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Microfinance, Cold-Storage Infrastructure, and Market Linkages as Determinants of Profitability in Perishable Agricultural Enterprises: Evidence from Karnataka, India

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Abstract

Small-scale perishable agriculture businesses in Karnataka, India, still lose a considerable amount of production because of post-harvest spoiling problems, lack of capacity to store products in cold storage, and market fragmentation. The aim of this study is to examine the correlation among the profitability performance of 450 agriculture entrepreneurs who produce products that are easily perishable to the following: access to microfinance, availability of cold storage infrastructure, quality of market linkages, entrepreneurial training, access to government subsidy, and risk-management. Out of five districts, namely Hassan, Mandya, Chickballapur, Kolar, and Ramanagara, the entrepreneurs were selected. The researcher used Pearson's correlation, ordinary least squares multiple linear regression, one-way analysis of variance, and two-way analysis of variance and analyzed cross-sectional data obtained from primary surveys carried out from January to March 2026. The positive relation between all the six main variables and the profitability performance index is statistically justified at the significance level of $p < 0.05$. The whole model accounts for 73.1% of the variation in profitability performance ($R^2 = 0.731$, adjusted $R^2 = 0.726$, $F(9, 440) = 133.19$, $p < 0.001$). The interaction between the two factors is not significant, indicating that the variables have additive rather than synergistic effects on the data; the most powerful standardized predictor is quality of market-linkage ($\beta = 0.469$), followed by access to microfinance ($\beta = 0.346$) and infrastructure of cold-storage ($\beta = 0.331$). This study is subject to self-reporting and is cross-sectional; therefore, conclusions about relations and not causes or effects are made. Future research should apply quasi-experimental methods, such as difference-in-differences that leverage staggered introduction of microfinance and cold-chain services, adopt objective accounting variables, validate constructs at the item-level, and utilize panel designs to replicate such linkages and associations under stronger causal identification and in more Indian states.

Keywords: Microfinance, Perishable Agriculture, Cold Storage, Market Linkage, Profitability, Karnataka, Multiple Linear Regression, Analysis of Variance.

Introduction

Despite the reduction in the agriculture sector's share of GDP, it still generates the highest employment among all sectors in India. Horticultural commodities are particularly vulnerable to post-harvest losses because of their susceptibility to being sold to reliable buyers downstream, requiring rapid handling, refrigeration, and maintenance of proper post-harvest attributes.

Estimated perishable good losses are approximately one-sixth to one-third of the production nationwide. The barriers identified as challenges are smallholder financing, cold-chain capacity, and market integration. The small-holder dominated areas of Karnataka, which contribute approximately 60% of horticulture production in India, will be an ideal case study to explore the relationship between institutional, financial, and infrastructural factors and the profitability of the perishables business.

The Self-Help Group (SHG) -Bank Linkage Program (NABARD, 2019) has significantly boosted microfinance in India since the 1990s. It is a type of microfinance provided to uncollateralized households. While microcredit has been shown to facilitate the creation of businesses and the building of assets in a number of contexts, its application in value chains, where the product has a short shelf life, is questionable. Examples such as horticultural products are subject to price and weather volatility, require sufficient logistics, and deteriorate quickly; thus, credit alone is often insufficient and requires additional infrastructure and market access. The present study aimed to measure the interrelationships among the profitability performance of perishable agricultural entrepreneurs in Karnataka with respect to access to micro credit, cold storage facilities, the quality of market linkage, entrepreneurial training, access to government subsidies, and risk management practices.

This study helps to close three gaps in the literature. First, there have been few studies on microfinance and agriculture in India that have used perishable horticulture as an example of agriculture instead of the cereal-based or cash crop-based examples found in the majority of studies. Second, financial access does not form part of the comprehensive picture, and when it is considered in the few studies that explicitly mention financial access, it is treated separately. Third, there is a dearth of data at the district level for the horticulture sector in Karnataka from the perishables sub-segments, and most of the assessment on MSMEs only reports the results for MSMEs rather than focusing on perishables. To address these aspects, primary data were collected through purposive sampling of 450

agricultural entrepreneurs operating in five districts of Karnataka who were engaged in perishable horticultural activities. The sampling approach was chosen to ensure adequate representation of enterprises with varying levels of microfinance access and cold-storage exposure.

Related Works

Much has been written about microfinance and agricultural entrepreneurship, and the three schools of thought are outlined below. The first thread is on microfinance and self-help groups. S. K. M et al.(2025) demonstrate how male out-migration is restricted and jobs are generated in rural areas using two agri-social entrepreneurship enterprises in rural Karnataka through their qualitative case studies. There is limited and fragmented literature research on rural financial inclusion; most of which used quantitative methods of regression, either lacked strong theoretical basis or focused on a few developing countries, as per Keshari and Tiwari's extensive literature assessment between 2010 and 2025. The author's survey analysis of 426 women in SHG in three rural districts of Maharashtra reveals a positive association between physical banking services and access to credit, which helps improve the economic status of the household (Survase and Panda, 2026). The National Rural Livelihood Mission has been cited as one of the crucial policy connectivitiators in this relation. Karnataka's researchers (Karunakara Reddy and Hema, 2025) demonstrated increased efficiency of microfinance institutions when they adopted Fintech solutions for processing loans. Fidelis and Adeyeye (2025) developed and validated Rural Women Agripreneurship Empowerment Index (RWAEI) using confirmatory factor analysis and structural equation modelling with data from 1,146 rural women, communities in conflict-affected Northeastern, Nigeria. They proved that the labor employment and machine availability of enterprises are significant mediators between agripreneurship and empowerment. Kumari et al. (2025) surveyed 80 women involved in the mushroom, goat, dairy, and stitching businesses in Bhagalpur, Bihar. They discovered different types of businesses and their social and agro-economic empowerment was different.

