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Influence of Agricultural Credit, Financial Inclusion, and Technology Adoption on Farmers' Economic Performance: A Structural Equation Modeling Approach.

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Abstract

Agricultural modernization has become increasingly dependent on farmers' access to institutional finance and their ability to adopt innovative agricultural technologies. However, limited financial resources continue to constrain technology adoption among smallholder farmers, thereby affecting agricultural productivity and economic performance. The present study investigates the structural relationships among Agricultural Credit, Technology Adoption, and Farmers' Economic Performance using a Structural Equation Modeling (SEM) approach. A quantitative cross-sectional research design was employed, and primary data were collected from 384 smallholder farmers using a structured questionnaire. The sample size was determined using Cochran's formula with a 95% confidence level and a 5% margin of error. The proposed structural model was estimated using Maximum Likelihood Estimation (MLE). The empirical findings reveal that Agricultural Credit has a significant positive effect on Technology Adoption ($\beta = 0.46$, $t = 9.20$, $p < 0.001$), indicating that improved access to institutional finance enables farmers to invest in modern agricultural technologies. Furthermore, Technology Adoption exerts a strong positive influence on Farmers' Economic Performance ($\beta = 0.58$, $t = 9.66$, $p < 0.001$), demonstrating that the adoption of improved farming technologies enhances productivity, profitability, resource-use efficiency, and farm income. The results suggest that technology adoption serves as the primary mechanism through which agricultural credit is transformed into measurable economic benefits. The study concludes that integrated rural development policies combining accessible agricultural finance, technology dissemination, extension services, and financial inclusion can substantially improve agricultural productivity and strengthen rural livelihoods. The findings contribute to the literature on agricultural finance and rural development by providing empirical evidence supporting the sequential relationship between agricultural credit, technological innovation, and farmers' economic performance. The study also offers practical implications for policymakers, financial institutions, agricultural extension agencies, and development organizations seeking to promote sustainable agricultural growth and inclusive rural economic development.

Keywords: Agricultural Credit; Financial Inclusion; Technology Adoption; Farmers' Economic Performance; Structural Equation Modeling (SEM); Smallholder Farmers; Rural Development; Agricultural Finance; Precision Agriculture; Sustainable Agriculture.

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1. Introduction

Agriculture continues to play a central role in the economic development of emerging economies by contributing to food security, employment generation, poverty alleviation, and rural livelihoods. Despite rapid technological advancement in agricultural production systems, a large proportion of smallholder farmers continue to experience low productivity and unstable incomes due to limited access to financial resources, inadequate institutional support, and slow adoption of modern agricultural technologies. These structural constraints restrict farmers' ability to invest in productivity-enhancing inputs and ultimately hinder improvements in their economic performance (Schultz, 1964; Feder et al., 1985).

Agricultural transformation increasingly depends on the integration of financial inclusion, institutional credit, and technological innovation. The availability of affordable agricultural credit enables farmers to purchase improved seeds, fertilizers, irrigation equipment, farm machinery, and digital technologies that enhance production efficiency. However, access to credit alone does not automatically improve farm income. The effectiveness of financial resources largely depends on whether they are utilized for productive investments that increase agricultural productivity and profitability. Consequently, technology adoption functions as the critical mechanism through which financial resources are converted into improved economic outcomes (Karlan et al., 2014).

The modernization of agriculture has gained renewed attention in response to increasing global food demand, climate variability, shrinking landholdings, and rising production costs. Governments and international development organizations have emphasized financial inclusion and technology diffusion as complementary strategies for achieving sustainable agricultural development. Financial inclusion ensures that rural households have access to affordable banking services, credit facilities, insurance products, and digital payment systems, thereby reducing financial exclusion and improving investment opportunities (World Bank, 2022). Simultaneously, technological innovations—including precision agriculture, mechanization, climate-smart farming practices, mobile-based advisory services, and digital farm management systems—have demonstrated significant potential for improving productivity, reducing production risks, and increasing farm profitability (FAO, 2022).

