

FINANCIAL TECHNOLOGY AND RISK MANAGEMENT IN AGRICULTURAL ENTERPRISES

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Abstract

Agricultural sector is an extremely risky environment with high uncertainties, financial, climatic as well as market-related issues that have a great influence on the productivity, income stability, as well as long-term sustainability. This paper will discuss how Financial Technology (FinTech) can be utilized to improve the financial inclusion of people in Pakistan and to manage agricultural risk. Smallholder farmers that make up a significant portion of the national GDP and the employment sector characterized by severe liquidity restrictions, low usage of formal financial services, and high susceptibility to environmental shocks including floods, droughts, and price volatility dominate the sector.

The primary data were gathered via structured questionnaires to select the required data under the form of quantitative, cross-sectional research study and analyzed with the help of SPSS and PLS-SEM methods. The analysis assesses the nexuses between the FinTech adoption, financial inclusion, and agricultural risk management. The results indicate that the use of FinTechs, including mobile banking, digital payment, and digital lending and insurance solutions, can result in a considerable increase in financial inclusion by increasing access to credit, savings, and transaction services. Moreover, FinTech adoption and financial inclusion show a high positive influence on the agricultural risk management and this is associated with better income stability, productivity, and resilience of farmers. Financial inclusion is also a mediating variable, which enhances the indirect influence of FinTech on the risk management outcomes.

The paper concludes that FinTech is a disruptive instrument to use in solving structural inefficiencies in agricultural finance. Nevertheless, digital illiteracy, infrastructural, and regulatory limitations are some of the challenges that should be dealt with to maximize its potential. The results have significant implications on policy makers, financial institutions and development practitioners who want to facilitate sustainable agricultural development in Pakistan.

Keywords: Financial Technology (FinTech), Financial Inclusion, Agricultural Risk Management, Smallholder Farmers, Pakistan, Digital Finance, Rural Development.

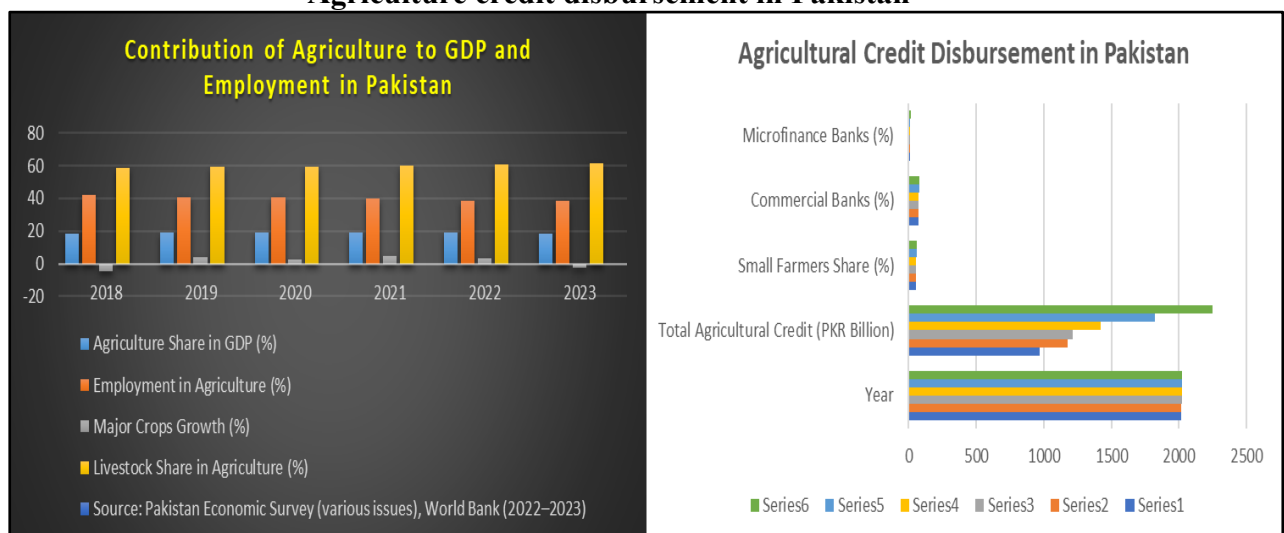
1. Introduction

Agriculture is one of the most complicated, unpredictable, and risky sectors in the global economy, and the multidimensional risks play a major role in determining productivity, profitability, and sustainability in the long run (World Bank, 2020; FAO, 2021; OECD, 2022; Barrett et al., 2019; Dercon, 2000). The agricultural businesses are the only ones that face a broad

spectrum of interconnected risks such as climatic variability, market volatility, institutional weakness, and technological inefficiencies (Binswanger-Mkhize, 2012; Hazell et al., 2010; Just and Pope, 2013; Carter et al., 2017). As opposed to industrial sectors, agriculture is highly sensitive to the environment, which makes the sector vulnerable to exogenous shocks, e.g., droughts, floods, pest infestation, and plant diseases (Intergovernmental Panel on Climate Change, 2022; Morton, 2007; Rosenzweig et al., 2014; Wheeler and von Braun, 2011). Structural weaknesses in financial systems, especially developing ones, also contribute to these vulnerabilities because the formal financial services and effective risk-mitigating tools are still not available to many people Demirgüç-Kunt et al., 2022; Beck et al., 2007; Karlan et al., 2014; Cull et al., 2018; Dupas & Robinson, 2013).

