

AI-DRIVEN CREDIT SCORING, FINANCIAL INCLUSION, AND SME FINANCING PERFORMANCE IN PAKISTAN

Inam Ullah

Department of Management Science, Abasyn University Peshawar

inamibspesh@gmail.com

Keywords

Artificial Intelligence, AI-Driven Credit Scoring, Financial Inclusion, SME Financing Performance, FinTech, Pakistan.

Article History

Received: 01 February 2026

Accepted: 17 March 2026

Published: 31 March 2026

Copyright @Author

Corresponding Author: *

Inam Ullah

Abstract

Artificial Intelligence (AI) has transformed financial services by enabling more efficient, accurate, and data-driven credit assessment processes. In emerging economies such as Pakistan, where small and medium-sized enterprises (SMEs) continue to experience significant financing constraints due to information asymmetry, limited credit histories, and collateral requirements, AI-driven credit scoring presents a promising solution for enhancing financial inclusion and improving financing outcomes. This study examined the influence of AI-driven credit scoring on SME financing performance, with financial inclusion serving as a mediating variable and digital financial infrastructure and regulatory support acting as moderating variables. A quantitative, cross-sectional research design was employed, and primary data were collected from SME owners and managers operating across Pakistan using a structured questionnaire. The proposed conceptual framework was empirically tested using Partial Least Squares Structural Equation Modeling (PLS-SEM). The findings indicated that AI-driven credit scoring significantly enhanced financial inclusion and SME financing performance. Financial inclusion partially mediated the relationship between AI-driven credit scoring and financing performance, while digital financial infrastructure and regulatory support strengthened the proposed relationships. The study contributes to the literature by extending Information Asymmetry Theory within the context of AI-enabled financial services and provides practical and policy implications for financial institutions, fintech companies, and regulators seeking to promote responsible AI adoption and inclusive SME financing. The findings offer valuable insights for advancing Pakistan's digital financial ecosystem and supporting sustainable economic development through technology-driven financial innovation.

Introduction

Small and medium-sized enterprises (SMEs) are widely recognized as the backbone of economic development, accounting for a significant share of employment, innovation, industrial output, and gross domestic product (GDP) across both developed and developing economies. In Pakistan, SMEs constitute approximately 90% of all business establishments, contribute around 40% to GDP, and generate nearly 80% of non-

agricultural employment. Despite their substantial contribution to national economic growth, SMEs continue to encounter persistent challenges in accessing formal financial services, particularly institutional credit. Limited collateral, inadequate financial records, high transaction costs, information asymmetry, and conventional credit assessment practices have significantly constrained SMEs' ability to secure timely and affordable financing (State Bank of Pakistan [SBP], 2024).

The rapid advancement of Artificial Intelligence (AI) has transformed financial services globally by introducing intelligent, data-driven solutions for credit assessment, fraud detection, risk management, and customer relationship management. Among these innovations, AI-driven credit scoring has emerged as one of the most promising technological developments in modern banking and financial services. Unlike conventional credit scoring systems, which primarily rely on historical financial statements and collateral-based lending, AI-driven credit scoring utilizes machine learning algorithms, big data analytics, natural language processing, and alternative data sources—including digital transactions, mobile payment histories, e-commerce activities, utility bill payments, and behavioral indicators—to generate more accurate and dynamic creditworthiness assessments (Bazarbash, 2019; OECD, 2024).

Recent developments in financial technology (FinTech) have further accelerated the adoption of AI-enabled lending systems worldwide. Financial institutions increasingly employ supervised and unsupervised machine learning models to reduce information asymmetry, improve loan approval accuracy, minimize default risks, and expand access to finance for previously underserved populations. Explainable Artificial Intelligence (XAI) has also gained considerable attention because it enhances transparency and accountability in automated credit decisions while addressing regulatory concerns regarding algorithmic fairness and discrimination (European Banking Authority, 2024).

Financial inclusion has become a central pillar of sustainable economic development and poverty reduction. It refers to the availability, accessibility, affordability, and effective use of formal financial services by individuals and businesses regardless of their socioeconomic status. For SMEs, financial inclusion encompasses timely access to credit, digital financial services, working capital financing, investment loans, and other financial products essential for business growth and competitiveness. International organizations such as the World Bank, International Monetary Fund (IMF), and Asian Development Bank (ADB)

emphasize that improving financial inclusion significantly enhances entrepreneurial development, productivity, employment generation, and economic resilience (World Bank, 2022).

Pakistan has experienced remarkable growth in digital financial services during the last decade. The expansion of branchless banking, mobile wallets, digital payment platforms, fintech companies, and the Raast instant payment system has created new opportunities for expanding financial inclusion. Simultaneously, the State Bank of Pakistan has introduced several policy initiatives, including the National Financial Inclusion Strategy (NFIS), Digital Banking Framework, and Regulatory Sandbox, to promote innovation within the financial sector. Nevertheless, despite these initiatives, a substantial proportion of SMEs remain financially excluded due to rigid lending procedures, insufficient collateral, limited formal credit histories, and inefficient risk assessment mechanisms (SBP, 2024).

Artificial Intelligence offers a transformative opportunity to address these structural barriers. By leveraging alternative data and advanced predictive analytics, AI-driven credit scoring enables financial institutions to evaluate borrowers with limited traditional credit histories while reducing operational costs and improving lending efficiency. Such systems have demonstrated superior predictive performance compared with traditional statistical credit scoring models and have enhanced lending decisions across various developed and emerging markets (Fuster et al., 2022). Furthermore, AI-based credit assessment may facilitate greater financial inclusion by enabling financial institutions to extend credit to underserved SMEs without substantially increasing portfolio risk.

