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The Impact of Technological Progress on the Demand for Cash in Iran: an ARDL Modeling Approach

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Abstract:
Technological progress has transformed the payment industry. Although alternative payment instruments such as bank cards share some characteristics with banknotes, they are not direct competitors to cash. First, cash possesses unique attributes—its functionality without electrical power and its inherent anonymity. Second, statistical data indicate that the ratio of cash to M1 has stabilized at approximately 10% in recent years, primarily due to its substitution with demand deposits.
In this paper, we model the demand for banknotes by incorporating technology-related characteristics alongside conventional theories of money demand. Our approach has important implications for central bank, particularly in liquidity management, currency issuance, effective management of physical currency, and continued investment in digital payment infrastructures.
We adopt a macroeconomic perspective that considers banknote demand from both transactional and asset viewpoints. To this end, we estimate an autoregressive distributed lag (ARDL) model, which allows us to analyze both short-term and long-term coefficients within a framework of model uncertainty. A key focus of our study is the estimation of a payment system development index using logistic growth and Gompertz models, through which we assess its impact on cash demand.
Our empirical evidence supports the notion of S-shaped growth in the adoption of payment technologies. The findings demonstrate that advancements in the payment sector have led to a significant decline in cash demand. Moreover, while increased real economic activity exerts a positive and significant influence on cash demand, a higher opportunity cost of holding cash has a pronounced negative impact.

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1. Introduction

Technological advancements have transformed the payment industry. Over the past two decades, payment service models and financial products have undergone significant changes (Committee on Payments and Market Infrastructures, 2018). In many countries, a large share of cash and physical payments has been replaced by fast and instant electronic tools (Bech & Hancock, 2020; Khiaonarong & Humphrey, 2022; Bech, Faruqui, Ougaard & Picillo, 2018; Committee on Payments and Market Infrastructures, 2018; Mojab et al., 2024; Jalali-Naini et al., 2024). However, despite significant progress in payment technologies, achieving a fully cashless economy remains a distant goal (Shy, 2023; Bech et al., 2018; Committee on Payments and Market Infrastructures, 2018; Jakobsen, 2018). In other words, while the demand for banknotes is gradually declining, cash and coins continue to play a significant role, particularly in developing economies.

The demand for cash arises from its dual function as, both, a medium of exchange and a store of value (Jalali-Naini et al., 2024). Traditional money demand theories, such as the Baumol-Tobin model, suggest that cash demand is influenced by two opposing forces: while higher economic activity tends to increase cash demand due to greater transactional needs, a rise in the opportunity cost of holding cash discourages its use (Assenmacher, Seitz & Tenhofen, 2019; Kohli, 1988). Meanwhile, rapid advancements in payment technology have become a key determinant of cash demand, as digital payment systems increasingly replace traditional cash transactions. Empirical data indicate that the ratio of cash in circulation to M1 has declined in many countries in recent years due to substitution with demand deposits (see Figure 2). However, cash retains unique characteristics—such as its functionality without electrical power and its inherent anonymity—which help sustain its role in the financial system.

This study employs an ARDL modeling framework to examine the determinants of banknote demand that consists of real economic activity, the opportunity cost of holding cash, and payment system development. To address model uncertainty, we estimate multiple ARDL specifications, ensuring robustness through rigorous variable selection and diagnostic testing. The analysis places particular emphasis on the payment system development index for the Iranian economy. To measure this impact, we estimate the index using logistic growth and Gompertz models and assess its influence on cash demand.

The remainder of the paper is structured as follows: Section 2 discusses the theoretical background, Section 3 presents the empirical results, and Section 4 concludes the study.

2. Theoretical Background

The theory of money demand has long been studied in economics, with early models focusing on cash transactions. However, these models were developed in an era when modern alternative payment instruments, such as bank cards, did not exist. As a result, early frameworks, including the Baumol-Tobin model, primarily explain the transaction costs of holding cash in terms of frequent trips to the bank.

The advent of modern payment tools, such as bank cards, has reduced the need for frequent cash withdrawals, thereby lowering the transaction costs associated with holding cash. While the Baumol-Tobin model remains relevant, it requires modification to account for the availability of alternative payment instruments. The demand for money arises from various motives, including its use for transactions, as a precautionary reserve, and as a store of value. The latter is emphasized in Friedman (1956). The Baumol-Tobin model primarily focuses on the transactional motive, emphasizing the trade-off between holding cash and the opportunity cost of forgoing interest-earning assets.