This is even more obvious in Pakistan, where agriculture is one of the foundations of the economy, adding about 18.20 percent of GDP and employing almost 38.40 percent of labor (Government of Pakistan, 2023; World Bank, 2022; PBS, 2023). This industry is characterized by smallholder farmers that work with a strong limitation of resources at their disposal and are highly vulnerable to environmental and market risks (Ahmad et al., 2018; Ali et al., 2017; Rehman et al., 2015). The dependence of agriculture and irrigation systems in Pakistan on climate and its sensitivity makes the country even more vulnerable to climate shocks. The rising number of severe weather phenomena (such as floods, droughts, heatwaves) have disturbed agricultural productivity and rural livelihoods greatly (IPCC, 2022; Mustafa et al., 2019; Rasul et al., 2012). The most prominent one is the 2022 floods in Pakistan that triggered massive crop, livestock, and infrastructure damage and resulted in significant income loss among agricultural populations (World Bank, 2023; UNDP, 2023). In line with this, frequent droughts in some parts of the country like Sindh and Balochistan have worsened the problem of water shortage and decreased agricultural production (Ashraf and Routray, 2013; Qureshi et al., 2010).

Figure:1 Contributions of agriculture to GDP and Employment in Pakistan & Agriculture credit disbursement in Pakistan

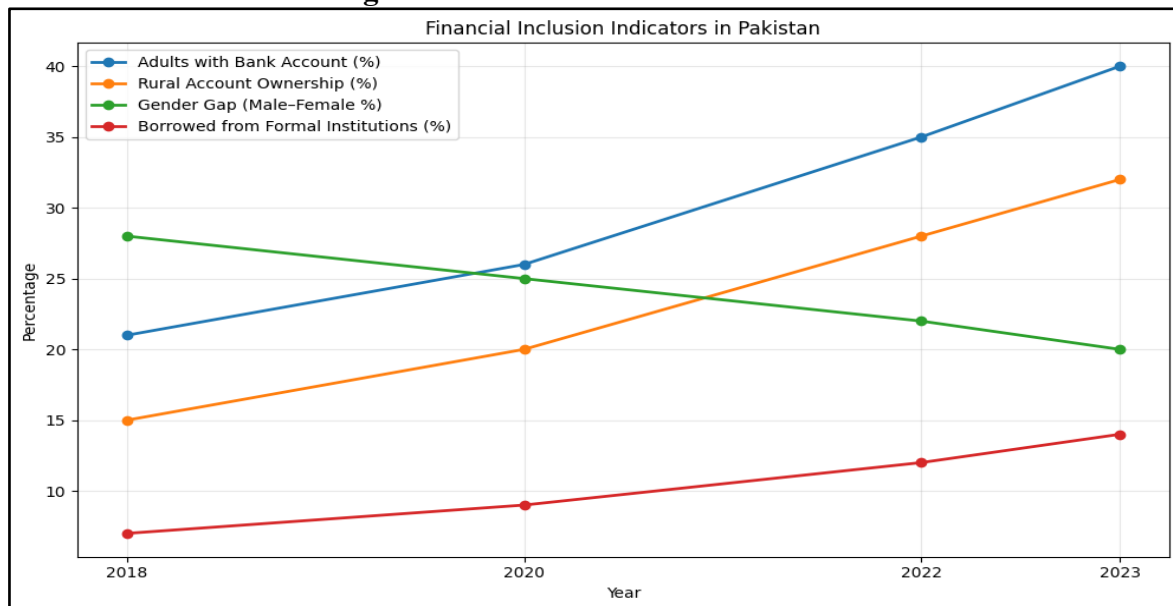


Source: State Bank of Pakistan (SBP), Agricultural Credit Reports (2018–2023)

The nature of the agricultural business organisations is that the nature of the income is seasonal and unpredictable. Income of farmers is usually paid once or twice a year after harvesting cycles, and expenses, such as input expenses, wages and workers expenditures, and household spending, are paid during the whole year (Stephens & Barrett, 2011; Fink et al., 2020; Dillon

and Barrett, 2017). This disparity is especially sharp in Pakistan, where minor farmers tend to work on small plots of land and have no financial reserves (PBS, 2023). As a result, liquidity is a widespread issue forcing farmers to turn to informal methods of accessing credit such as middlemen and moneylenders, who are often linked to high-interest rates and abusive schemes (Aleem, 1990; Khan and Nadeem, 2017; Hussain et al., 2019). Such dependence does not only make farmers vulnerable financially but also makes their bargaining power weak in agricultural markets (Jan et al., 2019). Monetary instability is further aggravated by risks associated with the market. World market changes in major crops (wheat, rice, cotton, and sugarcane) cause price volatility due to changes in the global commodity market, government intervention, and supply chain inefficiencies (Dorosh and Salam, 2008; Gilbert and Morgan, 2010; Minot, 2014; FAO, 2021). Production costs, such as fertilizers, fuel, and electricity, have also risen, which has made production very expensive, which lowers the level of profitability in the farms (Government of Pakistan, 2023; OECD, 2022). There is the additional aspect of uncertainty that is exchange rate instability, especially to the input-dependent agricultural systems (SBP, 2023). Consequently, the financial risk management is not just a strategic issue but the key to resilience and sustainability of agricultural businesses (Hardaker et al., 2015; OECD, 2011; World Bank, 2019).