Although extensive international research has examined AI applications in banking and fintech, empirical evidence regarding AI-driven credit scoring within developing economies remains limited. Existing studies have predominantly focused on algorithmic performance, predictive accuracy, and credit risk management in developed countries, while comparatively little

attention has been devoted to examining whether AI-enabled credit assessment contributes to financial inclusion and improves SME financing performance within emerging markets such as Pakistan. Moreover, previous research rarely integrates AI-driven credit scoring, financial inclusion, and SME financing performance within a comprehensive conceptual framework. The moderating influence of Pakistan's evolving digital financial infrastructure and regulatory environment has also received limited scholarly attention.

Given Pakistan's ongoing digital transformation, increasing fintech adoption, and national commitment to expanding financial inclusion, investigating the relationship between AI-driven credit scoring, financial inclusion, and SME financing performance has become both timely and academically significant. This study seeks to address these gaps by developing an integrated empirical framework that examines how AI-driven credit scoring influences SME financing performance through financial inclusion within the Pakistani context. The findings are expected to contribute to theory development, support evidence-based policymaking, and provide practical guidance for banks, fintech firms, regulators, and SME stakeholders seeking to build a more inclusive, efficient, and technology-driven financial ecosystem.

Problem Statement

Despite the strategic importance of SMEs to Pakistan's economic growth, employment generation, industrial diversification, and export development, access to formal finance remains one of the most significant barriers to their sustainable development. Conventional lending practices continue to rely heavily on collateral requirements, historical financial statements, and lengthy manual credit evaluation processes, excluding many viable SMEs from accessing institutional credit. Consequently, a substantial financing gap persists, limiting SME investment, innovation, productivity, and competitiveness.

Recent advances in Artificial Intelligence have fundamentally transformed credit risk assessment by enabling financial institutions to utilize

machine learning algorithms and alternative data sources to evaluate borrower creditworthiness more accurately than traditional methods. International evidence suggests that AI-driven credit scoring reduces information asymmetry, improves loan approval efficiency, lowers default rates, and expands credit access to underserved businesses. However, the adoption and effectiveness of AI-enabled credit assessment remain underexplored in developing economies, particularly Pakistan.

Although Pakistan has introduced various initiatives to promote digital finance and financial inclusion, including fintech regulations, digital banking licenses, and the National Financial Inclusion Strategy, empirical evidence regarding the effectiveness of AI-driven credit scoring in improving SME financing outcomes remains scarce. Existing literature has primarily concentrated on fintech adoption, digital banking, financial inclusion, or conventional credit risk management independently, while limited research has simultaneously examined AI-driven credit scoring, financial inclusion, and SME financing performance within a single integrated framework.

Furthermore, previous studies have predominantly focused on developed economies where digital infrastructure, regulatory frameworks, and financial ecosystems differ substantially from Pakistan. Consequently, the findings of international studies cannot be generalized to Pakistan without empirical validation. The unique characteristics of Pakistan's SME sector, including high levels of informality, limited digital financial records, inadequate credit histories, and uneven technological adoption, necessitate context-specific investigation.

Another important research gap concerns the underlying mechanism through which AI-driven credit scoring influences SME financing performance. Existing studies seldom investigate financial inclusion as a mediating mechanism linking AI-enabled credit assessment to financing outcomes. Likewise, limited attention has been given to the moderating influence of digital financial infrastructure and regulatory support in strengthening or weakening these relationships.

Therefore, there is a pressing need to develop and empirically validate a comprehensive framework that explains how AI-driven credit scoring contributes to financial inclusion and subsequently enhances SME financing performance in Pakistan. Addressing this gap will advance theoretical understanding while providing practical insights for policymakers, financial institutions, fintech companies, and SME owners seeking to leverage AI technologies to build a more inclusive and efficient financial system.

Research Questions

How does AI-driven credit scoring influence financial inclusion among SMEs in Pakistan?

What is the effect of financial inclusion on SME financing performance in Pakistan?

Does AI-driven credit scoring directly influence SME financing performance?

Does financial inclusion mediate the relationship between AI-driven credit scoring and SME financing performance?

Does digital financial infrastructure moderate the relationship between AI-driven credit scoring and financial inclusion?

Does regulatory support moderate the relationship between financial inclusion and SME financing performance?

Research Objectives

General Objective

To examine the influence of AI-driven credit scoring on SME financing performance through financial inclusion in Pakistan.

Specific Objectives

To examine the effect of AI-driven credit scoring on financial inclusion among SMEs in Pakistan.

To investigate the influence of financial inclusion on SME financing performance.

To determine the direct effect of AI-driven credit scoring on SME financing performance.

To examine the mediating role of financial inclusion in the relationship between AI-driven credit scoring and SME financing performance.

To investigate the moderating role of digital financial infrastructure in the relationship

between AI-driven credit scoring and financial inclusion.

To examine the moderating role of regulatory support in the relationship between financial inclusion and SME financing performance.

Significance of the Study

This study offers significant theoretical, practical, and policy contributions to the growing literature on artificial intelligence, financial inclusion, and SME finance.

Theoretical Significance: The study extends Information Asymmetry Theory by demonstrating how AI-driven credit scoring reduces information gaps between lenders and SMEs. It also integrates insights from the Resource-Based View and the Technology Acceptance Model into a unified framework that explains how AI-enabled lending enhances financial inclusion and financing performance in an emerging economy.

Practical Significance: The findings will assist commercial banks, Islamic banks, microfinance institutions, fintech companies, and digital lenders in designing more accurate, efficient, and inclusive AI-based credit assessment systems. SME owners and entrepreneurs will benefit from a better understanding of how AI-enabled financing can improve access to credit, reduce financing constraints, and support business growth.