Digital market connections and cold-chain infrastructure are the subject of the second thread. Andukuri et al.(2025) found in their study of 45 cold storages functioning in the chilli value chain in Guntur that smaller cold storages operate more efficiently using DEA. They also identified policy options, including cooperative models of storage and financing via warehouse receipts, as ways to make the sector more resilient. Joshi & Jain (2026) cite both primary and secondary sources of information to discuss the trends of cold chains in India in the years 2015–2025 and their correlation with the reduction in post-harvest losses. Rangar et al. (2025) authored the article titled ‘Cold-chain infrastructure for fruit and vegetable crops in India: challenges and prospects’. In a study, Chen et al. (2026) analyzed the provincial dynamics of grain production and fiscal instruments in China from 2007 to 2021 using panel kink and double-kink regressions to explore the impact of the non-linear relationship between policies. With the development of an infrastructure based on Hyperledger Fabric and the Internet of Things for cold-chain traceability, Duman and Aydoğan prove to be stable in the system, even under heavy transaction loads in 2025. Mehtab et al. (2026) review smart-farm-integrated cold thermal energy storage systems for solar-powered rural postharvest cooling. Gowda and Raj (2025) present a techno-economic paradigm to deal with cold storage intelligently and with reduced energy consumption in agricultural supply chains. With the data of 742 Kenyan smallholders, Nyamolo et al. (2025) show that co-designed socio-technical innovation bundles are impactful for farmers’ empowerment. Karanam and Lanka (2026) propose a three-echelon perishable food supply chain (PFSK) smart-contract architecture based on blockchain.

The third thread focuses on climate change, gender inequalities, and digital finance. By analyzing the China Labor-force Dynamics Survey (2014–2016), Chen and Dai (2026) discover that farmers’ income increases as a result of these digital inclusive finance services, and that local entrepreneurial dynamism enhances their links with the services, but that the use of the services is primarily among non-poor households with greater levels of digital competence. This study by Zhang and Song (2026) investigates

the factors influencing entrepreneurship choices and risk aversion of rural households in relation to digital financialization. Kipkoge et al. (2026) review the impact of microcredit on enhancing climate-smart practices and sustainable tomato production under arid and semi-arid conditions in Kenya and suggest offering microcredit services along with climate-indexed insurance contracts. The development of a viticulture multi-hazard risk-index insurance product is developed by Ardakani (2026) and developed by Agnusdei, Zouari and Miglietta (2026). This product features the use of drought, heat-stress, and frost indicators for a composite pricing structure. The study by Adamu, Garba, Umar, Baba, Murtala of determinants and patterns of women’s participation in agricultural value chains in Jigawa, Nigeria, shows that human capital investment is an important source of increased participation depth for women, in addition to access to credit. Based on the quantile regression analyses and focus group data from 511 households in Rejaf Payam, South Sudan, Sassi (2026) concludes that households with higher levels of women’s empowerment in agriculture tended to be more food secure. However, the advantages are restricted by structural disadvantages, such as spatial disadvantages and constraining gender norms.

In the totality of the literature encountered, a number of gaps are found. First, multi-sector models that integrate both microfinance and cold storage facilities and market linkages, in quality, entrepreneurial training, subsidies access, and risk management into one profitability-performance assessment are scarce. Second, district-level evidence in Karnataka on perishable horticulture is still limited. Third, the existing studies are based mainly on single-equation or bivariate analysis, lacking the adjustment of firm-specific heterogeneity. The above issues have been addressed in the present research by estimating a multivariate regression model with one-way and two-way ANOVA on the primary data collected from 450 perishable agricultural entrepreneurs in five districts of Karnataka.

Hypotheses

This study presents six directional hypotheses derived from the resource-based view of the firm (Barney, 1991), the credit-rationing paradigm of

financial intermediation with imperfect information (Stiglitz & Weiss, 1981), and the sustainable livelihoods framework (Scoones, 1998; Department for International Development, 1999). A firm-level competitive advantage is specified to be dependent on the capacity of the firm to convert a certain resource into valuable, rare, inimitable, and non-substitutable factors; with the former two being tangible assets and the latter two intangible assets, as in the case of cold-storage capacity and market linkages. According to the credit-rationing framework, the poor will have tight credit restrictions when credit is not backed by sufficient collateral and an exogenous increase in microfinance access should be linked to an increase in investment and profitability. The sustainable livelihoods framework views the welfare of the household as a function of five types of capital – human, social, natural, physical, and financial – in the context of vulnerability processes: shocks, trends, and seasonality.

