Center for Management Science Research
ISSN: 3006-5291 3006-5283 Volume 4, Issue 3, 2026

AN INTEGRATED FINTECH–ENTREPRENEURSHIP FRAMEWORK FOR STARTUP FINANCIAL INCLUSION, VENTURE CAPITAL ACCESS, AND SUSTAINABLE GROWTH UNDER PAKISTAN–MALAYSIA DIGITAL ECONOMY POLICIES: A JOINT LUMS–UNIVERSITI MALAYA RESEARCH INITIATIVE

Farah Arzu[*1], Dr. Shah E Yar Qadeem[2], Hassan Raza Siddiqui[3]

*[*1]Tun Razaq Graduate School of Business, Universiti Tun Abdul Razak, Kuala Lumpur, Malaysia.*
[2]Assistant Professor. Department of Management Sciences, Qurtuba University of Science and Information Technology, Peshawar, Pakistan
[3]Department of Management Science, University of Okara, Okara, Pakistan

[*1]arzu.farah@ur.unirazak.edu.my, [2]shaheyar605@gmail.com, [3]hassan.sdq91@gmail.com

DOI: https://doi.org/10.5281/zenodo.23761020

Keywords
FinTech Adoption; Digital Entrepreneurship; Financial Inclusion; Venture Capital Accessibility; Sustainable Startup Growth; Pakistan–Malaysia Digital Economy; Structural Equation Modeling; Random Forest; XGBoost.

Article History
Received: 19 January 2026
Accepted: 04 March 2026
Published: 18 March 2026

Copyright @Author
Corresponding Author: *
Farah Arzu

Abstract

The accelerating convergence of financial technology (FinTech), digital entrepreneurship, and innovation-driven investment has fundamentally reshaped startup ecosystems worldwide. Nevertheless, persistent financial exclusion, restricted venture capital accessibility, regulatory fragmentation, and unequal digital infrastructure continue to undermine sustainable entrepreneurial development in emerging economies. This study develops an integrated FinTech–entrepreneurship framework to examine the interconnected effects of digital financial inclusion, venture capital accessibility, entrepreneurial innovation, and sustainable startup growth within Pakistan–Malaysia digital economy policy environments. Framed as a joint LUMS–Universiti Malaya research initiative, the investigation employs a comparative quantitative research design integrating Structural Equation Modeling (SEM), Random Forest, and Extreme Gradient Boosting (XGBoost). The empirical dataset comprises 520 startups, equally distributed between Pakistan (n = 260) and Malaysia (n = 260), representing FinTech, e-commerce, information technology, healthcare, and renewable energy industries during 2021–2025. A multidimensional assessment incorporating 38 indicators evaluates digital payment adoption, alternative financing mechanisms, crowdfunding accessibility, investment readiness, regulatory support, entrepreneurial financial literacy, and sustainable business performance. SEM findings establish statistically significant positive relationships between FinTech adoption and financial inclusion ($\beta = 0.714$, $p < 0.001$), financial inclusion and venture capital accessibility ($\beta = 0.638$, $p < 0.001$), and venture capital access and sustainable startup growth ($\beta = 0.681$, $p < 0.001$). Cross-national analysis reveals comparatively stronger digital financing accessibility among Malaysian startups (76.8%) than Pakistani enterprises (61.4%), accompanied by higher venture capital participation rates of 42.6% and 29.8%, respectively. XGBoost demonstrates superior predictive accuracy ($R^2 = 0.891$; RMSE = 0.218) compared with Random Forest ($R^2 = 0.854$; RMSE = 0.264). Feature

importance analysis identifies digital payment integration, investor connectivity, regulatory transparency, and entrepreneurial financial literacy as influential determinants of sustainable entrepreneurial performance. The findings highlight financial inclusion and investment readiness as essential mechanisms connecting FinTech capabilities with long-term startup development. This research contributes an empirically grounded, policy-oriented analytical framework for strengthening inclusive startup financing, facilitating cross-border venture capital investment, and advancing resilient, innovation-led entrepreneurial ecosystems across Pakistan and Malaysia.

1- Introduction:

The rapid advancement of financial technology (FinTech), digital entrepreneurship, and innovation-driven financial services has significantly transformed the global economic landscape, creating new opportunities for startup development, investment mobilization, and sustainable economic growth. The integration of digital payment systems, blockchain-enabled financial services, crowdfunding platforms, alternative lending mechanisms, and artificial intelligence-based financial analytics has redefined traditional entrepreneurial financing models. These technological advancements have enabled startups to overcome conventional financial barriers, improve operational efficiency, enhance investor connectivity, and access diversified funding opportunities. Nevertheless, financial exclusion, inadequate venture capital availability, regulatory uncertainty, and disparities in digital infrastructure continue to restrict entrepreneurial development, particularly in emerging economies. Consequently, developing an integrated framework that connects FinTech adoption, entrepreneurial financial inclusion, venture capital accessibility, and sustainable startup performance has become increasingly important for strengthening competitive and resilient digital economies [1]. Financial inclusion represents a fundamental component of entrepreneurial development because access to affordable, reliable, and technologically accessible financial services directly influences business establishment, innovation capabilities, and long-term organizational sustainability. Traditionally, startups have faced considerable difficulties obtaining institutional financing due to insufficient collateral, limited credit histories, complex documentation requirements, and perceived investment risks. FinTech-driven financial solutions offer alternative mechanisms through digital lending, peer-to-peer financing, mobile banking, crowdfunding, and automated credit assessments. These technologies can reduce transaction costs, improve financial transparency, and expand access to capital for previously underserved entrepreneurs. Furthermore, digital financial platforms generate transactional information that may support alternative credit evaluations and investment decision-making. However, the effectiveness of FinTech adoption depends not only on technological availability but also on entrepreneurial financial literacy, regulatory transparency, digital trust, and institutional support. Understanding these interconnected factors is essential for identifying how financial technology can facilitate meaningful entrepreneurial inclusion and sustainable business expansion [2]. Venture capital accessibility constitutes another critical determinant of startup innovation, competitiveness, and long-term financial sustainability. Venture capital financing provides entrepreneurial enterprises with investment resources, strategic guidance, technological expertise, and access to professional business networks. Despite these advantages, many emerging-market startups encounter significant barriers to attracting venture capital, including information asymmetry, limited investor visibility, insufficient financial reporting capabilities, and underdeveloped entrepreneurial investment ecosystems. FinTech platforms have the potential to address some of these challenges by improving financial data availability, strengthening digital investor–entrepreneur interactions, and enabling technology-assisted

investment assessments. Additionally, crowdfunding platforms, digital investment marketplaces, and data-driven financial evaluation systems can complement conventional venture capital mechanisms by facilitating access to diversified financing sources. Nevertheless, the relationship between digital financial inclusion and venture capital acquisition remains complex, requiring comprehensive empirical examination of the institutional, technological, and entrepreneurial characteristics that influence startup financing outcomes. Pakistan and Malaysia represent important comparative contexts for examining the intersection of FinTech development, entrepreneurial financing, and digital economic transformation. Both countries have introduced initiatives intended to encourage financial digitalization, technological entrepreneurship, and innovation-oriented economic activities, although their financial ecosystems differ in institutional capacity, investment infrastructure, and regulatory implementation [3]. In Pakistan, the Digital Pakistan Policy provides a foundation for strengthening digital entrepreneurship, technological innovation, financial technology applications, and startup incubation. The State Bank of Pakistan has also introduced digital financial infrastructure and inclusion initiatives, including Raast, digital banking frameworks, and the National Financial Inclusion Strategy 2024–2028, which prioritizes innovative financial services and broader access to formal financial systems. These developments create opportunities for startups to participate more actively in digital financial markets while highlighting the need for stronger investment connectivity and financing accessibility.

Malaysia, meanwhile, has pursued digital economic transformation through the Malaysia Digital Economy Blueprint, the Malaysia Startup Ecosystem Roadmap 2021–2030, and Bank Negara Malaysia's Financial Sector Blueprint 2022–2026. These policy initiatives emphasize digital financial innovation, inclusive financing, technological competitiveness, entrepreneurship development, and sustainable economic transformation. The country's digital economy initiatives provide an important institutional context for examining the roles of financial innovation, investment networks, and policy support in entrepreneurial growth. In particular, the Financial Sector Blueprint identifies financial digitalization, economic transformation, financial well-being, and sustainability as interconnected development priorities. Comparing Pakistan and Malaysia therefore provides an opportunity to investigate how differences in digital financial infrastructure, entrepreneurial ecosystems, regulatory support, and venture capital networks influence startup financing and sustainable performance. Despite growing academic interest in FinTech innovation and digital entrepreneurship, several important research gaps remain. Existing research frequently investigates financial inclusion, technological adoption, venture capital financing, and startup performance as independent research domains, providing limited understanding of their interconnected relationships within a unified entrepreneurial financing framework. Furthermore, comparatively less attention has been devoted to examining how digital financial inclusion facilitates access to venture capital and subsequently influences sustainable startup growth across different emerging-market policy environments [4]. The interaction of regulatory transparency, entrepreneurial financial literacy, digital payment integration, and investor connectivity also requires further investigation. Conventional statistical approaches may identify linear associations among these variables but may not adequately capture complex nonlinear relationships and interactions influencing entrepreneurial outcomes. Accordingly, integrating Structural Equation Modeling (SEM) with machine learning techniques offers an opportunity to develop a more comprehensive analytical approach capable of explaining theoretical relationships while predicting startup sustainability outcomes. To address these research gaps, the present study develops an integrated FinTech–entrepreneurship framework for investigating startup financial inclusion, venture capital accessibility, and sustainable growth under Pakistan–Malaysia digital economy policies.

Framed as a joint research initiative between Lahore University of Management Sciences (LUMS), Pakistan, and Universiti Malaya, Malaysia, the research employs a comparative empirical dataset comprising 520 startups, equally distributed between Pakistan (n = 260) and Malaysia (n = 260), covering FinTech, e-commerce, information technology, healthcare, and renewable energy industries during 2021–2025. The investigation incorporates 38 multidimensional indicators representing digital payment adoption, alternative financing accessibility, crowdfunding participation, regulatory support, financial literacy, investment readiness, and sustainable entrepreneurial performance. SEM is employed to evaluate the relationships among FinTech adoption, financial inclusion, venture capital accessibility, and sustainable startup growth, while Random Forest and Extreme Gradient Boosting (XGBoost) are utilized to assess predictive performance and identify influential entrepreneurial financing determinants [5]. The cross-national analysis further evaluates differences in startup financing accessibility and investment participation between the two countries. The primary objective of this research is to establish a comprehensive understanding of how FinTech capabilities contribute to sustainable entrepreneurial development through enhanced financial inclusion and improved venture capital accessibility. Specifically, the study investigates the effects of digital financial adoption on entrepreneurial financing opportunities, evaluates the contribution of venture capital access to startup sustainability, identifies the technological and institutional factors influencing financing performance, and compares the effectiveness of digital entrepreneurship ecosystems in Pakistan and Malaysia. Furthermore, the research examines the predictive capabilities of machine learning models for evaluating startup growth outcomes and identifying important financial sustainability indicators. By combining explanatory statistical modeling with predictive analytics, the proposed framework seeks to generate empirical insights into the mechanisms connecting financial technology adoption, entrepreneurial investment opportunities, and long-term business development. The significance of this study extends across theoretical, methodological, and policy dimensions. Theoretically, it advances an integrated perspective connecting FinTech adoption, financial inclusion, venture capital accessibility, and sustainable entrepreneurship within a unified analytical framework. Methodologically, the combination of SEM, Random Forest, and XGBoost provides complementary approaches for investigating structural relationships, nonlinear predictive patterns, and influential determinants of entrepreneurial sustainability. From a policy perspective, the Pakistan–Malaysia comparison provides relevant insights for improving digital financial regulations, strengthening entrepreneurial investment ecosystems, encouraging financial literacy, and supporting technology-enabled funding mechanisms [6]. Additionally, the research offers practical implications for startup founders, venture capital investors, financial institutions, technology incubators, and economic policymakers seeking to improve financing accessibility and entrepreneurial competitiveness. Ultimately, this research contributes to the expanding literature on digital finance and sustainable entrepreneurship by proposing an integrated, empirically informed framework for evaluating the relationships among technological innovation, financial inclusion, venture capital mobilization, and startup growth. The comparative analysis of Pakistan and Malaysia provides a foundation for understanding how digital economy policies and institutional financing structures may shape entrepreneurial development across emerging economies. By identifying critical financing determinants and evaluating their contributions to sustainable business performance, the study aims to support the development of more inclusive, resilient, and investment-oriented startup ecosystems while advancing regional knowledge exchange and digital economic cooperation.