Figure.2 Financial Inclusion Indicator

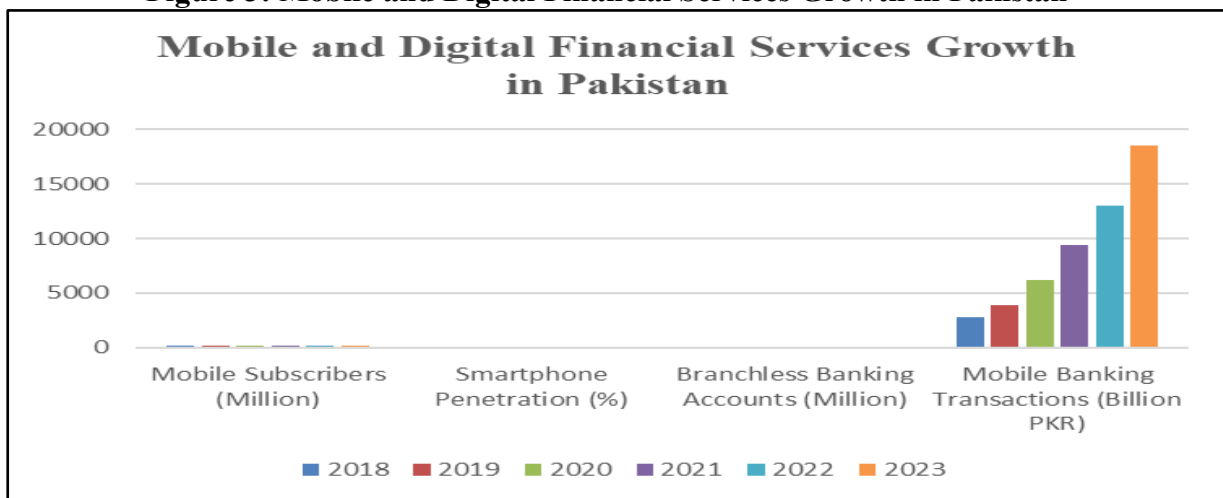


Source: World Bank Global Findex Database (2021), SBP (2023)

Financial inclusion in rural Pakistan is still low even though financial services are of paramount importance. The percentage of the farmers who do not have access to the formal banking services, insurance products, and institutional credit is high (Demirguc-Kunt et al., 2022; State Bank of Pakistan, 2022). The structural barriers that limit access to formal financial systems include the unavailability of collateral, financial illiteracy, geographic remoteness, and underdeveloped rural finance continue to limit access to formal financial systems (Besley, 1995; Stiglitz and Weiss, 1981; Beck et al., 2007; Zins and Weill, 2016). Even though there are new agricultural credit programs and agricultural credit schemes introduced by the institutions like the State Bank of Pakistan and the Zarai Taraqiati Bank Limited, the outreach is still lacking, especially to the smallholder and the marginalized populations (SBP, 2022;

ZTBL, 2023). This financial marginalization limits the farmers to invest in productivity-enhancing technologies and the adoption of climate-resilient practices, which keep farmers in low productivity and vulnerable cycles (Feder et al., 1990; Foster and Rosenzweig, 2010; Bryan et al., 2014). Financial Technology (FinTech) has become one of the solutions to these problems, and it has a high potential to enhance agricultural finance systems (Arner et al., 2020; Milian et al., 2019; Gomber et al., 2018; Frost et al., 2019). The term FinTech can be defined as the usage of digital technologies, such as mobile apps, big data analytics, artificial intelligence (AI), blockchain, and the cloud computing to provide innovative financial services (Schueffel, 2016; Lee and Shin, 2018; Thakor, 2020). The mobile connectivity and digital infrastructure has been rapidly spreading in Pakistan, thus opening up new opportunities to provide financial services to rural underserved populations (GSMA, 2023; PTA, 2023). Mobile banking and mobile money are digital financial services, which have been central in improving financial inclusion. Easypaisa and JazzCash are applications that allow farmers to carry out financial operations, store money, and accept payments without using the brick and mortar banking institutions (Jack and Suri, 2014; Suri and Jack, 2016). Moreover, online lending services use alternative data to determine creditworthiness, thus increasing credit accessibility to people who have no formal financial history (Berg et al., 2020; Jagtiani and Lemieux, 2019). The innovations are cost-effective in terms of transaction costs and efficiency in the delivery of financial services (Philippon, 2016; Beck et al., 2016).

Figure 3: Mobile and Digital Financial Services Growth in Pakistan



Source: Pakistan Telecommunication Authority (PTA), SBP Branchless Banking Reports (2018–2023)

In addition to financial inclusion, FinTech is very essential in risk management of agriculture. Conventional instruments like crop insurance have been known to suffer due to the problem of accessibility, affordability, and operational inefficiency (Hazell et al., 2010; Cole et al., 2013). Nevertheless, such innovations like index-based insurance with the assistance of weather and satellite data allow providing automatic and timely payments in the event of climatic shocks (Jensen et al., 2018; Miranda and Farrin, 2012; Carter et al., 2017). In Pakistan, such programs as the Prime Minister Crop Insurance Scheme can be discussed as an attempt to enhance the protection of agricultural risks, but the uptake of these programs is limited due to the lack of awareness and accessibility (Government of Pakistan, 2023).

Moreover, it becomes easier to conduct a more complex risk assessment and decision-making process with the integration of big data analytics and artificial intelligence (Wolfert et al., 2017;



Liakos et al., 2018). Those technologies make it possible to make predictive insights on the level of weather, soil conditions, and market trends and proactively implement risk management strategies by farmers (Klerkx et al., 2019). In Pakistan, new agri-technologies are becoming more and more sources of digital advisory services, which improves productivity and financial performance (FAO, 2022; Khan et al., 2021).

The blockchain technology can also bring much potential to enhance the levels of transparency, traceability, and trust in agricultural supply chains (Kshetri, 2018; Tripoli and Schmidhuber, 2020). Blockchain has the potential to provide financing to the small-scale farmers, which are traditionally viewed as the high-risk borrowers due to their information asymmetry and the possibility of risky transactions (Saber et al., 2019). Its adoption in Pakistan however is limited because of infrastructural and regulatory factors.

