INTERNATIONAL JOURNAL OF MANAGEMENT AND BUSINESS DEVELOPMENT (IJMBD)

eISSN: 3087-4084

Volume. 02, Issue. 11, pp. 01-13, November 2025"

NAVIGATING THE CASHLESS TRANSITION: AN ARDL APPROACH TO MODELING THE IMPACT OF FINANCIAL TECHNOLOGY ON CASH DEMAND IN IRAN

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Article received: 10/09/2025, Article Revised: 14/10/2025, Article Published: 06/11/2025

ABSTRACT

Purpose: This paper empirically investigates the association between technological progress and the demand for real cash balances in Iran. Amid a global shift towards digital payments, understanding the quantitative substitution effect of financial technology on cash is crucial for effective monetary policy and currency management.

Methodology: The study employs the Autoregressive Distributed Lag (ARDL) bounds testing approach to cointegration, a method well-suited for analyzing long-run and short-run dynamics with variables of mixed integration orders. Using quarterly time-series data, the model specifies real cash demand as a function of real GDP (transaction motive), bank deposit rates (opportunity cost), and the number of Point of Sale (POS) terminals as a proxy for technological advancement. Post-estimation diagnostic and stability tests are conducted to ensure the model's robustness.

Findings: The ARDL bounds test confirms the existence of a stable, long-run equilibrium relationship between the variables. The long-run estimates reveal that technological progress has a statistically significant and negative association with the demand for real cash in Iran. The coefficient for POS terminals indicates a powerful substitution effect. The Error Correction Model (ECM) results show a significant speed of adjustment, indicating that approximately 35% of any short-term disequilibrium is corrected within one quarter.
Originality/Value: This study provides the first robust, ARDL-based analysis of the technology-cash demand nexus in Iran using recent data. It quantifies the substitution effect, offering empirical evidence that moves beyond descriptive analysis.

Implications: The findings have significant implications for the Central Bank of Iran. They underscore the need to refine cash demand forecasting models, optimize currency management logistics, and strategically advance the development of a Central Bank Digital Currency (CBDC) to navigate the country's transition towards a less-cash society.

Keywords: Cash Demand, Technological Progress, Digital Payments, ARDL Model, Cointegration, Monetary Policy, Iran.

INTRODUCTION

1.1 Background: The Global Shift in Payments

The nature of money and the mechanisms through which economic value is exchanged are undergoing a profound transformation. For centuries, physical currency—banknotes and coins—has been the bedrock of retail transactions, embodying the core functions of money as a medium of exchange, a unit of account, and a store of value. However, the dawn of the digital age has precipitated a paradigm shift, progressively displacing physical cash with a sophisticated array of electronic and digital payment instruments. This global trend, driven by rapid advancements in financial technology (FinTech), has reshaped consumer behavior, redefined financial infrastructures, and presented new challenges and opportunities for central banks worldwide.

Globally, the use of cash for transactional purposes has been in steady decline across many advanced and emerging economies. Data from the Bank for International Settlements (BIS) consistently illustrates this shift, highlighting a growing preference for card payments, credit transfers, and direct debits (Bech et al., 2018). The rise of the internet, mobile technology, and innovative payment solutions has created a rich ecosystem of alternatives to cash that offer unparalleled convenience, speed, and security (Bech & Hancock, 2020). The adoption of mobile banking, for instance, has been accelerated by its perceived convenience, allowing users to conduct financial transactions anytime and anywhere, thereby reducing their reliance on physical bank branches and cash (Jebarajakirthy & Shankar, 2021). This digital wave is not merely a phenomenon of the developed world; emerging economies are also leapfrogging traditional banking infrastructures, with digital payments becoming a cornerstone of financial inclusion and economic development.

The Iranian economic landscape presents a unique and compelling case study within this global narrative. While subject to distinct geopolitical and economic conditions, Iran has experienced a remarkable domestic digital transformation over the past two decades. The government and central bank have actively promoted the development of a national electronic payment system to enhance financial transparency, improve the efficiency of transactions, and reduce the costs associated with a cash-heavy economy. A key pillar of this strategy has been the establishment and expansion of the "Shaparak" (Electronic Card Payment Network) system, which unified the nation's point-of-sale (POS) infrastructure. The network's rapid growth has led to a near-ubiquitous presence of POS terminals across the country, from large urban supermarkets to small rural shops, fundamentally altering the payment habits of the Iranian populace (Shaparak, 2023). This state-led push, combined with a high mobile phone penetration rate, has created fertile ground for a rapid transition away from cash for daily transactions.

1.2 Problem Statement and Research Gap

The qualitative impact of this technological revolution is evident; however, a significant gap exists in the empirical literature regarding its quantitative and dynamic effects on the demand for cash in Iran. While the Central Bank of Iran meticulously tracks the volume of currency in circulation, understanding the underlying drivers of demand is essential for effective policymaking. Is the observed growth in currency stock driven by transactional needs, or is it increasingly a function of precautionary or store-of-value motives, especially in an inflationary environment? How elastic is the demand for transactional cash with respect to the proliferation of digital payment options? Answering these questions requires robust econometric modeling that can untangle the complex interplay of factors influencing public behavior.