Policy Significance: The study will provide evidence-based recommendations for the State Bank of Pakistan, the Securities and Exchange Commission of Pakistan, the Ministry of Finance, and other regulatory bodies regarding responsible AI governance, digital financial infrastructure, explainable AI, data privacy, and inclusive lending policies. The findings can support the refinement of Pakistan's National Financial Inclusion Strategy and digital finance initiatives by promoting secure, transparent, and equitable AI adoption within the financial sector.

Overall, the study contributes to the achievement of Sustainable Development Goals (SDGs), particularly SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, Innovation and Infrastructure), and SDG 10 (Reduced Inequalities), by generating empirical evidence on how AI-enabled financial innovation can

strengthen SME development and foster inclusive economic growth in Pakistan.

Literature Review

Artificial intelligence (AI) has emerged as one of the most transformative technologies in the financial sector, fundamentally changing how financial institutions assess credit risk, detect fraud, manage portfolios, and deliver financial services. The integration of machine learning, big data analytics, natural language processing, and predictive algorithms has significantly improved the efficiency and accuracy of financial decision-making. Among these innovations, AI-driven credit scoring has attracted considerable scholarly attention because of its ability to overcome the limitations of conventional credit assessment systems. Traditional credit scoring models primarily rely on historical financial records, collateral availability, and repayment history, making them less effective for evaluating borrowers with limited formal financial information. AI-driven models, in contrast, analyze both conventional and alternative data sources—including digital payment records, mobile transactions, e-commerce activities, utility payments, and behavioral indicators—to produce more comprehensive and accurate creditworthiness assessments (Li et al., 2024; Tigges et al., 2024).

Recent empirical evidence demonstrates that AI-based credit scoring significantly improves prediction accuracy compared with conventional statistical models. Machine learning algorithms such as Random Forest, XGBoost, Gradient Boosting, and Deep Neural Networks have consistently outperformed traditional logistic regression in identifying creditworthy borrowers while reducing classification errors and default risk. Bitetto et al. (2024) found that machine learning techniques substantially improve credit risk prediction for small businesses, particularly when lenders possess limited borrower information. Similarly, research on AI-enabled lending shows that advanced predictive models facilitate more objective and efficient lending decisions by reducing information asymmetry between lenders and borrowers. These findings

suggest that AI has the potential to reshape credit markets by expanding access to finance without compromising portfolio quality.

Financial inclusion has become an important objective of financial sector reforms across developing economies. It refers to the availability, accessibility, affordability, and effective utilization of formal financial services by individuals and businesses. For SMEs, financial inclusion extends beyond simple access to bank accounts and includes affordable credit, digital payment systems, investment financing, working capital facilities, and financial advisory services. Numerous studies report that financial inclusion enhances entrepreneurial activity, improves firm productivity, stimulates innovation, and contributes to inclusive economic growth. However, despite considerable policy initiatives, SMEs in developing countries continue to experience substantial financing constraints because of collateral requirements, limited credit histories, and high transaction costs.

Artificial intelligence has increasingly been recognized as a mechanism for strengthening financial inclusion through intelligent credit assessment. Rather than relying solely on traditional financial information, AI systems generate predictive insights from alternative data that reflect borrowers' economic behavior. Li et al. (2024), using evidence from more than one million underserved borrowers, demonstrated that AI-enabled credit scoring simultaneously increased loan approval rates while reducing default rates, indicating that technological innovation can improve both financial inclusion and credit quality. Their findings challenge the traditional assumption that expanding lending necessarily increases credit risk and instead suggest that improved prediction accuracy enables financial institutions to serve previously excluded borrowers more effectively.

Another important stream of literature focuses on fintech lending and alternative data analytics. Fintech institutions have transformed SME financing by employing AI-based algorithms capable of assessing borrowers with limited financial histories. Tigges et al. (2024) argue that AI-supported lending reduces information

asymmetry through the integration of unconventional data sources and real-time behavioral information. Their qualitative analysis further emphasizes that AI facilitates more inclusive lending by enabling financial institutions to evaluate previously unbanked populations while simultaneously improving operational efficiency. Nevertheless, the authors also caution that responsible AI implementation requires transparency, fairness, explainability, and effective governance to prevent algorithmic discrimination and privacy violations.

The literature also highlights the importance of explainable artificial intelligence (XAI) in financial decision-making. Although sophisticated machine learning models often outperform traditional techniques, their "black-box" nature raises concerns regarding transparency, accountability, and regulatory compliance. Financial regulators increasingly require lending institutions to explain automated credit decisions to borrowers. Consequently, researchers advocate the integration of explainable AI techniques that improve model interpretability without sacrificing predictive performance. Explainability enhances stakeholder trust, facilitates regulatory compliance, and reduces ethical concerns associated with algorithmic decision-making.

SMEs represent one of the most financially constrained sectors worldwide because they generally lack collateral, audited financial statements, and established credit histories. The financing gap is particularly pronounced in emerging economies where formal financial institutions perceive SMEs as high-risk borrowers. Existing studies consistently indicate that financing constraints reduce firm growth, innovation, employment generation, and long-term competitiveness. AI-driven credit assessment offers a promising solution by enabling lenders to evaluate creditworthiness through dynamic behavioral indicators rather than static financial variables. Consequently, AI has the potential to improve financing performance by increasing loan accessibility, reducing processing time, lowering borrowing costs, and improving financing efficiency.