Although FinTech has the potential of transformation, there are a number of challenges in its implementation in the agricultural sector of Pakistan. Poor digital literacy, a lack of internet connectivity, and poor Smartphone uptake are some of the significant obstacles to rural areas that are characterized by the digital divide (Aker and Mbiti, 2010; PTA, 2023). Digital financial services are also limited by socio-economic disparities, such as gender differences (Demirgüç-Kunt et al., 2022; GSMA, 2023). Also, the lack of awareness, regulatory uncertainties, and cybersecurity threats are obstacles to successful implementation of FinTech solutions (Arner et al., 2020; SBP, 2022).

The institutional and regulatory frameworks are thus essential in determining the FinTech adoption. The policymakers have to reduce the risk of innovation versus consumer protection, data privacy, and financial stability (Claessens et al., 2018; Frost et al., 2019). The efforts like the National Financial Inclusion Strategy (NFIS) and investments into digital infrastructure are significant steps to making FinTech-based agricultural transformation possible in Pakistan (World Bank, 2022; SBP, 2022).

Theoretically, FinTech adoption in agricultural risk management may be theoretically explained by the financial intermediation theory, information asymmetry theory, and the innovation diffusion theory (Stiglitz and Weiss, 1981; Rogers, 2003; Venkatesh et al., 2012). FinTech minimizes the information asymmetry through the use of alternative data and real-time information, which enhances credit distribution and risk measurement (Berg et al., 2020). It is adopted based on perceived utility, ease of use and the socio-economic aspect and especially in the rural setting (Davis, 1989; Rogers, 2003).

Considering the rising significance of FinTech in changing the agricultural finance, there is the necessity of deeply integrated and thorough examination of its influence in the financial inclusion and risk management, specifically in the context of Pakistan. The current literature is not fully synthesized and the evidence of the world and the reality of the local are not completely combined (Milian et al., 2019; Gomber et al., 2018). Thus, the proposed research is a systematic literature review of empirical and theoretical studies published since 2018 and related to the contribution of FinTech to improving financial inclusion and eliminating risk factors in agricultural businesses, particularly in Pakistan.

To sum up, agricultural sector in Pakistan is confronted with serious financial, environmental, and institutional issues which require context-specific and innovative solutions. FinTech is one of the promising directions that can be used to enhance financial inclusion, risk management, and resilience. Its success is however subject to structural barrier, inclusive access and supportive policy frameworks. These dynamics are very critical in understanding the sustainable agricultural development in an environment that is becoming more uncertain around the world.

Problem Statement

The agricultural enterprises are run by high uncertainties in terms of finance, climatic and market conditions which pose risks on their productivity and sustainability. Poor financial system structures, inaccessibility to formal credit and heavy reliance on informal lending systems compound these problems in developing economies like Pakistan. Although agriculture is very important to the Pakistani economy, the high percentage of smallholder farmers is financially marginalized and does not have access to proper risk mitigation instruments.

Financial Technology (FinTech) has become a potential solution in recent years to improve the financial inclusion and better risk management with the use of digital financial services, data-driven decision-making, and innovative financial products. Nevertheless, the current literature has mostly concentrated on the general financial inclusion or innovation in technology, but few studies have paid any attention to the aligning role of the FinTech in agricultural risk management. In addition, there is limited empirical data regarding the impact of the use of FinTech solutions on the financial stability, productivity, and resilience of farmers, especially in Pakistan.

Also, there is a strong inequality between various regions Sindh and Balochistan, where digital infrastructure and financial services are unevenly distributed. The availability of socio-economic factors, such as low digital literacy and gender inequality and institutional inefficiencies, also make the adoption of FinTech in rural localities more difficult.

That is why it is highly urgent to investigate the systematic analysis of the way in which FinTech may improve financial inclusion and risk reduction in agricultural businesses, considering the peculiarities of the socio-economic and institutional realities in Pakistan. The gap needs to be bridged in order to come up with effective policies and strategies that enhance sustainable development of agriculture.

2. Research Objectives

To evaluate the degree of financial inclusion among Pakistani agricultural businesses and examine the major operational and financial concerns.

To assess how Financial Technology (FinTech) solutions, such as digital lending, mobile banking, and insurance technologies, are adopted and used in the agriculture industry.

To investigate how financial technology (FinTech) affects agricultural risk management, specifically in terms of enhancing resilience, productivity, and income stability.

3. Research Questions

- 1 What are the main operational and financial risks, and how financially integrated are Pakistani agricultural businesses?
- 2 How widely are FinTech solutions used and used in the agricultural industry?
- 3 What effects does FinTech have on the results of agricultural risk management, such as resilience, productivity, and income stability?

Significance of the Study

This research paper is relevant to the current body of literature on FinTech, financial inclusion, and risk management of agriculture in Pakistan, where agriculture is still prone to financial, climatic, and market risks. It emphasizes the role of the digital financial technology to overcome structural issues and enhance risk management among the farmers. The study fills a gap in academia, as it combines FinTech, financial inclusion, and risk management within a framework and provides a more in-depth explanation of the overall effect of the three in developing economies. Policy wise, the results can be used by the policy makers to guide institutions like the State Bank of Pakistan to facilitate the adoption of digital financial services,

enhance financial inclusion in rural areas and develop enabling regulatory frameworks. In practice, the study is useful to farmers, financial institutions, and FinTech providers as it provides information on how they can create the most accessible and user-friendly financial solutions to boost productivity and reduce risks. In general, the study can underpin the attempt to foster financial inclusion, enhance economic stability, and sustainable agricultural growth in Pakistan.