Assume that M represents the money supply and V_T the transactions velocity of money, then the value MV_T represents the total value of transactions conducted in the economy (e.g., Friedman, 1956). To better understand the role of different payment instruments in money demand, we extend the traditional money demand equation by distinguishing between transactions settled in cash and those conducted using modern payment tools, such as credit and debit cards, mobile payment apps, contactless payments, and other digital transaction methods. Following Jalali-Naini et al. (2024), we use the following equation:

$$MV_T = \sum_{i=1}^{N_1} p_{1i} q_{1i} + \sum_{i=1}^{N_2} p_{2i} q_{2i} \qquad (1)$$

where p_{1i} and q_{1i} represent the price and quantity of transactions settled using cash for basket i, while p_{2i} and q_{2i} represent the price and quantity of transactions settled using alternative and modern payment instruments (e.g., bank cards) for basket i. Similarly, N_1 denotes the number of baskets settled with cash, and N_2 represents those settled with alternative payment tools. We exclude traditional and non-digital payment instruments, such as checks and gold, as well as digital tools that are not considered legal tender or authorized by the central bank, such as fiat stablecoins (e.g., Tether).[1] The above equation indicates that there are two dimensions: “frequency” (reflected in $N_1 + N_2$) and “value” (i.e., MV_T). Evidence regarding the incomplete correlation between these two dimensions can be found in Mojab et al. (2023) by comparing Shaparak data with survey data. This comparison shows that for higher-valued purchased baskets, bank cards are more likely to be used.[2]

[1] The topic of cryptocurrencies and their substitution for various forms of money is another subject that has been addressed in a separate study (Jalali-Naini & Rabie Hamedani, 2016).

[2] Shaparak, Iran's electronic card payment backbone, provides complementary data from its economic reports (e.g., Shaparak, 2023). Extracted as cumulative graphs, these reports include metrics like "Transaction Amount Ranges for Point-of-Sale Devices," presented as percentages with up to two decimal places. The analysis utilizes the key metric "cumulative percentage of transaction count.

The demand for cash and coins arises from their unique features. Some of these features are exclusive to cash, such as the ability to conduct anonymous transactions, immediate and final settlement without requiring a third party (e.g., a commercial bank), and the capability to make payments during special circumstances such as power outages, lack of internet accessibility or down-time, or natural disasters. Cash is also demanded for precautionary reasons, such as to address unforeseen needs (Shy, 2023; Rösl & Seitz, 2022). The lower the risk of such special circumstances, the less likely people are to hold cash and coins, ceteris paribus. Additionally, cash demand may be driven by currency hoarding, particularly the holding of foreign currencies in countries with high inflationary expectations (Porter & Judson, 1996; Shy, 2023).

In recent years, the share of cash and coins in M (Equation 1) has declined in many countries (Figure 1). Besides concerns about physical contact during pandemics (e.g. COVID-19) , holding cash inherently presents challenges, such as theft or loss and the inability to track payment records. Technological innovations in the payment industry, the emergence and widespread adoption of credit, debit, and prepaid cards, as well as greater access to these tools, have contributed to a decline in cash usage (Amromin & Chakravorti, 2009; Stix, 2004). Consumers increasingly prefer non-cash payments due to their convenience, efficiency, and cost-effectiveness (Jebarajakirthy & Shankar, 2021). Modern payment instruments have evolved to offer a range of alternatives to cash, from credit and debit cards to electronic wallets and QR code-based payments. While these tools enhance convenience, their adoption depends on infrastructure, digital literacy, and financial awareness. As digital payments become more prevalent, factors such as technological access, financial education, and regulatory frameworks will increasingly shape cash demand. Understanding these dynamics is crucial for policymakers striving to balance financial innovation with economic inclusivity. As long as central banks are responsible for providing the means of payment demanded by the public, this issue will remain a key concern for them.

3. Data and Empirical Results

3.1 Trend Analysis

Advancements in payment technologies have reshaped the use of both traditional and modern payment instruments, altering the composition of money supply and transactional preferences over time. Figure 1 illustrates the trends in the real value of currency in circulation (CIC), demand deposits (DD), and the money supply (M1) in Iran from 1981 to 2022. A key observation is the steady decline in the share of currency in circulation within M1, though this trend has been punctuated by periodic fluctuations due to regulatory changes and shifts in payment behavior. Note that, the sharp increase in the volume of currency in circulation in 2008 is primarily a statistical fluke, resulting from the issuance hence inclusion of central bank-issued Iran Cheques and not a genuine shift in demand. Prior to this period, check-money instruments issued by commercial and commercial banks were increasingly used as substitutes for cash. Despite their legal status, a significant portion of these instruments remained in circulation rather than being returned to banks, effectively functioning as cash within the economy. This trend accelerated as banks entered bilateral agreements to accept each other's check-money instruments and the issuance of Iran Cheques by intermediary banks, effectively expanding the monetary base beyond official central bank-issued currency. This indicates that, during a specific period, the public's demand for currency was not exclusively met by currency and coins issued by the central bank. We take this issue into our calculations in the next section. While there may be debates regarding the extent and nature of this adjustment, it is essential, as there is no evidence of a any noticeable economic event in 2008 that would explain the observed changes in the demand for currency and coins during that period. Of course, this trend cannot be completely ignored, as large-denomination banknotes can also lead to an increase in demand (Kohli, 1988). Therefore, it would be more appropriate to analyze these statistics using adjusted data based on the recommendations of Arshadi and Einian (2011).