Despite numerous government initiatives promoting institutional finance and agricultural modernization, technology adoption among smallholder farmers remains uneven across developing countries. Many farmers continue to rely on traditional cultivation practices because of inadequate access to formal credit, high borrowing costs, information asymmetry, limited financial literacy, and uncertainty regarding the economic benefits of modern technologies. These challenges create a financing gap that delays agricultural modernization and weakens farmers' long-term economic resilience (Feder et al., 1985).

From a theoretical perspective, this study is primarily grounded in the Induced Innovation Theory proposed by Hayami and Ruttan (1985). The theory argues that technological innovation emerges as a response to relative resource scarcity and changing economic conditions. Farmers adopt innovations that improve the efficiency of scarce production factors, such as labor, capital, water, and land. As agricultural production becomes increasingly

constrained by limited resources, modern technologies become economically attractive because they enable farmers to maximize productivity while minimizing input costs. However, the adoption of these technologies requires substantial initial investment, making access to agricultural credit an essential prerequisite for technological transformation.

The study is further supported by Schultz's Theory of Transforming Traditional Agriculture (Schultz, 1964), which emphasizes that smallholder farmers are rational economic decision-makers rather than inherently resistant to innovation. Schultz argued that farmers readily adopt improved technologies when they possess sufficient financial resources, access to information, and supportive institutional environments. According to this perspective, low agricultural productivity is primarily a consequence of limited investment opportunities rather than unwillingness to innovate. Therefore, expanding institutional credit enables farmers to overcome liquidity constraints and invest in productivity-enhancing technologies.

Another important theoretical foundation is the Diffusion of Innovation Theory developed by Rogers (2003). This theory explains that technology adoption occurs through a gradual process influenced by perceived usefulness, compatibility, complexity, observability, and trialability of innovations. Farmers are more likely to adopt agricultural technologies when they perceive clear economic advantages and possess adequate financial capacity to bear the associated investment costs. Institutional credit reduces the financial risks associated with innovation adoption, thereby accelerating the diffusion process among rural communities.

The present study also draws upon Financial Intermediation Theory, which argues that financial institutions improve economic efficiency by mobilizing savings, allocating capital efficiently, reducing transaction costs, and managing investment risks. In agricultural settings, banks and rural financial institutions serve as intermediaries that channel financial resources toward productive agricultural investments. Efficient financial intermediation enables farmers to acquire modern production technologies that increase productivity, improve resource utilization, and enhance overall farm profitability (Levine, 2005).

In addition, the Sustainable Livelihood Framework provides further theoretical justification for the proposed relationships. The framework emphasizes that households improve their livelihoods through the effective utilization of multiple forms of capital, including financial capital, physical capital, human capital, natural capital, and social capital. Agricultural credit strengthens financial capital, while technology adoption enhances physical and human capital. Together, these assets improve agricultural productivity, increase household income, reduce vulnerability to external shocks, and promote sustainable rural development (Scoones, 1998).

The proposed conceptual model assumes that agricultural credit functions as the initial enabling factor that removes liquidity constraints and facilitates investment in modern agricultural technologies. Technology adoption subsequently acts as the principal mechanism translating financial investment into higher crop productivity, reduced production costs, improved resource efficiency, greater profitability, and enhanced economic performance. Thus, technology adoption serves as the transmission channel through which agricultural credit generates measurable economic benefits for farming households.

Although previous studies have independently examined agricultural credit, financial inclusion, technology adoption, and farm performance, relatively few have investigated the complete structural pathway linking these variables within a unified Structural Equation Modeling (SEM) framework. Most existing research has focused on direct relationships while overlooking the mediating role of technology adoption in transforming financial resources into improved economic outcomes. This study addresses this research gap by empirically examining the sequential causal relationship between agricultural credit, technology adoption, and farmers' economic performance using SEM.