Within Pakistan, the SME financing landscape continues to face structural challenges despite substantial financial sector reforms. The State Bank of Pakistan has implemented numerous initiatives, including the National Financial Inclusion Strategy, Digital Banking Framework, branchless banking regulations, and fintech licensing mechanisms. These reforms have expanded digital financial services and increased the adoption of mobile banking, electronic payments, and digital lending platforms. Nevertheless, access to formal finance among Pakistani SMEs remains comparatively low because conventional lending practices continue to emphasize collateral and historical financial records. Recent conceptual and empirical studies conducted within Pakistan indicate that AI-enabled credit scoring and alternative data analytics possess considerable potential for improving financial inclusion by enabling lenders to evaluate borrowers beyond traditional credit histories. However, empirical validation of these relationships remains limited.

Although the existing literature demonstrates the growing importance of AI in financial services, several important research gaps remain. First, previous studies have predominantly concentrated on the technical performance of machine learning algorithms rather than examining their broader socioeconomic implications for financial inclusion and SME development. Second, most empirical evidence originates from developed economies, where financial markets, regulatory systems, and digital infrastructure differ considerably from those of emerging countries such as Pakistan. Third, limited research has investigated the mediating role of financial inclusion in explaining how AI-driven credit scoring influences SME financing performance. Fourth, relatively few studies have examined the moderating influence of digital financial infrastructure and regulatory support within AI-enabled lending ecosystems. Consequently, the relationship among AI-driven credit scoring, financial inclusion, and SME financing performance remains insufficiently explored within Pakistan's unique institutional environment. Addressing these gaps provides an

opportunity to advance both theoretical understanding and practical policy formulation by developing an integrated framework tailored to Pakistan's evolving digital financial ecosystem.

Underpinning Theory

Information Asymmetry Theory

Information Asymmetry Theory, originally developed by Akerlof (1970) and subsequently extended by Stiglitz and Weiss (1981), provides the most appropriate theoretical foundation for examining the relationship between AI-driven credit scoring, financial inclusion, and SME financing performance. The theory argues that financial markets operate inefficiently when one party possesses more information than the other. In lending markets, borrowers generally possess more accurate information regarding their financial condition, repayment capacity, and business prospects than lenders. This imbalance creates adverse selection and moral hazard problems, causing financial institutions to restrict lending, demand excessive collateral, or charge higher interest rates.

SMEs are particularly vulnerable to information asymmetry because many operate informally, maintain limited financial documentation, and possess short or nonexistent credit histories. As a result, lenders experience substantial uncertainty regarding borrower quality and frequently classify SMEs as high-risk applicants. Conventional credit scoring systems are often unable to distinguish between creditworthy and risky SMEs, thereby limiting access to finance for otherwise viable businesses.

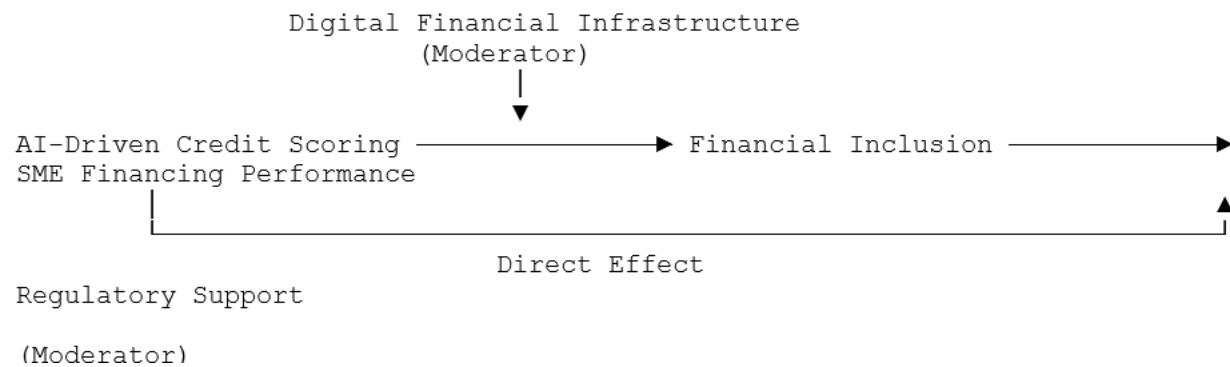
AI-driven credit scoring directly addresses this information asymmetry by incorporating alternative data sources and advanced machine learning algorithms into credit assessment. Rather than depending exclusively on historical financial records, AI models evaluate digital transactions, mobile payment behavior, e-commerce activity, utility payments, social signals, and other behavioral indicators that collectively provide a more comprehensive assessment of borrower creditworthiness. The increased predictive

accuracy enables financial institutions to reduce uncertainty, improve risk assessment, and extend credit to borrowers previously excluded under traditional lending systems. Empirical evidence indicates that AI-enabled credit scoring simultaneously improves loan approval rates and reduces default rates by identifying reliable borrowers more accurately than conventional models (Li et al., 2024).

Within the context of this study, Information Asymmetry Theory explains the causal mechanism through which AI-driven credit scoring enhances financial inclusion. Improved credit information reduces informational barriers, enabling lenders to provide formal financing to SMEs that were previously underserved. Enhanced financial inclusion subsequently improves SME financing performance by increasing access to affordable credit, reducing financing delays, lowering borrowing costs, and supporting business growth. Therefore, Information Asymmetry Theory offers a comprehensive explanation for both the direct and indirect relationships proposed in the conceptual framework, making it the most appropriate underpinning theory for investigating AI-driven credit scoring and SME financing performance in Pakistan.

Conceptual Framework

The conceptual framework proposes that AI-Driven Credit Scoring positively influences SME Financing Performance both directly and indirectly through Financial Inclusion. AI-enabled credit assessment reduces information asymmetry, enhances creditworthiness evaluation, and facilitates access to formal financial services for SMEs. Increased financial inclusion, in turn, improves SMEs' access to affordable and timely financing, thereby enhancing financing performance. Furthermore, Digital Financial Infrastructure strengthens the relationship between AI-driven credit scoring and financial inclusion, while Regulatory Support strengthens the relationship between financial inclusion and SME financing performance.



