

Bridging Technological Innovation and Human Resource Practices: an Empirical Study of Operational Performance in Cooperative and Private Sugar Factories

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ABSTRACT

Technological innovation and human resource (HR) practices are increasingly viewed as complementary drivers of organizational performance, yet their joint effect remains under-examined in traditional agro-processing settings. This study examines the relationship between technological innovation adoption, HR practices, and operational performance among 393 employees across six cooperative and private sugar factories in Western Maharashtra, India. Using a validated 120-item questionnaire and a cross-sectional design, three hypotheses were tested via Pearson correlation, multiple regression, and one-way ANOVA. Innovation adoption showed a strong positive relationship with operational efficiency ($r = .647, p < .001$), HR practices a moderate positive relationship with innovation adoption ($r = .529, p < .001$), and integrated HR-innovation practices a strong positive relationship with organizational performance ($r = .626, p < .001$). A combined regression model explained 47.0% of the variance in organizational performance, with innovation adoption as the dominant predictor ($\beta = .602$). Ownership structure did not significantly differentiate any of the four constructs, suggesting innovation-HR dynamics operate similarly across governance forms. The study proposes an integration framework linking HR practices and innovation adoption, offering practical implications for sugar-industry managers and policymakers aiming to strengthen performance through coordinated HR and technology strategies.

Keywords: technological innovation adoption, human resource practices, organizational performance, cooperative sugar factories, agro-processing industry, India.

INTRODUCTION

The sugar industry occupies a distinctive position in the Indian rural economy, particularly in Maharashtra, where cooperative sugar factories have historically anchored agrarian livelihoods since the commissioning of Asia's first cooperative sugar mill in the state in 1950. Political-economy research on this sector has long noted that the cooperative sugar factories of Western Maharashtra combine dense local embeddedness with distinctive governance features — concentrated control rights among elected boards, seasonal and often informal labour arrangements, and close linkages to farmer-members — that together shape both efficiency and equity outcomes in ways not fully captured by conventional investor-owned-firm models (Banerjee et al., 2001; Lalwani, 2008).

In recent years, however, the sector has faced mounting pressure to modernize. Fluctuating global sugar prices, rising input costs, environmental compliance requirements, and the broader wave of Industry 4.0 technologies — automation, digitalization, sustainable-energy systems, and integrated IT/ERP infrastructure — have compelled both cooperative and private sugar factories to reassess their operating models. Recent work applying an extended Technology-Organization-Environment framework specifically to the sugar sector in developing economies has shown that process readiness, workforce capability, and stakeholder collaboration across the value chain are decisive, and often underestimated, factors in whether such technologies are successfully absorbed (Pandey et al., 2025). At the same time, the sector's cooperative segment continues to grapple with governance constraints and limited professionalization of management, while commentary on Human Resource Development (HRD) in cooperative sugar units has emphasized that training, performance appraisal, and quality-of-work-life improvements remain underdeveloped relative to the pace of technological change facing the industry.

A substantial body of literature has separately examined technology adoption in agro-industrial settings (Pandey et al., 2025) and the role of HR practices in organizational and innovation outcomes (Alkhalaf & Al-Tabbaa, 2024; Bos-Nehles et al., 2023; Nguyen & Dao, 2023), but comparatively few empirical studies have examined how these two domains interact within a single workforce, and fewer still have done so in the specific institutional context of cooperative-versus-private ownership in a labour-intensive, seasonal agro-processing industry such as

sugar manufacturing. This gap is theoretically consequential because technology adoption is rarely a purely technical process: its success depends substantially on the human systems, recruitment and training practices, and change-readiness of the workforce implementing it (Armenakis et al., 1993; Holt et al., 2007; Mishra & Pathak, 2024). Understanding whether, and how strongly, HR practices and innovation adoption reinforce one another — and whether this relationship differs across cooperative and private governance structures — has direct implications for how sugar-industry managers sequence and resource their modernization efforts.