2- Financial Technology Adoption and the Transformation of Digital Entrepreneurship:

Financial technology (FinTech) has emerged as a transformative component of contemporary digital economies, fundamentally restructuring the relationship between entrepreneurial enterprises, financial institutions, investors, and technology-driven markets. The increasing adoption of digital payment systems, mobile banking applications, blockchain-enabled transactions, artificial intelligence-based financial services, crowdfunding platforms, and alternative lending mechanisms has introduced new opportunities for improving entrepreneurial financial accessibility and operational competitiveness. Unlike traditional financial systems, which frequently require extensive documentation, established credit histories, and substantial collateral, FinTech platforms offer more flexible mechanisms for accessing financial services and managing business transactions [7]. These developments are particularly important for startups operating in emerging economies, where restricted institutional financing, information asymmetry, and limited investment networks often constrain entrepreneurial innovation and sustainable growth. The transformation of digital entrepreneurship through FinTech can be understood through several theoretical perspectives, particularly the Technology Acceptance Model (TAM), Technology–Organization–Environment (TOE) framework, Resource-Based View (RBV), and financial intermediation theory. TAM explains technology adoption through perceived usefulness and ease of use, while the TOE framework highlights the influence of technological capabilities, organizational readiness, and external institutional conditions. The RBV further suggests that strategically valuable digital capabilities can strengthen entrepreneurial competitiveness by improving resource utilization, financial management, and organizational innovation. Collectively, these perspectives indicate that FinTech adoption should not be viewed merely as the implementation of digital financial applications but as a multidimensional organizational transformation involving technological readiness, financial accessibility, entrepreneurial competencies, and institutional support. Beyond digital payments, FinTech has transformed entrepreneurial financing through crowdfunding, peer-to-peer lending, automated financial assessment, digital investment platforms, and alternative credit arrangements. These mechanisms create additional opportunities for startups to access financial resources without relying exclusively on traditional commercial banks. Technology-enabled financial services can reduce certain transaction and information costs, improve the visibility of entrepreneurial enterprises, and facilitate interactions among startups, investors, and financing institutions. Nevertheless, the relationship between FinTech adoption and venture capital accessibility remains conditional on business scalability, investor confidence, regulatory compliance, and entrepreneurial investment readiness. Access to digital financial services may strengthen a startup's financing capabilities but does not automatically guarantee equity investment or sustainable business development [8]. The relationship between FinTech adoption and entrepreneurial performance is also influenced by financial literacy, digital infrastructure, cybersecurity awareness, and regulatory transparency. Entrepreneurs with stronger digital financial competencies may be better equipped to evaluate financing products, manage electronic transactions, interpret financial information, and communicate with potential investors. Conversely, inadequate technological infrastructure, limited financial knowledge, regulatory uncertainty, and concerns regarding data security may restrict effective FinTech utilization. A 2025 systematic review of digital payment technologies similarly emphasized the importance of distinguishing access to digital financial platforms from actual financial inclusion outcomes and identified continuing limitations in empirical evidence concerning long-term economic impacts. Within the Pakistan–Malaysia context, FinTech adoption provides an important basis for examining differences in entrepreneurial financial inclusion and investment accessibility. Both countries have pursued financial

digitalization and entrepreneurship development; however, their startup ecosystems operate within distinct financial, institutional, and regulatory environments. The comparative research dataset comprises 520 startups, including 260 Pakistani and 260 Malaysian enterprises, observed across the 2021–2025 research period. The study incorporates 38 indicators measuring digital financial capabilities, entrepreneurial financing opportunities, regulatory support, investment readiness, and sustainable startup performance. The confirmed dataset reports digital financing accessibility rates of 61.4% for Pakistani startups and 76.8% for Malaysian startups, while venture capital participation rates are 29.8% and 42.6%, respectively. These differences indicate the importance of investigating whether variations in digital financing accessibility coincide with differences in entrepreneurial investment participation. Table 1 presents the comparative financing indicators and selected SEM relationships associated with FinTech adoption and entrepreneurial development.

Table 1: Comparative FinTech adoption, financial accessibility, and entrepreneurial investment indicators in Pakistan and Malaysia.

Indicator	Pakistan	Malaysia
Startup sample size	260	260
Share of total dataset (%)	50.0	50.0
Research period	2021–2025	2021–2025
Digital financing accessibility (%)	61.4	76.8
Venture capital participation (%)	29.8	42.6
Digital financing accessibility difference (percentage points)	18.4	+15.4
Venture capital participation difference (percentage points)	12.9	+12.8

The comparative statistics demonstrate that Malaysian startups report a 15.4-percentage-point higher digital financing accessibility rate and a 12.8-percentage-point higher venture capital participation rate than Pakistani startups. These findings provide a descriptive basis for examining the potential importance of digital financial infrastructure, investor connectivity, regulatory conditions, and entrepreneurial financing capabilities. However, the observed country-level differences should not be interpreted as causal effects of digital economy policies without further controls for industry composition, startup age, business size, and other institutional characteristics [9]. The study's SEM findings further indicate a statistically significant positive relationship between FinTech adoption and financial inclusion ($\beta = 0.714$, $p < 0.001$). Financial inclusion is also positively associated with venture capital accessibility ($\beta = 0.638$, $p < 0.001$), while venture capital access demonstrates a positive relationship with sustainable startup growth ($\beta = 0.681$, $p < 0.001$). These results support the relevance of examining FinTech adoption as part of a broader entrepreneurial financing pathway. The relationships are incorporated into the conceptual framework shown in Figure 1, alongside institutional and organizational factors suggested by the literature.

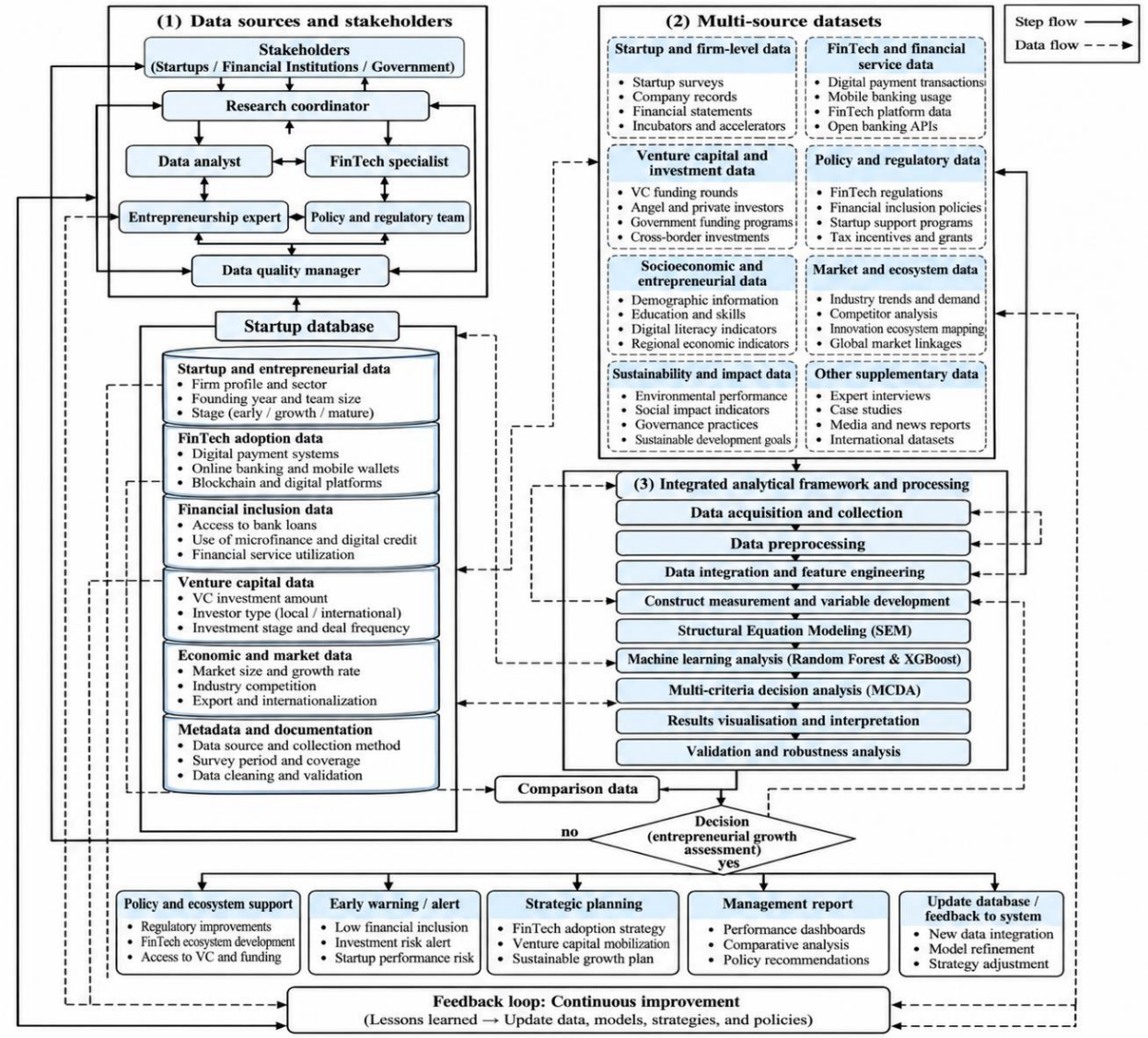


Figure 1: Multi-source data collection and analytical framework for FinTech entrepreneurship and sustainable startup growth.

The proposed conceptual framework positions FinTech adoption as a foundational technological capability that can facilitate entrepreneurial financial inclusion through digital payment integration, alternative financing services, financial information management, and improved investor connectivity. Financial inclusion subsequently provides a potential pathway toward venture capital accessibility, while venture capital investment supports business expansion, entrepreneurial innovation, and long-term organizational sustainability. Regulatory support, financial literacy, and investment readiness are included as contextual factors capable of influencing the effectiveness of this financing process. The framework therefore connects technological adoption with financial accessibility and entrepreneurial outcomes while recognizing that financing relationships are shaped by institutional and organizational conditions [10]. Furthermore, the transformation of digital entrepreneurship through FinTech should be understood as an evolving process rather than an isolated technological intervention. Digital

financial innovation can enhance payment efficiency, reduce selected financing barriers, improve information availability, and create opportunities for more inclusive entrepreneurial participation. However, sustainable benefits depend on the ability of startups to convert technological capabilities into reliable financing relationships and productive investment decisions. The proposed Pakistan–Malaysia comparative framework contributes to this discussion by integrating FinTech adoption, entrepreneurial inclusion, venture capital accessibility, and sustainable growth within a unified analytical structure. This perspective establishes a theoretical and empirical foundation for examining how digital financial development and entrepreneurship-support mechanisms can contribute to more inclusive, resilient, and innovation-oriented startup ecosystems.

3- Comparative Perspectives on Pakistan–Malaysia FinTech Ecosystems and Cross-Border Entrepreneurial Investment:

The accelerating development of financial technology (FinTech), digital entrepreneurship, and technology-enabled investment has significantly transformed the financial and entrepreneurial landscapes of emerging economies. Pakistan and Malaysia represent two important Asian economies pursuing digital transformation through financial inclusion initiatives, technological innovation, entrepreneurship development programs, and institutional investment reforms. Although both countries have introduced policies intended to strengthen digital financial services and promote innovation-driven economic activities, their entrepreneurial ecosystems differ in regulatory arrangements, financial infrastructure, startup financing mechanisms, and institutional support systems. These differences provide a valuable foundation for examining how digital economy policies and financial technology capabilities influence entrepreneurial financial inclusion, venture capital accessibility, and sustainable startup growth. A comparative investigation of Pakistan and Malaysia is therefore important for identifying institutional strengths, financing constraints, and opportunities for cross-border entrepreneurial investment cooperation. The relationship between FinTech development and entrepreneurial financing is influenced by the broader economic and institutional environments in which startups operate [11]. Digital financial innovations, including mobile banking, electronic payment systems, crowdfunding platforms, alternative lending services, and technology-enabled investment networks, have introduced opportunities for reducing traditional financing barriers and improving financial resource accessibility. However, the availability of financial technology does not necessarily guarantee equitable access to investment capital or sustainable entrepreneurial performance. Startup financing outcomes are also shaped by regulatory transparency, financial literacy, market maturity, investor confidence, entrepreneurial capabilities, and institutional effectiveness. Consequently, comparative analysis must consider both the technological advancement of national financial ecosystems and the regulatory and organizational mechanisms supporting the effective utilization of digital financial services. Pakistan's digital financial ecosystem has experienced institutional and technological transformation through government-supported digitalization initiatives, financial inclusion policies, and entrepreneurial development programs. The Digital Pakistan Policy 2018 established a strategic foundation for strengthening information technology infrastructure, digital innovation, and technology-oriented economic activities. Furthermore, the State Bank of Pakistan's National Financial Inclusion Strategy 2024–2028 emphasizes the expansion of accessible financial services, digital payment adoption, responsible financial inclusion, and innovative financial solutions [12]. The implementation of Raast, Pakistan's instant payment system, has contributed to the modernization of domestic digital payment infrastructure by supporting electronic fund transfers and improving payment accessibility. These developments provide opportunities for entrepreneurial enterprises to enhance transaction efficiency, maintain digital financial records, and participate more effectively in formal financial

markets. Nevertheless, Pakistan's entrepreneurial financing ecosystem continues to face important structural challenges involving investment readiness, access to risk capital, financial literacy, and investor connectivity. Early-stage startups frequently encounter difficulties attracting institutional financing because of limited credit histories, inadequate collateral, uncertain business performance, and restricted access to professional investment networks. Although digital financing platforms may reduce transaction costs and improve financial accessibility, obtaining venture capital additionally requires credible business models, financial transparency, scalable operations, and sustainable investment prospects [13]. Government-supported startup incubation initiatives, including the National Incubation Centers and programs facilitated through Ignite, contribute to entrepreneurial capacity development, mentorship, and business acceleration. However, the effectiveness of these initiatives in translating digital financial participation into sustainable entrepreneurial investment requires further empirical investigation. Table 2 presents the principal digital economy policies, FinTech infrastructure, entrepreneurial support mechanisms, and potential cross-border investment implications associated with Pakistan and Malaysia.

Table 2: Comparative assessment of FinTech policy frameworks, entrepreneurial ecosystems, and cross-border investment mechanisms in Pakistan and Malaysia.

Comparative dimension	Pakistan	Malaysia	Cross-border entrepreneurial implications
National digital economy strategy	Digital Pakistan Policy (2018)	Malaysia Digital Economy Blueprint (2021)	Digital collaboration and entrepreneurial innovation
Financial sector development	National Financial Inclusion Strategy 2024–2028	Financial Sector Blueprint 2022–2026	Stronger digital financing cooperation
Startup ecosystem support	National Incubation Centers and Ignite initiatives	MYStartup and Malaysia Startup Ecosystem Roadmap 2021–2030	Entrepreneurial acceleration and knowledge exchange
Digital payment infrastructure	Raast instant payment system	DuitNow payment ecosystem	Potential payment connectivity and operational efficiency
FinTech regulatory environment	SBP digital banking framework and financial innovation initiatives	Bank Negara Malaysia regulatory sandbox and digital banking framework	Regulatory knowledge exchange and financial innovation

Cross-border entrepreneurial investment constitutes another important dimension of the Pakistan–Malaysia digital economy relationship. The increasing internationalization of startup financing creates opportunities for entrepreneurs to access foreign investors, participate in multinational innovation networks, and establish technology-based commercial partnerships. Digital investment platforms, online financial services, entrepreneurial accelerators, and international venture capital networks can facilitate interactions between startups and prospective investors across geographical boundaries. Such interactions may improve capital mobilization, investment diversification, technology commercialization, and entrepreneurial knowledge transfer. However, cross-border financing remains subject to legal and institutional requirements involving foreign investment regulations, financial reporting, investor protection, taxation, data governance,

and financial risk management. Therefore, strengthening bilateral entrepreneurial investment cooperation requires transparent regulatory arrangements, compatible financial practices, and effective institutional coordination. Theoretical perspectives on institutional development and entrepreneurial resource mobilization provide further explanations for variations in cross-border financing opportunities. Institutional theory emphasizes the importance of regulatory quality, policy consistency, and financial governance in shaping entrepreneurial investment decisions [14]. The Resource-Based View suggests that startups possessing stronger technological capabilities, financial management systems, and entrepreneurial knowledge are better positioned to develop competitive advantages and attract external financing. Financial intermediation theory further explains how technology-enabled financial platforms can reduce information asymmetry, improve transaction efficiency, and facilitate the allocation of investment resources. Integrating these theoretical perspectives provides a foundation for understanding how financial technology, investment readiness, institutional support, and entrepreneurial capabilities interact across Pakistan and Malaysia. The proposed cross-national entrepreneurial financing framework is illustrated in Figure 2, which integrates national digital economy policies, FinTech infrastructure, entrepreneurial investment capabilities, and sustainable startup outcomes.