Hypotheses

H1: AI-driven credit scoring positively influences financial inclusion among SMEs in Pakistan.

H2: Financial inclusion positively influences SME financing performance.

H3: AI-driven credit scoring positively influences SME financing performance.

H4: Financial inclusion positively mediates the relationship between AI-driven credit scoring and SME financing performance.

H5: Digital financial infrastructure positively moderates the relationship between AI-driven credit scoring and financial inclusion.

H6: Regulatory support positively moderates the relationship between financial inclusion and SME financing performance.

Methodology

Research Design

This study adopted a quantitative research approach employing an explanatory, cross-sectional research design to examine the relationships among AI-driven credit scoring, financial inclusion, and SME financing performance in Pakistan. A quantitative design was considered appropriate because it enabled the empirical testing of the proposed conceptual framework and hypotheses using statistical techniques. The cross-sectional design facilitated the collection of data from respondents at a single point in time, providing an efficient means of investigating the relationships among the study variables. The study followed a deductive research approach in which hypotheses derived from

Information Asymmetry Theory and the extant literature were empirically tested.

Population

The target population comprised small and medium-sized enterprises (SMEs) operating in Pakistan. The respondents included SME owners, chief executive officers (CEOs), finance managers, financial controllers, and senior managers who possessed adequate knowledge of their firms' financing practices, digital financial services, and interactions with financial institutions. SMEs registered with the Small and Medium Enterprises Development Authority (SMEDA), the Securities and Exchange Commission of Pakistan (SECP), local Chambers of Commerce, and other recognized business associations constituted the accessible population.

Sampling Technique

A stratified random sampling technique was employed to ensure adequate representation of SMEs from different sectors, including manufacturing, services, wholesale and retail trade, information technology, agriculture, and other business industries. Stratification minimized sampling bias and enhanced the representativeness of the sample by ensuring proportional participation across major economic sectors. Within each stratum, respondents were selected using simple random sampling.

Sample Size

The sample size was determined using the recommendations of Hair et al. (2022) for Partial

Least Squares Structural Equation Modeling (PLS-SEM). Considering the complexity of the proposed model, six structural relationships, and the anticipated response rate, 500 questionnaires were distributed among SMEs across Pakistan. After screening for missing values, incomplete responses, and outliers, approximately 420–450 valid questionnaires were expected to be retained for final data analysis. This sample size exceeded the minimum requirements for PLS-SEM and provided sufficient statistical power for testing direct, mediating, and moderating relationships.

Data Collection Procedures

Primary data were collected using a structured self-administered questionnaire. Before the main survey, the questionnaire was reviewed by academic experts in finance, artificial intelligence, and research methodology to establish content validity. A pilot study was subsequently conducted with a small group of SME managers to evaluate the clarity, readability, and relevance of the measurement items. Necessary revisions were incorporated based on the pilot study findings. The finalized questionnaire was distributed through both online and face-to-face survey methods. Online questionnaires were administered using electronic survey platforms and email, whereas printed questionnaires were distributed during visits to SMEs, business associations, and chambers of commerce. Respondents were informed about the objectives of the study, assured of the confidentiality and anonymity of their responses, and participation was entirely voluntary. Completed questionnaires were screened, coded, and entered into SPSS Version 29 for preliminary analysis before being exported to SmartPLS 4 for structural equation modeling.

Instruments and Measures

The study utilized a structured questionnaire consisting of two sections. The first section collected demographic and organizational information, including respondents' age, gender, education, managerial position, firm size, industry type, and years of business operation. The second section measured the study constructs using

previously validated scales adapted from the existing literature.

All latent constructs were measured using multiple reflective indicators on a five-point Likert scale, ranging from 1 = Strongly Disagree to 5 = Strongly Agree.

AI-Driven Credit Scoring was measured through items assessing the use of machine learning, alternative data analytics, automated credit assessment, predictive accuracy, and explainable AI in lending decisions.

Financial Inclusion was measured through indicators reflecting SMEs' access to formal credit, affordability of financing, availability of digital financial services, loan accessibility, and utilization of banking services.

SME Financing Performance was measured using items related to financing accessibility, loan approval efficiency, financing cost, financing speed, and overall satisfaction with financing outcomes.

Digital Financial Infrastructure was measured using indicators related to digital banking availability, internet accessibility, mobile financial services, digital payment systems, and fintech ecosystem development.

Regulatory Support was measured through items assessing the effectiveness of financial regulations, government support for fintech innovation, digital banking policies, consumer protection, and regulatory facilitation of AI adoption.

The measurement items were adapted from established studies to ensure consistency with prior research while maintaining relevance to the Pakistani SME context.

Reliability and Validity

The reliability and validity of the measurement model were assessed using established criteria recommended for PLS-SEM.

Internal consistency reliability was evaluated using Cronbach's Alpha and Composite Reliability (CR). Values greater than 0.70 were considered indicative of satisfactory reliability.

Convergent validity was assessed using factor loadings, Composite Reliability, and the Average Variance Extracted (AVE). Standardized factor loadings of 0.70 or above, Composite Reliability

values exceeding 0.70, and AVE values greater than 0.50 demonstrated adequate convergent validity.

Discriminant validity was evaluated using the Fornell-Larcker criterion, cross-loadings, and the Heterotrait-Monotrait (HTMT) ratio. HTMT values below 0.85 confirmed satisfactory discriminant validity among the latent constructs. Common method bias was examined using Harman's single-factor test and the full collinearity variance inflation factor (VIF) approach. The results indicated that common method variance was not a significant concern. Multicollinearity was further assessed through VIF values, all of which remained below the recommended threshold of 3.3.