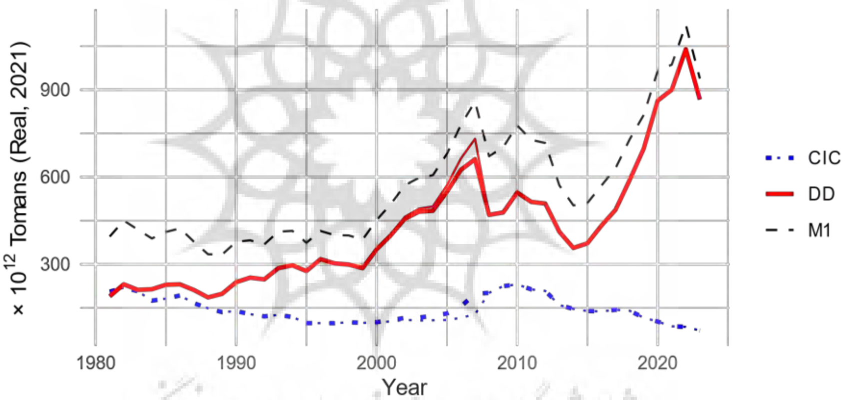

Figure 1. Trends in Currency in Circulation (CIC) and Demand Deposits (DD) Over Time (Trillions of Rials, Adjusted for CPI) in Iran. Between 1999 and 2007, the thin lines alongside the CIC and DD curves represent the unadjusted series (see: Arshadi & Einian, 2011).

To place Iran's experience in a broader context, Figure 2 presents the trends in the ratio of currency in circulation (CIC) to M1 across several economies, allowing for cross-country comparisons. Although exceptions exist, the data reveal a general downward trend in the CIC-to-M1 ratio across all three country groups. However, the rate of decline varies, with some economies experiencing a steady reduction, while others exhibit more abrupt shifts, likely influenced by factors such as policy interventions, financial infrastructure development, and consumer adoption of digital payments. Notably, Iran stands out as one of the countries where the CIC-to-M1 ratio has declined at a relatively rapid pace in recent years, reflecting the accelerating shift towards electronic payments and the reduced reliance on physical cash.

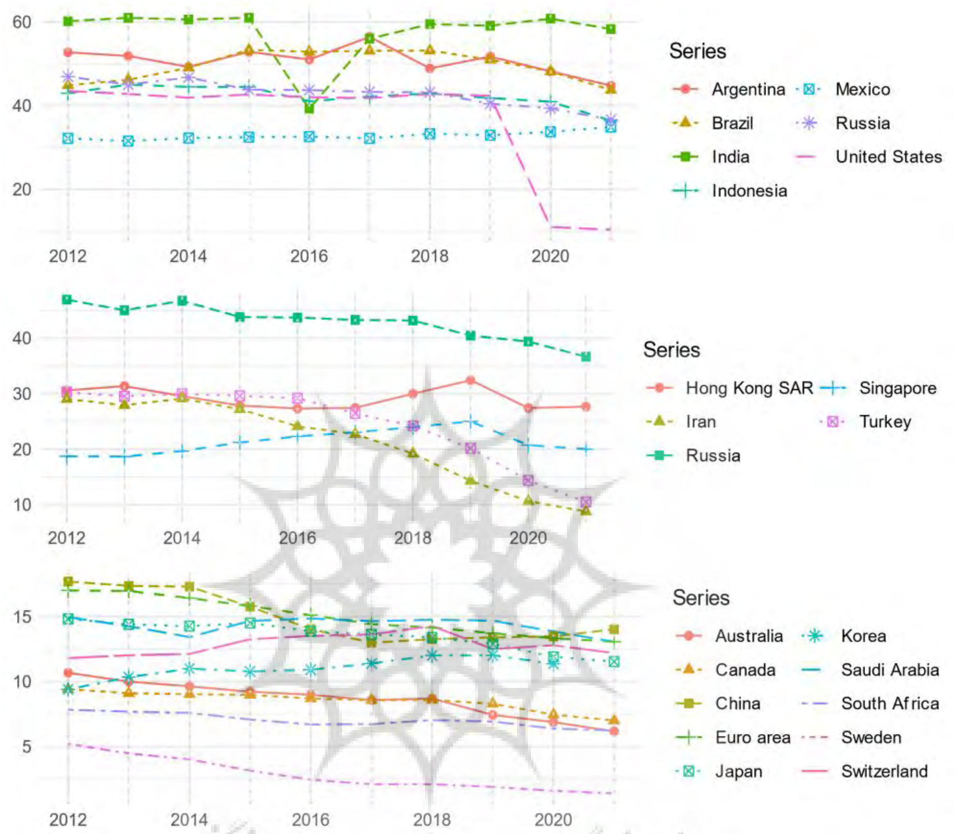

Figure 2. Trends in the Ratio of Currency in Circulation (CIC) to Money Supply (M1) Across Selected Countries. Source of Data: Bank for International Settlements (2024).