- H1: Access to microfinance enhances the profitability performance of perishable agricultural entrepreneurs.
- H2: Proficient performance in cold-storage and post-harvest facilities is advanced with prosperity performance.
- H3: “Profitability performance is positively related to market-linkage quality”.
- H4: Entrepreneurial training positively influences the profitability of enterprises.
- H5: The association between government subsidy access and profitability is positive and significant.
- H6: There is a positive relationship between risk management practices and profitability performance.

Control variables include firm age, owner education, and years of agricultural entrepreneurial experience, as these factors have independent effects on firm profitability.

Methodology

Research Design

This study is a quantitative, descriptive research with a positivist epistemological approach. The design is suitable for the analysis of conditional relationships between two or more explanatory variables and one continuous profitability-

performance variable. As the design is cross-sectional and non-experimental, these estimates are viewed as associations, not as causal effects. The data were collected via a structured questionnaire from the selected districts of Karnataka among the perishable agricultural entrepreneurs during the harvesting season 2026.

Sample and Data Generation

The target population was small and medium-scale registered perishable farming enterprises with horticultural crops in cultivation, processing, and/or trading sectors in Karnataka. Fieldwork was conducted from January to March 2026. Purposive sampling was preferred over random sampling because a comprehensive sampling frame of all perishable agricultural enterprises in the five districts was not available, and the study specifically required variation in microfinance access and cold-storage exposure. These five districts (Hassan, Mandya, Chickballapur, Kolar, and Ramanagara) were chosen because of their relevance to horticultural and perishable commodity activities. A total of 450 entrepreneurs were reached within the districts, with 90 entrepreneurs per district providing valid responses. The sampling method was purposive; therefore, the findings of the study should be analyzed as an analytical subpopulation representative of the firm profile selected instead of the representatives of all companies in Karnataka.

Variables and Instrumentation

Table 1 describes the research variables, their definitions, and measurement scales. The dependent variable is termed the Profitability Performance Index (PPI) as this avoids any explicit allusion to profit-maximising behavior. All six dimensions are rated on five-point Likert-type scales (range from 1 to 5, corresponding to strongly disagree, neutral, and agree in that order), except for Government Subsidy Access, which is dichotomously coded (1 = strongly disagree/don't know/0 = yes) based on confirmed access to PM-KISAN or State-Level Horticultural Subsidy. These control variables were quantified in years (or as ordinals) for enterprise-specific variation: firm age, owner education, and years of experience.

Table 1 Definition and Measurement of Study Variables

Variable	Notation	Description	Measurement Scale
Profitability Performance Index	PPI	Composite index of profitability performance (margins, growth, efficiency)	Continuous (0–100)
Microfinance Access	MFA	Extent of utilisation of microcredit/SHG loans for enterprise operations	Likert 1–5
Cold-Storage Infrastructure	CSI	Availability and quality of cold-chain and post-harvest facilities	Likert 1–5
Market-Linkage Quality	MLQ	Strength of contractual and digital ties with wholesalers and exporters	Likert 1–5
Entrepreneurial Training	ET	Participation in agri-business and technical skill programmes	Likert 1–5
Government Subsidy Access	GSA	Receipt of PM-KISAN or state horticulture subsidies	Binary (0/1)
Risk-Management Practices	RMP	Use of insurance, diversification, and contingency planning	Likert 1–5
Firm Age	FAge	Number of years since enterprise establishment	Years (2–25)
Owner Education	OEdu	Highest formal educational qualification attained	Ordinal 1–5
Years of Experience	YExp	Total years of entrepreneurial experience in agriculture	Years (1–35)

Construction of the Profitability Performance Index

The three metrics considered in a company's Profitability Performance Index are its self-reported net profit margin, sales growth, and cost efficiency. Because in this study, growth, profitability, and cost efficiency have all been given the same importance as indicators of enterprise-level financial success, these dimensions are scaled and weighted accordingly. Therefore, the index should not be used to calculate a net profit directly, but rather as an indication of overall profitability or performance. Future item-level validation work should attend to a reporting limitation in archived data, in that it does not include the item-level responses needed to re-calculate Cronbach's alpha, composite reliability, average variance extracted, or Harman's single-factor test. This has been recognized in the results interpretation.

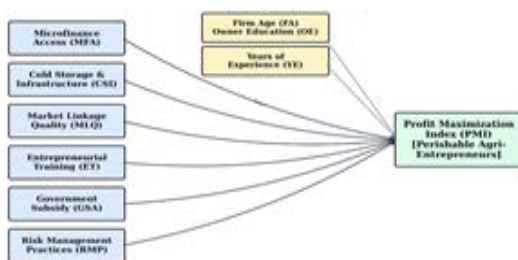


Figure 1 Conceptual Research Framework Depicting Hypothesized Influences on Profitability Performance among Perishable Agricultural Entrepreneurs

Statistical Analysis

Data analysis was performed using Python packages (NumPy and Pandas) with a two-tailed test, where the significance level was set at $\alpha = 0.05$. Descriptive statistics, such as mean, standard deviation, skewness, and kurtosis, were computed to study the distributional properties. Second, we determined whether there were any indications of excessive multicollinearity and/or bivariate linear relationships by estimating the Pearson product-moment correlation. Third, assuming that all other variables were constant, we applied ordinary least squares (OLS) multiple linear regression to estimate the conditional connections that each predictor had with the Profitability Performance Index (PPI). Variance Inflation Factors (VIFs) were re-evaluated in the archived data to ensure that there was no multicollinearity present. The fourth step was a one-way and two-way analysis of variance (ANOVA) to compare the mean values of profitability performance between the cold-storage and microfinance-access strata.

