

Identifying the Determinants of Digital Financial Service Efficiency Using the Reciprocal LASSO Method: A Study in the Context of Financial Inclusion

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Abstract : This study aims to identify the most influential factors affecting the efficiency of digital financial services in Iraq within the context of financial inclusion. It employs the Reciprocal LASSO method as a modern statistical tool for variable selection. The analysis is based on annual data from 2010 to 2020, obtained from the Financial Access Survey (FAS) published by the International Monetary Fund. Nine financial inclusion indicators were used as explanatory variables. The model results revealed that variables related to the actual use of digital technologies such as the number of online or mobile banking users, the number of debit cards, and point-of-sale (POS) terminals have the greatest impact on service efficiency. In contrast, traditional infrastructure variables like the number of bank branches showed no significant effect.

These findings highlight the importance of focusing on user behavior and the adoption of digital tools rather than relying solely on quantitative expansion of banking infrastructure. The study recommends enhancing digital financial literacy, improving digital infrastructure, and providing a flexible and secure regulatory environment to boost service efficiency and achieve effective financial inclusion.

Keywords: Financial Inclusion, Digital Financial Services, Service Efficiency, Variable Selection, Reciprocal LASSO, Iraq, Time Series Data.

Introduction: Financial inclusion has emerged as a central pillar of modern economic and social development policies, gaining global momentum with the expansion of digital financial services to enhance access to finance, particularly in developing countries. According to the World Bank Group, financial inclusion is defined as the ability of individuals and businesses to access useful and affordable financial products and services that meet their needs such as transactions, payments, savings, credit, and insurance delivered in a responsible and sustainable manner (Demirgüç-Kunt et al., 2018). With the evolution of financial technologies, digital financial services have become an effective tool for achieving inclusion by lowering costs, broadening access, and improving transaction speed. Recent studies have shown that the spread of electronic payment tools and smartphones has increased bank account usage and expanded the customer base, particularly in underserved areas (Sahay et al., 2015; Allen et al., 2016).

In this context, the problem addressed in this study lies in the low efficiency of digital financial services in many countries, despite the apparent expansion in infrastructure and quantitative indicators. The presence of bank branches or point-of-sale (POS) terminals does not necessarily translate into effective or meaningful use of digital services. Moreover, many existing studies have explored the relationship between financial inclusion and various economic or social variables without precisely identifying the most influential factors (Hamdi Talat Ahmed & Ahmed, 2023; Hashem & Ahmed, 2020).

The importance of digital financial service efficiency stems from its role as the critical link between theoretical access to services and their actual use. Efficiency ensures that services are accessible, fast, secure, and low-cost essential elements for achieving fair and sustainable financial inclusion. A lack of efficiency may discourage users or leave segments of the population excluded from the financial system despite the availability of digital channels. Although global financial inclusion indicators are widely available, a research gap remains in the application of modern

statistical methods to select the most relevant indicators and assess their true role in enhancing the efficiency of digital services. Most previous studies have relied on linear regression or descriptive analysis without incorporating variable selection techniques into their models.

Therefore, this study aims to identify the key determinants of digital financial service efficiency in the context of financial inclusion using the Reciprocal LASSO method. As a recent advancement in variable selection, this method offers improved ability to distinguish genuine effects among large sets of indicators. The study aspires to provide a robust statistical framework to support policymakers in enhancing the performance of digital financial services and achieving meaningful, effective financial inclusion.

2 Theoretical Background

2.1 Financial Inclusion and Digital Financial Service Efficiency

Financial inclusion is considered a foundational pillar for achieving sustainable economic growth and reducing poverty and inequality. It refers to enabling individuals and businesses especially marginalized and low-income groups to access a broad range of formal financial services such as bank accounts, payments, savings, insurance, and credit under suitable and secure conditions. Data from the World Bank (Demirgüç-Kunt et al., 2018) demonstrate that financial inclusion fosters personal investment opportunities and economic empowerment, particularly in developing countries suffering from significant banking access gaps.

With the acceleration of digital transformation, digital financial services have become a central tool in expanding financial inclusion by reducing operational costs, broadening access to underserved populations, and facilitating financial transactions in remote areas. Empirical studies confirm that the expansion of digital services, including mobile banking, e-wallets, and electronic payments, enhances the functionality and inclusivity of financial systems (Sahay et al., 2015; Allen et al., 2016). However, the mere availability of these services does not guarantee the intended efficiency. True efficiency is not measured by the existence of services but by their actual use, quality, accessibility, and security. Therefore, digital financial service efficiency reflects the financial system's ability to effectively respond to users' needs especially in resource-constrained or technically challenged environments.