Accordingly, the study focuses on two primary objectives. First, it investigates whether access to agricultural credit significantly promotes the adoption of modern agricultural technologies among smallholder farmers. Second, it evaluates whether technology adoption significantly enhances farmers' economic performance by improving productivity, profitability, and income generation. Understanding these structural relationships contributes to both academic literature and agricultural policy by providing empirical evidence regarding the mechanisms through which financial interventions promote sustainable agricultural development.

The study proposes that agricultural modernization is not merely a consequence of increased financial investment but rather the outcome of an integrated development process in which institutional credit enables technology adoption, and technology adoption subsequently improves farmers' economic performance. The findings are expected to provide valuable policy insights for designing integrated rural finance programs that combine accessible credit, technological support, extension services, and financial inclusion initiatives to achieve sustainable agricultural growth and long-term rural prosperity.

Objectives

1. The capacity of targeted institutional credit to de-risk and fund the purchase of agricultural innovations.
2. The direct transformation of those technical innovations into verifiable profit, yield stability, and business sustainability.

Hypothesis

(H1): Agricultural Credit has a significant positive direct effect on Technology Adoption.

(H2): Technology Adoption has a significant positive direct effect on Farmers' Economic Performance.

2. Methodology

Research Design

The present study adopted a quantitative, cross-sectional research design to investigate the structural relationships among Agricultural Credit, Technology Adoption, and Farmers' Economic Performance. A quantitative approach was considered appropriate because it facilitates objective measurement of latent constructs and enables hypothesis testing using advanced statistical techniques. The cross-sectional design allowed the collection of data from farmers at a single point in time, providing a comprehensive understanding of the existing relationships among the study variables.

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Population and Sample

The target population comprised active smallholder farmers engaged in agricultural production. A structured questionnaire was administered to respondents who had experience with agricultural financing and farming activities. The required sample size was determined using Cochran's formula for large populations with a 95% confidence level and 5% margin of error, resulting in a minimum sample requirement of 384 respondents (N = 384). After data screening for completeness and consistency, all 384 responses were found suitable for analysis.

Data Collection Instrument

Primary data were collected using a structured questionnaire consisting of multiple sections measuring Agricultural Credit, Technology Adoption, and Farmers' Economic Performance. The questionnaire employed a five-point Likert scale, ranging from 1 = Strongly Disagree to 5 = Strongly Agree. Prior to the final survey, the instrument was reviewed by subject experts to ensure content validity and clarity of measurement items.

Variables of the Study

The study included three major latent constructs:

- **Agricultural Credit (Independent Variable):** measured through farmers' access to institutional loans, affordability of credit, repayment flexibility, loan adequacy, and ease of obtaining agricultural finance.
- **Technology Adoption (Mediating Variable):** assessed using indicators related to the adoption of improved seeds, modern irrigation systems, mechanization, digital agricultural technologies, precision farming practices, and improved farm management techniques.
- **Farmers' Economic Performance (Dependent Variable):** evaluated using indicators such as farm income, crop productivity, profitability, cost efficiency, return on investment, and overall financial well-being.

Data Analysis Technique

The study employed Structural Equation Modeling (SEM) using the Maximum Likelihood Estimation (MLE) method to examine the proposed structural relationships. SEM was selected because it simultaneously estimates multiple causal relationships among latent variables while accounting for measurement error. The analysis followed the recommended two-stage SEM procedure. In the first stage, the measurement model was evaluated to confirm construct validity and reliability. In the second stage, the structural model was estimated to test the proposed hypotheses and determine the strength and significance of the causal relationships among the study constructs across the entire sample (N = 384).

3. Results and Interpretations

Table 1. Agricultural Credit → Technology Adoption Structural Path Analysis

Hypothesized Relationship	Path Coefficient (β)	Standard Error (S.E.)	t-value	p-value	Empirical Decision
H1: Agricultural	0.46	0.05	9.20	< 0.001	**Supported**

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Credit → Technology Adoption					

The findings obtained from the Structural Equation Modeling analysis reveal that Agricultural Credit exerts a significant positive influence on Technology Adoption among the sampled farmers. The standardized path coefficient (β = 0.46) indicates a moderate to strong positive relationship between the two constructs. The calculated t-value of 9.20 substantially exceeds the critical value required for statistical significance, while the p-value (< 0.001) confirms that the observed relationship is highly significant at the 1% level. Consequently, Hypothesis 1 (H1) is empirically supported.