Literature Review

The agricultural business is a business with one of the most unstable and unpredictable business environments where risk management is not only beneficial but also a survival strategy in the long run. The industry is marked with distinct structural and operational limitations that expose it to high financial risks. Among the most essential problems is the uneven pattern of income that is observed among farmers, which is often paid once or twice a year. This requires a diligent financial planning process to distribute funds over long durations of time using sound savings, borrowing, and investment choices (Klapper et al., 2019). Besides such irregular cash flows, agricultural production is also very prone to external shocks. The threat of weather variability, climate change, pest attacks, and disease outbreaks are significant threats to crop production and livestock welfare. Moreover, the uncertainty of the financial situation is caused by unstable market prices and input costs, which in many cases lead to unstable revenue flows and a significant increase in uncertainty (Klapper et al., 2019). Even with these issues, a large percentage of rural households do not have access to formal financial services including insurance, savings vehicles and credit facilities. This restricted financial inclusion means that they cannot effectively deal with risks, invest in productivity-enhancing technologies or recover when an economy is hit by a shock. As a result, agricultural businesses are very susceptible to micro as well as macroeconomic shocks. Financial risk management has been integrated into the operations of enterprises in the modern economic system. The risk factors appear in different aspects of financial and economic operations, and it is necessary to systematize them, assess them, and reduce them (Ozerova et al., 2021; 2020; 2021). In the case of agricultural business, economic security and long-term development are directly connected with the timely evaluation and control of financial risks. The application of financial technology (FinTech) in the current paradigm of risk management is a revolutionary opportunity to fill the current gaps and increase access to financial services among farmers and their resiliency.

2. Types of Financial Risks in Agricultural Enterprises

The financial risks that agricultural enterprises have to face are multidimensional and can be divided into several large groups. These risks include production risks, which are the most basic and are caused due to the unpredictable weather patterns, climate variability, and biological factors like pests and animal diseases. These risks are capable of causing extreme losses in production and endangering the sustainability of the farming activities (Davydenko et al., 2023; Bohdaniuk et al., 2024). Another type of risk that is critical is price volatility. Unpredictable changes in the prices of agricultural products, the cost of inputs including fertilizers and fuel, and the dynamics of the global market impose a lot of uncertainty in terms of profitability and stable revenues (Matei et al., 2022; Alekseeva et al., 2024; Bohdaniuk et al., 2024). Cash flow management is also seen as a financial risk. The seasonal characteristics of agricultural production necessitate that the liquidity and working capital should be managed with care by the enterprises to maintain the continuity of operations during the production cycle (Khalatur et al., 2020). The issue of credit risks also complicates financial management especially in agricultural supply chains where enterprises depend on external financing and

have to deal with counterparty risks (Yang et al., 2022). Also, the currency and exchange rate risks impact the enterprises involved in international trade or those having foreign currency liabilities (Davydenko et al., 2023; Bohdaniuk et al., 2024). Disruptions in the supply chains, such as input delivery delays or accessibility limitations in the markets, also result in serious financial implications (Yang et al., 2022). The contemporary risk assessment practices reiterate that the risks should be assessed within various financial aspects, such as liquidity, solvency, profitability, financial stability, and operational efficiency (Tkach et al., 2019; Berest et al., 2025). The interplay of macroeconomic variables, including inflation, credit restrictions, and environmental shocks, is also regarded by contemporary frameworks because they all affect the process of financial decision-making in agricultural businesses (Makohon et al., 2025).

3. Role of Financial Technology in Agricultural Risk Management

Digital financial inclusion is a new paradigm in agricultural finance, which uses new technologies, including data mining, artificial intelligence (AI), and machine learning (ML), to enhance the delivery of financial services. These technologies make it possible to collect and analyze data efficiently, allowing to price the risks correctly and have fewer financing limitations on the agricultural enterprises (Zhu et al., 2021). FinTech solutions also play a key role in increasing access to financial services such as credit, savings, and mobile payment systems to the farmers. The enhanced access to such services leads to higher productivity of agricultural activities, more effective use of high-quality inputs, and food production systems resilience (Mapanje et al., 2023). New technologies like blockchain are revolutionizing the agricultural supply chain finance by providing a decentralized and transparent system of transactions that cannot be changed. Those sites allow real-time risk monitoring, increase information sharing, and decrease credit risks due to better traceability and accountability (Wu et al., 2023; Wu et al., 2022). Likewise, AI-based credit evaluation systems and big data analytics enhance the reliability of transactions and reduce the asymmetry of information, which lowers the cost of financing (Wan et al., 2024). Real-world uses of agricultural FinTech show that it is effective in various areas. As a case in point, FarmDrive in Kenya is an initiative that uses mobile technology and data analytics to build digital credit profiles, allowing farmers to receive financing without collateral (Mori, 2023). Moreover, online insurance services provide customized products, which cover farmers against natural risks and market data volatility through predictive analytics (Xu et al., 2025; Zhong et al., 2021). Precision agriculture technologies also increase the level of productivity and allow carrying out more accurate creditworthiness evaluations, decreasing the reliance on the traditional use of collateral-based lending (Sheyoputri, 2024; Wei et al., 2025; Joorbonian, 2024). Nevertheless, digital technology implementation also presents some new risks such as cybersecurity threats, data management issues, and algorithmic biases, requiring a prudent and balanced approach to implementation (Desyatnyuk et al., 2025).