Equation (1). OLS Regression Model

$$\text{PPI}_i = \beta_0 + \beta_1 \text{MFA}_i + \beta_2 \text{CSI}_i + \beta_3 \text{MLQ}_i + \beta_4 \text{ET}_i + \beta_5 \text{GSA}_i + \beta_6 \text{RMP}_i + \beta_7 \text{FAge}_i + \beta_8 \text{OEdu}_i + \beta_9 \text{YExp}_i + \varepsilon_i$$

In this context, PPI stands for Respondent i 's Profitability Performance Index, β_0 as the intercept,

β_1 to β_6 as the coefficients for the six focal predictors (MFA, CSI, MLQ, ET, GSA, and RMP), β_7 to β_9 as the coefficients for the three control variables (FAge, OEdu, and YExp), and ϵ_i as the stochastic error term.

Equation (2). One-way ANOVA F-Statistic.

$$F = (MS_{\text{between}}) / (MS_{\text{within}}) = (SS_{\text{between}} / df_{\text{between}}) / (SS_{\text{within}} / df_{\text{within}})$$

The Fisher's Snedecor statistic is obtained by comparing the treatment differences in the total sample, SS_{between} , to the differences in the values within each group, SS_{within} , using the difference between the degrees of freedom for each, df_{between} and df_{within} , respectively: $F = SS_{\text{between}} / (df_{\text{between}}) / SS_{\text{within}} / (df_{\text{within}})$. The mean squares between and within groups are indicated by MS_{between} and MS_{within} , respectively. The suitable Sums of Squares are SS_{between} or SS_{within} . Between-group Variation (df_{between}) and Within-group Variation (df_{within}) are represented

by the degrees of freedom of between and within groups, respectively.

Results and Discussion

Sample Characteristics

All ordinal and continuous variables have descriptive statistics shown in Table 2. The profitability performance index has a highly scored and somewhat left-skewed distribution, with an average of 86.78 (SD= 10.08, min= 53.89, max = 98.00). The entrepreneurial training score shows the lowest mean score of 2.72 (SD = 1.19) out of the three independent variables, while the market-linkage quality score has the highest mean score of 3.19 (SD = 1.18), indicating that skill-development programmes could be scaled up. With a mean of 0.48, government subsidy access is equally distributed, showing that subsidy systems are somewhat penetrated. No normality diagnostics may be used to summarize Government Subsidy Access since it is binary.

Table 2 Descriptive Statistics of Study Variables (N = 450)

Variable	Mean	SD	Min	Max	Skewness	Kurtosis
Profitability Performance Index	86.78	10.08	53.89	98.00	-0.652	-0.364
Microfinance Access	2.96	1.16	1.00	5.00	-0.148	-0.816
Cold-Storage Infrastructure	2.76	1.11	1.00	5.00	0.268	-0.578
Market-Linkage Quality	3.19	1.18	1.00	5.00	-0.237	-0.770
Entrepreneurial Training	2.72	1.19	1.00	5.00	0.091	-0.901
Govt. Subsidy Access	0.48	0.50	0.00	1.00	0.089	-2.001
Risk-Management Practices	2.85	1.18	1.00	5.00	0.027	-0.816
Firm Age (years)	12.01	4.15	2.00	21.00	-0.021	-0.896
Owner Education	2.99	0.98	1.00	5.00	0.012	-0.751
Years of Experience	16.20	6.97	1.00	31.00	0.008	-0.924

The empirical distribution of the Profitability Performance Index is shown in Figure 2. The histogram shows that there are more respondents at the extremes of either end of the histogram and the kernel density overlaid, thus suggesting a ceiling effect that should be considered when interpreting any regression results.

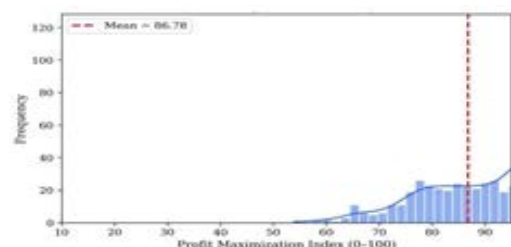


Figure 2 Histogram and Kernel-density Estimate of the Profitability Performance Index (n = 450)

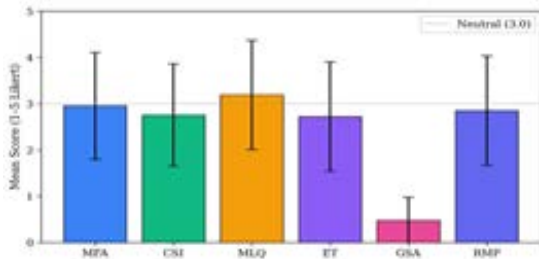


Figure 3 Mean Scores and Standard Deviations of the Six Independent Variables Measured on a Five-point Likert Scale

Five-point Likert scales were used for all the independent variables, and the standard deviation and mean scores for each are presented in Figure 3. Considering the sample, there is an opportunity to expand the breadth of skill-building programs

because Market-Linkage Quality utilized the highest score ($M = 3.19$) and Entrepreneurial training utilized the lowest score ($M = 2.72$).