This study addresses this gap by empirically examining the relationship between technological innovation adoption, HR practices, and operational performance among employees of six sugar factories in the Sangli-Satara belt of Western Maharashtra, India. Specifically, the study aims to: (a) assess the strength of the relationship between innovation adoption and operational efficiency; (b) assess the strength of the relationship between HR practices and innovation adoption/success; (c) examine whether integrated HR-innovation practices predict organizational performance; and (d) test whether these relationships differ systematically between cooperative and private ownership structures. In doing so, the study contributes an empirically grounded integration framework linking HR practices and innovation adoption that can inform both scholarly understanding and managerial practice in agro-processing industries in emerging economies, while also extending the ownership-structure debate in the cooperative-economics literature (Kapelko et al., 2019; Monteiro & Straume, 2018) into the domain of workforce-level innovation and HR perceptions.

LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

Technological Innovation Adoption in Agro-Processing Industries

Technology adoption at the organizational level is well explained by the Technology-Organization-Environment (TOE) framework, which posits that a firm's adoption of technological innovation is jointly shaped by technological, organizational, and environmental contexts (Tornatzky & Fleischer, 1990). Within agro-processing industries specifically, an extended TOE-P (process-augmented TOE) framework developed for the sugar sector in developing economies shows that, because sugar processing is an unusually process-intensive industry, readiness for Industry 4.0 technologies depends not only on the conventional technological, organizational, and environmental factors but also on process-level readiness — the capacity of existing production processes to absorb automation and digital monitoring without disrupting the continuous, seasonally constrained crushing cycle (Pandey et al., 2025). This process dimension is particularly relevant to Indian cooperative and private sugar factories, where crushing-season time pressure limits the window available for technology rollout and workforce retraining.

More broadly, sugar and sugarcane research has documented that innovation — spanning automation, digitalization, sustainable-energy practices, and IT/ERP infrastructure — is central to the sector's productivity, profitability, and long-term sustainability. Complementing the technology-organization-environment view, an extended TOE framework that explicitly incorporates a 'people dimension' alongside the conventional technological, organizational, and environmental contexts has been proposed for Industry 4.0 technology adoption in HRM settings, using total interpretive structural modelling to show that workforce-related enablers occupy a central, high-driving-power position in the hierarchy of factors that determine successful technology adoption (Mishra & Pathak, 2024). This reinforces the theoretical premise of the present study: that innovation adoption in a traditional, labour-intensive sector cannot be adequately understood without incorporating the HR systems that support it.

HR Practices and Innovation Success

A parallel and substantial literature has examined how HR practices shape organizational innovation outcomes. Grounded in the resource-based view (Barney, 1991) and the Ability-Motivation-Opportunity (AMO) framework, this literature argues that bundles of HR practices — recruitment and selection, training and development, performance appraisal, compensation, and employee engagement — build the ability, motivation, and opportunity employees need to generate and implement innovative behaviour (Appelbaum et al., 2000; Bos-Nehles et al., 2023). Empirical studies across varied sectors have found that HR-enhancing practices are positively associated with innovation performance: in French manufacturing SMEs, AMO-oriented HRM practices were found to enhance innovation performance both directly and through their effect on employees' abilities, motivation, and opportunities to innovate (Alkhalaf & Al-Tabbaa, 2024), while a study of Vietnamese enterprises across industrial and service sectors found that high-performance HRM practices affect firm performance indirectly, through innovation, in addition to a direct effect on innovation itself (Nguyen & Dao, 2023). In Sri Lankan SMEs, HRM practices were similarly found to be significant, positive predictors of firm innovation (Mathushan & Shantha, 2024).