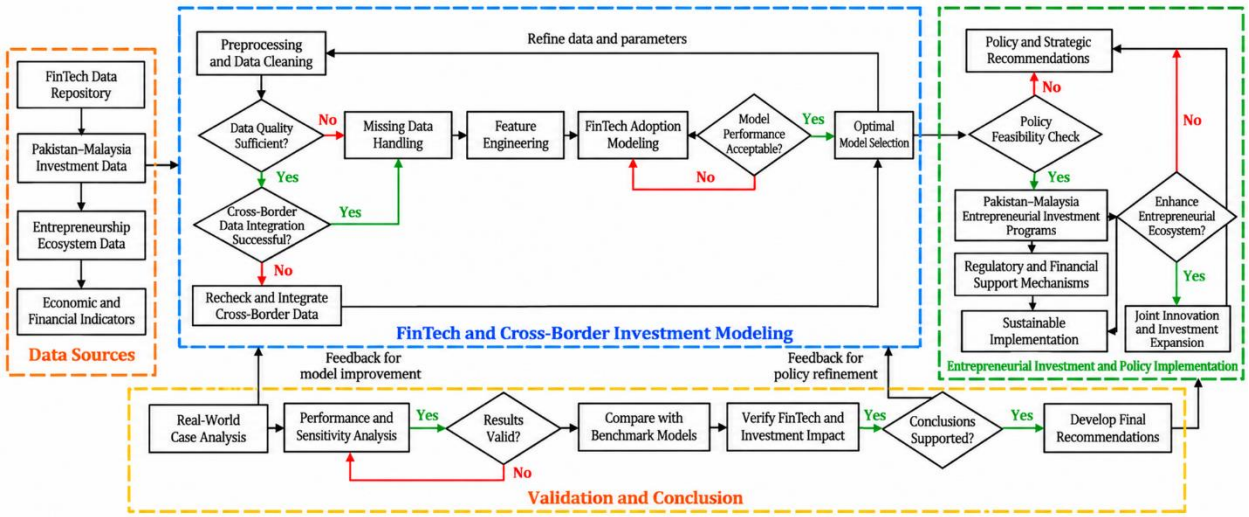


Figure 2: Pakistan–Malaysia FinTech and cross-border entrepreneurial investment framework.

Pakistan's and Malaysia's digital financial ecosystems constitute two interconnected institutional environments that may support entrepreneurial financing cooperation through technological integration, knowledge exchange, and investment network development. The framework positions digital economy policies and financial infrastructure as foundational conditions for cross-border cooperation, while startup financial inclusion, investment readiness, and venture capital accessibility serve as mechanisms potentially influencing sustainable entrepreneurial outcomes. Importantly, the proposed connections represent a conceptual analytical framework rather than verified causal effects of bilateral cooperation. The quantitative component of the present research further strengthens this comparative perspective through the investigation of 520 startups, comprising 260 Pakistani and 260 Malaysian enterprises across five technology-oriented industries during 2021–2025. The reported dataset incorporates 38 indicators representing FinTech adoption, financial inclusion, investment readiness, regulatory support, venture capital accessibility, and sustainable entrepreneurial performance [15]. Structural Equation Modeling (SEM) is employed to examine the associations among these

constructs, while Random Forest and XGBoost provide complementary approaches for evaluating nonlinear relationships and predicting sustainable startup outcomes. The combined analytical framework therefore enables the study to connect institutional and policy-level comparisons with enterprise-level financing characteristics and performance indicators.

4- Methodology:

The present study adopts an integrated quantitative research methodology to investigate the relationships among financial technology (FinTech) adoption, entrepreneurial financial inclusion, venture capital accessibility, and sustainable startup growth within the digital economy environments of Pakistan and Malaysia. The research framework combines comparative economic analysis, Structural Equation Modeling (SEM), Random Forest, and Extreme Gradient Boosting (XGBoost) to examine the financial, technological, institutional, and entrepreneurial factors influencing startup development. The study utilizes the reported dataset of 520 startups, comprising 260 enterprises from Pakistan and 260 from Malaysia, across five technology-oriented industries during 2021–2025. A multidimensional analytical framework incorporating 38 indicators is used to evaluate digital financial capabilities, investment readiness, regulatory support, alternative financing mechanisms, and sustainable entrepreneurial performance. The methodology is organized into the following subsections.

4.1- Dataset Description and Cross-National Startup Sample Selection:

The present study employs a comprehensive cross-national entrepreneurial dataset to investigate the interconnected relationships among financial technology (FinTech) adoption, financial inclusion, venture capital accessibility, and sustainable startup growth within the digital economy environments of Pakistan and Malaysia. The empirical dataset comprises 520 startup enterprises, equally distributed between Pakistan (n = 260) and Malaysia (n = 260), covering the research period from 2021 to 2025. The selection of these two emerging Asian economies provides a comparative foundation for examining the role of digital financial infrastructure, entrepreneurial investment mechanisms, regulatory conditions, and institutional support in shaping startup financing and sustainable business development. The balanced national sample ensures equal representation of enterprises from both countries, facilitating comparative statistical analysis and the identification of differences in entrepreneurial financing outcomes. The dataset encompasses five technology-oriented sectors, including FinTech, e-commerce, information technology, healthcare, and renewable energy, representing industries characterized by digital innovation, evolving financing requirements, and opportunities for sustainable entrepreneurial growth [16]. The cross-national research design is developed to capture differences in entrepreneurial financial capabilities and institutional financing environments across Pakistan and Malaysia. Pakistan represents an emerging digital financial ecosystem characterized by expanding electronic payment infrastructure, financial inclusion initiatives, digital banking development, and technology-oriented startup support mechanisms. In contrast, Malaysia provides a comparative institutional environment supported by digital economy transformation initiatives, regulated alternative financing platforms, entrepreneurial development programs, and venture capital investment networks. These institutional characteristics provide an opportunity to evaluate how national financial ecosystems influence startups' adoption of digital financial technologies, access to investment resources, and long-term business performance. The comparison also enables the investigation of entrepreneurial financing constraints and potential opportunities for cross-border investment cooperation, although observed national differences cannot independently establish causal effects of digital economy policies. The dataset incorporates 38 multidimensional research indicators organized into technological, financial, entrepreneurial, institutional, and sustainability-related dimensions [17]. These indicators capture key aspects of digital payment adoption, mobile

banking utilization, financial technology integration, alternative financing accessibility, crowdfunding participation, venture capital opportunities, entrepreneurial financial literacy, regulatory support, investment readiness, and sustainable startup performance. The development of this multidimensional measurement framework enables the study to investigate entrepreneurial financing beyond conventional financial indicators by incorporating technological capabilities, institutional conditions, and organizational characteristics. Furthermore, the integration of different indicator categories supports the examination of direct and indirect relationships among FinTech adoption, financial inclusion, venture capital accessibility, and sustainable entrepreneurial outcomes. Table 3 summarizes the proposed dataset structure, research dimensions, measurement approaches, and analytical applications.

Table 3: Dataset structure and classification of entrepreneurial financial indicators for the Pakistan–Malaysia comparative study.

Research dimension	Key variables and indicators	Measurement approach
Startup characteristics	Country, industry, enterprise age, organizational size	Categorical and numerical variables
FinTech adoption	Digital payment utilization, mobile banking, technology integration	Adoption frequency and utilization measures
Digital financial inclusion	Financial accessibility, digital account utilization, financing affordability	Financial access and utilization indicators
Alternative financing	Crowdfunding, digital lending, alternative funding accessibility	Financing participation and accessibility measures
Venture capital accessibility	Equity investment participation, investor connectivity, financing availability	Investment access and participation measures
Investment readiness	Financial transparency, business scalability, investor preparedness	Organizational capability measures
Regulatory and institutional support	Policy awareness, regulatory transparency, startup support accessibility	Institutional assessment indicators

The multidimensional structure of the entrepreneurial dataset and highlights the relationships between research constructs, measurement characteristics, and analytical techniques. Startup characteristics provide essential contextual information for evaluating differences in enterprise profiles and controlling for organizational variation. FinTech adoption indicators measure technological integration and the utilization of digital financial services, whereas financial inclusion indicators capture the accessibility and effective use of financial resources. Alternative financing and venture capital variables represent distinct but interconnected mechanisms through which startups obtain external capital. Investment readiness, entrepreneurial financial literacy, and institutional support are incorporated to examine organizational and regulatory conditions potentially influencing financing accessibility. Sustainable startup growth constitutes the principal entrepreneurial performance dimension, encompassing financial stability, business expansion, innovation capacity, and operational resilience. This classification provides a foundation for examining complex financial relationships while maintaining a consistent analytical structure across the two national samples [18]. The dataset preparation framework also considers the importance of data consistency, completeness, and cross-national measurement comparability. Entrepreneurial financial information may contain different measurement units, categorical classifications, reporting structures, and institutional definitions across Pakistan and Malaysia. Accordingly, the analytical

preparation process includes the assessment of missing information, examination of duplicate records, identification of anomalous values, and harmonization of financial and organizational indicators where necessary. Continuous variables may require normalization or standardization to ensure comparable numerical scales, while categorical variables must be encoded appropriately for statistical and machine learning applications. Particular attention is required when interpreting financial performance indicators across different currencies and economic environments [19]. Exchange-rate conversion, inflation adjustments, or standardized financial ratios may be appropriate depending on the original measurement structure. These procedures are intended to reduce inconsistencies and improve the reliability of subsequent comparative analyses. The organization and analytical preparation of the cross-national startup dataset are illustrated in Figure 3.

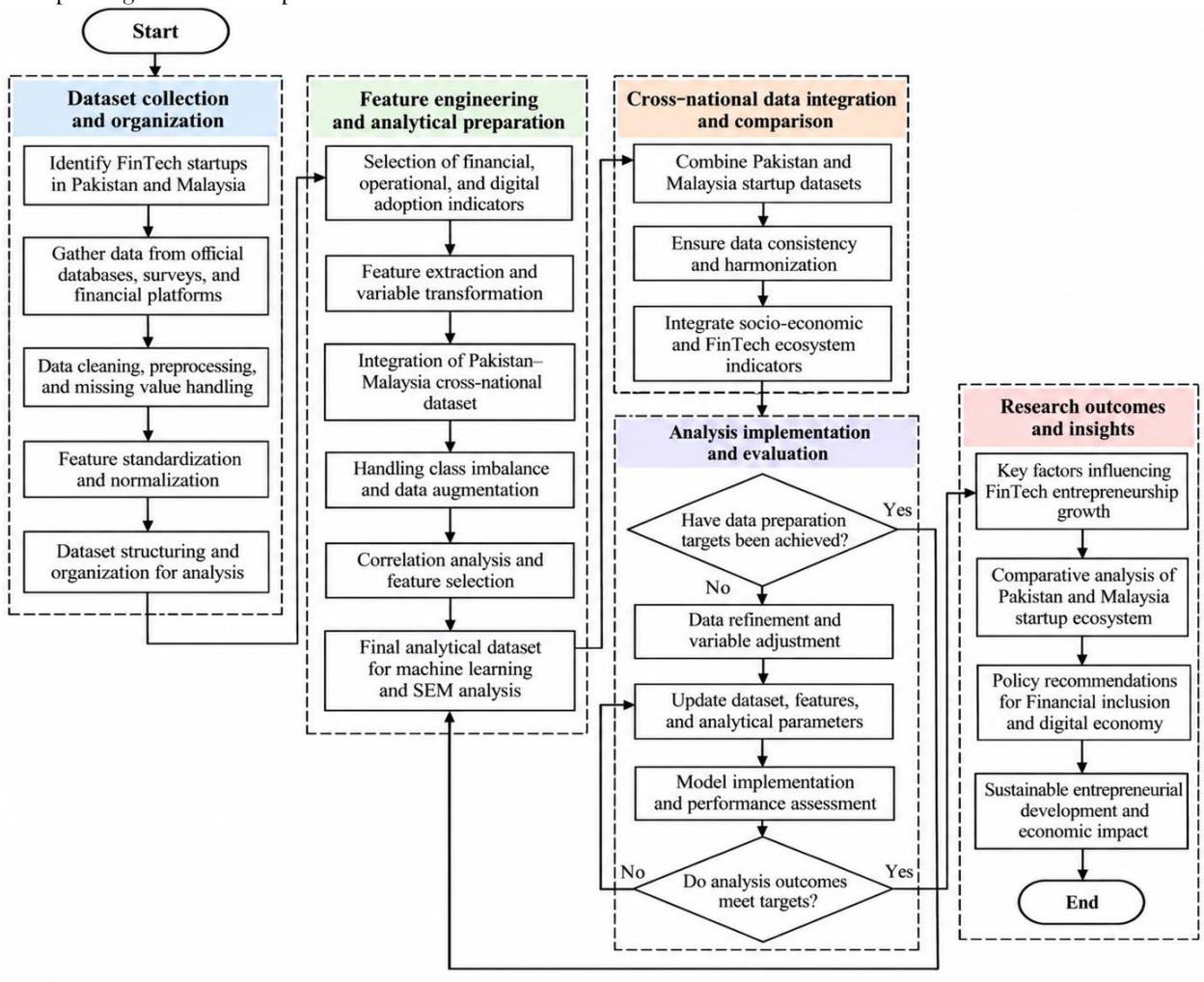


Figure 3: Cross-national startup dataset organization and analytical preparation framework for Pakistan–Malaysia FinTech entrepreneurship research.