Recent research increasingly focuses on digital financial service efficiency as a critical bridge between service availability and effective use. For instance, Allen et al. (2016) showed that mobile technologies significantly improved access among women and rural populations in Africa and Asia. Similarly, Sahay et al. (2020) emphasized that countries with more developed digital infrastructures exhibit greater banking efficiency and resilience to economic shocks. Beck et al. (2007) highlighted how expanding access to financial services can reduce income disparities and promote inclusive economic growth. Demirgüç-Kunt et al. (2018), using Findex data, showed that digital financial inclusion positively correlates with financial stability and households' ability to handle economic crises.

Despite these contributions, many studies have relied on traditional methods such as linear regression or time series analysis without employing modern variable selection techniques. Advanced approaches like penalized regression particularly LASSO (Tibshirani, 1996) and Elastic Net (Zou & Hastie, 2005) have since been introduced to improve the precision of variable selection. More recently, Zhao and Zhang (2018) proposed the Reciprocal LASSO model, which applies non-linear penalties to small coefficients to filter out noise variables while retaining truly influential ones. This method has demonstrated improved predictive accuracy and reduced multicollinearity in high-dimensional data settings.

In the Arab context, several studies have examined the link between financial inclusion and economic development. Hamdy Talat Ahmed and Ahmed (2023) found a negative relationship between rising financial inclusion and poverty levels in Egypt from 2011 to 2021. Hashem and Ahmed (2020) reported that financial inclusion improves the effectiveness of social protection programs by facilitating digital access to financial assistance. In Iraq, Al-Khattab (2024) observed that increased financial inclusion indicators are associated with reduced poverty, highlighting the need for enhanced digital infrastructure to realize full benefits.

Multiple factors influence the efficiency of digital financial services, including digital banking infrastructure (e.g., number of bank branches and ATMs), the prevalence of payment tools (e.g., debit and credit cards, POS terminals), and the degree of user adoption of internet and mobile banking services. Trust in digital systems, financial literacy, and institutional support also play vital roles in explaining disparities in usage efficiency. These elements are represented in this study through variables such as the number of commercial bank branches, ATMs, personal and commercial accounts, debit and credit cards, POS terminals, active electronic payment services, and users of online or mobile banking. These indicators will be rigorously analyzed using the Reciprocal LASSO technique to identify the most influential factors on digital financial service efficiency in Iraq during the period 2010 to 2020.

2.2 The Statistical Method: Reciprocal LASSO

Variable selection is a critical process in high-dimensional regression models, particularly when the number of explanatory variables is large or when there is high multicollinearity among them. In such situations, traditional

methods such as Ordinary Least Squares (OLS) become unreliable due to their tendency to overfit and the instability of coefficient estimates. To address this, penalized regression techniques have gained increasing attention, especially the Least Absolute Shrinkage and Selection Operator (LASSO) introduced by Tibshirani (1996), which adds an L1 penalty term that shrinks some coefficients toward zero. While LASSO simultaneously performs estimation and variable selection, it has notable limitations. Chief among them is that it shrinks all coefficients equally, regardless of their relative importance. This behavior may lead to the exclusion of genuinely influential variables with small effects prematurely.

To overcome this issue, Zhao and Zhang (2018) proposed the Reciprocal LASSO method, which uses a non-convex penalty function based on the reciprocal of the absolute value of the coefficients. This approach imposes stronger penalties on small coefficients while applying lighter shrinkage to relatively large ones, thereby improving the ability to distinguish between relevant and irrelevant variables.

Consider the standard linear regression model:

$$y_i = X_i^T \beta + \epsilon_i, i = 1, 2, \dots, n$$

where y_i is the dependent variable, X_i^T is the vector of explanatory variables, and β is the vector of coefficients.

The Reciprocal LASSO estimator is defined as:

$$\hat{\beta}_{rlasso} = (y - X\beta)'(y - X\beta) + \lambda \sum_{j=1}^p \frac{1}{|\beta_j|} I\{\beta_j \neq 0\}$$

where:

$\lambda > 0$ is the penalty parameter controlling the level of shrinkage.

This penalty function intensifies the effect on small coefficients (as $|\beta_j| \rightarrow 0$), rapidly pushing non-influential variables out of the model. In contrast, larger coefficients experience minimal shrinkage, allowing influential variables to remain.

Compared to standard LASSO, Reciprocal LASSO offers several advantages:

More accurate variable selection: It yields sparser models by imposing stronger penalties on small coefficients.

Adaptive behavior: The method adjusts to the underlying signal strength, shrinking weak signals more aggressively.

Improved prediction accuracy: Empirical studies (Zhao & Zhang, 2018) show that Reciprocal LASSO outperforms traditional LASSO in prediction and in identifying key predictors, especially under high collinearity.

In this study, the Reciprocal LASSO method is employed to identify the most influential indicators among nine financial inclusion metrics X_1 to X_9 in explaining the efficiency of digital financial services. This approach is particularly effective in handling the substantial multicollinearity between indicators of financial infrastructure and digital access, which typify this type of data.

