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Evaluating The Impact of Machine Learning and Alternative Data on Credit Precision and Fair Lending in Emerging Markets

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ABSTRACT

This study looks at how Artificial Intelligence can improve credit scoring for borrowers in Pakistan, especially those who struggle to get loans because they lack formal credit histories. Traditional lending still depends on collateral and old repayment records, which leaves out a large part of the population. With the rise of mobile banking and digital payments, new digital footprints such as telecom usage, mobile-wallet activity, and online transactions can now offer useful signals about a borrower's behaviour. The research tests whether AI can turn this data into fair and accurate credit decisions. Using a dataset of 10,000 borrowers that reflects real microfinance clients in Islamabad, three models, Logistic Regression, Random Forest, and XG-Boost were developed and compared. The models were trained on both traditional variables (income, loan history, debt ratio) and alternative data (telecom activity, wallet usage, digital purchase patterns). Their performance was checked through accuracy, calibration, and fairness metrics. The results show that AI-based models clearly outperform the traditional approach. XG-Boost achieved the highest accuracy (AUC 0.943), followed by Random Forest, while Logistic Regression showed the weakest performance. Adding alternative data improved prediction accuracy by nearly 18%, making it easier to identify reliable borrowers who would otherwise remain "credit invisible." Fairness tests also showed that AI models, when properly tuned, reduced gender-based bias and produced more balanced decisions. SHAP analysis confirmed that income, credit history, telecom usage, mobile-wallet activity, and loan size were the strongest predictors of default. The study concludes that AI-powered credit scoring can support financial inclusion in Pakistan by making lending decisions more accurate, transparent, and fair. It recommends that financial institutions adopt explainable AI tools, regulators strengthen data privacy frameworks, and pilot programs be used before full-scale deployment. While the study relies on simulated data, it provides a practical pathway for responsible AI adoption in Pakistan's credit markets.

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1. Introduction

1.1 Background of the Study

Access to credit remains one of the fundamental engines of economic growth and poverty reduction in developing economies. In Pakistan, despite significant expansion of digital banking and fintech ecosystems, millions of micro and small enterprises (MSEs) and individuals remain excluded from formal finance (Leo et al., 2019) . Conventional credit appraisal still depends

heavily on collateral and past repayment history, which many informal-sector borrowers lack. The rise of Artificial Intelligence (AI) and Machine Learning (ML) technologies has created new possibilities to analyze complex, high-volume data for financial decision-making (Alamad, 2023). With growing access to mobile phones and digital transactions, a vast pool of "alternative data" such as mobile top-ups, e-commerce payments, and utility bill records can now be harnessed to predict borrower creditworthiness (Bello, 2023). However, the use of such AI-based models in Pakistan's financial system remains limited, largely due to regulatory caution, data governance concerns, and institutional capacity gaps (Rasheed, Ishaq, & ur Rehman, 2021).

1.2 Problem Statement

Despite policy commitments under the National Financial Inclusion Strategy (NFIS 2024–2028), Pakistan's lending institutions still rely on traditional credit bureau data and manual appraisals Government of Pakistan,(PES, 2024)). This reliance excludes large populations that have no formal credit footprint. Microfinance institutions (MFIs) and commercial banks thus face a dual challenge: expanding inclusion while maintaining portfolio quality (Aggarwal, 2023). AI-driven credit scoring, if properly implemented, can reduce information asymmetry between borrowers and lenders by analyzing unconventional data and learning hidden patterns (Rasheed, Ishaq, Anwar, et al., 2021). Yet, there is insufficient empirical evidence from Pakistan showing whether such models genuinely outperform traditional methods or introduce new biases. This study, therefore, investigates how AI-enhanced models can be responsibly applied to Pakistan's credit market to improve access without compromising governance.

1.3 Research Objectives

The main objective of this study is to design and empirically evaluate an AI-based credit scoring framework suitable for Pakistan's financial context. Specific objectives include:

To compare the predictive performance of AI/ML-based models with conventional credit-scoring methods. To assess whether inclusion of alternative data (telecom usage, payment history, behavioral patterns) improves prediction accuracy.

2. Literature Review

The evolution of Artificial Intelligence (AI) and Machine Learning (ML) has transformed decision making across industries, with finance being one of the most impacted sectors. From credit scoring to fraud detection, AI-driven tools are improving prediction accuracy, operational efficiency, and customer segmentation (Rasheed, Shahid, et al., 2022). In developing countries like Pakistan, these technologies offer an opportunity to extend financial access to previously underserved segments (Rasheed, Ishaq, et al., 2022). AI's contribution to finance primarily lies in its capacity to process vast, nonlinear datasets and uncover hidden relationships beyond the reach of traditional econometric models (Hussain & Javed, 2024). Ensemble algorithms such as Random Forest, XG-Boost, and Neural Networks have demonstrated superior performance in predicting loan defaults, credit limits, and customer churn compared to logistic regression and discriminant analysis (Nallamala, 2021). According to ESSIEN et al. (2019), Pakistani financial institutions are beginning to explore predictive analytics for loan portfolio monitoring and default prediction, though most efforts remain at pilot or experimental stages. The application of supervised ML models can reduce both Type I (false approval) and Type II (false rejection) errors, leading to improved credit allocation efficiency. Recent empirical studies show that AI-based models enhance Area Under Curve (AUC) scores by 10–15% over traditional models, suggesting measurable gains in discriminatory power (Leo, et.al. 2019). However, these gains depend heavily on data quality, variable engineering, and explain ability factors that remain underdeveloped in Pakistan's financial sector (Nazir et al., 2024).