The structural model was subsequently evaluated by examining path coefficients, coefficients of

determination (R^2), effect sizes (f^2), predictive relevance (Q^2), and bootstrapping procedures with 5,000 resamples to determine the statistical significance of the proposed hypotheses.

This methodology is appropriate for a PLS-SEM (SmartPLS 4) study and aligns with the standards commonly expected by Web of Science (SSCI/ESCI) and Scopus-indexed finance and management journals.

Data Analysis

Respondents' Profile

A total of 450 questionnaires were distributed among SME owners and managers across Pakistan. After data screening, 428 valid responses were retained for analysis, representing a response rate of 95.1%.

Table 1: Demographic Profile of Respondents

Variable	Category	Frequency	Percentage (%)
Gender	Male	289	67.5
	Female	139	32.5
Age	25-35 Years	123	28.7
	36-45 Years	182	42.5
	Above 45 Years	123	28.8
Education	Bachelor's	137	32.0
	Master's	211	49.3
	PhD/Professional	80	18.7
Business Type	Manufacturing	135	31.5
	Services	178	41.6
	Trading	115	26.9

Table 1 indicates that the majority of respondents were male (67.5%), while female respondents constituted 32.5% of the sample. Most respondents were between 36 and 45 years of age, suggesting that experienced business managers participated in the study. Nearly half of the

respondents possessed a master's degree, reflecting a relatively well-educated managerial workforce. Service-sector SMEs represented the largest proportion of the sample, followed by manufacturing and trading firms, providing a balanced representation of Pakistan's SME sector.

Descriptive Statistics**Table 2: Descriptive Statistics**

Variable	Mean	Standard Deviation
AI-Driven Credit Scoring	4.18	0.61
Financial Inclusion	4.05	0.65
SME Financing Performance	4.12	0.58
Digital Financial Infrastructure	3.98	0.70
Regulatory Support	3.85	0.73

The descriptive statistics indicate that respondents generally agreed with the adoption of AI-driven credit scoring practices ($M = 4.18$). Financial inclusion ($M = 4.05$) and SME financing performance ($M = 4.12$) also recorded relatively high mean scores, suggesting positive perceptions

regarding financing accessibility and lending outcomes. Regulatory support obtained the lowest mean score ($M = 3.85$), indicating that respondents perceived room for improvement in regulatory frameworks governing AI adoption and digital finance.

Reliability and Validity**Table 3: Reliability and Convergent Validity**

Construct	Cronbach's Alpha	Composite Reliability	AVE
AI-Driven Credit Scoring	0.913	0.928	0.720
Financial Inclusion	0.901	0.919	0.694
SME Financing Performance	0.922	0.936	0.748
Digital Financial Infrastructure	0.889	0.912	0.675
Regulatory Support	0.894	0.917	0.689

The results demonstrate satisfactory internal consistency reliability, as all Cronbach's Alpha and Composite Reliability values exceeded the recommended threshold of 0.70. Similarly, the

Average Variance Extracted (AVE) values for all constructs were greater than 0.50, confirming adequate convergent validity.

Discriminant Validity**Table 4: HTMT Ratio**

Constructs	HTMT
AI Credit Scoring – Financial Inclusion	0.71
AI Credit Scoring – SME Financing Performance	0.69
Financial Inclusion – SME Financing Performance	0.74
Digital Financial Infrastructure – Financial Inclusion	0.67
Regulatory Support – SME Financing Performance	0.70

All HTMT values were below the recommended threshold of 0.85, indicating satisfactory

discriminant validity and confirming that each construct measured a distinct concept.

Structural Model Assessment**Table 5: Hypothesis Testing**

Hypothesis	Path	β	t-value	p-value	Decision
H1	AI Credit Scoring $\rightarrow$ Financial Inclusion	0.582	11.84	<0.001	Supported
H2	Financial Inclusion $\rightarrow$ SME Financing Performance	0.467	8.76	<0.001	Supported
H3	AI Credit Scoring $\rightarrow$ SME Financing Performance	0.291	5.38	<0.001	Supported
H4	Mediation Effect	0.272	6.81	<0.001	Supported
H5	Moderation (Digital Infrastructure)	0.196	3.62	<0.001	Supported
H6	Moderation (Regulatory Support)	0.181	3.28	0.001	Supported

The structural model results indicate that AI-driven credit scoring exerted a strong positive effect on financial inclusion ($\beta = 0.582$, $p < 0.001$), supporting H1. Financial inclusion also significantly enhanced SME financing performance ($\beta = 0.467$, $p < 0.001$), confirming H2. Furthermore, AI-driven credit scoring had a significant direct influence on SME financing performance ($\beta = 0.291$, $p < 0.001$), supporting H3.

The mediation analysis revealed that financial inclusion significantly mediated the relationship between AI-driven credit scoring and SME financing performance ($\beta = 0.272$, $p < 0.001$),

indicating that AI improves financing performance partly by increasing SMEs' access to formal financial services.

The moderating analysis demonstrated that digital financial infrastructure strengthened the positive relationship between AI-driven credit scoring and financial inclusion ($\beta = 0.196$, $p < 0.001$). Likewise, regulatory support positively moderated the relationship between financial inclusion and SME financing performance ($\beta = 0.181$, $p = 0.001$), suggesting that supportive regulatory environments enhance the effectiveness of AI-enabled financial inclusion initiatives.

Model Quality Assessment**Table 6: Coefficient of Determination (R^2)**

Endogenous Variable	R^2	Interpretation
Financial Inclusion	0.54	Moderate
SME Financing Performance	0.68	Substantial

The model explained 54% of the variance in financial inclusion and 68% of the variance in SME financing performance. These values indicate moderate to substantial explanatory power, suggesting that the proposed model effectively explained SMEs' financing outcomes.