3.2 Model Data and Descriptive Statistics

This study aims to model the determinants of currency in circulation, considering both per capita and real values to account for inflation and population effects. Guided by the theoretical framework, the explanatory variables are classified into three key categories, each capturing a distinct economic mechanism influencing cash demand. Key indicators for real economic activity are real GDP, real aggregate consumption, and real private consumption. The opportunity cost of holding cash is the free market exchange rate (USD/IRR) movements or the inflation rate. Finally, to approximate financial development, we employ polynomial, logistic, and Gompertz growth trends, each reflecting different assumptions about the pace and saturation of technological adoption. Detailed explanations of these trends are provided in the relevant section. Table 1 provides an overview of the variables, including their symbols and descriptive statistics. While multiple indicators of payment industry development were computed, only one is reported here for brevity due to their high correlation.

Table 1
Descriptive Statistics

	id	Mean	SD	Q1	Med.	Q3
Currency in Circulation (Per Capita, Real 2021)	cic	2.341	1.042	1.644	2.033	2.815
Gross Domestic Product (Per Capita, Real 2011)	gdp	7.671	1.386	6.864	7.208	8.952
Consumption (Per Capita, Real 2011)	con	4.426	1.173	3.437	4.025	5.099
Private Consumption (Per Capita, Real 2011)	conp	3.187	0.929	2.404	2.981	4.005
Exchange Rate (Thousand Toman, Real 2011)	exr	2.18	0.693	1.6	2.252	2.663
Inflation Rate (Percent)	inf	21.491	10.887	13.462	19.355	27.793
Exchange Rate Growth (Percent, Nominal)	gexn	22.852	30.8	3.764	13.372	29.857
Payment System Development (Index, 1)	dev1	0.245	0.341	0.001	0.023	0.484

Note. Unless stated otherwise, all monetary values are reported in millions of Tomans. The exchange rate variable reflects the free market USD/IRT rate. Details on the computation of the Payment Industry Development Index can be found in Section 3.3. The data sources include the Central Bank of Iran and the Statistical Center of Iran.

Table 2 presents the results of the Augmented Dickey-Fuller (ADF) test for the variables of interest in this paper. The null hypothesis states that the variable contains a unit root.

Table 2
Augmented Dickey-Fuller Unit Root Result

	with Intercept		with Trend	
	Level	Diff	Level	Diff
ln_cic	-1.2	-4.1***	-1.8	-4.1**
ln_gdp	-0.73	-6.2***	-4**	-6.2***
ln_con	0.15	-4.4***	-2	-5***
ln_conp	-0.38	-4.7***	-2.9	-4.8***
ln_exr	-1.6	-6.8***	-1.6	-6.8***
inf	-3.1**	-7***	-3.3*	-7.2***
gexn	-5.9***	-5.6***	-6.2***	-5.6***

Note. The symbols ***, **, and * denote statistical
ignificance at the levels of 0.01, 0.05, and 0.1, respectively.

The results largely align with theoretical expectations and prior empirical findings and confirming the stationarity properties commonly observed in similar studies. Specifically, the results indicate that per capita currency holding, the exchange rate, and real output exhibit unit roots at levels. However, they become stationary after first difference, hence they have integration of order one, I(1). Conversely, the inflation rate and exchange rate growth are stationary.

3.3 Payment System Development Index

To model the development of the payment industry, we employ growth models that capture the typical adoption trajectory of technological innovations: an initial slow uptake, followed by rapid expansion, and eventual market saturation. The concept of S-curves in technological innovation diffusion was first introduced by Mansfield (1961) and later refined by Fisher and Pry (1970) whose work laid the foundation for quantitative models of technology adoption.[1] Both the Logistic and Gompertz models describe growth processes, yet they differ in their underlying dynamics and suitability for various adoption patterns. The Logistic model assumes symmetrical growth, where the adoption rate accelerates initially before slowing down symmetrically as it nears market saturation thus forming an "S-shaped" curve. In contrast, the Gompertz model follows an asymmetric pattern, with a prolonged early adoption phase, rapid acceleration, and a gradual tapering-off, making it better suited for industries with delayed adoption and slower saturation. These differences make the Logistic model well-suited for industries with balanced adoption and saturation rates, while the Gompertz model is more appropriate for cases where early adoption is slow and saturation occurs gradually.

The expansion of private banking in the early 2000s—marked by the establishment of Iran's first private bank in 2001—coincided with notable advancements in the payment industry. However, while improvements in payment infrastructure are well-documented, the extent and quality of the adoption of alternative payment instruments is much less explored. Central Bank statistics, available from 2007, predominantly include data on debit cards, ATMs, and POS terminals. We construct a payment industry development index based on these indicators, with additional methodological details provided in the original study. Unlike Jalali-Naini et al. (2024), we construct the index both with and without ATM statistics to assess their relative impact. As illustrated in Figure 3, ATM ATM-related data were more salient during the early era of electronic banking, and excluding them delays the estimated onset of the technology saturation phase.