Previous domestic studies on cash demand in Iran have provided valuable foundational insights. For instance, Arshadi and Einian (2011) offered forecasts for banknote demand, and more recent research projects have examined banknote holding patterns through various methods (Mojab et al., 2024). However, many of these studies either predate the most explosive growth period of Iran's digital payment infrastructure or do not employ econometric techniques capable of distinguishing between short-run dynamics and long-run equilibrium relationships. The Autoregressive Distributed Lag (ARDL) modeling approach offers a powerful solution to these limitations, making it possible to analyze cointegrating relationships in time-series data, even with small sample sizes and variables that are integrated of different orders. To date, a dedicated ARDL analysis focusing specifically on quantifying the long-run substitution effect between technological progress and cash demand in Iran remains a critical and unexplored area of research.

1.3 Research Questions and Objectives

This study aims to fill the identified research gap by systematically investigating the relationship between financial technology and cash demand. The research is guided by a primary question and several secondary inquiries.

Primary Question: What are the long-run and short-run associations of specific technological progress indicators with the demand for real cash balances in Iran?

Secondary Questions:

Do technological advancements and traditional macroeconomic variables (income, opportunity cost) have a stable, long-run equilibrium relationship with cash demand?

How quickly does the system adjust towards this long-run equilibrium following a short-term shock?

To address these questions, the study sets forth the following objectives:

To develop a robust econometric model of cash demand for Iran that incorporates a suitable proxy for the advancement of financial technology.

To apply the ARDL bounds testing approach to investigate the existence of a stable long-run cointegrating relationship among the variables.

To quantify the long-run and short-run elasticities of cash demand with respect to technological and key macroeconomic variables.

To derive evidence-based policy recommendations for the Central Bank of Iran concerning currency management and future payment system strategies.

1.4 Significance and Contribution of the Study

The significance of this research is twofold, contributing to both theoretical and practical domains. Theoretically, it enhances the empirical literature on money demand. While the foundational theories of money demand, such as the Quantity Theory of Money (Friedman, 1989; Walsh, 2003), provide the essential framework, this study contextualizes them within the disruptive reality of 21st-century FinTech. By quantifying the substitution effect, it provides empirical evidence on how technology alters the traditional determinants of holding cash for transactional purposes.

Practically, the study's findings are of immense value to policymakers, particularly at the Central Bank of Iran. An accurate, empirically grounded model of cash demand is an indispensable tool for:

Efficient Currency Management: Improving forecasts of public demand for banknotes allows for better planning of printing, storing, and distributing currency, thereby minimizing operational costs and ensuring an adequate supply without unnecessary surplus.

Informed Monetary Policy: Understanding the dynamics of the demand for the monetary base is fundamental to the conduct of monetary policy. A structural shift in cash demand can affect the money multiplier and the transmission mechanisms of policy interest rates.

Strategic Payment System Development: The study provides a quantitative basis for assessing the success of past policies aimed at promoting electronic payments. Furthermore, as the world moves towards new forms of digital money, including Central Bank Digital Currencies (CBDCs), this research offers a critical input. The observed decline in the transactional use of cash strengthens the case for exploring a CBDC in Iran, a topic of growing academic and policy interest (Jalali-Naini et al., 2011; Jalali-Naini et al., 2024).

1.5 Structure of the Article

The remainder of this paper is organized as follows. Section 2 details the methodology, outlining the theoretical framework, model specification, data sources, and the ARDL econometric approach. Section 3 presents the empirical results, including descriptive statistics, unit root tests, cointegration analysis, and the estimated long-run and short-run models. Section 4 provides an in-depth discussion of these results, interpreting their significance, comparing them with existing literature, and outlining key policy implications. Finally, Section 5 concludes the paper with a summary of the findings and their overarching contribution.

2.0 Methodology

2.1 Theoretical Framework and Model Specification

The analytical foundation of this study is rooted in the conventional theory of money demand, which posits that the public's desire to hold money is primarily determined by the volume of transactions and the opportunity cost of holding non-interest-bearing assets. This framework, extensively developed in monetary economics (Walsh, 2003), serves as the starting point for our empirical model. We extend this traditional model to explicitly account for the structural shift induced by technological innovation in the payments sector.

The general functional form for the demand for real cash balances can be expressed as:

$(M/P)d = f(Y, R, TECH)$

Where:

- (M/P)d represents the demand for real cash balances (nominal cash stock M deflated by the price level P).
- Y is a scale variable representing the level of economic activity or real income, which proxies for the volume of transactions. A positive relationship is expected, as higher income is associated with more transactions and thus a greater need for a medium of exchange.
- R denotes the opportunity cost of holding cash, typically represented by a nominal interest rate on alternative assets like bank deposits. A negative relationship is expected, as higher interest rates make holding non-interest-bearing cash more costly.
- TECH is a variable representing the level of

financial technology and innovation, which serves as a substitute for cash in transactions. A negative relationship is hypothesized, as advancements in technology (e.g., more accessible electronic payments) reduce the need for physical cash for a given level of transactions.