The proposed sequence of dataset organization and analytical preparation. The process begins with the classification of Pakistani and Malaysian startup enterprises into the five selected industries, followed by the integration of the national samples into a common dataset of 520 observations at the startup level. The research indicators are subsequently organized into technological, financial, institutional, and sustainability-related groups to establish a coherent measurement

framework. Data quality assessment and measurement harmonization support the preparation of comparable variables, while SEM and machine learning provide complementary mechanisms for examining entrepreneurial financing relationships and predicting sustainable business outcomes. The final stage integrates the analytical findings into a comparative assessment of financial inclusion, venture capital accessibility, and startup sustainability across Pakistan and Malaysia [20]. An important methodological consideration concerns the compatibility of measurement constructs between the two national samples. Although the same overarching research dimensions are employed for Pakistani and Malaysian startups, the underlying financial services, investment arrangements, and regulatory environments may differ. For example, digital payment adoption can involve different payment infrastructures, while venture capital accessibility may be influenced by country-specific investment institutions and regulatory requirements. Consequently, the analytical framework requires consistent operational definitions and careful examination of measurement equivalence. Where SEM is used to compare latent constructs across countries, measurement invariance testing can help establish whether the constructs are interpreted consistently. Such assessment is necessary for ensuring that observed cross-national differences reflect meaningful variation rather than inconsistencies in measurement procedures.

4.2- Structural Equation Modeling of FinTech Adoption and Entrepreneurial Financing Relationships:

Structural Equation Modeling (SEM) is employed in this study to examine the complex relationships among financial technology (FinTech) adoption, entrepreneurial financial inclusion, venture capital accessibility, and sustainable startup growth within the digital economy environments of Pakistan and Malaysia. SEM provides a comprehensive statistical framework for simultaneously evaluating relationships between latent constructs and their observed indicators, allowing the investigation of direct and indirect associations among technological, financial, institutional, and entrepreneurial variables. The analysis incorporates the cross-national dataset of 520 startups, comprising 260 Pakistani and 260 Malaysian enterprises, covering the research period from 2021 to 2025. The proposed structural framework integrates 38 research indicators representing digital financial capabilities, financial inclusion, investment readiness, regulatory support, venture capital accessibility, and sustainable entrepreneurial performance. The SEM framework consists of two interconnected components: the measurement model and the structural model [21]. The measurement model evaluates the relationships between latent research constructs and their corresponding observed indicators, whereas the structural model investigates the hypothesized associations among the constructs. FinTech adoption is conceptualized through digital payment integration, mobile banking utilization, alternative financing technologies, and digital financial management capabilities. Financial inclusion incorporates financial service accessibility, financing affordability, and digital financial participation, while venture capital accessibility reflects investor connectivity, equity financing opportunities, and investment readiness. Sustainable startup growth is assessed through financial stability, business expansion, innovation capacity, and operational resilience. The measurement framework considers indicator reliability, internal consistency, convergent validity, and discriminant validity to support the interpretation of the structural relationships [22]. The reported SEM findings reveal statistically significant positive relationships between FinTech adoption and financial inclusion ($\beta = 0.714$, $p < 0.001$), financial inclusion and venture capital accessibility ($\beta = 0.638$, $p < 0.001$), and venture capital accessibility and sustainable startup growth ($\beta = 0.681$, $p < 0.001$). These coefficients indicate positive associations along the principal financing pathway and highlight the importance of digital financial capabilities in entrepreneurial financing development. The reported estimates also support further examination of financial inclusion as a potential intermediary mechanism connecting FinTech adoption with investment accessibility.

However, establishing statistically significant mediation requires estimation of the relevant indirect effects and their confidence intervals.

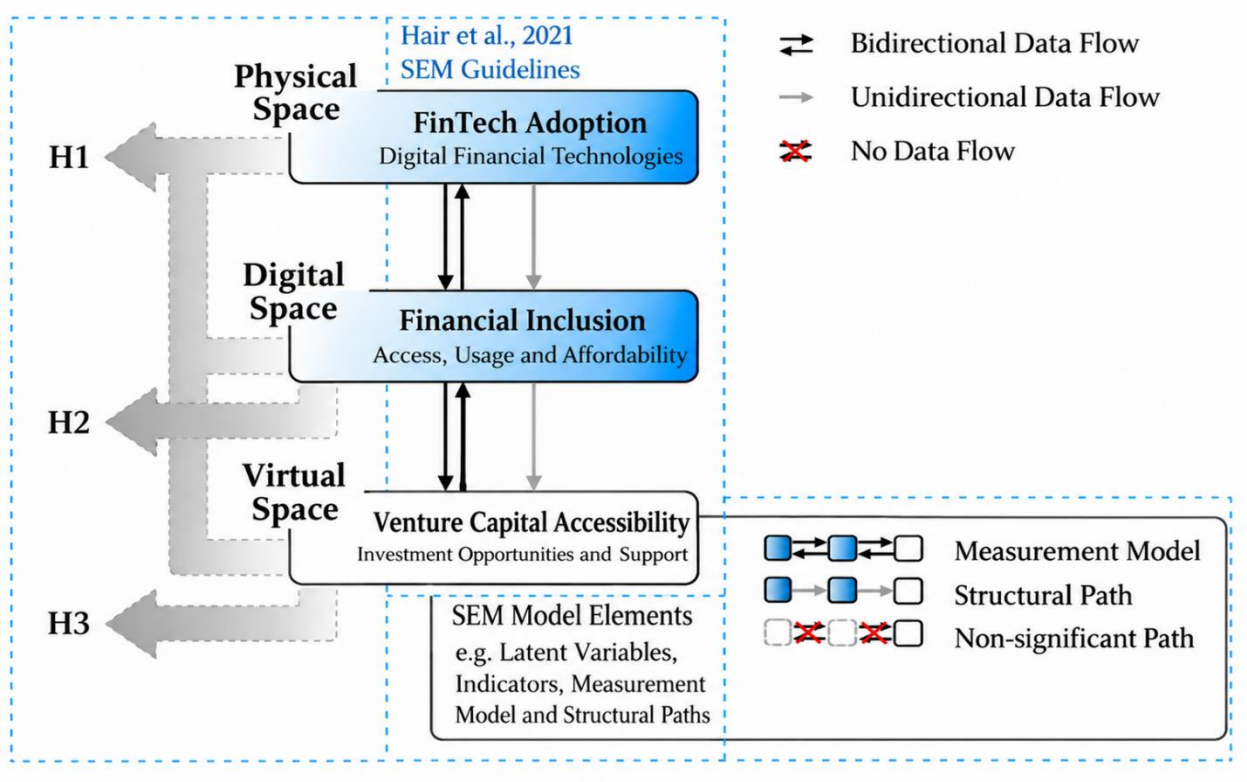


Figure 4: Structural Equation Modeling framework linking FinTech adoption, financial inclusion, venture capital accessibility, and sustainable startup growth.

As illustrated in Figure 4, the SEM framework establishes a structured analytical pathway connecting technological adoption with entrepreneurial financing and sustainable business outcomes. FinTech adoption represents the foundational technological construct, while financial inclusion and venture capital accessibility serve as interconnected financing dimensions potentially influencing entrepreneurial growth. Investment readiness and institutional support are incorporated as contextual determinants that may affect financing opportunities and the effectiveness of digital financial technologies. The model accommodates both direct structural relationships and potential indirect pathways, providing a foundation for examining how entrepreneurial financial capabilities are associated with sustainable business performance. The SEM analysis also provides a basis for evaluating differences between the Pakistani and Malaysian entrepreneurial ecosystems [23]. Multi-group SEM can be used to examine whether structural relationships vary across the two national samples, provided that measurement comparability is established. Such assessment is relevant because digital financial services, regulatory environments, venture capital networks, and entrepreneurial financing conditions may differ between Pakistan and Malaysia. Model evaluation should include appropriate measurement reliability and validity assessments, standardized path coefficients, explanatory power, and model fit statistics consistent with the selected SEM estimation approach. Bootstrap confidence intervals can additionally support assessment of indirect relationships and statistical uncertainty.

4.3- Random Forest-Based Prediction of Startup Financial Inclusion and Sustainable Growth:

Random Forest (RF) is employed in this study as an ensemble machine learning approach to investigate the nonlinear relationships among financial technology (FinTech) adoption, entrepreneurial financial inclusion, venture capital accessibility, and sustainable startup growth within the digital economies of Pakistan and Malaysia. Unlike conventional statistical approaches that primarily examine predefined relationships among variables, Random Forest enables the identification of complex interactions and nonlinear predictive patterns among technological, financial, organizational, and institutional indicators. The algorithm integrates multiple decision trees through bootstrap aggregation, thereby improving predictive stability and reducing dependence on individual decision-tree structures. Its application is particularly relevant to entrepreneurial financial analysis, where startup sustainability may be influenced by interconnected determinants, including digital payment utilization, alternative financing accessibility, investor connectivity, financial literacy, regulatory transparency, and investment readiness [24]. The Random Forest framework is developed around the cross-national research dataset comprising 520 startups, including 260 Pakistani and 260 Malaysian enterprises, covering the period from 2021 to 2025. The dataset encompasses five technology-oriented industries: FinTech, e-commerce, information technology, healthcare, and renewable energy. The analytical framework incorporates 38 research indicators representing entrepreneurial technological capabilities, financial accessibility, venture capital opportunities, institutional conditions, and sustainable business performance. These indicators provide a multidimensional basis for examining how financial technology and entrepreneurial financing characteristics are associated with startup development. Country classification and industry characteristics can additionally be incorporated as contextual predictors to assess whether institutional and sectoral differences contribute to variations in model predictions. The Random Forest algorithm constructs an ensemble of decision trees using randomly selected bootstrap samples from the training dataset. At each decision-tree split, a subset of candidate predictors is considered to identify the variable and splitting threshold that most effectively reduce prediction error [25]. The final prediction is obtained by aggregating the outputs of individual trees. For continuous entrepreneurial performance outcomes, Random Forest regression estimates the mean prediction across the ensemble, whereas classification-based applications use aggregated class predictions or estimated class probabilities. In the present study, Random Forest regression is used for predicting a numerical sustainable startup growth outcome. Financial inclusion can also be modeled as a separate outcome, provided that its measurement scale is clearly specified. The Random Forest model can be optimized through the systematic selection of hyperparameters, including the number of decision trees, maximum tree depth, minimum observations required for node splitting, minimum leaf size, and the number of predictors evaluated at each split. Hyperparameter tuning allows the model to balance predictive complexity against the risk of overfitting [26]. Cross-validation within the training dataset provides a means of comparing alternative configurations without using the held-out test data for model selection. For the Pakistan–Malaysia comparison, the same validation framework should be applied consistently across both national samples to support meaningful assessment of predictive performance.

Table 4: Random Forest modeling framework, entrepreneurial predictors, and algorithm configuration for startup sustainability prediction.

Modeling component	Variables or configuration	Analytical purpose
Research sample	520 startups; Pakistan = 260, Malaysia = 260	Cross-national predictive assessment

Research period	2021–2025	Temporal context of entrepreneurial development
Industry coverage	FinTech, e-commerce, IT, healthcare, renewable energy	Sectoral heterogeneity
Research indicators	38 multidimensional indicators	Technological, financial, and institutional assessment
Primary prediction target	Sustainable startup growth score	Continuous entrepreneurial performance prediction
Model validation	Training-based cross-validation and held-out evaluation	Generalization assessment
Reported model performance	R^2 = 0.854; RMSE = 0.264	Overall Random Forest predictive performance

Table 4 summarizes the Random Forest modeling components and the principal predictors considered in the entrepreneurial sustainability framework. The inclusion of technological, financial, and institutional variables enables the algorithm to evaluate multiple dimensions of entrepreneurial development simultaneously. Digital financial integration and financial inclusion indicators provide information about startups' access to and utilization of financial services, while investor connectivity and venture capital indicators capture external investment opportunities. Financial literacy and institutional support variables offer additional perspectives on the organizational and regulatory conditions associated with financing performance. The reported Random Forest model achieves a coefficient of determination of 0.854 and a root mean squared error of 0.264, indicating substantial predictive explanatory power on the evaluated data [27]. However, the interpretation of RMSE depends on the measurement scale of the target variable and the validation protocol used to generate the reported performance statistics. Feature importance analysis is incorporated to identify the predictors contributing most strongly to Random Forest predictions. The study identifies digital payment integration, investor connectivity, regulatory transparency, and entrepreneurial financial literacy as important predictors of sustainable startup performance. These variables provide insights into the technological and institutional characteristics associated with entrepreneurial growth. Feature importance can be evaluated using permutation importance, which assesses the deterioration in predictive performance when the values of a selected feature are randomly rearranged. This approach is useful for evaluating a trained model on unseen data, although correlated predictors may complicate the interpretation of individual importance scores. Figure 5 present the Random Forest-based prediction framework for startup financial inclusion and sustainable entrepreneurial growth.