To ensure comparability, the ratio of ATMs, cards, and POS terminals to the population is linearly scaled within a range of 0.1 to 1, where 0.1 represents the estimated adoption level in 2007 and 1 denotes near-complete adoption at the end

[1] For a comprehensive review of these models see Kucharavy and Guio (2011).

of the study period. Since the formal expansion of private banking and digital payment infrastructure began in 2001, we set the index to zero before this period. The missing values between 2002 and 2006 are interpolated to ensure a continuous dataset. The estimation results for four models (Logistic and Gompertz, with and without ATM statistics) of the payment industry development index are presented in Figure 3. Additional details regarding the calculations are available upon request.

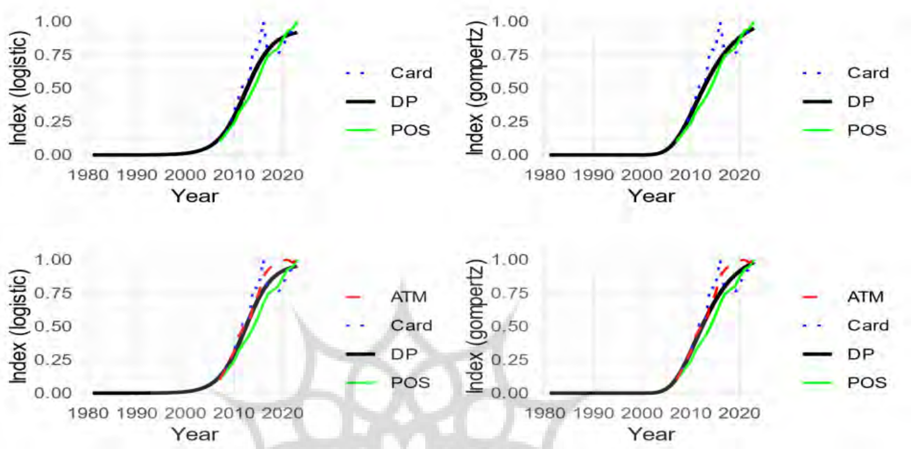

Figure 3. Development Indices for the Payment Industry. The vertical axis label indicates whether the logistic or Gompertz model is used. ATM statistics are used in the two bottom plots.

3.4 Estimation Result

3.4.1 Addressing Model Uncertainty in Variable Selection

An agnostic modeling approach is employed, estimating 120 model specifications based on different variable combinations consisting of GDP, consumption, and private consumption, real exchange rate, inflation, and growth of nominal exchange rate. The inclusion of multiple indicators for payment system development and various lag structures in the ARDL model results in a relatively large model space.

A total of 120 models are estimated, with optimal lag lengths selected based on the Akaike Information Criterion (AIC), allowing for a maximum of four lags. To ensure that the best model is free from serial correlation, we apply the Durbin-Watson test. Additionally, we test for weak exogeneity, ensuring that explanatory variables are not correlated with the equation's error term. We conduct Granger causality tests between the ARDL residuals and each explanatory variable individually, using up to three lags. If the null hypothesis of no Granger causality is rejected, the variable is considered non-exogenous.

Under this uncertainty-based modeling framework, we first analyze the frequency distribution of long-run and short-run coefficients across models. These results are presented in Figures 4 and 5.

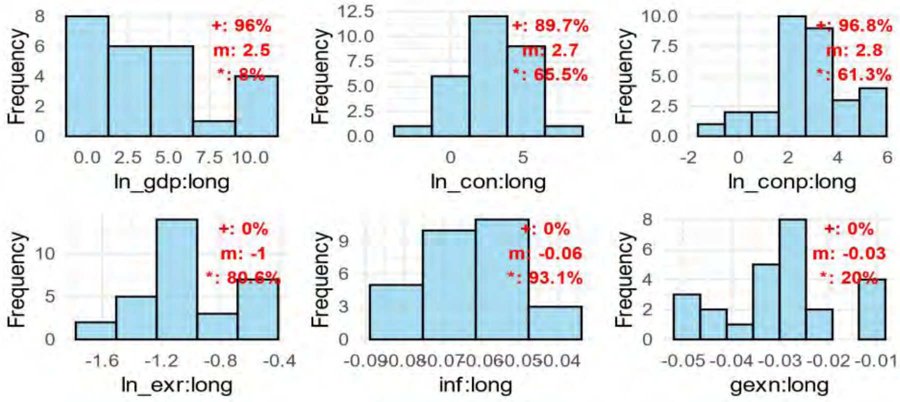

Figure 4. Distribution of Estimated Long-run Coefficients in ARDL Models. Variable symbols are provided below the charts (gdp: gross domestic product, con: total consumption, conp: private consumption, inf: inflation, exr: real exchange rate, gexn: growth rate of the nominal exchange rate). 'ln_' before the variables represent natural log of the variables. ***, **, and * indicate the percentage of statistically significant coefficients at the 1%, 5%, and 10% levels, respectively. The '+' sign denotes the proportion of coefficients that are positive. The 'm' sign indicates the median. The total number of estimated models is 543, and variables in each row are not simultaneously included in a single regression. The results were obtained using the "auto.ardl" function from the ARDL package (Natsiopoulos & Tzeremes, 2023).