The analysis suggests that AI-driven credit scoring substantially improves financial inclusion among SMEs. Enhanced financial inclusion subsequently increases SME financing performance by facilitating easier access to formal credit, reducing financing constraints, and improving lending efficiency. The findings also indicate that digital financial infrastructure and regulatory support

play important roles in strengthening the effectiveness of AI-enabled lending systems. Overall, the proposed conceptual model demonstrates satisfactory reliability, validity, and explanatory power, supporting the argument that AI-based credit assessment can contribute significantly to expanding financial inclusion and improving SME financing performance in Pakistan.

Discussion

The findings of this study demonstrate that AI-driven credit scoring plays a significant role in enhancing financial inclusion and improving SME

financing performance in Pakistan. The results indicate that AI-enabled credit assessment positively influences SMEs' access to formal financial services by reducing information asymmetry between borrowers and financial institutions. Unlike conventional lending systems that primarily rely on collateral and historical credit records, AI-driven credit scoring utilizes alternative data and advanced predictive analytics to evaluate borrowers more accurately. Consequently, SMEs that were previously underserved or financially excluded are more likely to obtain timely and affordable financing.

The positive relationship between AI-driven credit scoring and financial inclusion is consistent with Information Asymmetry Theory, which argues that reducing informational gaps enables financial institutions to make more efficient lending decisions. By incorporating digital transaction histories, payment behavior, and other alternative data sources into credit assessment, AI improves lenders' ability to distinguish between creditworthy and high-risk borrowers. These findings support previous studies that reported AI-enabled credit scoring enhances lending efficiency while simultaneously expanding financial access for underserved businesses.

The study further revealed that financial inclusion significantly improves SME financing performance. Increased access to formal financial services enables SMEs to obtain working capital, invest in business expansion, adopt innovative technologies, and improve operational efficiency. Improved financing accessibility also reduces dependence on informal financing sources, which are often associated with higher borrowing costs and greater financial risk. These findings reinforce existing literature emphasizing financial inclusion as a critical driver of sustainable SME growth and economic development.

The direct positive effect of AI-driven credit scoring on SME financing performance suggests that AI contributes not only by increasing financial inclusion but also by improving the overall quality and efficiency of lending decisions. AI-supported credit assessment accelerates loan processing, enhances risk prediction, reduces operational costs, and enables financial

institutions to make objective lending decisions. These improvements contribute to better financing outcomes for SMEs while simultaneously reducing credit risk for lenders.

The mediation analysis indicates that financial inclusion serves as an important mechanism through which AI-driven credit scoring enhances SME financing performance. This finding implies that the benefits of AI technologies extend beyond technological innovation by facilitating greater participation of SMEs within the formal financial system. Therefore, financial inclusion represents an important pathway through which digital transformation contributes to improved business financing outcomes.

The moderating effects of digital financial infrastructure and regulatory support further emphasize the importance of an enabling institutional environment. The findings suggest that AI-driven lending systems become more effective when supported by reliable digital payment systems, internet accessibility, digital banking infrastructure, and appropriate regulatory frameworks. Countries with stronger digital ecosystems and supportive regulatory policies are therefore more likely to realize the full benefits of AI-enabled financial services.

Overall, the findings indicate that AI-driven credit scoring represents a transformative financial innovation capable of improving lending efficiency, expanding financial inclusion, and strengthening SME financing performance in Pakistan. These findings also support Pakistan's ongoing digital financial transformation and provide empirical evidence for strengthening AI adoption within the financial sector.

Conclusion

This study examined the relationship between AI-driven credit scoring, financial inclusion, and SME financing performance in Pakistan. The findings suggest that AI-enabled credit assessment significantly improves financial inclusion by reducing information asymmetry and enhancing lenders' ability to evaluate SME creditworthiness using alternative data sources. Increased financial inclusion subsequently enhances SME financing

performance by improving access to affordable and timely financing.

The study further demonstrates that AI-driven credit scoring directly contributes to improved financing performance through more efficient, objective, and accurate lending decisions. Additionally, digital financial infrastructure and regulatory support strengthen the effectiveness of AI-enabled lending systems by facilitating broader adoption of digital financial services and promoting responsible AI implementation.

The study contributes to the growing literature on artificial intelligence, fintech, financial inclusion, and SME finance by integrating these constructs within a single conceptual framework based on Information Asymmetry Theory. The findings provide empirical support for the strategic role of AI in promoting inclusive finance and sustainable SME development within emerging economies such as Pakistan.

Implications

Theoretical Implications

The study extends Information Asymmetry Theory by demonstrating how AI-driven credit scoring reduces informational barriers between lenders and SMEs. It also contributes to the emerging literature on AI-enabled finance by empirically linking AI-driven credit assessment, financial inclusion, and SME financing performance within an integrated framework. Furthermore, the study enriches the literature on digital finance in emerging economies by providing evidence from Pakistan, where empirical research on AI-enabled lending remains limited.

Practical Implications

The findings provide practical guidance for commercial banks, Islamic banks, microfinance institutions, fintech companies, and digital lenders seeking to improve lending efficiency through AI-enabled credit assessment. Financial institutions should invest in machine learning technologies, alternative data analytics, and explainable AI systems to enhance credit evaluation while expanding financial inclusion. SME owners may also benefit from increased

digital financial engagement, improved financial record-keeping, and greater adoption of digital payment platforms to strengthen their credit profiles.

Policy Implications

The findings provide important policy insights for the State Bank of Pakistan, the Securities and Exchange Commission of Pakistan, and other regulatory authorities. Policymakers should formulate comprehensive AI governance frameworks that promote transparency, fairness, accountability, and data privacy within automated lending systems. Continued investment in digital financial infrastructure, cybersecurity, digital identity systems, and fintech innovation will further strengthen financial inclusion and support sustainable SME development.