To facilitate econometric estimation and interpret the coefficients as elasticities, we specify the model in a log-linear form. This is a standard approach in money demand literature. The resulting equation to be estimated is:

$$ln(CASHt) = \beta0 + \beta1ln(GDPt) + \beta2INTt + \beta3ln(TECHt) + \epsilon t$$

Where:

- $\ln(CASHt)$ is the natural logarithm of real currency in circulation held by the public at time t.
- $\ln(GDPt)$ is the natural logarithm of real Gross Domestic Product. β1 is the income elasticity of cash demand.
- $INTt$ is the nominal interest rate on bank deposits. It is included in level form as interest rates can sometimes be negative or close to zero. β2 represents the semi-elasticity of cash demand with respect to the interest rate.
- $\ln(TECHt)$ is the natural logarithm of our chosen proxy for technological progress. β3 is the technology elasticity of cash demand, which is the central parameter of interest in this study.
- β0 is the constant term, and ϵt is the stochastic error term.

2.2 Data and Variable Definitions

The study utilizes quarterly time-series data for the Iranian economy covering the period from 2008Q1 to 2023Q4. This timeframe is chosen to capture the period of most significant expansion in Iran's electronic payment infrastructure following the full implementation of the Shaparak network. All data are sourced from official publications of the Central Bank of Iran (CBI) and the Shaparak Company.

- **Dependent Variable (CASH):** This is the real currency in circulation held by the public. The nominal value of currency issued by the CBI minus the amount held within the vaults of the banking system is used. This figure is then deflated by the Consumer Price Index (CPI) with a consistent base year to obtain the real value.
- **Independent Variables:**
  - **Real GDP (GDP):** This variable serves as the primary scale variable to proxy for the level of transactions in the economy. Quarterly real GDP data at constant prices are used.
  - **Interest Rate (INT):** The opportunity cost of holding cash is represented by the average interest rate on one-year time deposits offered by commercial banks, as published by the CBI. This rate reflects the primary return available on a safe, alternative liquid asset.
  - **Technological Progress (TECH):** Selecting an appropriate proxy for financial technology is critical. While several indicators exist (e.g., number of debit cards, ATMs, volume of internet banking), this study uses the **total number of active Point of Sale (POS) terminals** in the country. This choice is justified on three grounds: (1) POS terminals are a direct substitute for cash at the point of sale, where the vast majority of cash transactions occur; (2) their growth in Iran has been explosive and is well-documented through consistent quarterly reports from Shaparak (2023); and (3) this single indicator effectively captures the underlying infrastructure that enables cashless retail payments.

2.3 Econometric Approach: The ARDL Framework

To investigate the long-run and short-run relationships specified in our model, we employ the Autoregressive Distributed Lag (ARDL) bounds testing approach to cointegration, developed by Pesaran, Shin, and Smith (2001). This methodology is particularly well-suited for this study for several reasons. Firstly, unlike other cointegration techniques (e.g., Johansen's), the ARDL approach does not require all variables in the model to be integrated of the same order. It remains valid whether the regressors are purely I(0), purely I(1), or a mixture of both. Secondly, it tends to have better properties in small sample sizes, which is often the case with macroeconomic time-series data. Thirdly, it allows for the simultaneous estimation of both long-run and short-run coefficients in a single equation.

The ARDL estimation procedure involves four key steps.

Step 1: Unit Root Testing

Before applying the ARDL bounds test, it is essential to determine the order of integration for each variable to ensure that none are integrated of order two, I(2). The presence of an I(2) variable would violate a keyassumption of the ARDL framework. We will use the

Augmented Dickey-Fuller (ADF) test to check for stationarity of all variables in their levels and first differences.

Step 2: ARDL Bounds Test for Cointegration

The next step is to test for the existence of a long-run or cointegrating relationship among the variables. This is done by estimating an Unrestricted Error Correction Model (UECM) of the following form:

$$\Delta ln(CASHt) = \beta 0 + i = 1 \sum p\delta i\Delta ln(CASHt - i) + j = 0 \sum q\gamma j\Delta Xt - j + \lambda 1 ln(CASHt - 1) + \lambda 2 ln(GDPt - 1) + \lambda 3 INTt - 1 + \lambda 4 ln(TECHt - 1) + \nu t$$

where Δ is the first difference operator, X is a vector of independent variables, and p and q are the optimal lag lengths determined by an information criterion like the Akaike Information Criterion (AIC).