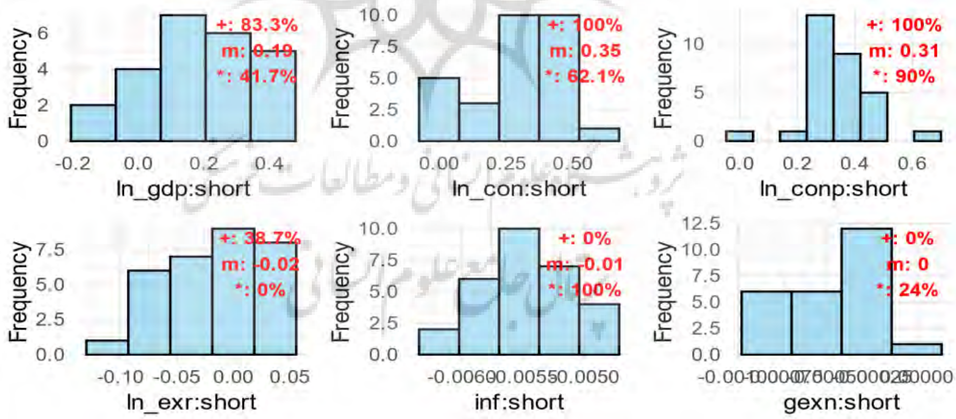

Figure 5. Distribution of Estimated Short-run Coefficients in ARDL Models. See Figure 4.

An analysis of the coefficient frequency distribution, focusing solely on coefficient signs while disregarding significance and magnitude, reveals general consistency with theoretical expectations, though some uncertainty remains. Most coefficients associated with real sector economic activity variables—GDP, total consumption, and private consumption—exhibit positive signs. In the long run, the proportion of positive coefficients for GDP, total consumption, and private consumption is 96%, 90%, and 97%, respectively. In the short run, these figures are 83%, 100%, and 100%, respectively. These results suggest that higher real sector activity, holding other factors constant, correlates with increased banknote demand in both the short- and long-run. Furthermore, the findings indicate that private consumption is the most empirically suitable determinant of banknote demand.

To assess coefficient magnitude without considering statistical significance, we focus on the median values. The median long-run coefficients for GDP, total consumption, and private consumption are 2.5, 2.7, and 2.8, respectively. In the short run, these values are 0.19, 0.35, and 0.31. These results suggest that, holding other factors constant, a 1% increase in GDP, total consumption, or private consumption corresponds to an estimated 2.5–2.8% rise in banknote demand in the long run and a 0.2–0.4% increase in the short run. These estimates are derived from the median coefficient distribution, and alternative measures such as the mean yield similar results, reinforcing the robustness of the findings.

Figures 4 and 5 display the statistical significance of the estimated coefficients. At a 10% significance level, 8% of the GDP coefficients, 65% of the overall consumption coefficients, and 61% of the private consumption coefficients are statistically significant. In the short run, these figures increase to 42% for GDP, 62% for overall consumption, and 90% for private consumption. The results indicate that short-run coefficients tend to exhibit greater statistical significance than long-run coefficients. Additionally, private consumption coefficients display higher significance levels than those of other economic activity indicators. However, given potential data limitations, detailed comparisons of significance percentages should be interpreted with caution.

The distributions of the coefficients of the variables reflecting opportunity cost (the real exchange rate, inflation, and exchange rate growth) are illustrated in the second row of Figures 4 and 5. These coefficients are expected to be negative.

In all regression models, the estimated coefficients are negative for every variable except for short-run GDP coefficients—only 61% of which are negative. In terms of magnitude (without considering significance), the average long-run coefficients for the exchange rate, inflation, and exchange rate growth are -1, -0.06, and -0.03, respectively. This implies that a 1% increase in inflation leads to an estimated 0.06% decline in banknote demand. Regarding statistical significance, inflation coefficients are significant in a greater number of regressions than the real exchange rate and nominal exchange rate growth coefficients, in both the long and short-run.

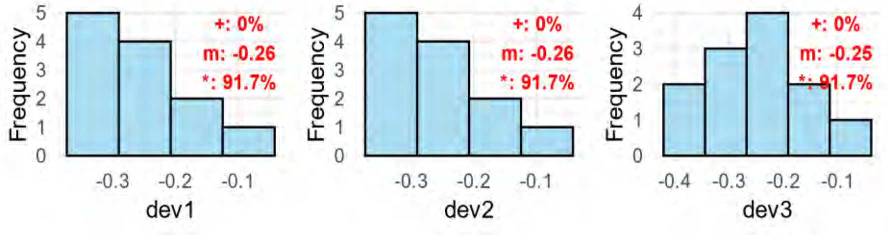

Figure 6. The frequency distribution of estimated coefficients for various payment system development indicators in the ARDL model is presented. 'dev1', 'dev2', and 'dev3' represent estimated indicators based on different assumptions, as explained in Section 3.3. Refer to Figure 4 for further details.