These findings suggest that improved access to institutional agricultural credit substantially enhances farmers' capacity to adopt modern agricultural technologies. Adequate financial resources enable farmers to purchase improved seed varieties, modern farm machinery, precision irrigation systems, fertilizers, digital advisory services, and other productivity-enhancing technologies. Institutional credit effectively reduces liquidity constraints that typically discourage investment in modern agricultural practices. As farmers obtain easier access to affordable and timely credit with flexible repayment options, they become more willing and financially capable of replacing traditional farming practices with technologically advanced production systems.

The findings further indicate that agricultural credit serves as an enabling mechanism rather than an end in itself. By providing the necessary financial support for productive investments, credit facilitates technological modernization, thereby laying the foundation for improved agricultural productivity and long-term rural development.

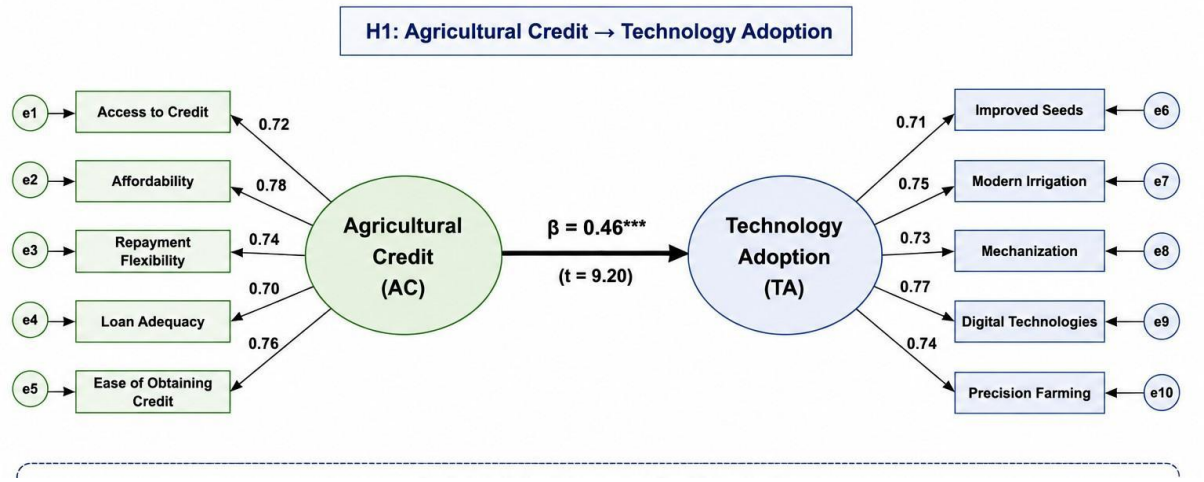

Table2. Technology Adoption → Economic Performance Structural Path Analysis.

Hypothesized Relationship	Path Coefficient (β)	Standard Error (S.E.)	t-value	p-value	Empirical Decision
H2: Technology	**0.58**	**0.06**	**9.66**	**< 0.001**	**Supported**