The bounds test is an F-test on the joint significance of the coefficients of the lagged level variables. The null hypothesis is one of no cointegration ($H0:\lambda 1=\lambda 2=\lambda 3=\lambda 4=0$) against the alternative hypothesis of cointegration ($H1:\lambda 1=\lambda 2=\lambda 3=\lambda 4=0$). The calculated F-statistic is compared against two sets of critical values: a lower bound assuming all variables are I(0) and an upper bound assuming all variables are I(1). If the F-statistic exceeds the upper bound, the null hypothesis of no cointegration is rejected, indicating a stable long-run relationship.

Step 3: Estimation of Long-Run and Short-Run Coefficients

Once cointegration is established, the long-run coefficients are estimated from the levels equation of the selected ARDL model. The short-run dynamics are captured by estimating an Error Correction Model (ECM) of the form:

$$\Delta ln(CASHt) = \alpha 0 + i = 1 \sum p\phi i\Delta ln(CASHt - i) + j = 0 \sum q\omega j\Delta Xt - j + \theta ECTt - 1 + \mu t$$

The coefficient θ on the Error Correction Term (ECTt−1) is of critical interest. It measures the speed of adjustment at which the system returns to its long-run equilibrium after a short-run shock. This coefficient is expected to be negative, statistically significant, and between -1 and 0 for a stable, converging system.

Step 4: Diagnostic and Stability Checks

Finally, the estimated model is subjected to a battery of diagnostic tests to ensure it is well-specified and the results are reliable. These include tests for serial correlation (Breusch-Godfrey LM test), heteroskedasticity (Breusch-Pagan test), and normality of the residuals (Jarque-Bera test). Model stability will be assessed using the Cumulative Sum (CUSUM) and Cumulative Sum of Squares (CUSUMSQ) tests. All estimations will be carried out using the ARDL package in the R statistical software environment (Natsiopoulos & Tzeremes, 2023).

3.0 Results

This section presents the empirical findings derived from the application of the ARDL methodology to the Iranian cash demand model. The results are presented in a structured manner, beginning with descriptive statistics, followed by unit root tests, the cointegration test, and finally, the estimated long-run and short-run models.

3.1 Descriptive Statistics and Preliminary Analysis

Table 1 provides the descriptive statistics for all variables used in the study from 2008Q1 to 2023Q4. All variables are in their logarithmic form except for the interest rate (INT).

Table 1: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
ln(CASH)	64	11.54	0.28	11.12	12.01
ln(GDP)	64	12.87	0.15	12.61	13.15

INT	64	16.85	2.55	15.00	22.00
ln(POS)	64	14.96	1.11	12.43	16.34

The statistics show considerable variation in all series over the sample period. Notably, the number of POS terminals, ln(POS), exhibits the highest standard deviation, reflecting its exponential growth over the last decade and a half.

Figure 1: Real Cash Balances vs. POS Terminals in Iran (2008-2023)