4. Traditional Risk Management Tools in Agriculture

The conventional approaches to managing agricultural risks may be based on the integration of technical and financial instruments aimed at reducing the number of different risks (Stojanovic et al., 2017). Technical risk management is also applied to mitigate risk through diversification of production which limits the exposure to risk by diversifying activities into several crops or livestock businesses. Irrigation systems and drainage are water management systems that are utilized to counter weather risks. Better farming methods and practices such as crop rotation, pest management practices and animal health protection practices increase resiliency to biological risks. Besides, the creation of financial and physical reserves give a cushion to against unforeseen shocks (Stojanovic et al., 2017; Syrotyuk et al., 2025). This is

equally important with financial instruments. Crop insurance and income stabilization programs are insurance products that have protection against the loss of production and income (Nematovich, 2019). The risks associated with the volatility of prices can be addressed with the help of market-based instruments, futures contracts, options, and hedges (Khakhula et al., 2023; Alekseeva et al., 2024). The best risk financing plans include savings, borrowing as well as insurance to provide business continuity (Gurenko et al., 2004). Outsourcing and contract farming are contractual agreements that minimize market uncertainties (Khakhula et al., 2023). The existence of governmental interventions also reinforces conventional risk management structures by the way of state sponsored insurance, strategic buffer stock and controls to provide stability in agricultural markets (Nematovich, 2019; Syrotyuk et al., 2025).

5. Literature Comparison Table

The literature review points to diverse priorities of the studies in terms of the focus on the risk types and the tools of risk management. Stojanovic et al. (2017) concentrate on production, price, institutional, and financial risks and focus on insurance as one of the main mitigation options. Syrotyuk et al. (2025) cover natural, market and legislative risks, which are diversification, insurance and state support mechanisms. Nematovich (2019) focuses on the issue of climatic and biological risks, but it pays much attention to agro-insurance. The analysis offered by Khakhula et al. (2023) is very extensive and includes climatic, economic, and geopolitical risks with both traditional and digital financial tools like futures contracts and digital technologies. Alekseeva et al. (2024) highlight financial risks and price volatility specifically with the help of investment diversification, and grain options. Gurenko et al. (2004) concentrate on the production shocks and promote the combined risk financing schemes that are insurance, savings, and borrowing.

6. Digital Risk Management Systems and Innovation

The current digital risk management systems are altering the conventional reactive management systems into proactive and predictive models. This can be achieved by real-time monitoring to identify financial risks early enough, before they turn into a crisis leading to dire financial situations (Wang, 2022). Business intelligence tools are beneficial in decision-making because they offer evidence-based information, especially in agricultural insurance, where they minimize risk levels and enhance the accuracy of risk forecasting (Amini et al., 2021). The systems based on blockchains also enhance the risk monitoring as they allow safe and transparent transactions in the agricultural supply chains (Wu et al., 2023; Wu et al., 2022). With the help of the artificial intelligence and the big data analytics, the identification of risks and the development of the strategies beforehand is possible with a high level of accuracy, and the financial decision-making process in the uncertain conditions is highly enhanced (Desyatnyuk et al., 2025). Also, enterprise resource planning (ERP) systems, cloud accounting, and digital documentation increase the transparency, minimize human error, and maximize the efficiency of the operations (Golub, 2025). Nevertheless, such innovations present new problems, such as risk of cybersecurity and risk of algorithm, that must be constantly monitored and controlled (Desyatnyuk et al., 2025).

7. Challenges in FinTech Adoption in Agriculture

FinTech in agricultural business is associated with a high level of structural and socioeconomic obstacles. Access to electricity and internet is limited by infrastructure constraints, especially in the rural regions, and it is a barrier to the utilization of digital financial services (Mapanje et al., 2023). Poor digital literacy particularly among the elderly farmers also limits adoption. Also, the barriers to financial services in the country are systemic, including gender inequality, low educational attainment, and the poor infrastructure in rural areas (Fifo et al., 2026). This

digital divide is a paradox because people who could benefit the most with the help of FinTech solutions are not always able to do it. As much as FinTech is an opportunity to enhance financial inclusion and efficiency, it is important to overcome these underlying challenges to facilitate its use in a large scale (Mapanje et al., 2023).

8. Policy and Institutional Frameworks

The government policies are central in helping to integrate FinTech in the agricultural risk management. The implementation of technologies like blockchain to monitor risks and provide transparency of the supply chain can be facilitated by regulatory frameworks (Wu et al., 2023). It is necessary that the agricultural insurance services be expanded through the involvement of the private in the partnership with the government, and the establishment of the competitive financial markets. Subsidies, regulatory assistance, and precision investment in digital infrastructure are some of the ways governments can encourage innovation (Nematovich, 2019). The overall policy solutions should also address bettering the rural financial systems, the ESG standards, and digital adoption in the agricultural businesses (Zhu, 2022; Bereza, 2024).

9. Impact of FinTech on Agricultural Enterprise Performance

Financial technology combined with conventional risk management approaches to agricultural business greatly enhances the success of the agricultural businesses. Digitization is more efficient, more profitable and more resilient as it allows allocating resources and minimizing risks better (Kushnarenko et al., 2019). Risk management systems allow informed decision-making and allow enterprises to react to the changes in the market (Burtseva et al., 2020). FinTech apps help enhance financial efficiency throughout supply chains, solving credit, operational, and procurement risks (Wang et al., 2022; Gardas et al., 2019; Kamble et al., 2019). Agricultural businesses that integrate their operations have better financial and operational stability and innovation ability. Digital technologies along with ESG practices and proper risk management are also the key to sustainable development and fewer financial losses (Trusova et al., 2022; Bereza, 2024).