Pearson Correlation Matrix

The 10 research variables presented in Table 3 show the Pearson correlation values. The Profitability Performance Index with all six focus predators has a positive correlation of $r = 0.547$ ($p < 0.001$) for Market-Linkage Quality and a statistically significant positive correlation of $r = 0.080$ ($p < 0.05$) with Government Subsidy Access. Microfinance Access ($r = 0.348$, $p < 0.001$) and profitability performance ($r = 0.385$, $p < 0.001$) have the highest bivariate correlations that follow profitability performance and market-linkage quality. The recomputing of the VIF reveals that there is no multivariate collinearity and the inter-predictor correlations are also not large.

Table 3 Pearson Correlation Matrix of Study Constructs (N = 450)

Variable	1	2	3	4	5	6	7	8	9	10
1. Profit Index	1.000									
2. Microfinance Access	0.348***	1.000								
3. Cold- Storage Infra	0.385***	0.251***	1.000							
4. Market-Linkage Qual	0.547***	0.322***	0.308***	1.000						
5. Entrepreneurial Train	0.212***	0.208***	0.215***	0.186***	1.000					
6. Govt. Subsidy	0.080*	0.372***	0.174***	0.186***	0.161***	1.000				
7. Risk Management	0.345***	0.216***	0.274***	0.253***	0.303***	0.170***	1.000			
8. Firm Age	0.239***	0.089*	0.086*	0.125**	0.045	0.134***	0.066	1.000		
9. Owner Education	0.139***	0.146***	0.109*	0.098*	0.191***	0.083*	0.118**	0.198***	1.000	
10. Experience	0.266***	0.076	0.011	0.051	-0.009	0.049	0.050	0.348***	0.173***	1.000

Note. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ (two-tailed).

The Pearson correlations are represented in Figure 4, with darker colors representing more favorable relationships. The figure is complemented by the ranking chart, which illustrates a tight tie between profit and market linkage quality. Relatively moderate inter-predictor correlation gives a stable regression.



Figure 4 Visual Heatmap of Pearson Correlations among Study Constructs

Multiple Linear Regression Results

In Table 4, we can view the summary of the OLS regression results. The adjusted R^2 is 0.726 and the R^2 is 0.731 for the model when the nine predictors are considered together, suggesting that the predictors explain about 73% of the variation in the Profitability Performance Index. The overall F-statistic for the fitted model is 133.19 with a significance level of < 0.001 , indicating that the model is statistically significant. All six coefficients indicating the focal predictors are positive and significant ($p < 0.05$), which supports the respective hypotheses (H1-H6). Microfinance Access ($\beta = 0.346$, $B = 3.019$, $p < 0.001$) and Cold-Storage Infrastructure ($\beta = 0.331$, $B = 3.008$, $p < 0.001$) are the subsequent strongest standardized predictors, with Market-Linkage Quality emerging as the most powerful ($H = 0.469$, $B = 4.000$, $p < 0.001$). Additionally, there is a positive contribution from risk-management practices

($\beta = 0.267$, $B = 2.278$, $p < 0.001$), entrepreneurial training ($\beta = 0.226$, $B = 1.919$, $p < 0.001$), and access to government subsidies ($\beta = 0.069$, $B = 1.390$, $p = 0.006$).

Profitability performance was positively correlated with the following control variables: firm age ($\beta = 0.138$, $B = 0.334$, $p < 0.001$), owner education ($\beta = 0.113$, $B = 1.168$, $p < 0.001$), and years of experience ($\beta = 0.130$, $B = 0.188$, $p < 0.001$). The VIF values for the selected variables are shown to be calculated again, which lies in an acceptable range of 1.008 to 1.179, indicating that multicollinearity is not and is not likely to affect the parameter estimations.

Table 7 presents the nested specification comparison. In the microfinance-only model, the core finance-infrastructure-market model boosts R^2 from 0.121 to 0.534; in the entire model, R^2 climbs to 0.731 and RMSE decreases to 5.22.

Table 4 Multiple Linear Regression Results (Dependent Variable: Profitability Performance Index)

Variable	B	SE	β	t	p-value	VIF
(Constant)	33.859	1.707	—	19.834	< 0.001	—
Microfinance Access	3.019	0.218	0.346	13.876	< 0.001	1.019
Cold-Storage Infrastructure	3.009	0.226	0.331	13.297	< 0.001	1.013
Market-Linkage Quality	4.001	0.214	0.469	18.674	< 0.001	1.035
Entrepreneurial Training	1.919	0.211	0.226	9.091	< 0.001	1.008
Government Subsidy Access	1.390	0.502	0.069	2.771	0.006	1.015
Risk-Management Practices	2.278	0.213	0.267	10.715	< 0.001	1.020
Firm Age	0.334	0.065	0.138	5.178	< 0.001	1.157
Owner Education	1.168	0.260	0.113	4.494	< 0.001	1.044
Years of Experience	0.188	0.039	0.130	4.853	< 0.001	1.179

Note. $R^2 = 0.731$; Adjusted $R^2 = 0.726$; $F(9, 440) = 133.19$, $p < 0.001$. B = unstandardised coefficient; β = standardised coefficient; SE = standard error; VIF = variance inflation factor.