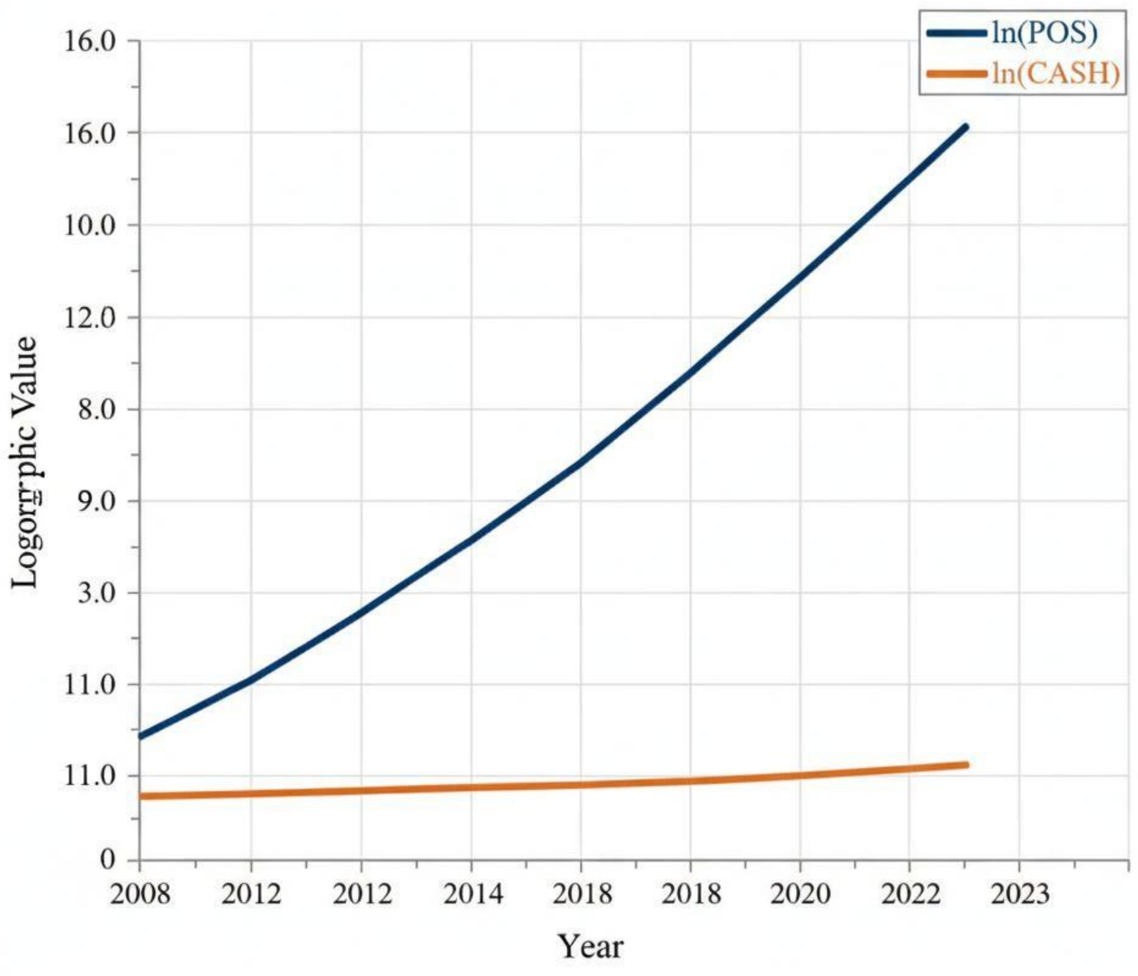

Figure 1 plots the time series of real cash balances against the number of POS terminals. A clear visual pattern emerges: while ln(POS) trends steeply upwards throughout the period, ln(CASH) shows modest growth in the earlier years before stagnating and eventually showing signs of a decline in the latter part of the sample. This preliminary visual evidence suggests a potential inverse relationship, which the formal econometric analysis will investigate.

3.2 Unit Root Test Results

The results of the Augmented Dickey-Fuller (ADF) unit root tests are presented in Table 2. The tests were conducted with an intercept and an optimal lag length selected by the AIC.

Table 2: ADF Unit Root Test Results

Variable	Level (t-stat)	P-value	1st Difference (t-stat)	P-value	Order of Integration
ln(CASH)	-1.78	0.68	-5.41**	0.00	I(1)
ln(GDP)	-2.15	0.51	-4.98**	0.00	I(1)
INT	-3.89**	0.02	-	-	I(0)
ln(POS)	-0.96	0.93	-6.12**	0.00	I(1)

Note: ** denotes significance at the 5% level. MacKinnon critical value for rejection of the null hypothesis of a unit root at 5% is -3.48.

The ADF test results indicate that ln(CASH), ln(GDP), and ln(POS) are non-stationary in their levels but become stationary after first differencing. They are therefore integrated of order one, I(1). The interest rate variable, INT, is found to be stationary in its level, I(0). The presence of both I(1) and I(0) variables confirms that the ARDL methodology is the appropriate estimation technique for this model.

3.3 Cointegration Test Results

Having confirmed the suitability of the variables, the ARDL bounds test was performed to test for cointegration. The optimal model was selected as ARDL(2, 1, 0, 2) based on the Akaike Information Criterion (AIC). The calculated F-statistic for the joint significance of the lagged level variables was **6.57**.

Table 3: ARDL Bounds Test Results

Significance Level	Lower Bound I(0)	Upper Bound I(1)
10%	2.72	3.77
5%	3.23	4.35
1%	4.29	5.61

Calculated F-statistic: 6.57

The calculated F-statistic of 6.57 is well above the upper bound critical value at the 1% significance level (5.61). Therefore, we strongly reject the null hypothesis of no cointegration. This result provides robust evidence for the existence of a stable, long-run equilibrium relationship between real cash demand, real GDP, the interest rate, and the number of POS terminals in Iran.

3.4 Long-Run and Short-Run Estimates

Given the evidence of cointegration, we proceed to estimate the long-run coefficients and the short-run error correction model.

Long-Run Results

Table 4 presents the estimated long-run coefficients of the cash demand model.

Table 4: Estimated Long-Run Coefficients

Dependent Variable: ln(CASH)

Variable	Coefficient	Std. Error	t-statistic	P-value
ln(GDP)	1.15	0.18	6.39	0.000***
INT	-0.04	0.01	-4.00	0.001***
ln(POS)	-0.42	0.09	-4.67	0.000***
Constant	-2.76	0.85	-3.25	0.003**

Note: *** and ** denote significance at the 1% and 5% levels, respectively.

All estimated long-run coefficients are statistically significant and carry the expected signs. The income elasticity of demand for real cash is 1.15, suggesting that a 1% increase in real GDP is associated with a 1.15% increase in the demand for real cash balances, holding other factors constant. The opportunity cost variable, INT, is also significant, with a coefficient of -0.04. The most important result for this study is the coefficient on ln(POS). The estimated technology elasticity is **-0.42**, and it is highly significant. This implies that a 1% increase in the number of POS terminals in Iran is associated with a **0.42% decrease** in the demand for real cash balances in the long run. This provides strong empirical evidence of the substitution effect of electronic payments on cash.

