment in the world, 1950–2010. J. Dev. Econ. 104, 184–198.
Beckmann, L., Debener, J., Hark, P.F., Pfingsten, A., 2024. CBDC and the shadow of bank disintermediation: US stock market insights on threats and remedies. Finance Res Lett. 67, 105868.
Berger, A.N., Bouwman, C.H., 2013. How does capital affect bank performance during financial crises? J. Financ. Econ. 109 (1), 146–176.
Brunnermeier, M.K., Niepelt, D., 2019. On the equivalence of private and public money. J. Monet. Econ. 106, 27–41.
Cheng, P., 2023. Decoding the rise of Central Bank Digital Currency in China: designs, problems, and prospects. J. Bank. Regul. 24 (2), 156–170.
Cohen, B.J., 2001. Electronic money: new day or false dawn? Rev. Int. Polit. Econ. 8 (2), 197–225.
Corbet, S., Cumming, D., Glatzer, Z., Johan, S., 2024. Understanding the rapid development of CBDC in emerging economies. Finance Res. Lett. 70, 106226.
Fernández-Villaverde, J., Sanches, D., Schilling, L., Uhlig, H., 2021. Central bank digital currency: central banking for all? Rev. Econ. Dyn. 41, 225–242.
Heitmann, D., Koch, J.-A., Islam, M.S., Eva, S.A., 2025. The impact of central bank digital currencies on the financial stability of banks: dynamic panel estimation. Finance Res Lett., 107791
Khiaonarong, T., Humphrey, D., 2019. Cash use across countries and the demand for central bank digital currency. J. Paym. Strategy Syst. 13 (1), 32–46.
Li, S., Huang, Y., 2021. The genesis, design and implications of China's central bank digital currency. China Econ. J. 14 (1), 67–77.
Ma, C., Wu, J., Sun, H., Zhou, X., Sun, X., 2023. Enhancing user experience in digital payments: a hybrid approach using SEM and neural networks. Finance Res. Lett. 58, 104376.
Raskin, M., Yermack, D., 2018. Digital currencies, decentralized ledgers and the future of central banking. Research Handbook On Central Banking. Edward Elgar Publishing, pp. 474–486.
Tronnier, F., Qiu, W., 2024. How do privacy concerns impact actual adoption of central bank digital currency? An investigation using the e-CNY in China. Quant. Finance Econ. 8 (1), 126–152.
Ueda, K., 2024. Effects of bank branch/ATM consolidations on cash demand: evidence from bank account transaction data in Japan. J. Jpn. Int. Econ. 71, 101305.
Wang, H., 2023. How to understand China's approach to central bank digital currency? Comput. Law Secur. Rev. 50, 105788.
Xu, J., 2022. Developments and implications of central bank digital currency: the case of China e-CNY. Asian Econ. Policy Rev. 17 (2), 235–250.
Zhang, G., Chan, K.C., 2025. Central bank digital currency and corporate cash holdings: evidence from China's e-CNY pilot. J. Corp Finance, 102847.