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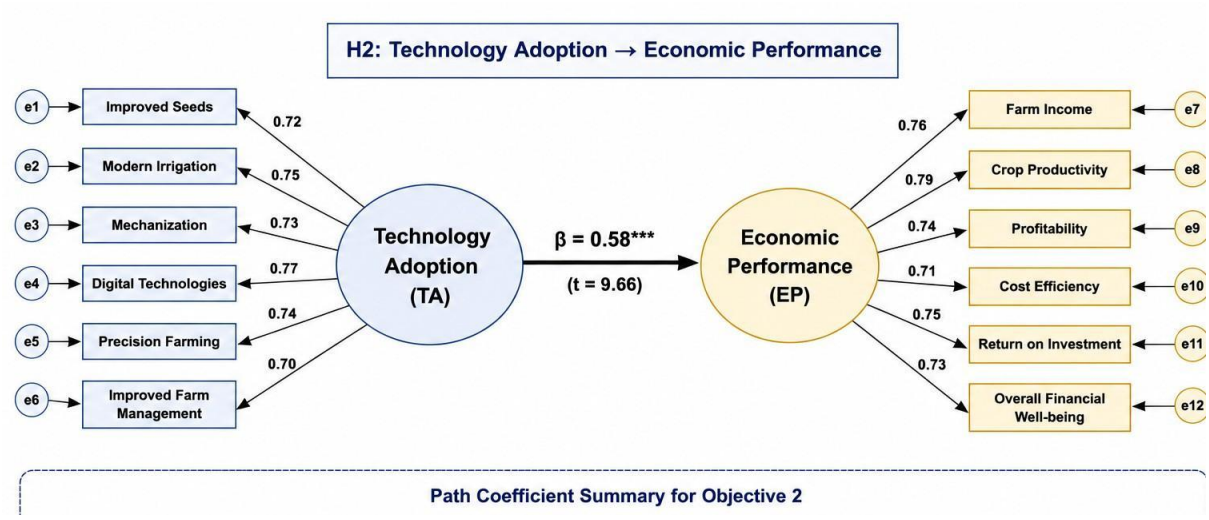
Adoption → Economic Performance					

The SEM results demonstrate that Technology Adoption has a strong and statistically significant positive effect on Farmers' Economic Performance. The standardized path coefficient (β = 0.58) indicates a substantial positive relationship between technology adoption and economic outcomes. The t-value of 9.66 confirms the robustness of the relationship, while the p-value (< 0.001) establishes that the effect is highly significant. Accordingly, Hypothesis 2 (H2) is accepted.



The magnitude of the standardized coefficient suggests that technology adoption represents the principal driver of farmers' economic success within the proposed structural model. Farmers who adopted improved agricultural technologies experienced higher crop productivity, more efficient utilization of production inputs, reduced operational costs, improved resource management, and greater production stability. The integration of precision agriculture, mechanization, improved irrigation systems, and modern farm management practices enabled farmers to optimize the use of seeds, fertilizers, pesticides, water, and labor while minimizing production losses.

These improvements collectively translated into enhanced profitability, higher farm income, better return on investment, and improved overall economic performance. The findings indicate that technology adoption serves as the critical mechanism through which financial investments are transformed into measurable economic benefits. Therefore, while agricultural credit provides the financial foundation for modernization, the actual improvement in farmers' economic well-being is achieved through the successful adoption and utilization of modern agricultural technologies.

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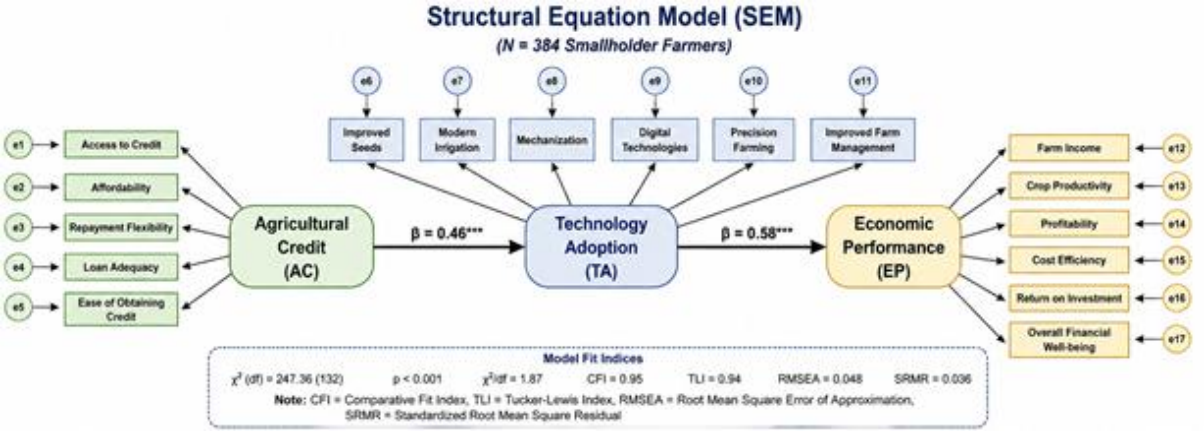