The Profitability Performance Index values that were fitted are shown in Figure 5, along with the observed values. Data are cross-sectional and self-reports, meaning that they require careful interpretation, yet clustering is a great deal tighter than the 45-degree reference line, consistent with an R^2 of the model of 0.731 (also meeting the lower limits of the model's R) for acceptable prediction accuracy.

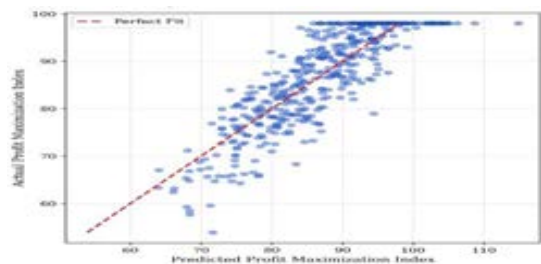


Figure 5 Scatter Plot of Actual Versus Predicted Profitability Performance Index Values ($R^2 = 0.731$)

The scatter plot in Figure 6 shows the residual plot of the data. The next plot is a residual plot for the data in Figure 6. The assumptions of homoscedasticity and linearity are reasonably met: the points are evenly spread out both above and below the zero line, and there are no obvious funnel patterns.

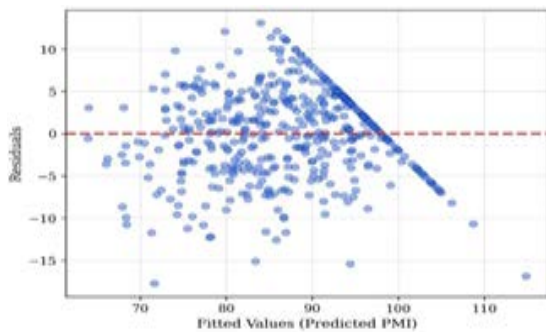


Figure 6 Residual Plot Illustrating the Distribution of Residuals Against Fitted Values

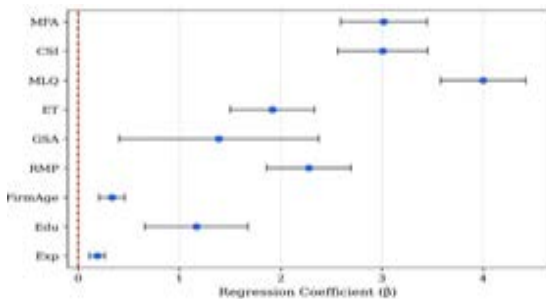


Figure 7 Forest Plot of Standardised Regression Coefficients with 95% Confidence Intervals

The forest plot of the standardized regression coefficients and their 95% confidence intervals is shown in Figure 7. The three largest and most significant creditors of the standardized variables with non-zero confidence intervals are market-linkage quality, access to microfinance services, and cold-storage facilities.

Analysis of Variance

Table 5 compares the profitability performance index of these three groups using a one-way analysis of variance (ANOVA) based on tertile splits of microfinance access. As can be seen from the results, the variations in groups of people who obtain microfinance account for around 8.7% of the variations in profitability performance ($F(2, 447) = 21.34, p < 0.001, \eta^2 = 0.087$). In the Low ($M = 83.07, SD = 10.67, n = 151$), Medium ($M = 88.04, SD = 9.35, n = 264$), and High ($M = 93.30, SD = 6.75, n = 35$) access groups, the means of the groups increase.

The two-way analysis of variance (Table 6) was conducted using microfinance-Access Group and Cold-Storage Level (high-non-high) as fixed variables. With $F(2, 444) = 0.89$ and $p = 0.413$, we can see that both main effects are statistically significant, but the interaction term is not. In this specific dataset, the relationship between the correlations between MFI access and cold storage does not seem to be complementary, but rather additive. These ANOVA results support the regression results, as they do not provide any false causalities or counter-interaction relationships.

Table 5 One-Way ANOVA: Profitability Performance Index by Microfinance-Access Group

Source	SS	df	MS	F	p-value	η^2
Between Groups	3976.69	2	1988.35	21.34	< 0.001	0.087
Within Groups	41643.87	447	93.16			
Total	45620.56	449				

Table 6 Two-Way ANOVA: Profitability Performance Index by Microfinance Group and Cold-Storage Level

Source	SS	df	MS	F	p-value
Microfinance Group	3827.91	2	1913.95	22.65	< 0.001
Cold-Storage Level	3981.83	1	3981.83	47.13	< 0.001
Group $\times$ Storage	149.85	2	74.92	0.89	0.413
Error	37512.20	444	84.49		
Corrected Total	45620.56	449			

The profitability performance index was box-plotted for the three tertiles of access to microfinance (see Figure 8). As illustrated in Table 5, there is no overlap in the interquartile ranges, and, starting with the Low group, monotonical increases of the median profit levels across the groups. As seen in Table 5, the significant omnibus F-test has no overlap in interquartile range and shows increasing monotonicity of median profit level starting at low site.