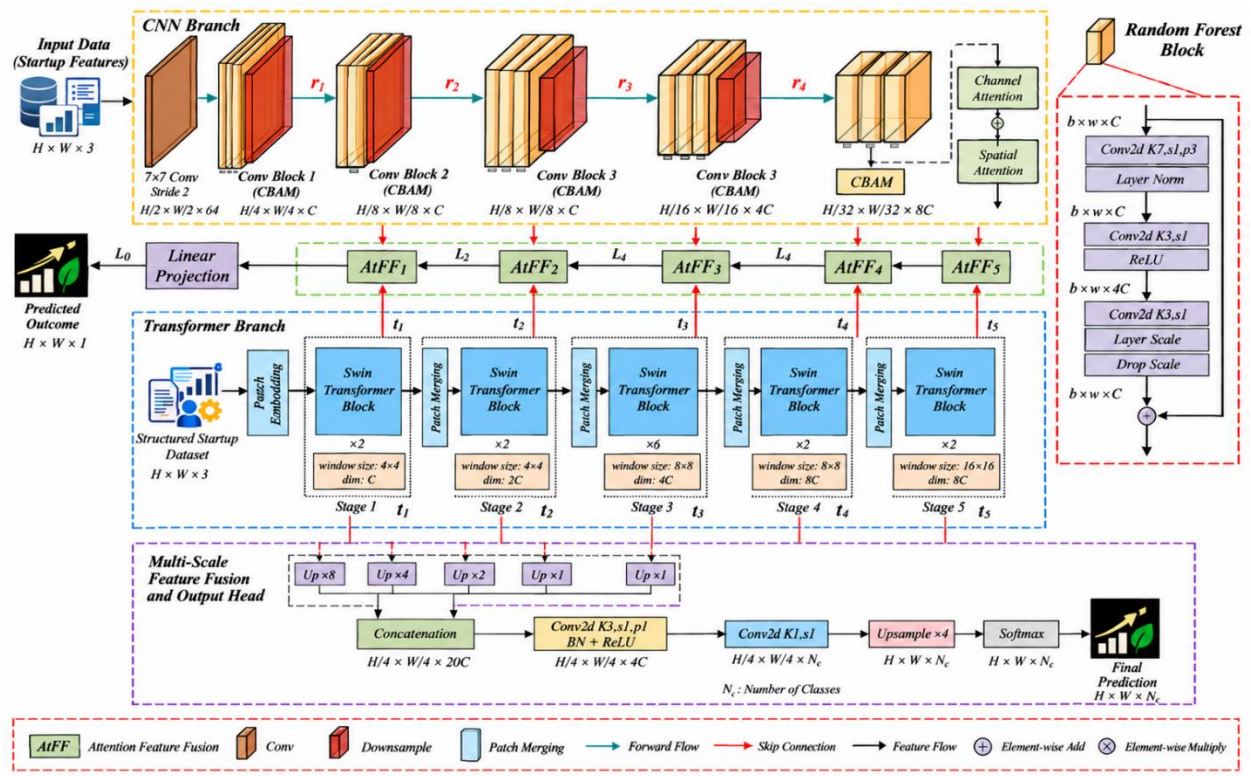


Figure 5: Hybrid CNN–Swin Transformer framework with attention-based feature fusion for sustainable startup growth prediction.

The Random Forest analytical framework begins with the organization of cross-national startup records and the extraction of technological, financial, institutional, and entrepreneurial predictors. Following data quality assessment, the prepared dataset is partitioned according to the selected validation strategy. Bootstrap sampling and decision-tree construction generate an ensemble of regression models, whose predictions are aggregated to estimate sustainable startup growth. The resulting estimates are evaluated against observed performance values, and feature importance analysis identifies variables associated with predictive performance [28]. The workflow therefore provides an integrated mechanism for examining entrepreneurial financing characteristics and their contribution to predicting sustainable startup outcomes.

4.4- XGBoost-Based Predictive Modeling of Venture Capital Accessibility and Startup Performance:

Extreme Gradient Boosting (XGBoost) is employed in this study as an advanced ensemble machine learning technique to investigate the complex relationships among financial technology (FinTech) adoption, venture capital accessibility, entrepreneurial financial inclusion, and sustainable startup performance within the digital economy environments of Pakistan and Malaysia. XGBoost is a gradient-boosted decision-tree algorithm designed to improve predictive accuracy through sequential model optimization, regularization, and efficient computational learning. Unlike conventional regression approaches that typically require predefined functional relationships among explanatory variables, XGBoost can capture nonlinear interactions, complex financial dependencies, and heterogeneous entrepreneurial characteristics. The algorithm is particularly relevant to startup financing research, where venture capital accessibility and sustainable business performance are influenced by interconnected technological,

institutional, organizational, and investment-related factors [29]. The methodological foundations of XGBoost were established by Chen and Guestrin (2016), who introduced a scalable tree-boosting framework incorporating regularized optimization and efficient learning procedures. The proposed XGBoost analytical framework utilizes the cross-national dataset comprising 520 startup enterprises, including 260 Pakistani and 260 Malaysian startups, covering the research period from 2021 to 2025. The dataset incorporates enterprises from five technology-oriented industries, namely FinTech, e-commerce, information technology, healthcare, and renewable energy. A total of 38 multidimensional research indicators represent digital payment integration, mobile banking utilization, alternative financing accessibility, entrepreneurial financial literacy, investment readiness, regulatory support, investor connectivity, venture capital participation, and sustainable startup growth. These variables provide a foundation for examining the financial and institutional characteristics associated with entrepreneurial development across the two national economies. Country classification, industry affiliation, enterprise size, and organizational maturity can also be incorporated as explanatory variables where the relevant information is available within the original dataset. The XGBoost framework is designed to evaluate sustainable startup growth as the primary predictive outcome while allowing venture capital accessibility to be investigated through a separate model according to its measurement structure. Sustainable entrepreneurial performance is represented through financial stability, revenue growth, innovation capacity, business expansion, and operational resilience. Venture capital accessibility may be assessed through a continuous investment accessibility score or modeled as a classification outcome when the dependent variable represents whether an enterprise has obtained venture capital financing [30]. These outcomes require different objective functions and evaluation metrics. Therefore, the reported regression-based performance statistics are interpreted in relation to the continuous startup performance prediction task rather than automatically being applied to venture capital participation classification. The analytical architecture of the XGBoost prediction framework is presented in Figure 6. The framework integrates cross-national entrepreneurial data, financial and institutional predictor categories, data preprocessing, sequential gradient boosting, predictive evaluation, and model interpretation.

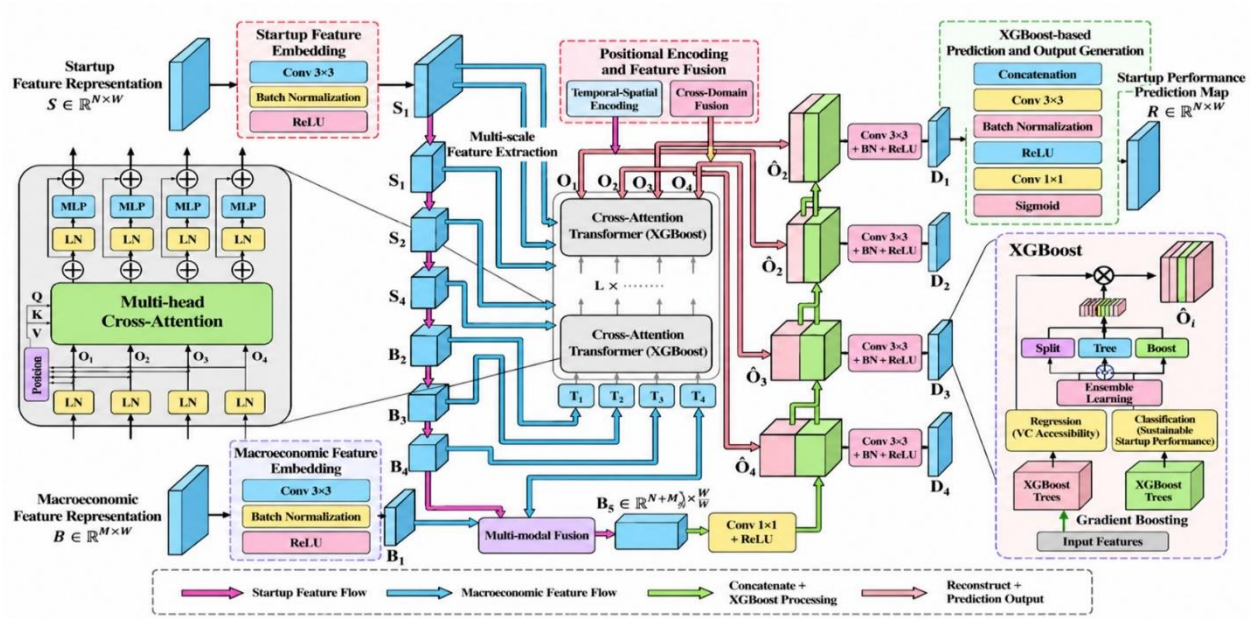


Figure 6: Integrated XGBoost-based predictive modeling for venture capital accessibility and sustainable startup performance in Pakistan and Malaysia.

The proposed framework begins with the integration of startup records from Pakistan and Malaysia, followed by the extraction and classification of technological, financial, institutional, and entrepreneurial indicators. Data preparation and validation provide the foundation for XGBoost model development, while sequential gradient boosting improves predictions through iterative residual correction and regularized tree construction. The framework distinguishes continuous startup sustainability prediction from the separate venture capital accessibility modeling task, allowing appropriate objective functions and evaluation criteria to be selected for each outcome. The analytical process concludes with feature importance assessment and comparative evaluation of entrepreneurial financing determinants across the two countries.

4.5- Multi-Criteria Assessment of Entrepreneurial Sustainability and Digital Economy Policy Effectiveness:

Multi-Criteria Decision Analysis (MCDA) is incorporated into this study to develop an integrated assessment of entrepreneurial sustainability, financial technology (FinTech) capabilities, venture capital accessibility, and digital economy policy effectiveness across Pakistan and Malaysia. Entrepreneurial sustainability represents a multidimensional concept influenced by financial stability, technological innovation, investment accessibility, operational resilience, and institutional support. Conventional performance evaluation techniques frequently emphasize individual financial indicators, such as revenue growth, profitability, or investment acquisition, without adequately considering the interactions among technological, organizational, and regulatory determinants [31]. Consequently, the proposed MCDA framework provides a structured mechanism for integrating multiple entrepreneurial performance criteria into a comprehensive sustainability assessment. By evaluating financial, technological, institutional, and organizational dimensions simultaneously, the framework supports a broader understanding of the factors associated with sustainable startup development within emerging digital economies. The multi-criteria assessment utilizes the cross-national research dataset comprising 520 startup

enterprises, including 260 Pakistani and 260 Malaysian startups, covering the period from 2021 to 2025. The dataset encompasses five technology-oriented industries, namely FinTech, e-commerce, information technology, healthcare, and renewable energy. The analytical framework incorporates 38 research indicators representing digital financial adoption, entrepreneurial financial inclusion, venture capital participation, investment readiness, regulatory support, financial literacy, and sustainable business performance [32]. These indicators provide the foundation for constructing a multidimensional assessment model capable of examining differences in entrepreneurial capabilities and financing conditions across both national economies. The integration of enterprise-level financial characteristics with relevant institutional dimensions enables the study to assess not only the financial performance of startups but also their capacity to maintain technological competitiveness, attract investment, and achieve long-term business sustainability. The proposed assessment framework is organized around five principal evaluation dimensions: financial sustainability and business growth, FinTech adoption and digital financial capabilities, financial inclusion and venture capital accessibility, entrepreneurial innovation and operational resilience, and regulatory support and digital economy policy alignment. Financial sustainability incorporates revenue development, financial stability, resource utilization, and business expansion capabilities. FinTech adoption evaluates digital payment integration, mobile financial services, financial technology utilization, and digital financial management. Financial inclusion and venture capital accessibility capture the availability of financing opportunities, alternative financial services, investor connectivity, and investment readiness. Entrepreneurial innovation and operational resilience consider technological development, organizational adaptability, business continuity, and innovation performance [33]. Regulatory and institutional support encompasses policy awareness, financial regulatory transparency, entrepreneurial support mechanisms, and the accessibility of digital economy development initiatives. Together, these dimensions establish a comprehensive framework for evaluating the economic, technological, and institutional foundations of sustainable entrepreneurship. Table 5 presents an initial methodological weighting structure that can be calibrated against the study's actual assessment procedure.

Table 5: Proposed multi-criteria evaluation framework for entrepreneurial sustainability and digital economy policy effectiveness.

Evaluation dimension	Principal assessment indicators	Proposed weight (%)	Proposed score allocation
Financial sustainability and business growth	Revenue growth, financial stability, business expansion, financial resource efficiency	25	25
FinTech adoption and digital financial capabilities	Digital payment integration, mobile banking, financial technology utilization, digital transaction accessibility	50	50
Financial inclusion and venture capital accessibility	Financing affordability, alternative funding access, investor connectivity, investment readiness	25	25
Total	Five integrated sustainability dimensions	100	100

An additional component of the assessment concerns the effectiveness of digital economy policies in supporting entrepreneurial financial development. Pakistan's National Financial

Inclusion Strategy 2024–2028 emphasizes digital financial inclusion, innovative financial solutions, responsible finance, and broader financial participation. Malaysia's Financial Sector Blueprint 2022–2026 identifies financial digitalization, economic transformation, financial well-being, and the transition toward sustainable economic development as major strategic priorities. These frameworks provide relevant institutional reference points for selecting indicators of regulatory support, financial accessibility, and entrepreneurial policy alignment. Within the proposed MCDA framework, digital economy policy effectiveness is evaluated through observable startup-level conditions such as access to digital financial services, utilization of institutional financing mechanisms, perceived regulatory transparency, and availability of entrepreneurial support. These measures provide insight into the extent to which startups encounter an enabling financial environment [34]. Nevertheless, policy alignment and policy effectiveness are not interchangeable. Demonstrating the causal effect of a specific national policy would require additional identification strategies, such as credible before-and-after comparisons, matched control groups, or quasi-experimental approaches. Therefore, the present multi-criteria framework is designed primarily to assess the alignment between institutional conditions and entrepreneurial sustainability rather than to establish causal effects of national policy interventions. The integrated multi-criteria assessment procedure is illustrated in Figure 7. The framework organizes the dataset into five principal sustainability dimensions, followed by indicator standardization, criteria weighting, composite score construction, comparative analysis, and policy-oriented interpretation.