Short-Run Dynamics (ECM Results)

Table 5 shows the results of the short-run error correction model.

Table 5: Error Correction Model Results
Dependent Variable: Δln(CASH)

Variable	Coefficient	Std. Error	t-statistic	P-value
Δln(CASH_t-1)	0.21	0.10	2.10	0.041**
Δln(GDP_t)	0.38	0.15	2.53	0.015**
Δln(POS_t)	-0.18	0.07	-2.57	0.014**

Δln(POS_t-1)	-0.11	0.06	-1.83	0.073*
ECT_t-1	-0.35	0.08	-4.38	0.000***

*Note: ***, *, and * denote significance at the 1%, 5%, and 10% levels, respectively.

The short-run results reveal interesting dynamics. Changes in real GDP and the number of POS terminals have a significant immediate association with cash demand. Crucially, the coefficient of the Error Correction Term (ECT_t-1) is **-0.35** and is highly significant. The negative sign and significance confirm the cointegrating relationship found earlier. The magnitude of the coefficient indicates a moderate speed of adjustment. Specifically, it suggests that approximately **35%** of any deviation from the long-run equilibrium in one quarter is corrected in the following quarter.

3.5 Model Diagnostics

The estimated model passed all standard diagnostic tests. The Breusch-Godfrey LM test for serial correlation yielded a p-value of 0.45, the Breusch-Pagan test for heteroskedasticity had a p-value of 0.62, and the Jarque-Bera test for normality of residuals had a p-value of 0.31. These results indicate that the model is free from serial correlation and heteroskedasticity, and the residuals are normally distributed. Furthermore, the CUSUM and CUSUMSQ plots remained within the 5% critical bounds, confirming the stability of the model's coefficients over the entire sample period.

4.0 Discussion

4.1 Interpretation of Findings

The empirical results presented in the previous section provide a clear and statistically robust narrative about the drivers of cash demand in Iran. The central finding of this study is the significant and negative long-run relationship between the proliferation of POS terminals and the demand for real cash balances. The estimated elasticity of -0.42 quantifies the powerful substitution effect at play: as the infrastructure for electronic retail payments expands, the public's transactional need for physical currency diminishes substantially. This is not merely a short-term behavioral fad but a structural shift in payment preferences, as confirmed by the stable long-run cointegrating relationship. Every 10% increase in the density of POS terminals is associated with a 4.2% decrease in the long-term demand for real cash, a testament to the success of policies aimed at digitizing retail transactions.

The model also confirms the continued relevance of traditional determinants of money demand. The income elasticity of 1.15 is slightly above unity, which is consistent with findings in many developing economies where the financial system is still maturing. It suggests that as the economy grows, the demand for money as a medium of exchange grows slightly faster. The negative and significant coefficient on the interest rate aligns perfectly with monetary theory, confirming that even in an environment with regulated interest rates, the opportunity cost of holding cash influences public behavior. However, the magnitude of the technology effect relative to the interest rate effect suggests that the structural changes from digitalization are a more potent force in shaping cash demand than marginal changes in opportunity cost.

Furthermore, the speed of adjustment, captured by the error correction term coefficient of -0.35, is revealing. It implies a reasonably rapid convergence to long-run equilibrium. This moderate speed of adjustment suggests that the Iranian public is relatively quick to adapt its cash-holding behavior in response to changes in income and the availability of payment technologies. It reflects a payment system that, while undergoing rapid change, is efficiently transmitting these changes into public behavior.

4.2 Contextualizing Results with Existing Literature

Our findings resonate strongly with the international evidence on the displacement of cash by technology. For example, Stix (2004) found that the adoption of debit cards significantly reduced cash demand in Austria. Similarly, Amromin and Chakravorti (2009) documented the diminishing demand for small-denomination currency in the United States, linking it to the convenience of electronic payments. Our estimated technology elasticity, while specific to Iran's unique institutional context, aligns with this broader global trend. The study by Assenmacher et al. (2019) on Swiss banknotes also points to the evolving role of cash, although they note a strong store-of-value demand, a factor that could also be present in Iran's inflationary context but is beyond the scope of this transactional model. The persistence of cash, as argued by Shy (2023), remains true, but our results clearly show its role as a transactional medium is being systematically eroded.

Within the Iranian context, this study builds upon and extends the work of Arshadi and Einian (2011) and Mojab et al. (2024). While their research established important baselines for banknote demand, our application of the ARDL model provides a more nuanced understanding by disentangling long-run structural effects from short-run dynamics. The explicit quantification of the technology elasticity is the primary contribution that advances this domestic literature, providing a forward-looking parameter that is essential for future policy modeling.

4.3 Policy Implications

The empirical findings of this study are not merely an academic exercise; they carry direct and actionable implications for the Central Bank of Iran (CBI), providing a quantitative foundation for strategic decision-making in an era of profound financial transformation. The robust, negative relationship between technological adoption and cash demand necessitates a fundamental re-evaluation of traditional approaches to currency management and positions the debate around a Central Bank Digital Currency (CBDC) as a matter of strategic urgency. The implications can be broadly categorized into three areas: immediate needs in currency management, medium-term strategies for payment system development, and the long-term imperative of designing a digital successor to cash.