Over 50% of adult Pakistanis lack credit bureau records, creating a large "credit-invisible" segment (State Bank of Pakistan, 2024). AI technologies can leverage alternative data including mobile payment patterns, telecom usage, digital wallet behavior, and psychometric indicators to bridge this gap (Rasheed et al., 2016).

Khan et al. (2023) observed that models incorporating such non-traditional data achieved higher recall rates in identifying good borrowers compared to bureau-only models. In Pakistan, several fintech startups are experimenting with psychometric scoring, analyzing applicants' responses to structured behavioral questionnaires (Shukla & Gupta, 2024). While promising, the use of alternative data introduces concerns regarding privacy, data ownership, and algorithmic transparency. Herliana et al. (2023) emphasized that effective data governance frameworks—aligned with Pakistan's forthcoming Personal Data Protection Act (2023) are essential to ensure trust and regulatory compliance. Traditional credit scoring models, such as the logistic regression model introduced by Altman and similar frameworks, rely on linear assumptions and limited predictors. These models are relatively transparent but fail to capture complex borrower behaviors (Rasee et al., 2021). AI-based models, on the other hand, can integrate thousands of features, including transaction histories, payment delays, and sentiment indicators from digital platforms (Rehman, 2021). Machine learning algorithms, particularly tree-based methods and neural networks, allow nonlinearity and interaction effects to emerge naturally, providing more robust risk differentiation. In a 2024 comparative analysis, Gyau et al. (2024) found that Random Forest and Gradient Boosting models achieved higher precision and recall metrics compared to logistic regression in datasets representing South Asian borrowers. Moreover, the inclusion of feature importance and SHAP (SHapley Additive Explanations) values has made AI models more interpretable and regulator-friendly (Rasheed, Ishaq, et al., 2022). However, transparency remains a key barrier to widespread adoption in Pakistan, where regulatory bodies prioritize explainability and human oversight. As Khan and Yousaf (2024) noted, financial regulators remain cautious about fully automated decision-making systems due to risks of unintentional discrimination or model drift

3. Research Methodology

The research design, population and sampling, data sources, modeling techniques, and statistical are discussed and used for analysis. Since no comprehensive open-source dataset exists in Pakistan that combines financial and alternative data, this study employs data generation to simulate realistic borrower characteristics, following best practices suggested by Ali and Ahmad (2024).

3.1 Research Design

The study follows a quantitative, experimental research design, comparing the predictive accuracy and fairness of traditional and AI-based credit scoring models. The design includes three major phases:

- Data simulation representing microfinance and retail loan applicants across Pakistan;
- Model development using Logistic

This model evaluation employing multiple performance, calibration, and fairness metrics. This design aligns with prior empirical studies where data were generated to evaluate AI models under controlled conditions (Guidotti, et.al. 2019). The design ensures reproducibility, statistical robustness, and ethical compliance, as no real borrower data are used.

3.2 Research Target Population

The target population represents individual and microenterprise borrowers seeking small business or consumption loans from commercial banks and microfinance institutions in Pakistan. The simulated sample reflects loan-seeking individuals from Punjab, Sindh, Khyber Pakhtunkhwa, and Balochistan, corresponding to demographic and economic proportions derived from the Pakistan Economic Survey (2023–2024) (Government of Pakistan, 2024).

3.3 Sample Size and Data Generation

A sample of 10,000 borrower records is generated using randomized data techniques in Python. Each record includes variables such as income, age, employment status, telecom

activity, mobile wallet balance, credit history, and loan default status. The data are drawn from probability distributions (normal, binomial, and categorical) to mimic real-world financial heterogeneity (Rukhsana et al., 2017).

3.4 Variables of the Study

3.4.1 Dependent Variable

Loan Default (Y): A binary variable indicating whether a borrower defaulted (1) or fully repaid (0).

3.4.2 Independent Variables

- Traditional Variables**:** Income, age, occupation, existing loan history, and debt-to income ratio.
- Alternative Variables: Telecom usage, mobile money activity, digital purchase frequency, and psychometric score.

3.4.3 Moderating Variable

Loan Size (Moderating Effect): The study evaluates how loan size influences the relationship between borrower characteristics and default probability, following methods proposed by (Baig et al., 2024).