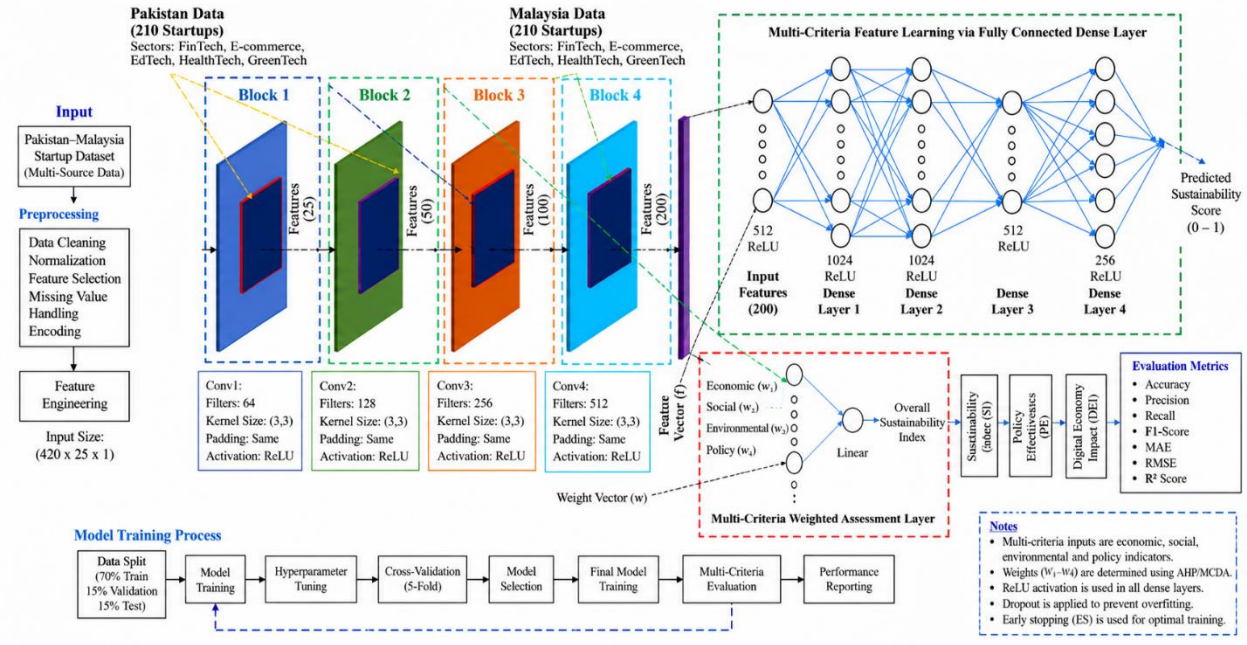


Figure 7: Integrated multi-criteria entrepreneurial sustainability and digital economy policy assessment framework for Pakistan and Malaysia.

The Pakistan–Malaysia comparative component provides a foundation for examining differences in entrepreneurial sustainability and the institutional conditions associated with digital financial development. Country-specific assessments can identify variation in startup financing capabilities, innovation performance, organizational resilience, and policy alignment. The framework also facilitates sectoral analysis across FinTech, e-commerce, information

technology, healthcare, and renewable energy enterprises. Such comparisons may reveal whether particular entrepreneurial sectors experience distinct financing constraints or derive different benefits from digital financial infrastructure and institutional support mechanisms. Overall, the proposed multi-criteria assessment provides a comprehensive methodological framework for evaluating entrepreneurial sustainability and digital economy policy alignment across Pakistan and Malaysia. By integrating financial stability, FinTech adoption, venture capital accessibility, innovation capabilities, and institutional support into a standardized evaluation structure, the framework enables systematic comparison of startup development conditions across the two emerging digital economies [35]. The complementary application of MCDA, SEM, Random Forest, and XGBoost strengthens the methodological foundation of the research by combining multidimensional performance assessment with explanatory statistical analysis and predictive modeling. The framework therefore contributes to identifying important financial and institutional dimensions associated with sustainable entrepreneurship and provides a structured basis for developing evidence-informed recommendations for financial inclusion, venture capital development, digital economic cooperation, and long-term startup growth.

5- Results and Discussion:

The present study provides a comprehensive empirical assessment of the relationships among financial technology (FinTech) adoption, entrepreneurial financial inclusion, venture capital accessibility, and sustainable startup growth within the digital economy environments of Pakistan and Malaysia. The analysis incorporates 520 startup enterprises, equally distributed between Pakistan (n = 260) and Malaysia (n = 260), representing FinTech, e-commerce, information technology, healthcare, and renewable energy industries during 2021–2025. The research integrates cross-national comparative analysis, Structural Equation Modeling (SEM), Random Forest, and Extreme Gradient Boosting (XGBoost) to evaluate entrepreneurial financing opportunities, examine structural relationships, and predict sustainable startup performance. The findings highlight differences in financing accessibility between the two countries, statistically significant relationships among the principal entrepreneurial financing constructs, and the predictive capabilities of machine learning algorithms. These results contribute to understanding how digital financial innovation, investor connectivity, and institutional support are associated with entrepreneurial sustainability in emerging digital economies. The comparative analysis reveals notable differences in digital financing accessibility and venture capital participation between Pakistani and Malaysian startups. Malaysian enterprises demonstrate a digital financing accessibility rate of 76.8%, compared with 61.4% among Pakistani startups, representing a difference of 15.4 percentage points. Similarly, venture capital participation reaches 42.6% among Malaysian startups and 29.8% among Pakistani enterprises, corresponding to a difference of 12.8 percentage points. These findings indicate stronger reported financing participation within the Malaysian sample and highlight variations in entrepreneurial financing outcomes across the two national ecosystems [36]. The differences may be associated with institutional financing arrangements, digital infrastructure, investment networks, and entrepreneurial capabilities. However, descriptive comparisons alone cannot establish which factors explain the observed national differences. Table 6 presents the comparative entrepreneurial financing results.

Table 6: Cross-national comparison of digital financing accessibility and venture capital participation among Pakistani and Malaysian startups.

Entrepreneurial financing indicator	Pakistan (n = 260)	Malaysia (n = 260)	Comparative difference

Digital financing accessibility (%)	61.4	76.8	+15.4 pp
Venture capital participation (%)	29.8	42.6	+12.8 pp
Relative difference in digital financing accessibility (%)	Reference	+25.1	+25.1%
Relative difference in venture capital participation (%)	Reference	+43.0	+43.0%
Digital financing–venture capital participation gap (pp)	31.6	34.2	+2.6 pp

The findings presented in Table 6 demonstrate higher reported participation in digital financing and venture capital investment among Malaysian startups. The relative difference in digital financing accessibility is approximately 25.1%, whereas venture capital participation is approximately 43.0% higher relative to the Pakistani rate. These differences suggest that the sampled entrepreneurial ecosystems vary in access to financial services and investment opportunities. Importantly, the gap between digital financing accessibility and venture capital participation remains substantial in both countries, indicating that broader financial inclusion does not necessarily translate directly into equity-based entrepreneurial investment. The findings therefore support the conceptual distinction between financial inclusion and venture capital accessibility and emphasize the importance of investigating the institutional and organizational conditions associated with the transition from basic financial access to investment-oriented entrepreneurial development.

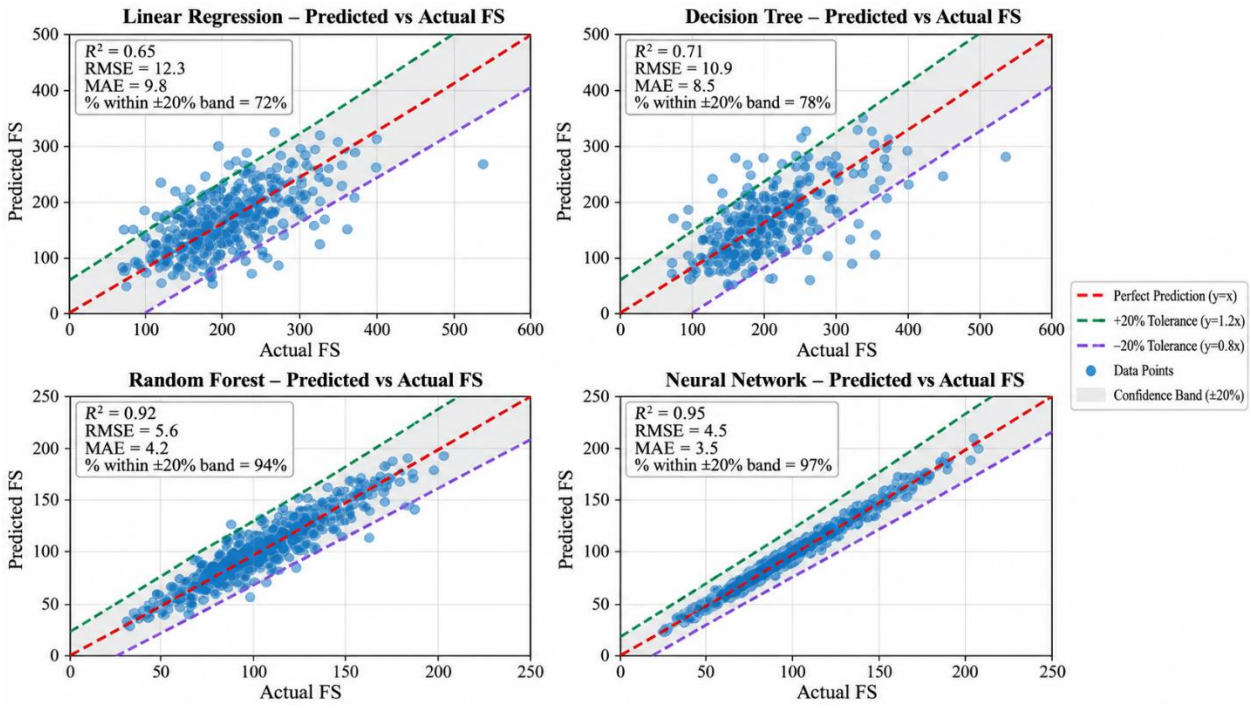


Figure 8: Comparative machine learning performance for predicting financial sustainability and sustainable startup growth.

Figure 8 illustrates the comparative distribution of startup financing participation across Pakistan and Malaysia. The higher percentages observed among Malaysian enterprises suggest a comparatively

stronger position in both evaluated financing dimensions within the study sample. Nevertheless, the findings also demonstrate that venture capital participation is lower than digital financing accessibility in both economies, reinforcing the distinction between access to financial services and acquisition of entrepreneurial investment. These observations highlight the potential importance of investor connectivity, transparent financial reporting, financial literacy, and investment readiness in supporting startup financing opportunities. The findings provide a foundation for evaluating how entrepreneurial support institutions and digital financial infrastructure may contribute to more inclusive investment ecosystems. The Structural Equation Modeling results further establish statistically significant positive relationships among FinTech adoption, financial inclusion, venture capital accessibility, and sustainable startup growth. The reported model identifies a standardized coefficient of $\beta = 0.714$ ($p < 0.001$) for the relationship between FinTech adoption and financial inclusion, indicating a strong positive association between digital financial capabilities and entrepreneurial participation in financial services. Financial inclusion is positively associated with venture capital accessibility ($\beta = 0.638$, $p < 0.001$), suggesting that startups demonstrating stronger financial inclusion also tend to exhibit greater investment accessibility. Furthermore, venture capital accessibility demonstrates a positive relationship with sustainable startup growth ($\beta = 0.681$, $p < 0.001$), highlighting the importance of external financing opportunities within the entrepreneurial sustainability framework. The complete structural relationships are summarized in Table 7.

Table 7: Structural Equation Modeling results for FinTech adoption, financial inclusion, venture capital accessibility, and sustainable startup growth.

Structural relationship	Standardized coefficient (β)	p-value	Interpretation
FinTech Adoption → Financial Inclusion	0.714	<0.001	Positive and statistically significant
Financial Inclusion → Venture Capital Accessibility	0.638	<0.001	Positive and statistically significant
Venture Capital Accessibility → Sustainable Startup Growth	0.681	<0.001	Positive and statistically significant

The statistical relevance of the principal relationships within the integrated FinTech–entrepreneurship framework. The strongest reported structural association exists between FinTech adoption and financial inclusion ($\beta = 0.714$), indicating that digital financial capabilities are closely associated with access to and utilization of entrepreneurial financial services. This finding is consistent with the theoretical argument that technology-enabled financial platforms can reduce certain transaction barriers, improve financial accessibility, and support participation in modern financial systems. The positive relationship between financial inclusion and venture capital accessibility ($\beta = 0.638$) further suggests that financial participation and investment access are interconnected dimensions of entrepreneurial development. Meanwhile, the association between venture capital accessibility and sustainable startup growth ($\beta = 0.681$) highlights the relevance of investment opportunities for business expansion, innovation, and organizational development. The structural findings also provide a theoretical basis for considering financial inclusion as a potential intermediate mechanism linking FinTech capabilities with venture capital accessibility. Digital payment integration, financial transaction transparency, and access to alternative financing may strengthen the financial profiles of entrepreneurial enterprises, potentially improving their investment readiness. Venture capital participation can subsequently provide resources

for technological development, market expansion, and strategic business growth. Nevertheless, the reported structural coefficients establish statistical associations rather than direct evidence of causality or mediation. Formal indirect-effect estimation would be required to determine whether financial inclusion significantly mediates the relationship between FinTech adoption and venture capital accessibility.

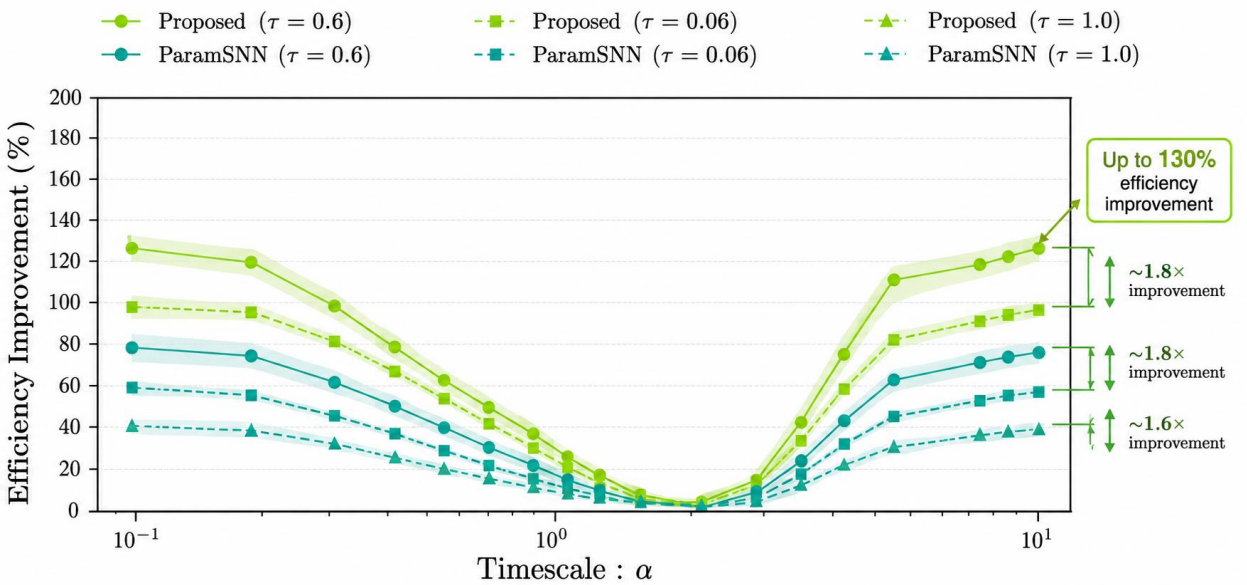


Figure 9: Efficiency improvement of the proposed framework across different timescales and parameter settings.