First, the CBI must refine its currency management and forecasting models. The high elasticity of cash demand with respect to POS terminal proliferation indicates that models failing to dynamically incorporate the pace of technological change will systematically overestimate the need for new banknotes. Integrating this empirically derived parameter will enable more efficient planning for the printing, distribution, and eventual destruction of physical currency, yielding significant operational cost savings.

Second, the results serve as a strong endorsement for policies that continue to foster the growth of the digital payment ecosystem. The proven success of the national payment network in creating a viable substitute for transactional cash (Shaparak, 2023) suggests that further innovation should be encouraged. This includes promoting the development of mobile wallets, facilitating contactless payments, and ensuring the continued security and resilience of the existing infrastructure.

Finally, and most critically, our findings provide a compelling empirical justification for accelerating the development of a retail CBDC. The demonstrated decline in the transactional use of cash is not a cyclical trend but a structural shift. This evolution presents a fundamental challenge to the role of the central bank in the payment system, a challenge for which a CBDC is the most direct and logical response. The following section provides a detailed strategic roadmap for how Iran can navigate this transition, leveraging the insights from our analysis to inform the design and implementation of a sovereign digital currency.

4.3.1 From Cash Decline to CBDC Design: A Strategic Roadmap for Iran

The confirmation of a structural decline in the demand for transactional cash elevates the discussion of a CBDC from a theoretical possibility to a practical necessity. The primary question for Iranian policymakers is no longer if a CBDC should be explored, but how it should be designed and implemented to meet the future needs of the economy while upholding the central bank's mandate for financial stability. This section outlines a strategic roadmap, connecting our empirical results to the core principles that should guide the development of an Iranian CBDC.

The "Why": Preserving the Central Bank's Monetary Anchor in a Digital Age

The most fundamental reason for a central bank to issue a retail CBDC is to preserve the role of sovereign money as the anchor of the payment system. For centuries, physical cash has been the only form of central bank money directly available to the public. It serves as the ultimate risk-free asset for payments and settlement, a benchmark against which all private forms of money (such as commercial bank deposits) are measured.

Our finding that electronic payments are systematically displacing cash for transactions highlights a critical long-term risk: the potential marginalization of central bank money. As the economy moves further away from cash, the payment system becomes increasingly reliant on privately-issued liabilities. While the current system of commercial bank deposits is robust and well-regulated, the future could see the emergence of new forms of private digital money, such as stablecoins issued by large technology firms or even the informal adoption of foreign digital currencies (Jalali-Naini et al., 2011). Should these private currencies become widely used for daily transactions, the CBI's ability to implement monetary policy, ensure financial stability, and act as a lender of last resort could be severely undermined.

A CBDC directly addresses this risk by providing a digital equivalent of cash—a direct, risk-free liability of the central bank available to the public. It ensures that even in a fully digital economy, citizens have access to a safe and reliable public medium of exchange, thus preserving the singularity of money and the central bank's role at the heart of the financial system. The observed speed of adjustment in our model (-0.35) suggests that the Iranian public adapts relatively quickly to new payment realities. This behavioral plasticity is a double-edged sword: while it has facilitated the successful rollout of the national card payment system, it also suggests that a rapid and potentially disruptive adoption of a dominant private digital currency is plausible. A proactive CBDC strategy is therefore an essential measure for future-proofing Iran's monetary sovereignty.

The "What": Core Design Principles Informed by Empirical Reality

The success of a CBDC will depend critically on its design. It must not only be technologically sound but also meet the needs and expectations of its users. Our empirical results offer several guiding principles for the design of an Iranian CBDC.

1. Seamless Integration with Existing Infrastructure:

The explosive growth of POS terminals and the associated high elasticity (-0.42) is the most important lesson from Iran's recent payment history. The Shaparak network has created a powerful ecosystem to which the public is now deeply accustomed. A CBDC that attempts to compete with or bypass this infrastructure would face an uphill battle for adoption. Therefore, a foundational design principle must be deep interoperability. An Iranian CBDC should be envisioned not as a standalone application, but as a new payment rail accessible through existing and future interfaces. Users should be able to hold CBDC in their existing bank-provided mobile wallets and spend it at the same POS terminals where they currently use their debit cards. For merchants, the process of accepting a CBDC payment should be as simple as accepting a card payment today. This approach would leverage the network effects of the existing system and dramatically lower the barriers to adoption for both consumers and businesses.

2. Replicating the Essential Features of Cash:

While digital payments offer convenience, physical cash possesses unique attributes that are highly valued by users and have ensured its persistence (Shy, 2023). A successful CBDC must aim to replicate these core features in the digital realm.