Figure 6 presents the estimated coefficients for payment system development indicators. Since the results are consistent across different specifications, only three representative charts are reported. All estimated coefficients are negative, suggesting that, holding other factors constant, improvements in the payment system have reduced banknote demand. The estimated coefficient is approximately -0.26, meaning that a 1% increase in the payment system development index corresponds to a 0.26% decline in banknote demand. Over the 2010s, this index nearly tripled, highlighting the substantial growth of the payment system. However, due to the saturation phase of the chosen growth model, the index's growth has significantly slowed toward the end of the sample period. Statistical significance results show that over 92% of the estimated coefficients are significant at the 10% level, reinforcing the robustness of these findings.

3.4.2 Best Model Result with the estimated development index

Table 3 presents the estimation results of the best-performing model, selected using the Akaike Information Criterion (AIC), which provides the most accurate fit among the evaluated specifications. The short-run coefficients for consumption and inflation are 0.07 and -0.01, respectively, while their corresponding long-run coefficients, accounting for the lagged dependent variable, are 3.5 and -0.051. Overall, these results are consistent with the findings from the sensitivity analysis.

Table 3
The best estimated ARDL model selected based on the AIC criterion

	Estimate	Std. Error	t value	Pr(>|t|)
Intercept	-0.31	0.11	-2.81	0.01
L(ln_cic, 1)	0.89	0.03	29.11	0
ln_con	0.07	0.21	0.35	0.73
L(ln_con, 1)	0.31	0.22	1.45	0.16
Inf	-0.01	0	-5.69	0
dev4	-0.32	0.06	-5.18	0
Residual standard error	0.06 on 36 degrees of freedom			
F-statistic	367.7 on 5 and 36 DF, p-value: < 2.2e-16			
Multiple R-squared	0.99			
Adjusted R-squared	0.98			
AIC, SIC	-110.1, -98			
DW	1.9			

Note. The results were obtained using the "auto.ardl" function from the ARDL package (Natsiopoulos & Tzeremes, 2023). The symbol L represents the lag operator.

3.4.3 More on Payment System Development Index

In this study, the parameters of logistic and Gompertz models were estimated based on payment industry statistics, such as the number of point-of-sale (POS) terminals. An alternative approach involves modeling payment system development using polynomial trends. This method allows polynomial parameters to be estimated directly within the regression model, without relying on external variables such as POS statistics. In the sensitivity analysis presented in the previous section, these polynomial variables were tested as substitutes for the logistic and Gompertz indices. More details are provided in this subsection.

Table 4
Re-estimation of the Best Model with Changes in the Payment System Development Index and Consideration of a Polynomial Function of Time

	M1	M2	M3	M4	M5
(Intercept):long	-2.8**	2.1**	0.86	-4**	-23
ln_con:long	3.5***	-0.08	0.98	4.2***	16
inf:long	-0.051***	-0.072**	-0.051**	-0.038***	-0.14
(Intercept):short	-0.31***	0.17**	0.1	-0.56***	-1.1***
ln_con:short	0.071	-0.0067	0.12	0.21	0.27
inf:short	-0.0056***	-0.006***	-0.006***	-0.0052***	-0.0065***
dev4	-0.32***				
trend			-0.0035	0.01**	0.063**
trend2				-5e-04***	-0.003**
trend3					3.5e-05*
AIC	-110.1*	-95.9	-95.8	-104.7	-103.5
SIC	-98*	-85.7	-83.8	-90.8	-86.4
DW	1.9	2	2.1	1.8*	2.1

Note. Each column belongs to a specific model. Model M1 represents the results of the best model, which were reported in Table 3. The other models are estimated by altering the Payment Industry Development Index and considering linear, quadratic, cubic, and trend-free specifications. Refer to the footnote of Table 3 for details.

Table 4 highlights significant differences in goodness-of-fit statistics, particularly AIC and SIC, between the models. However, the primary objective here is not model selection itself but rather understanding the underlying trend in payment system development. Based on the maintained hypothesis in this paper, the Payment System Development Index should explain variations in cash demand, if other factors, such as the volume of economic activities and the opportunity cost of holding cash, remain constant. To further test this hypothesis, we estimate the index using polynomial functions of time.
A linear polynomial function is not empirically supported. In model 'M4', a quadratic function is used, yielding statistically significant coefficients. This result suggests that payment system development follows an increasing trend with decelerating growth, consistent with the saturation phase of a typical S-curve. Although model M4 includes a higher-degree polynomial term, the additional coefficient is relatively small and closely resembles the quadratic trend in model M4. Overall, these results suggest that estimating the Payment System Development Index as a polynomial function of time reveals a downward concavity, consistent with the logistic and Gompertz development indices shown in Figure 3. The implications are twofold: first, the slowing growth rate indicates that further expansion of the payment system may require targeted interventions or innovations; and second, forecasting future trends should account for this deceleration, suggesting a shift from rapid initial growth to a more mature, stabilized phase.