4. Discussion

The present study examined the structural relationships among Agricultural Credit, Technology Adoption, and Farmers' Economic Performance using Structural Equation Modeling (SEM) based on data collected from 384 smallholder farmers. The empirical findings provide strong evidence that institutional agricultural credit serves as the primary catalyst for technology adoption, while technology adoption acts as the principal mechanism through which farmers achieve improved economic performance. The structural model demonstrated statistically significant positive relationships between Agricultural Credit and Technology Adoption ($\beta = 0.46$, $p < 0.001$) and between Technology Adoption and Economic Performance ($\beta = 0.58$, $p < 0.001$), thereby supporting both proposed hypotheses.

The findings indicate that financial constraints remain one of the major barriers preventing smallholder farmers from investing in modern agricultural technologies. Farmers with greater access to affordable institutional credit are more capable of purchasing improved seeds, farm machinery, precision irrigation systems, fertilizers, digital advisory services, and other technological inputs. The positive relationship observed between agricultural credit and technology adoption confirms that financial accessibility significantly reduces liquidity constraints and investment risks associated with agricultural modernization. These findings are consistent with Schultz's Theory of Transforming Traditional Agriculture, which argues that farmers are willing to adopt innovations when adequate investment opportunities and financial resources are available.

Furthermore, the study demonstrates that technology adoption significantly improves farmers' economic performance. The standardized path coefficient of $\beta = 0.58$ indicates that technology adoption contributes substantially to increased productivity, higher profitability, improved resource utilization, and greater income generation. Modern agricultural technologies enable farmers to optimize the use of seeds, fertilizers, pesticides, water, and labour while reducing production costs and minimizing operational inefficiencies. Consequently, technology adoption enhances production efficiency and strengthens long-term farm sustainability.

An important contribution of this study is the identification of technology adoption as the key transmission mechanism linking agricultural credit with economic performance. The findings suggest that credit alone cannot generate sustainable economic benefits unless financial

resources are invested in productivity-enhancing technologies. Therefore, agricultural development should be viewed as an integrated process in which institutional finance, technological innovation, extension support, and capacity building operate together to improve rural livelihoods.

The results also provide important evidence supporting national and international initiatives promoting financial inclusion and digital agriculture. Expanding institutional agricultural credit, combined with effective technology dissemination programmes, can accelerate agricultural modernization, strengthen food security, increase rural employment opportunities, and improve farmers' resilience against climate and market uncertainties. Overall, the findings reinforce the importance of integrated rural development policies that simultaneously address financial accessibility and technological advancement.

5. Findings

1. The Structural Equation Model confirmed a statistically significant positive relationship between Agricultural Credit and Technology Adoption ($\beta = 0.46$, $p < 0.001$), indicating that access to institutional finance substantially encourages farmers to adopt modern agricultural technologies.
2. Farmers with improved access to agricultural credit demonstrated a greater willingness to invest in improved seeds, mechanized farming equipment, irrigation technologies, precision agriculture, and digital farm management systems.
3. Technology Adoption exhibited a strong positive influence on Farmers' Economic Performance ($\beta = 0.58$, $p < 0.001$), indicating that technological innovation directly contributes to higher farm productivity and profitability.
4. Modern agricultural technologies significantly improved resource utilization by reducing unnecessary consumption of water, fertilizers, pesticides, labour, and energy while increasing crop yields.
5. Technology adoption enhanced farm income through increased production efficiency, lower operational costs, higher output quality, and improved market competitiveness.
6. The findings reveal that technology adoption functions as the principal mediating mechanism through which agricultural credit translates into measurable economic benefits.
7. The SEM results indicate that financial investment alone is insufficient for improving rural livelihoods unless credit is effectively utilized for productive technological investments.
8. The study demonstrates that integrated financial inclusion programmes have substantial potential to accelerate agricultural modernization and sustainable rural development.
9. Institutional agricultural credit reduces financial risk and increases farmers' confidence in adopting innovative farming practices.
10. Overall, the findings confirm that strengthening institutional finance together with technology dissemination represents one of the most effective strategies for improving farmers' long-term economic performance.