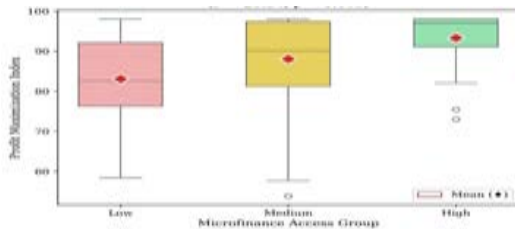


Figure 8 Boxplot of Profitability Performance Index Across Microfinance-access Tertiles (Low, Medium, High) Diamond Markers Denote Group Means

Discussions

Based on the regression results, Market-Linkage Quality (0.469) was in the first place, followed by Microfinance Access (0.346) and Cold-Storage Infrastructure (0.331). The resource-based view (RBV) theory (Barney, 1991) considers relational and intangible resources as sources of competitive advantage, and the case study findings in Karnataka reveal that agri-social enterprises rely on relational downstream resources for price realization (S. K. M. et al., 2025). The tight connection with market linkages is in line with this. Previous cross-county studies in China have demonstrated that the adoption of digital finance has further enhanced its income benefits in counties with entrepreneurial dynamism (Chen & Dai, 2026). This finding is consistent with the findings.

The relationships among cold-storage infrastructure and microfinance access are both strong and positive ($B > 3.0$). Nonetheless, the non-significant two-way ANOVA interaction fails to show that there is a positive interaction between the

returns from microfinance and cold storage exposure. Thus, it seems that post-harvest infrastructure and financial access are complementary and independent pieces in an ecosystem that facilitates profitability. Scoones (1998) reading resonates with Stiglitz and Weiss' (1981) prediction of the tightness of the credit-rationing constraint on those with decreasing collateral, and claims that physical and financial capital are complementary but different dimensions of the endowment. Thus, an extra push in microfinance should go hand-in-hand with a corresponding increase in the investment and earnings of enterprises.

The effects of entrepreneurial training and risk management practices are also evident. As documented in the climate-indexed insurance literature (Kipkoge et al., 2026; Ardakani et al., 2026), this sector is beset by volatilities, pest infestations, and climatic shocks. Cultivar and component diversification, purchase of weather-indexed insurance, and contingency reserves are recommended to avoid risk from extra-profit outcomes. Investments in human capital are converted to real profits through training that imparts knowledge on record-keeping, digital marketing, and post-harvest handling of fruits. This is in line with the tradition of extension as an integral component of the credit line, as suggested by Feder et al. (2010), and coupled with recent empirical findings in rural conflict-stricken areas of Nigeria indicating that access to machines, in addition to human capital and not just credit alone, is key to empowerment (Adamu et al., 2026).

All four of the layered model specifications were estimated from the same dataset and are compared in Table 7. The analysis indicated that the addition of the fundamental finance-infrastructure-market predictors significantly increased the model fit as compared to models containing controls and microfinance alone models, which explained a smaller portion of the variance in profitability and performance. The entire model demonstrates that training, access to subsidies, risk management, and controls are all important contributors, other than the key predictors.

Table 7 Model Specification Comparison for Profitability-Performance Prediction

Model	Predictor set	N	R ²	Adj. R ²	ΔR^2	F-value	RMSE	MAE	AIC	BIC
M1 Controls only	Firm age, owner education, years of experience	450	0.103	0.097	—	17.14	9.53	8.00	2037.39	2053.83
M2 Microfinance only	Microfinance access	450	0.121	0.119	0.018	61.79	9.44	7.72	2024.35	2032.57
M3 Core model	Microfinance access, cold-storage infrastructure, market-linkage quality	450	0.534	0.531	0.413	170.63	6.87	5.51	1742.50	1758.94
M4 Full model	Core model + entrepreneurial training, government subsidy access, risk-management practices, and controls	450	0.731	0.726	0.197	133.19	5.22	4.19	1506.80	1547.89

Note. ΔR^2 is calculated relative to the preceding model. RMSE = root mean squared error; MAE = mean absolute error; AIC = Akaike information criterion; BIC = Bayesian information criterion. Lower RMSE, MAE, AIC, and BIC indicate better model performance.

Theoretical Contributions

There are three theoretic papers below. First, the research contributes to resource-based theories (Barney, 1991) by showing how the profitability performance of concrete infrastructure resources, such as cold storage facilities, varies, while intangible resources such as relations and resources in the market and institutional resources such as microfinance and subsidies do not. This is consistent with the arguments for credit restriction when faced with incomplete information and confirms that access to microfinance should be viewed within a broader set of policies and programs, including training and market access policies (Stiglitz & Weiss, 1981). Finally, the study joins the previous work on sustainable livelihoods (Scoones, 1998; Department for International Development, 1999) by introducing the notion of the profitability of performance as an outcome shaped by multiple capital stocks, both financial and non-financial, such as physical, human, and social.