4. Conclusion

The results consistently indicate that indicators of real economic activity—namely GDP, consumption, and private consumption—positively influence the demand for banknotes. Specifically, consumption emerges as the most significant predictor, with a high proportion of its coefficients being both positive and statistically significant across various model specifications. This underscores the pivotal role of consumption in driving cash demand, aligning with theoretical expectations that higher economic activity necessitates greater liquidity in the form of physical currency. Furthermore, Proxies for the opportunity cost of holding cash, including inflation and nominal exchange rate growth, generally exhibit a negative relationship with banknote demand. Inflation stands out as a consistently significant factor.
Indicators representing the development of the payment system consistently show a negative and significant effect on the demand for banknotes. This negative relationship is robust across a wide array of model specifications, highlighting the transformative impact of advanced payment systems in diminishing reliance

on physical cash. Further analysis using polynomial trends reveals that the development of the payment system follows an upward trajectory with decelerating growth, suggesting that initial advancements rapidly reduce cash demand, while subsequent improvements yield diminishing returns.

The findings of this study have several important implications for policymakers and financial institutions. First, understanding that real economic activity—particularly consumption—drives cash demand can guide central bank decisions related to liquidity management and currency issuance. Second, the negative impact of inflation on cash demand underscores the importance of maintaining price stability to effectively manage the circulation of physical currency.

Moreover, the significant role of payment system development in reducing cash demand highlights the necessity for continued investment in digital payment infrastructures. Notably, the observed deceleration in the Payment System Development Index suggests that the rate of growth in digital payment adoption is slowing as the market nears saturation. This implies that, as the benefits of traditional investments in digital payment infrastructures diminish over time, tailored strategies and innovations may be required to stimulate further growth. Overall, such implications reinforce the need for an adaptive policy framework that supports both economic stability and ongoing technological advancement in the payment system.

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تأثیر پیشرفت‌های فناوری بر تقاضای وجه نقد در ایران: رویکرد مدلسازی ARDL

چکیده:

پیشرفت‌های فناوری، صنعت پرداخت را دگرگون کرده است. اگرچه ابزارهای پرداخت جایگزین مانند کارت‌های بانکی برخی ویژگی‌های مشترک با اسکناس دارند، اما رقیب مستقیم وجه نقد محسوب نمی‌شوند. اولاً، وجه نقد دارای ویژگی‌های منحصر به فردی است مانند قابلیت استفاده بدون نیاز به برق و ماهیت ناشناس آن. ثانیاً، داده‌های آماری نشان می‌دهند که نسبت وجه نقد به نقدینگی اولیه (M1) در سال‌های اخیر در حدود ۱۰٪ تثبیت شده است، که عمدتاً به دلیل جایگزینی آن با سپرده‌های دیداری است.

در این مقاله، تقاضا برای اسکناس را با در نظر گرفتن ویژگی‌های مرتبط با فناوری در کنار نظریه‌های متعارف تقاضای پول مدل‌سازی می‌کنیم. نتایج ما پیامدهای مهمی برای بانک مرکزی دارد، به‌ویژه در زمینه مدیریت نقدینگی، انتشار پول، مدیریت مؤثر وجه نقد فیزیکی و تداوم سرمایه‌گذاری در زیرساخت‌های پرداخت دیجیتال.

ما از دیدگاه کلان اقتصادی بهره می‌گیریم که تقاضای اسکناس را از جنبه‌های معاملاتی و دارایی مورد بررسی قرار می‌دهد. در این راستا، یک مدل خودرگرسیونی با وقفه‌های توزیعی (ARDL) برآورد می‌کنیم که امکان تحلیل ضرایب کوتاه‌مدت و بلندمدت را در چارچوب عدم‌قطعیت مدل فراهم می‌سازد. یکی از محورهای اصلی مطالعه ما، برآورد شاخص توسعه سیستم پرداخت با استفاده از مدل‌های رشد لجستیک و گومپرتز است که از طریق آن تأثیر این شاخص بر تقاضای وجه نقد را ارزیابی می‌کنیم.

شواهد تجربی ما از رشد S-شکل در پذیرش فناوری‌های پرداخت حمایت می‌کند. یافته‌ها نشان می‌دهند که اینگونه پیشرفت‌ها در بخش پرداخت منجر به کاهش قابل‌توجهی در تقاضای وجه نقد شده است. علاوه بر این، در حالی که افزایش فعالیت‌ها در بخش واقعی اقتصاد تأثیر مثبت و معنادار بر تقاضای وجه نقد دارد، هزینه فرصت بالاتر برای نگهداری پول نقد نیز بر تقاضای وجه نقد تأثیر منفی برجای می‌گذارد.