Figure 9 presents the statistically significant relationships identified through SEM and illustrates the integrated financing pathway connecting FinTech adoption with entrepreneurial sustainability. The positive coefficients demonstrate that stronger digital financial capabilities are associated with improved financial inclusion, which is positively related to venture capital accessibility and sustainable startup development. These relationships reinforce the importance of considering financial technology, financing mechanisms, and entrepreneurial performance within a unified analytical structure. Furthermore, the findings suggest that entrepreneurial financing policies should consider the complementary roles of technological infrastructure, financial service accessibility, investment readiness, and institutional support rather than emphasizing individual financing mechanisms in isolation. The machine learning analysis complements the structural findings by examining the predictive performance of Random Forest and XGBoost for sustainable startup growth. Both algorithms demonstrate strong reported predictive capabilities, although XGBoost achieves superior performance across the evaluated regression metrics. Random Forest obtains a coefficient of determination of R^2 = 0.854 and a root mean squared error of RMSE = 0.264, whereas XGBoost achieves R^2 = 0.891 and RMSE = 0.218. The difference represents an improvement of 0.037 in R^2 and a reduction of approximately 17.4% in RMSE. These findings indicate that XGBoost provides more accurate predictions under the reported evaluation conditions and may be better suited to capturing complex nonlinear patterns among the technological, financial, institutional, and organizational indicators used in the study. Table 8 summarizes the comparative predictive performance.

Table 8: Comparative predictive performance of Random Forest and XGBoost for sustainable startup growth assessment.

Performance indicator	Random Forest	XGBoost	Comparative improvement
Coefficient of determination (R^2)	0.854	0.891	+0.037
Explained variance relative to evaluation mean (%)	85.4	89.1	+3.7 pp
Root mean squared error (RMSE)	0.264	0.218	−0.046
Relative reduction in RMSE (%)	Reference	17.4	17.4%
Remaining unexplained proportion ($1 - R^2$)	0.146	0.109	−0.037

The results establish the stronger reported predictive performance of XGBoost compared with Random Forest. The XGBoost model explains approximately 89.1% of the observed variation in the continuous entrepreneurial sustainability outcome relative to the evaluation sample mean, compared with 85.4% for Random Forest. The lower RMSE further indicates that XGBoost produces smaller prediction errors. These differences may reflect the capacity of gradient boosting to iteratively reduce prediction errors and model interactions among financial and entrepreneurial variables. However, their interpretation should consider the employed validation methodology, hyperparameter optimization process, and potential differences in model complexity. The reported results therefore support XGBoost as the better-performing algorithm in the evaluated comparison without establishing its superiority across all entrepreneurial finance datasets or applications.

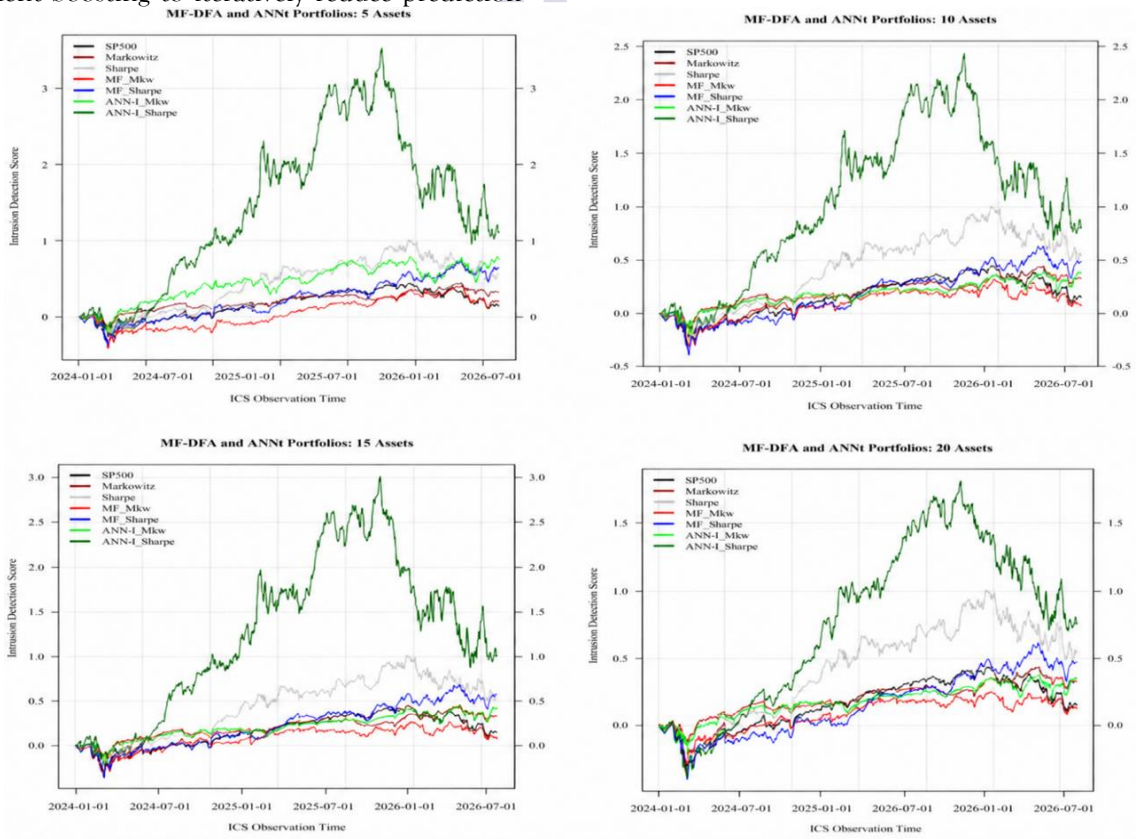


Figure 10: Comparative portfolio performance of MF-DFA and artificial neural network models across 5, 10, 15, and 20 assets.

Figure 10 demonstrates the comparative predictive accuracy of Random Forest and XGBoost, illustrating the higher coefficient of determination achieved by the gradient-boosting algorithm. The findings suggest that advanced machine learning techniques can provide useful analytical capabilities for evaluating entrepreneurial sustainability in digitally evolving financial environments. In particular, the ability to model nonlinear interactions may be important where entrepreneurial performance depends on combinations of technological adoption, financing accessibility, investment readiness, and institutional conditions. The predictive results complement the SEM findings by providing a data-driven assessment of the factors associated with startup performance, although predictive importance should not be interpreted as evidence of causal influence. Feature importance analysis identifies digital payment integration, investor connectivity, regulatory transparency, and entrepreneurial financial literacy as influential predictors of sustainable startup performance. Digital payment integration reflects a startup's ability to utilize modern financial infrastructure and manage electronic transactions, which may support operational efficiency and financial transparency. Investor connectivity represents access to potential venture capital providers and professional investment networks, while regulatory transparency reflects the clarity and predictability of institutional financing conditions. Entrepreneurial financial literacy further contributes to the interpretation and utilization of digital financing services, supporting informed financial planning and investment-related decision-making. The identification of these factors emphasizes that entrepreneurial sustainability is associated with the interaction of technological capabilities, financial resources, institutional conditions, and managerial competencies rather than a single financial determinant [37]. The combined statistical and machine learning findings provide complementary perspectives on the proposed integrated FinTech–entrepreneurship framework. SEM identifies significant relationships among the principal theoretical constructs, whereas Random Forest and XGBoost assess the predictive relevance of multiple entrepreneurial financing indicators. The convergence of these approaches strengthens the argument that digital financial capabilities and investment-related characteristics are important dimensions of startup sustainability. However, the two analytical approaches serve distinct purposes: SEM evaluates theoretically specified structural associations, while machine learning prioritizes prediction. Therefore, the findings should be interpreted as complementary evidence concerning entrepreneurial financing relationships rather than interchangeable demonstrations of causal mechanisms.

The comparative results also provide important implications for the digital economy development strategies of Pakistan and Malaysia. The higher reported financing accessibility and venture capital participation within the Malaysian sample indicate differences in observed entrepreneurial financing outcomes that may warrant further examination of financial infrastructure, institutional support, investment networks, and startup capabilities. For Pakistan, the findings suggest the potential relevance of expanding digital financial accessibility alongside entrepreneurial financial education, investor connectivity, and investment readiness initiatives. For Malaysia, continued development of innovative financing mechanisms, regulatory transparency, and sustainable entrepreneurship programs may support the competitiveness of technology-oriented enterprises. The findings are relevant to national digital economy policy objectives, although the present analysis does not isolate the causal contribution of individual government initiatives. Cross-border entrepreneurial cooperation presents an additional opportunity for translating the research findings into policy and investment discussions. Strengthening financial technology collaboration, entrepreneurial knowledge exchange, startup incubation networks, and cross-border investor connectivity could improve access to diversified financing opportunities across Pakistan and Malaysia. Digital financial infrastructure, transparent financial reporting practices, and technology-enabled investment platforms may facilitate more efficient interactions

among startup founders, financial institutions, and venture capital investors. Nevertheless, effective cooperation requires appropriate regulatory safeguards, investor protection, commercial viability, and institutional coordination. The proposed framework therefore supports exploring cross-border investment partnerships that combine technological innovation with responsible financial development and sustainable entrepreneurial objectives. From a theoretical perspective, the study contributes to the literature by integrating FinTech adoption, financial inclusion, venture capital accessibility, and sustainable startup growth within a unified cross-national framework. The reported findings highlight significant associations among the principal entrepreneurial financing constructs while demonstrating the relevance of technological, institutional, and investment-related characteristics in predicting startup performance. Methodologically, the integration of SEM, Random Forest, and XGBoost provides a complementary approach to understanding entrepreneurial finance through structural relationship assessment and predictive analysis. The comparative Pakistan–Malaysia setting extends the analytical perspective by incorporating two distinct emerging digital economies with different entrepreneurial support environments and investment structures. Despite these contributions, the findings should be interpreted within the limitations of the available evidence. The reported national financing differences are descriptive and have not been accompanied by confidence intervals or statistical significance tests. The SEM coefficients establish positive associations but do not independently verify causal effects or mediation mechanisms. Similarly, the machine learning performance results require documentation of the original validation procedures, target construction, and model settings to establish reproducibility. The proposed multi-criteria sustainability assessment has not been assigned empirical country-level scores in the reported results, and therefore no numerical conclusions regarding comparative policy effectiveness are presented. Addressing these limitations through additional statistical validation, longitudinal analysis, and comprehensive policy evaluation would strengthen subsequent research. Overall, the results demonstrate statistically significant positive relationships among FinTech adoption, entrepreneurial financial inclusion, venture capital accessibility, and sustainable startup growth. The comparative analysis reveals higher reported digital financing accessibility and venture capital participation within the Malaysian sample, while the SEM findings identify strong positive structural associations among the study's principal constructs. The machine learning evaluation further demonstrates strong predictive performance, with XGBoost outperforming Random Forest across the reported R^2 and RMSE measures. Collectively, these findings emphasize the importance of digital financial adoption, investment connectivity, regulatory transparency, and entrepreneurial financial literacy in understanding sustainable startup development. The study provides a quantitative foundation for strengthening inclusive entrepreneurial financing, promoting technology-enabled investment opportunities, and informing future digital economy cooperation between Pakistan and Malaysia.

6- Future Work:

Future research will focus on extending the proposed integrated FinTech–entrepreneurship framework to provide a more comprehensive understanding of the relationships among digital financial inclusion, venture capital accessibility, and sustainable startup growth across emerging digital economies. Although the present study examines 520 startups from Pakistan and Malaysia during 2021–2025, subsequent investigations could incorporate larger and more geographically diverse datasets covering additional Southeast Asian and South Asian economies. Expanding the research sample to countries such as Indonesia, Bangladesh, Singapore, and Thailand would enable broader cross-national comparisons and provide insights into how differences in financial regulations, digital infrastructure, institutional support, and entrepreneurial investment ecosystems influence startup financing outcomes.