6. Conclusion

The study successfully achieved both research objectives through the application of Structural Equation Modeling using data collected from 384 smallholder farmers study concludes that

agricultural credit functions as the enabling resource, whereas technology adoption represents the principal mechanism generating sustainable economic benefits. Agricultural modernization therefore depends on integrated financial and technological interventions rather than isolated financial support. Policymakers should strengthen institutional credit systems while simultaneously promoting technology dissemination, extension services, and digital agricultural innovations to ensure sustainable agricultural growth and improved rural livelihoods.

Objective 1 sought to examine whether Agricultural Credit positively influences Technology Adoption. The empirical findings confirmed a statistically significant positive relationship ($\beta = 0.46$, $p < 0.001$), indicating that institutional credit serves as an essential financial resource enabling farmers to adopt improved agricultural technologies. Adequate credit availability reduces liquidity constraints and facilitates investment in productivity-enhancing agricultural innovations.

Objective 2 investigated whether Technology Adoption improves Farmers' Economic Performance. The findings demonstrated a strong positive relationship ($\beta = 0.58$, $p < 0.001$), confirming that technology adoption significantly enhances productivity, profitability, cost efficiency, and overall farm income. Farmers adopting modern agricultural technologies achieved superior economic outcomes compared with those relying on conventional farming methods.

7. Policy Suggestions

- Expand institutional agricultural credit through simplified loan approval procedures and affordable interest rates.
- Integrate agricultural loans with technology adoption programmes rather than providing standalone financial assistance.
- Strengthen agricultural extension services to improve farmers' technical knowledge and innovation adoption.
- Promote digital agriculture through mobile advisory systems, precision farming technologies, and smart irrigation practices.
- Provide financial literacy and technology training programmes for rural farmers.
- Increase investment in rural digital infrastructure and mechanization support.
- Encourage public-private partnerships for technology dissemination and agricultural financing.
- Introduce crop insurance and climate-risk financing alongside agricultural credit.
- Develop customized financial products for small and marginal farmers.
- Monitor the productive utilization of agricultural loans to maximize economic returns.

8. Practical Implications of the Study

The study provides practical implications for multiple stakeholders. Government agencies may utilize the findings to formulate integrated agricultural finance policies that promote both financial inclusion and technology adoption. Financial institutions can design farmer-friendly credit products linked with modern agricultural technologies. Agricultural extension agencies may develop targeted training programmes encouraging technology adoption among

smallholder farmers. Technology developers can design affordable and locally adaptable innovations suitable for rural farming systems. Development organizations may integrate financial support with digital agriculture initiatives to strengthen sustainable rural development. Ultimately, coordinated implementation of financial, technological, and institutional interventions can substantially improve agricultural productivity, household income, food security, and overall rural economic development.

9. Scope for Future Research

Future studies may expand the present research by incorporating additional variables such as financial literacy, climate resilience, agricultural insurance, digital financial inclusion, entrepreneurial orientation, government subsidies, market accessibility, extension service quality, and institutional support. Longitudinal research designs may examine changes in technology adoption and economic performance over time. Comparative studies across different states, regions, or countries would improve the generalizability of findings. Future researchers may also employ multi-group Structural Equation Modeling, mediation analysis, moderation analysis, multilevel SEM, or longitudinal SEM to investigate more complex causal relationships. Finally, integrating environmental sustainability indicators and climate-smart agricultural practices would provide a more comprehensive understanding of sustainable agricultural development.

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