Research Gap

Although the financial technology (FinTech), agricultural finance, and risk management have been widely written about, there are still gaps throughout the world and in Pakistan. Although research has focused on the agricultural risks and economic functions (World Bank, 2020; FAO, 2021; Hardaker et al., 2015), and the role of FinTech in the financial inclusion (Arner et al., 2020; Gomber et al., 2018; Frost et al., 2019), their interplay, particularly FinTech. The bulk of the research on digital financial services tends to be on African and developed economies (Jack and Suri, 2014; Suri and Jack, 2016; Aron, 2018), and little empirical data is available on Pakistan, where researchers primarily discuss general financial inclusion (State Bank of Pakistan, 2022; Khan et al., 2021). The research on agricultural risks focuses on traditional approaches and does not entail a significant assimilation of modern technologies such as AI, big data, and blockchain (Hazell et al., 2010; Carter et al., 2017; Wolfert et al., 2017; Kshetri, 2018).

Also, the existing literature tends to divide the views of finances and technology, failing to provide a coherent framework (Milian et al., 2019; Philippon, 2016). The role of FinTech in productivity, income stability, and resilience has little empirical evidence, especially in developing nations (Frost et al., 2019; World Bank, 2022).

Studies on the region and micro-level are lacking in Pakistan, which ignores inequalities in such provinces as Sindh and Balochistan (PBS, 2023; SBP, 2022). Other barriers like the digital

divide, gender inequality, and regulatory challenges are also not well studied in agricultural settings (Aker and Mbiti, 2010; GSMA, 2023; Arner et al., 2020).

Lastly, technological change is fast, and it is essential to have new research that incorporates the current trends (20182025), particularly in emerging markets such as Pakistan.

3. Research Methodology

This study adopts a quantitative and cross-sectional research to examine the relationships among FinTech adoption, financial inclusion, and agricultural risk management in Pakistan. The target population covers both the smallholder and medium-scale farmers and agriculture stakeholders, and the data is gathered using non-probability convenience sampling because of the accessibility limitations. The sample size of 150-300 respondents can be said to be sufficient in multivariate analysis. Structured questionnaire is used to collect primary data on a 5-point Likert scale based on measurement items applicable in validated studies and modified to suit Pakistan, with secondary data coming in the form of the World Bank, FAO, and State Bank of Pakistan. The research adheres to a mediation model with FinTech adoption (comprising of mobile banking, digital payment, digital lending, and InsurTech) as the independent variable, financial inclusion as the mediating variable, and agricultural risk management (measured by income stability, productivity, and resilience) as the dependent variable with the control variables being age, education, income, size of farm, and access to digital technology. The analysis of the data is done using SPSS and PLS-SEM, beginning with the descriptive statistics and reliability (Cronbachs Alpha = 0.70) test, then the measurement model (reliability, convergent and discriminant validity) and structural model (path coefficients, bootstrapping, R², f², Q² and mediation analysis). The model quantifies both direct and indirect impacts, in which FinTech adoption has a direct and indirect impact on agricultural risk management via financial inclusion, which offers a holistic view of the relationships.

4.2 Descriptive Statistics

Variable	Mean	Standard Deviation
FinTech Adoption (FTA)	3.62	0.78
Financial Inclusion (FI)	3.45	0.81
Agricultural Risk Management (ARM)	3.58	0.74

The descriptive statistics indicate that the mean of FinTech Adoption (Mean = 3.62, SD = 0.78), Financial Inclusion (Mean = 3.45, SD = 0.81) and Agricultural Risk Management (Mean = 3.58, SD = 0.74) are all above the middle. It means that the respondents tend to agree that FinTech adoption is moderate and beneficial to financial inclusion and agricultural risk management. The value of the standard deviation which is less than 1 indicates that the responses are fairly consistent with little variation between the participants.

4.3 Reliability Analysis

Variable	Cronbach's Alpha
FinTech Adoption	0.82
Financial Inclusion	0.79
Agricultural Risk Management	0.85

The reliability results indicate Cronbach's Alpha values of 0.82 for FinTech Adoption, 0.79 for Financial Inclusion, and 0.85 for Agricultural Risk Management. Since all values exceed the acceptable threshold of 0.70, the measurement scales are considered reliable. This confirms that the survey items are internally consistent and effectively measure their respective constructs.

4.4 Correlation Analysis

Variables	FTA	FI	ARM
FTA	1	0.62**	0.58**
FI	0.62**	1	0.65**
ARM	0.58**	0.65**	1

The outcome of the correlation analysis indicates that there are strong positive relationships between all the variables at the 1% level of significance. Financial Inclusion has a positive correlation with FinTech Adoption ($r = 0.62, p < 0.01$) which means the more one uses FinTech, the better the financial access. The relationship between Financial Inclusion and Agricultural Risk Management is also positive with significant correlation ($r = 0.65, p < 0.01$) indicating that the better access to financial resources, the higher the possibility of farmers to manage their risk. Furthermore, Agricultural Risk Management has a positive correlation with FinTech Adoption ($r = 0.58, p < 0.01$), proving the fact that digital financial services help to enhance the resilience of agricultural activities.

4.5 Regression Analysis

Model Summary

Model	R	R ²	Adjusted R ²
Model 1	0.68	0.46	0.44

The regression findings show that the regression model has a statistical significance ($F = 35.12, p = 0.000$). FinTech Adoption and Financial Inclusion have a strong explanatory power as the R² value of 0.46 indicates that 46 percent of the variation in Agricultural Risk Management can be attributed to those two variables. Results of the coefficient indicate that FinTech Adoption (0.52, $t = 6.45, p = 0.000$) and Financial Inclusion (0.41, $t = 5.32, p = 0.000$) exert a positive and statistically significant impact on Agricultural Risk Management. This shows that agricultural risk management is better with a rise in FinTech adoption and financial inclusion, although FinTech Adoption is comparatively more influential.