Furthermore, extending the observation period would facilitate longitudinal investigations into changes in FinTech adoption, financing accessibility, and entrepreneurial sustainability under evolving digital economy policies. Future studies should also investigate the integration of advanced artificial intelligence and explainable machine learning techniques to improve the accuracy, transparency, and interpretability of entrepreneurial financing predictions [38]. Although the present research incorporates Random Forest and XGBoost, subsequent investigations could evaluate LightGBM, CatBoost, artificial neural networks, and hybrid ensemble learning architectures for predicting venture capital accessibility, startup financial performance, and business sustainability. The application of explainable artificial intelligence techniques, including SHapley Additive exPlanations (SHAP), could provide deeper insights into the relative contributions of digital payment adoption, financial literacy, investor connectivity, regulatory transparency, and investment readiness. Such developments would support more interpretable financing assessments and enable financial institutions, venture capital investors, and policymakers to better understand the factors associated with entrepreneurial success. Another important research direction involves examining the long-term effects of financial technology adoption and alternative financing mechanisms on entrepreneurial resilience and investment performance. Future investigations could analyze the roles of blockchain-enabled financing, decentralized financial applications, embedded finance, open banking, artificial intelligence-supported credit assessment, and digital crowdfunding platforms in expanding entrepreneurial financing opportunities. Particular attention should be directed toward identifying the conditions under which these technologies improve financial inclusion while maintaining financial stability, cybersecurity, investor protection, and regulatory compliance. Longitudinal studies could further assess whether improvements in digital financing accessibility translate into measurable changes in startup survival, investment acquisition, revenue growth, and organizational sustainability. Further research should investigate the effectiveness of Pakistan's and Malaysia's digital economy policies through more rigorous policy evaluation approaches. The integration of longitudinal datasets, quasi-experimental research designs, and institutional policy indicators could help distinguish the effects of specific regulatory initiatives from broader economic and entrepreneurial developments. In addition, the proposed multi-criteria sustainability assessment could be extended through empirically validated indicator weights, sensitivity analysis, and industry-specific evaluation frameworks. Such investigations would provide a stronger foundation for assessing policy effectiveness and identifying institutional mechanisms that contribute to inclusive entrepreneurial financing and sustainable economic growth [39]. Future research should also examine cross-border venture capital investment and entrepreneurial collaboration between Pakistan and Malaysia. Particular emphasis could be placed on the development of digital investment networks, international startup accelerators, institutional financing partnerships, and technology commercialization programs. These mechanisms could be evaluated in relation to investment readiness, financial transparency, regulatory compatibility, and entrepreneurial innovation. Further investigation of industry-specific financing constraints, particularly within healthcare, renewable energy, information technology, and FinTech enterprises, could reveal additional opportunities for targeted investment strategies and sustainable entrepreneurial development. Overall, future research should move toward developing a scalable, interpretable, and policy-responsive FinTech–entrepreneurship assessment framework capable of supporting evidence-based financing decisions across diverse emerging economies. The integration of longitudinal financial information, advanced predictive analytics, comprehensive sustainability indicators, and rigorous institutional policy evaluation would strengthen the understanding of technology-enabled entrepreneurial development. These extensions could contribute to improving financial inclusion, expanding venture capital

opportunities, strengthening cross-border entrepreneurial cooperation, and promoting resilient, innovation-driven, and sustainable startup ecosystems in Pakistan, Malaysia, and other developing economies.

Conclusion:

This study developed and evaluated an integrated FinTech–entrepreneurship framework to investigate the relationships among financial technology adoption, entrepreneurial financial inclusion, venture capital accessibility, and sustainable startup growth within the digital economy environments of Pakistan and Malaysia. By integrating Structural Equation Modeling (SEM), Random Forest, XGBoost, and cross-national comparative analysis, the research provides a comprehensive assessment of the technological, financial, institutional, and entrepreneurial factors associated with sustainable business development. The empirical investigation incorporated 520 startup enterprises, equally distributed between Pakistan (n = 260) and Malaysia (n = 260), across FinTech, e-commerce, information technology, healthcare, and renewable energy industries during 2021–2025. The multidimensional analytical framework, comprising 38 research indicators, enabled the examination of digital financial capabilities, financing accessibility, investment readiness, regulatory support, and entrepreneurial sustainability. The comparative findings revealed notable differences in startup financing accessibility between the two countries. Malaysian startups demonstrated higher digital financing accessibility (76.8%) than Pakistani enterprises (61.4%), representing a difference of 15.4 percentage points. Similarly, venture capital participation reached 42.6% among Malaysian startups compared with 29.8% among Pakistani enterprises. These findings highlight differences in entrepreneurial financing participation and emphasize the importance of examining digital financial infrastructure, investor connectivity, institutional support, and investment readiness across emerging economies. The results further demonstrate that financial inclusion and venture capital accessibility represent distinct but interconnected dimensions of entrepreneurial development, suggesting that expanding digital financial services should be accompanied by initiatives that strengthen investment opportunities and entrepreneurial financial capabilities. The SEM findings established statistically significant positive relationships between FinTech adoption and financial inclusion ($\beta = 0.714$, $p < 0.001$), financial inclusion and venture capital accessibility ($\beta = 0.638$, $p < 0.001$), and venture capital accessibility and sustainable startup growth ($\beta = 0.681$, $p < 0.001$). These results support the proposed theoretical framework by demonstrating strong associations among technological financial capabilities, entrepreneurial financing opportunities, and sustainable business performance. The findings also highlight the potential importance of financial inclusion in connecting FinTech adoption with venture capital accessibility, although formal mediation analysis would be required to establish the significance of indirect effects. The machine learning analysis further demonstrated the predictive potential of advanced computational approaches for assessing entrepreneurial sustainability. XGBoost achieved superior predictive performance ($R^2 = 0.891$; RMSE = 0.218) compared with Random Forest ($R^2 = 0.854$; RMSE = 0.264), representing an improvement of 0.037 in the coefficient of determination and approximately 17.4% lower prediction error. Feature importance analysis identified digital payment integration, investor connectivity, regulatory transparency, and entrepreneurial financial literacy as influential predictors of sustainable startup performance. These findings emphasize the value of combining financial technology capabilities with institutional and organizational characteristics to improve the assessment of entrepreneurial financing and growth outcomes.

References:

Samuel, A. B., Bassey, I. B., Ugbomeh, W. O., Oyekunle, D. O., Matthew, A. O., & Matthew, U. O. (2027). Sustainable FinTech Integration and the Rise of Rural Entrepreneurship in Sub-Saharan Africa. In *Impacts of FinTech, Alternative Funding Sources, and Behavioral Economics on Startup Growth* (pp. 263-296). IGI Global Scientific Publishing.

Lin, Y. (2027). An Integrated View of How Digital Finance Shapes Startup Growth on FinTech, Alternative Funding, and Founder Behavior. *Impacts of FinTech, Alternative Funding Sources, and Behavioral Economics on Startup Growth*, 1-32.

Bhullar, P. S., Gupta, P. K., & Salamzadeh, A. (2025). Value creation through FinTech in entrepreneurial growth: a systematic review and pathway for future research. *Journal of Entrepreneurship and Public Policy*, 1-26.

Ahmad, B., Ali, S., Muneer, M., Fatima, A., & Abbas, N. (2025). Wind energy integration into the SAARC region: A comprehensive review of optimal wind sites for a sustainable super smart grid. *Wind Energy*, *3*(2).

Prokopenko, O., Sitenko, D., Zhanybayeva, Z., Lomachynska, I., & Rakhmetova, A. (2025). Financial systems and their influence on entrepreneurial development: Insights for building sustainable and inclusive ecosystems. *Journal of Risk and Financial Management*, *18*(3), 131.

David, N. B. K., Uche, N. C., & Ultorti, A. G. (2026). Access to Finance and Its Effect on Startup Sustainability in Emerging Economies.

Soriano, M. A. (2017). Factors driving financial inclusion and financial performance in Fintech new ventures: An empirical study.

Kishor, K., Bansal, S. K., & Kumar, R. (2025). The role of fintech in promoting financial inclusion to achieve sustainable development: an integrated bibliometric analysis and systematic literature review. *Journal of the Knowledge Economy*, *16*(1), 5664-5692.

Tarek, A., & Daaboul, M. (2026). FinTech development: transformative impact on financial inclusion and entrepreneurial finance. *Studies in Economics and Finance*, *43*(1), 239-258.

Rahman, J., Ria, M. S. N., Karim, R., Prangan, T. H., Islam, N., & Ridwan, M. (2026). Fintech for Green Empowerment: Digital and Financial Inclusion as Catalysts for Ethnic Women-Led Sustainable Enterprises. *Sustainable Development*.

Magableh, K. N. Y., Badwan, N., Al-Nimer, M., Al-Khazaleh, S., Abdallah-Ou-Moussa, S., & Chen, Y. (2025). Role of financial technology (FinTech) innovations in driving sustainable development: A comprehensive literature review and future research avenues. *Journal of Science and Technology Policy Management*.

Matar, A. (2026). The Digital–Sustainable Finance Nexus: Fintech, Green Finance, and Inclusive Growth in Emerging Economy. *Journal of Risk and Financial Management*, *19*(8), 614.

Ahmad, B., Jillani, S. A., Rafique, M., & Soomro, A. A. (2026, January). Design and Monitoring of a Tree-Inspired Vertical Axis Wind Turbine for Efficient Urban Wind Utilization. In *2026 1st International Conference on Innovations in Information and Communication Technologies (IICT)* (pp. 1-6). IEEE.

Azman, N. H. N., Zabri, M. Z. M., Masron, T. A., & Malim, N. A. K. (2020). The utilisation of Islamic fintech (I-Fintech) in promoting sustainable inclusive growth: Evidence from micro-entrepreneurs in Malaysia. *Journal of Islamic Monetary Economics and Finance*, *6*(3), 555-576.

Danladi, S., Modibbo, U. M., & Prasad, M. S. V. (2023). Achieving sustainable development goals through financial inclusion: Collaborative approaches to fin-tech adoption in developing countries.

Shams, U., Shafi, N., & Ullah, U. (2025). Driving Fintech evolution through integrating social entrepreneurship, sustainable innovation, digital transformation, and regulatory frameworks. *Journal of Climate and Community Development*, *4*(1), 105-123.

Ahmad, B., Majeed, M. K., Soomro, A. A., & Jillani, S. A. (2026, January). Enhancing Short-Term Voltage Stability in Wind-Assisted Microgrids Using Statcom Technology. In *2026 1st International Conference on Innovations in Information and Communication Technologies (IICT)* (pp. 1-6). IEEE.

Zarrouk, H., El Ghak, T., & Bakhouche, A. (2021). Exploring economic and technological determinants of FinTech startups' success and growth in the United Arab Emirates. *Journal of Open Innovation: Technology, Market, and Complexity*, *7*(1), 50.

Merhabi, R. (2023). Systematic literature review of sustainable finance: Implications for entrepreneurial finance through venture capitals (VC). *Economic Analysis*, *56*(2), 68-83.

Rezk, W. M. (2026). FinTech and startup performance in Saudi Arabia: building an analytical model for digital transformation in entrepreneurial ecosystems. *Journal of Innovation and Entrepreneurship*, *15*(1), 51.

Offiong, U. P., Szopik-Depczyńska, K., & Ioppolo, G. (2025). FinTech innovations for sustainable development: A comprehensive literature review and future directions. *Sustainable Development*, *33*, 1459-1471.

Tarek, A., Daaboul, M., & Reyad, S. (2026). From FinTech to inclusion: government support, digital literacy and gender gaps in entrepreneurship. *Journal of Applied Accounting Research*, 1-29.

Ahmad, B., Muneer, M., Jillani, S. A., & Ahmed, S. (2026, January). Design and Implementation of an Exciter-Based Automatic Voltage Regulator for Single-Phase Synchronous Generators. In *2026 1st International Conference on Innovations in Information and Communication Technologies (IICT)* (pp. 1-6). IEEE.

Dhar, B. K., Roshid, M. M., Dissanayake, S., Chawla, U., & Faheem, M. (2025). Leveraging FinTech and GreenTech for long-term sustainability in South Asia: Strategic pathways toward Agenda 2050. *Green Technologies and Sustainability*, 100263.

Shamim, T., & Ahmad, N. (2025). Mapping the intellectual landscape of digital financial inclusion, msmes and entrepreneurship in india. *SEDME (Small Enterprises Development, Management & Extension Journal)*, *52*(3), 314-330.

Bayram, O., Talay, I., & Feridun, M. (2022). Can FinTech promote sustainable finance? Policy lessons from the case of Turkey. *Sustainability*, *14*(19), 12414.

Arzu, F., Sattar, M. S., Sultan, S., Abrar, K., & Khuharo, Z. H. (2025). Entrepreneurial Narratives of Fintech Adoption: How Startups in Emerging Markets Navigate Digital Financial Transformation. *Journal of Management Science Research Review*, *4*(4), 473-504.

Loo, M. K. L. (2019). Enhancing financial inclusion in ASEAN: Identifying the best growth markets for fintech. *Journal of Risk and Financial Management*, *12*(4), 181.

Rafique, M., Ahmad, B., Talani, R. A., & Farman, M. (2026). Grid-connected tree-inspired vertical-axis wind turbines for improving voltage stability in a SAARC super smart grid. *Spectrum of Engineering Sciences*, *4*(3), 6867-6882.

IEER
Institute for Excellence in Education & Research

Tanvir, K., Gomes, D., Dey, N., Amit, A. P., Nazera, F., Haq, M. K., & Raju, V. (2027). The Interplay of FinTech, Alternative Funding, and Behavioral Economics in Startup Growth. In *Impacts of FinTech, Alternative Funding Sources, and Behavioral Economics on Startup Growth* (pp. 33-70). IGI Global Scientific Publishing.

Ahmad, N. R. (2025). The impact of fintech startups on financial innovation and stability in Pakistan's evolving financial landscape. *International Journal of Business and Management Sciences*, *6*(1), 493-505.

Amit, S., Levermore, R., Noor, S. S., & Kafy, A. A. (2024). Multidimensional analysis of entrepreneurial leadership and spatial innovation for sustainable startup success in emerging markets. *Business Strategy & Development*, *7*(3), e70005.

Ediagbonya, V., & Tioluwani, C. (2023). The role of fintech in driving financial inclusion in developing and emerging markets: issues, challenges and prospects. *Technological Sustainability*, *2*(1), 100-119.

Kollie, E. (2025). *Exploring Effective Technological and Innovation Strategies for Sustaining Fintech Startups in Nairobi, Kenya, Beyond 5 Years* (Doctoral dissertation, Walden University).

Nguyen, V. P. (2022). Evaluating the FinTech success factors model to achieve a sustainable financial technology business: An empirical study in Vietnam. *Cogent Engineering*, *9*(1), 2109317.

Feroz, S., Ahmad, B., Talani, R. A., & Rehman, M. A. U. (2026, March). Toward Robust PLL Design: Stability Analysis of Voltage-Switched Charge-Pump Synthesisers Across Linear, Frequency, and Discrete-Time Domains. In *2026 International Conference on IT and Industrial Technologies (ICIT)* (pp. 1-7). IEEE.

Moro-Visconti, R., Cruz Rambaud, S., & López Pascual, J. (2020). Sustainability in FinTechs: An explanation through business model scalability and market valuation. *Sustainability*, *12*(24), 10316.

Bhatnagar, M., Taneja, S., & Özen, E. (2022). A wave of green start-ups in India—The study of green finance as a support system for sustainable entrepreneurship. *Green finance*, *4*(2), 253.

Soremekun, Y. M., Abioye, K. M., Sanyaolu, T. O., Adeleke, A. G., & Efunniyi, C. P. (2024). A conceptual model for inclusive lending through fintech innovations: Expanding SME access to capital in the US. *Contemporary Research and Review Journal*, *2*(1), 1-12.