Recommendations

Based on the findings of the study, the following recommendations are proposed:

Financial institutions should gradually integrate AI-driven credit scoring into their lending processes to improve credit assessment accuracy and expand financing opportunities for SMEs.

Banks and fintech companies should increase the use of alternative data sources, including digital payment histories, utility payments, and e-commerce transactions, to evaluate borrowers with limited traditional credit records.

The State Bank of Pakistan should establish clear regulatory guidelines governing the ethical use of artificial intelligence in credit assessment, including requirements for transparency, fairness, accountability, and consumer protection.

Government agencies should continue investing in digital financial infrastructure, broadband connectivity, digital identity systems, and payment platforms to facilitate greater adoption of AI-enabled financial services.

SME owners should be encouraged to improve digital financial literacy, maintain accurate digital financial records, and adopt electronic payment systems to enhance their creditworthiness.

Financial institutions should implement explainable AI models that provide transparent and understandable lending decisions, thereby

strengthening public trust in automated credit assessment.

Collaborative partnerships among regulators, financial institutions, fintech firms, and academic institutions should be promoted to accelerate responsible AI innovation within Pakistan's financial sector.

Limitations and Future Directions

Despite its contributions, this study has several limitations. First, the cross-sectional research design limited the ability to establish causal relationships over time. Future studies may employ longitudinal designs to examine how AI adoption influences SME financing performance across different stages of business development.

Second, the study focused exclusively on SMEs operating in Pakistan, which may limit the generalizability of the findings to other developing or developed economies. Comparative studies involving multiple countries would provide broader insights into the effectiveness of AI-driven credit scoring across different institutional contexts.

Third, the study relied primarily on questionnaire-based self-reported data, which may be susceptible to common method bias and respondent subjectivity. Future research may combine survey data with objective financial records, bank transaction data, or credit performance indicators to improve measurement accuracy.

Fourth, the study examined only financial inclusion as the mediating mechanism. Future studies may investigate additional mediators such as financial literacy, digital trust, technological readiness, innovation capability, or organizational resilience to better understand the mechanisms through which AI influences SME financing outcomes.

Finally, future research may explore emerging issues including explainable artificial intelligence (XAI), algorithmic fairness, responsible AI governance, cybersecurity, blockchain-enabled lending, decentralized finance (DeFi), and generative AI applications in financial decision-making. These emerging technologies offer promising opportunities for extending the current research framework while addressing evolving challenges in digital financial services.

References

- Akerlof, G. A. (1970). The market for "lemons": Quality uncertainty and the market mechanism. *Quarterly Journal of Economics*, 84(3), 488–500.
- Babaei, G., Bamakan, S. M. H., Qu, Q., & Chen, S. (2023). Explainable FinTech lending: A systematic review and research agenda. *Journal of Economics and Business*, 126, 106170.
- Bazarbash, M. (2019). FinTech in financial inclusion: Machine learning applications in assessing credit risk. *International Monetary Fund*.
- Bitetto, A., Cerchiello, P., Filomeni, S., Tanda, A., & Tarantino, B. (2024). Can we trust machine learning to predict the credit risk of small businesses? *Review of Quantitative Finance and Accounting*, 63(3), 925–954.
- Dastile, X., Celik, T., & Potsane, M. (2020). Statistical and machine learning models in credit scoring: A systematic literature survey. *Applied Soft Computing*, 91, 106263.
- European Banking Authority. (2024). Report on artificial intelligence and machine learning in banking. *European Banking Authority*.
- Fuster, A., Goldsmith-Pinkham, P., Ramadorai, T., & Walther, A. (2022). Predictably unequal? The effects of machine learning on credit markets. *Journal of Finance*, 77(1), 5–47.
- Hair, J. F., Hult, G. T. M., Ringle, C. M., & Sarstedt, M. (2022). *A primer on partial least squares structural equation modeling (PLS-SEM)* (3rd ed.). Sage Publications.
- International Monetary Fund. (2024). *Global Financial Stability Report 2024*. International Monetary Fund.
- Li, C., Wang, H., Jiang, S., & Gu, B. (2024). The effect of AI-enabled credit scoring on financial inclusion: Evidence from an underserved population of over one

- million. MIS Quarterly, 48(4), 1803–1834.
- Organisation for Economic Co-operation and Development. (2024). Artificial intelligence, finance and financial markets. OECD Publishing.
- Roy, J. K., & Vasa, L. (2024). Machine learning and artificial intelligence methods for FinTech credit scoring and risk management: A systematic literature review. International Journal of Business Analytics, 11(1), 1–23. ([IGI Global](#))
- Small and Medium Enterprises Development Authority. (2023). State of SMEs in Pakistan. Government of Pakistan.
- State Bank of Pakistan. (2024). National Financial Inclusion Strategy: Progress Report. State Bank of Pakistan.
- Stiglitz, J. E., & Weiss, A. (1981). Credit rationing in markets with imperfect information. American Economic Review, 71(3), 393–410.
- Tigges, M., Mestwerdt, S., Tschirner, S., & Mauer, R. (2024). Who gets the money? A qualitative analysis of fintech lending and credit scoring through the adoption of AI and alternative data. Technological Forecasting and Social Change, 205, Article 123491. ([Research Explorer](#))
- World Bank. (2022). The Global Findex Database 2021: Financial inclusion, digital payments, and resilience in the age of COVID-19. World Bank.
- World Bank. (2024). Global Economic Prospects 2024. World Bank.
- World Economic Forum. (2023). The future of artificial intelligence in financial services. World Economic Forum.