ANOVA Table

Model	F	Sig.
Regression	35.12	0.000

The results of the ANOVA indicate that the regression equation is statistically significant ($F = 35.12, p = 0.000$). Because the value of the significance is below 0.05, it implies that a combination of FinTech Adoption and Financial Inclusion has a meaningful influence on Agricultural Risk Management. This makes it clear that the whole model fits the data well and can be used to explain the changes in the dependent variable with great reliability.

Coefficients Table

Predictor	Beta	t-value	Sig.
FinTech Adoption	0.52	6.45	0.000
Financial Inclusion	0.41	5.32	0.000

The outcomes of the coefficients show that the independent variables have positive and statistically significant influence on Agricultural Risk Management. The beta of FinTech Adoption is 0.52 and t-value is 6.45 ($p = 0.000$) which means that the influence is strong and highly significant. There is also a positive impact of Financial Inclusion having a beta of 0.41 and t-value of 5.32 ($p = 0.000$). These results indicate that the two variables play an important role in enhancing Agricultural Risk Management with FinTech Adoption playing a relatively bigger role compared to Financial Inclusion.

4.6 Hypothesis Testing Results

Hypothesis	Result
H1: FinTech → Financial Inclusion	Supported
H2: FinTech → Agricultural Risk Management	Supported
H3: Financial Inclusion → Agricultural Risk Management	Supported

The results of the hypothesis testing prove that all hypotheses are accepted. FinTech Adoption has a significant positive effect on Financial Inclusion and Agricultural Risk Management, while Financial Inclusion also has a significant positive effect on Agricultural Risk Management. These results confirm the relationship hypotheses in the theoretical framework and support the significance of FinTech in improving financial access and risk management within the agricultural industry.

4.7 Discussion of Findings

The results of the present study suggest that the adoption of FinTech is an important step towards increasing financial inclusion to agricultural enterprises in Pakistan. Digital financial services are enhancing access to formal financial institutions, especially rural farmers who have been characterized by access barriers to banking services in the past. Mobile banking, digital wallets, and online payment systems are the digital financial services that are making access to formal financial institutions easier. The findings also indicate that the use of FinTech is associated with a high positive effect on agricultural risk management. The active utilization of the FinTech services by the farmers has been shown to bring about better financial stability, high productivity, and resilience to economic and environmental shock. This implies that digital financial technologies lower the transaction costs and access financial resources in a timely manner. Moreover, financial inclusion has been identified to be positively related to agricultural risk management. Financial services allow farmers to access credit, save money and manage their finances in a better way hence enhancing their capacity to deal with uncertainties. On the whole, the results indicate that FinTech plays a direct and indirect role in enhancing agricultural resilience through promoting financial inclusion and successful risk management strategies in the agricultural sector of Pakistan. This chapter gives the conclusion of the study in regards to the empirical findings in the previous chapter. It presents the main findings on how Financial Technology (FinTech) can be used in promoting financial inclusiveness and better management of agriculture-related risks. Furthermore, it also offers policy recommendations and offers future research directions.

5.2 Conclusion

The primary objective of this study was to examine the impact of FinTech on financial inclusion and agricultural risk management in Pakistan. The main aim of the study was to investigate how FinTech affects financial inclusion and agricultural risk management in Pakistan. The results indicate that the use of FinTech has a substantial impact on increasing access to financial services within the agricultural businesses. There are more digital financial solutions like mobile banking, online lenders, and digital payment systems that have minimized the barriers that are related to traditional banking systems. The research also concludes that financial inclusion is one of the main mechanisms whereby FinTech can have an impact on agricultural risk management. Access to formal financial services helps farmers to manage risks associated with income variability, climate shocks, and fluctuations in the market. This access will help them to stabilize income, enhance productivity, and create resilience to diverse risks. Moreover, the empirical findings prove that FinTech adoption and financial inclusion both have statistically significant positive impacts on agricultural risk management. This highlights the need to incorporate digital financial solutions in the agricultural industry with an

aim of ensuring sustainable development. In general, the paper finds that FinTech is a revolutionary tool that will boost financial inclusion and improve risk management within the Pakistani agricultural industry, especially with smallholder farmers who have limited access to finances.

5.3 Policy Recommendations

- Strengthen digital financial infrastructure in rural areas (internet & mobile access).
- Promote financial literacy and digital awareness among farmers.
- Expand access to digital credit using alternative lending models.
- Encourage public-private partnerships for integrated FinTech solutions.
- Develop supportive regulations through authorities like the State Bank of Pakistan.
- Promote digital agricultural insurance to manage climate risks.
- Use data-driven approaches to design customized financial services for farmers.

5.4 Implications, Limitations, and Future Research

This study has significant policy implications to policymakers, financial institutions, and FinTech providers that should be utilized to ensure financial inclusion and better agricultural risk management with the adoption of digital technologies. It demonstrates that FinTech can increase access to financial services, productivity, and economic stability of the farmers. Nonetheless, the research is restricted to Pakistan, cross-sectional, and the data is self-reported, which can influence the generalizability and accuracy. Future studies must dwell on new technologies, including blockchain and artificial intelligence, assess regional differences, and use qualitative approaches to acquire a better understanding of FinTech adoption.

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