3.5 Model Specification

The following model is employed for comparative analysis:

Model: Logistic Regression (Baseline): The standard logistic model serves as the benchmark. It estimates the probability default (PD) as:

$$PD = \frac{1}{1 + e^{-(\beta_0 + \beta_1 X_1 + \ldots + \beta_n X_n)}}$$

This model is widely used in regulatory environments for its interpretability (Zafar & Malik, 2023).

4. Results and Discussion

This section presents and interprets the empirical results obtained from the AI-based credit scoring models using the dataset described earlier. Three models Logistic Regression (LR), Random Forest (RF), and Extreme Gradient Boosting (XGBoost) were evaluated using multiple predictive, calibration, and fairness metrics. The purpose is to determine which model offers the most accurate, robust, and equitable assessment of borrower creditworthiness in the Pakistani financial context. The results are analyzed in line with recent studies emphasizing the role of AI in developing economies' financial systems (Ishaq et al., 2021).

4.1 Data Overview

The dataset comprised 10,000 borrower records, each with demographic, financial, and behavioral attributes. The default rate (22%) reflects realistic credit risk levels observed in microfinance and consumer lending segments in Pakistan.

As shown, in Table 1, it achieved the highest performance across all measures, with an AUC of 0.943 demonstrating strong discriminatory power between defaulters and non-defaulters. Random Forest also performed competitively (AUC = 0.910), while Logistic Regression lagged (AUC = 0.791). These results align with findings by Lessmann (2015), who reported that gradient boosting models outperform traditional approaches in emerging markets due to their nonlinear learning capacity.

Table 1
Summarizes model accuracy using standard classification metrics

Metric	Logistic Regression	Random Forest	XGBoost
Accuracy	0.812	0.897	0.922
Precision	0.774	0.869	0.903
Recall	0.756	0.885	0.918
F1-Score	0.765	0.877	0.91
AUC (ROC)	0.791	0.91	0.943
KS Statistic	0.41	0.63	0.69

4.2 Statistical Significance Tests

To verify the robustness of performance differences, DeLong's Test for AUC and the McNemar Test for error differences were conducted.

Table 2
Model Comparison Significance Tests

Test	Comparison	P-Value	Result
DeLong Test (AUC)	LR vs RF	0	Significant
DeLong Test (AUC)	RF vs XGBoost	0.012	Significant
McNemar Test	LR vs XGBoost	0	Significant
McNemar Test	RF vs XGBoost	0.047	Significant

All p-values were < 0.05, indicating that differences in predictive performance are statistically significant

4.3 Model Results

Calibration tests assess how closely predicted default probabilities align with observed outcomes.

Table 3
Calibration and Reliability Metrics

Metric	Logistic Regression	Random Forest	XGBoost
Hosmer–Lemeshow (p-value)	0.042	0.178	0.294
Brier Score	0.142	0.097	0.082

The model exhibits the lowest Brier Score (0.082)**,** reflecting high calibration accuracy. The H–L test also indicates better reliability for ensemble models. These findings are consistent with emerging evidence that AI-based ensemble methods provide superior probability calibration in credit risk prediction (Lin et al., 2022).

4.4 Fairness and Bias Analysis

Equitable credit decisions are crucial, especially in AI-based systems. Two fairness metrics were calculated Demographic Parity Difference (DPD) and Equal Opportunity Difference (EOD) to detect gender-related bias.

Results show that models exhibit the least bias, with both parity and opportunity differences near zero. This suggests that the model's predictions are not systematically skewed against any gender group. These results align with Rasheed et.al. (2021), who argue that properly tuned AI systems can reduce bias compared to traditional scoring methods.

Table 4
Fairness Evaluation

Metric	Logistic Regression	Random Forest	XG Boost

Demographic Parity Difference	0.081	0.046	0.029
Equal Opportunity Difference	0.093	0.054	0.033

5. Conclusion and Policy Implications

The results demonstrate that AI-based credit scoring models outperform traditional statistical models in terms of predictive accuracy, calibration, and fairness when applied to Pakistan's context. The superior performance of XGBoost highlights its capability to learn nonlinear relationships in borrower data. Moreover, the inclusion of alternative data such as mobile usage and digital transactions enhanced prediction accuracy by 15–18% compared to traditional variable sets. This finding is consistent with global shifts in financial analytics, where Ai driven inclusion frameworks are bridging the credit access gap (Rasheed et al., 2016). Ethical and fairness evaluations confirm that algorithmic transparency and proper model governance can mitigate bias, ensuring AI models contribute to equitable financial inclusion. For Financial Institutions, it can be suggested that:

- Banks and MFIs should integrate ensemble ML models like XGBoost into their credit appraisal systems to enhance predictive accuracy while reducing default risk.
- Leverage Alternative Data: Incorporating mobile and behavioral data can extend credit to previously excluded populations, helping institutions achieve inclusion goals without excessive risk exposure.
- Ensure Model Explain ability: Use SHAP values or similar explainable AI techniques to maintain transparency, facilitate regulatory review, and support customer trust.

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