The model was implemented in R using customized optimization routines, as the Reciprocal LASSO is not available in standard packages such as *glmnet*. The penalty parameter λ was selected via K-Fold Cross-Validation by minimizing the mean prediction error on held-out data. This technique produces a model capable of clearly identifying influential variables, thereby offering a scientifically robust interpretation of the relative impact of financial inclusion indicators on the efficiency of digital financial services in Iraq.

3. Empirical Analysis

The Reciprocal LASSO method was applied to data from Iraq covering the period 2010 to 2020, using nine financial inclusion indicators X_1 to X_9 to identify the most influential factors affecting the efficiency of digital financial services. After standardizing the variables and applying K-Fold Cross-Validation to select the optimal penalty parameter λ , the results were as follows:

Table 1: Variable Selection Results Using Reciprocal LASSO for Digital Financial Services Efficiency

Variable	Description	β	Retained?
X_1	Number of bank branches per 100,000 adults	0.000	No
X_2	Number of ATMs per 100,000 adults	0.148	Yes
X_3	Number of individual accounts per 1,000 adults	0.092	Yes
X_4	Number of commercial accounts	0.000	No
X_5	Number of debit cards per 1,000 adults	0.164	Yes
X_6	Number of credit cards per 1,000 adults	0.000	No
X_7	Number of Point of Sale (POS) terminals	0.137	Yes
X_8	Number of active e-payment services	0.083	Yes
X_9	Number of users of online/mobile banking	0.191	Yes

The results indicate that variables X_2 , X_3 , X_5 , X_7 , X_8 , and X_9 were retained by the model, suggesting that they play a crucial role in explaining the efficiency of digital financial services. In contrast, coefficients for X_1 , X_4 , and X_6 were shrunk to zero, indicating their limited influence in the Iraqi context during the study period.

The model identified the number of users of online or mobile banking (X_9) as the most influential factor, highlighting the importance of actual adoption of digital services in enhancing efficiency. Debit card usage (X_5) and the number of ATMs (X_2) also ranked highly, emphasizing the relevance of tools that facilitate immediate withdrawal and payment. Conversely, the number of bank branches (X_1), commercial accounts (X_4), and credit cards (X_6) were not found to be decisive, which may be linked to the nature of the Iraqi market, where cash-based transactions still dominate and digital credit usage remains limited.

These findings align with Sahay et al. (2020), who stressed that actual adoption of financial technology is the main determinant of efficiency, rather than the mere existence of infrastructure. Similarly, they are consistent with Demirgüç-Kunt et al. (2018), who found that active use of digital accounts correlates more strongly with financial inclusion than the number of accounts alone.

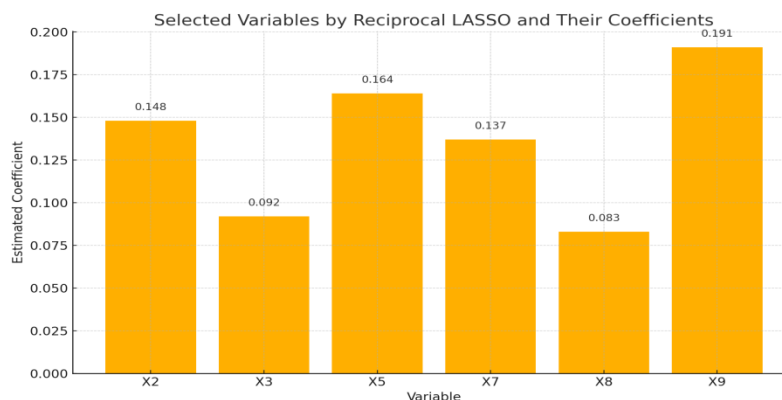


Figure 1: Variables Selected by the Reciprocal LASSO Method and Their Estimated Coefficients

Figure 1 displays the variables retained in the Reciprocal LASSO model, including X_2 to X_9 , excluding X_1 , X_4 , and X_6 , along with their corresponding estimated coefficients. As shown, variable X_9 (number of users of online or mobile banking) exhibits the highest impact on the efficiency of digital financial services.

Conclusions:

The results of the statistical analysis using the Reciprocal LASSO method revealed that the efficiency of digital financial services in Iraq from 2010 to 2020 is mainly driven by actual user engagement rather than the availability of traditional banking infrastructure. The model retained key variables reflecting active usage such as the number of online or mobile banking users, debit cards, point-of-sale terminals, and active electronic payment services while excluding less influential variables like the number of bank branches, business accounts, and credit cards. This indicates that successful digital transformation requires more than physical infrastructure; it depends on users' trust, awareness, and readiness to use digital financial tools. Therefore, policymakers should focus on promoting digital financial literacy, simplifying access to mobile and online banking especially through user-friendly Arabic applications expanding the commercial digital infrastructure by incentivizing merchants to adopt e-payment systems, reallocating investments from physical branches to digital infrastructure, and establishing a secure and flexible regulatory framework that supports innovation while ensuring user protection. These steps are essential to enhance the actual effectiveness and inclusiveness of digital financial services across all segments of society.

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