Practical and Policy Implications

These findings have implications for microfinance institutions. They can offer more than just disbursement, such as loan services, cold storage, risk management training, and the process of linking the digital market. The Karnataka government can consider augmenting the Agriculture Infrastructure Fund (AIF) to provide direct support

for solar-powered cold storage for microfinance customers after absorbing this complementarity in the regression. State horticulture departments should focus their efforts on forming producer companies and facilitating contract farming to improve the quality of market links and thus maximize their coefficient in the profit equation. The SHG-Bank Linkage Program (SHG-BLP) organized by NABARD, in the capacity of an operational platform, at the national level, while at the national level, cold-chain grants under the Pradhan Mantri Kisan Sampada Yojana are organized by the Ministry of Agriculture.

Suggestions

There are five specific recommendations. A first step to simplifying the loan products available through MFIs in Karnataka, for microfinance servicing the perishable horticulture industry, should be in rethinking the loan products in terms of bundled provision of services. For instance, for every loan cycle, an affiliate for refrigerated storage should be a component, an on-boarding module for digital marketplace platforms should be included, as well as a brief module of price-risk hedging. In addition, Andukuri et al. (2025) suggested that the District & State Horticulture office should set up a miniature scaled, smaller, efficient, publicized cold-chain center in the districts of Hassan, Mandya, Chickballapur, Kolar, and Ramanagara. Third, having regard to the low mean score of the sample in Entrepreneurial

Training, financial resources may be directed towards short tenure and modular entrepreneurial new business initiatives training courses focused on accountancy and digital marketing along with post-harvest management. Fourth, district-level banks and NABARD could expand the weather-indexed insurance pilots for banana, tomato, and grape belts (based on the multi-hazard risk-index frameworks developed in the viticulture insurance literature; Ardakani et al., 2026). Fifthly, in the same spirit of NRLM as a go-between between rural economic development and physical banking services of Survase and Panda (2026), the Karnataka State Rural Livelihoods Mission and National Rural Livelihoods Mission should tie up and involve SHG members in formalized market contracts.

Limitations and Future Research

There are four restrictions on the research. First, it is not possible to draw any conclusions about cause and effect from a cross-sectional design. As a result, it is not out of the question that more lucrative businesses would have better market connections and bigger loans. Second, there is the possibility of common-method bias due to the use of self-reported scales to assess several dimensions. As this dataset only contained scale scores, it was not possible to make reconcomputations of reliability, convergent validity, and Harman single-factor diagnostics. Lastly, the purposive selection method proved successful but might not work for other states or agro-ecological zones in India. Fourth, the high score of the profitability index indicates a potential ceiling effect in some aspects, as variance among firms with good performance may be reduced.

Future work based on microfinance and infrastructure configurations that could provide a cleaner causal identification and other states in India should focus on using natural-experiment approaches such as difference-in-differences and exogenous diffusion of microfinance or infrastructure rollouts, item-level construct validation, objective accounting records, and longitudinal panel designs to re-establish the associations described here under more likely causal identification and in other Indian states. These items might be useful in increasing the construct and policy relevance of the survey for researchers and

could be incorporated in a mixed-methods approach with qualitative interviews and observational data on cold-chain activities.

Conclusion

Microfinance access and its link with infrastructure, institutional, market, and managerial variables were the main foci of this study, which aimed to assess profitability performance among perishable agricultural businesses in Karnataka. The data from 450 respondents and a set of statistical techniques support each of the six hypotheses, which equate access to microfinance, access to cold holding, credit to entrepreneurial training, credit to government subsidies, and credit to risk management practices to improved profitability performance. All of the regression model accounts for 73.1% of the Profitability Performance Index. Infrastructure for cold storage, market linkages quality, and access to microfinance are the best performing standardized predictors. The results of the two-way ANOVA indicate that the main effects of microfinance access and cold-storage level are statistically significant, while the interaction term is not significant ($F = 0.89$, $p = 0.413$). This suggests that the two factors exert additive rather than synergistic effects on profitability performance in the present sample. The absence of a significant interaction does not rule out the possibility of complementary benefits in other contexts or under different operational conditions; however, no synergistic effect was detected in this dataset.

This study makes three new contributions. It reveals, from a resource-based perspective, the significance of cold-storage infrastructure, but the importance of relational resources (market linkages) and institutional resources (micro-finance, subsidies) is also evident. While accounting for firm maturity and human capital, the micro-level analysis of the data from Karnataka reveals that having a microfinance facility is positively associated with the profitability of the firms, thus complementing the credit-rationing body of literature on imperfect information in financial intermediation. It brings together a multi-dimensional outcome shaped by the financial, physical, human, and social capital endowments that it provides, capturing an

actualization of profitability performance into the sustainable lifestyles framework.

These results should be interpreted with caution. It should be emphasized that the regression coefficients and ANOVA contrasts should be interpreted as conditional relationships and not as causal effects given the characteristics of the data (cross-sectional, self-reported, purposively collected). An important note: We did not look for a synergy effect in addition to the two main effects in our two-way ANOVA model. Thus, while the interaction between microfinance and cold-storage is not significant, this does not imply that there is no additional effect if the two are combined. This conceptual framework provides the basis for longitudinally replicating the research project, item-validating for replications, and quasi-experimentally replicating the research.

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