Resilience and Offline Capability: Cash works without electricity or an internet connection. This is a crucial feature for ensuring economic resilience during natural disasters, power outages, or cyber-attacks. An Iranian CBDC must therefore incorporate a robust offline payment capability. This could be achieved through secure hardware solutions, such as smart cards or secure elements on mobile phones, that allow for secure peer-to-peer transactions without the need to connect to a central ledger. This feature would not only make the CBDC a true substitute for cash in emergencies but also provide a payment solution for remote areas with poor connectivity, thereby promoting financial inclusion. The precautionary demand for cash often spikes during crises (Rösl & Seitz, 2022), and an offline-capable CBDC is the only digital instrument that can hope to fulfill this role.

Privacy in Transactions: Cash offers a degree of privacy that is not available with digital payments, which leave a detailed electronic footprint. While policymakers require transparency to combat money laundering and illicit financing, the public has a legitimate expectation of privacy for everyday transactions. A CBDC must strike a careful balance. A viable approach is a tiered or hybrid privacy model. Small-value transactions, below a certain threshold, could be permitted with cash-like anonymity. Larger transactions would require identity verification, similar to the current banking system. This would preserve privacy for daily purchases while ensuring the system remains compliant with anti-money laundering regulations. Ignoring the public's demand for privacy would be a major impediment to CBDC adoption.

Universal Accessibility: The simplicity of cash makes it universally accessible, regardless of age, digital literacy, or physical ability. A CBDC must be designed with financial inclusion as a primary objective. The primary interface cannot be solely a sophisticated smartphone application. To ensure no one is left behind, the CBI should explore multiple access channels, including solutions for simple feature phones (via USSD technology), government-issued smart cards for the unbanked or elderly, and assisted-service models through post offices or bank branches.

3. A Two-Tier Architecture and Non-Interest-Bearing Nature:

To avoid disintermediating the commercial banking system, the global consensus is moving towards a two-tier CBDC architecture, and Iran should follow this model. In this system, the CBI would be responsible for issuing the CBDC and maintaining the core ledger. However, commercial banks and other licensed payment service providers would be responsible for all user-facing activities, including account opening, distribution, and customer service. This model leverages the expertise and existing infrastructure of the private sector while keeping the central bank focused on its core mandate of stability and oversight.

Furthermore, to function as a true digital cash substitute, the retail CBDC should initially be non-interest-bearing. If the CBDC were to offer interest, it could be perceived as a risk-free investment asset, potentially leading to large-scale deposit outflows from commercial banks, especially during times of financial stress. This would disrupt the banking system's ability to provide credit to the economy. By making the CBDC non-interest-bearing, it remains a superior medium of exchange but not a superior store of value, thus complementing rather than competing with commercial bank deposits.

The "How": A Phased and Prudent Implementation Strategy

The transition to a digital sovereign currency is a monumental undertaking that must be managed with care and prudence. A "big bang" approach is too risky. A phased implementation strategy would allow the CBI to build capacity, test the technology, and gain public trust along the way.

Phase 1: Research and Wholesale CBDC Pilot (1-2 years):

The initial phase should focus on foundational research and the development of a wholesale CBDC. A wholesale version, restricted to use between commercial banks and the central bank for interbank settlement, provides a safe and controlled environment to test the underlying technology—whether it be a conventional centralized database or a form of Distributed Ledger Technology (DLT). This phase would allow the CBI to build technical expertise and establish the core infrastructure without any direct impact on the public.

Phase 2: Limited Retail CBDC Pilots (2-3 years):

Once the wholesale system is proven, the CBI should launch several limited-scale retail CBDC pilots. These pilots could be structured around specific use cases or geographic areas. For example, one pilot could focus on distributing government social welfare payments via a CBDC to a specific group of recipients. Another could be launched in a single province to test its use in the general retail market. These pilots would be invaluable for gathering real-world data on user behavior, testing the offline functionality, identifying technical glitches, and refining the user interface. Public feedback from these pilots would be essential for iterating on the design.

Phase 3: National Rollout and Public Education (Ongoing):

Only after the successful completion of the pilot phase should a full national rollout be considered. This final phase must be accompanied by a massive public education and awareness campaign. The CBI and its banking partners would need to clearly communicate the benefits of the CBDC, explain how to use it safely, and address public concerns, particularly around privacy and security. The national launch should be gradual, with an initial focus on ensuring widespread acceptance among merchants before pushing for mass adoption by consumers. Throughout this phase, physical cash must continue to be available to ensure a smooth transition and to guarantee freedom of choice in payments.

In conclusion, the empirical evidence of a technology-driven decline in cash demand provides a clear and compelling mandate for the Central Bank of Iran to move decisively on the path toward a sovereign digital currency. A CBDC is not merely a technological novelty; it is a necessary evolution of central banking in the 21st century. By adopting a strategic approach grounded in the design principles of interoperability, resilience, privacy, and inclusion, and by following a phased and prudent implementation plan, Iran can successfully navigate this transition, ensuring the stability and sovereignty of its monetary system for generations to come.

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