In the Indian context specifically, innovative HR practices have been found to shape HR outcomes such as job satisfaction, organizational commitment, and organizational citizenship behaviour among software-firm employees in Kerala (Joseph et al., 2024), and HR practices such as training and development, performance appraisal, and employee involvement have been found to significantly influence organizational performance in

the Indian banking sector (Salman et al., 2024). Within the sugar industry itself, HR practices have historically been described as reward-driven and, in cooperative units, susceptible to bias that can hinder teamwork; more recent industry commentary has emphasized the need for stronger Human Resource Development (HRD) — training, performance appraisal, and quality-of-work-life improvements — to help cooperative sugar factories adapt to technological and market change. Taken together, this literature motivates treating HR practices not merely as an administrative function but as a strategic lever for innovation success, consistent with the present study's Part C-Part B linkage.

Employee Readiness, Change Management, and the HR-Innovation Relationship

The link between HR practices and innovation adoption is theorized to operate substantially through employee readiness for change. Armenakis et al. (1993) conceptualize readiness as a precursor to successful adoption, shaped by employees' beliefs about the discrepancy, appropriateness, efficacy, and valence of a proposed change, while Holt et al. (2007) operationalize readiness as a multidimensional construct encompassing change-specific efficacy, appropriateness, management support, and personal valence. Applied to a technology-adoption context, this suggests that HR practices that build change-specific efficacy (through training), communicate appropriateness (through structured change-management communication), and demonstrate management support are likely to strengthen, rather than merely coincide with, successful innovation adoption. This reasoning is consistent with the extended TOE-HRM model of Mishra and Pathak (2024), in which people-related enablers — including training, communication, and change-readiness — occupy a foundational position that drives higher-level technological and organizational enablers, providing the theoretical bridge between Part C (HR practices) and Part D (HR-innovation relationship: HR support, change management, employee readiness) of the present study's instrument.

Ownership Structure: Cooperative versus Private Sugar Factories

Whether cooperative ownership structurally advantages or disadvantages innovation and HR outcomes relative to private/investor-owned firms is contested in the literature. Using rich Portuguese panel data across a wide range of industries, Monteiro and Straume (2018) found that cooperatives were significantly less productive than investor-owned firms under a benchmark random-effects specification, though this conclusion did not hold under a more robust System-GMM approach — illustrating how sensitive ownership-performance comparisons are to methodological choice. In a longitudinal cross-country study, Kapelko et al. (2019) similarly found mixed and context-dependent efficiency differences between producer cooperatives and private firms. In the specific context of Maharashtra's cooperative sugar sector, Banerjee et al. (2001) documented how control-rights concentration among a small group of politically influential cooperative-society leaders shaped efficiency and equity outcomes, while Lalwani (2008) offered a political-economy account of how state patronage and cooperative governance structures jointly influenced the sector's trajectory. More recent industry commentary describes a sector under strain from mismanagement and financial stress, with an increasing need for professional, rather than politically mediated, management. This mixed and largely qualitative-or-financial evidence base motivates an explicit, quantitative test of whether cooperative and private ownership differentiate innovation adoption, HR practices, and their downstream relationship to performance among the sampled workforce — a worker-level perceptual angle that, to the authors' knowledge, has not been directly tested in this literature.

Integration Framework and Organizational Performance

Beyond examining innovation adoption and HR practices as separate predictors, this study is motivated by calls in the strategic HRM literature to treat HR practices and innovation as complementary, mutually reinforcing systems rather than independent levers (Appelbaum et al., 2000; Bos-Nehles et al., 2023). An integrated HR-innovation practice — in which HR systems are explicitly designed to support technology adoption, and technology adoption decisions account for workforce readiness — is theorized to yield stronger organizational performance outcomes (spanning operational efficiency, HR outcomes, financial performance, and quality outcomes) than either domain pursued in isolation. This reasoning is consistent with evidence that HR practices affect firm performance both directly and indirectly through innovation (Nguyen & Dao, 2023), and underlies the study's third and integrative hypothesis.

Hypotheses

Based on the foregoing review, the following hypotheses were formulated and tested:

- H1: There is a significant positive relationship between Innovation Adoption and Operational Efficiency.
- H2: There is a significant positive relationship between HR Practices and Innovation Adoption/Success.
- H3: There is a significant positive relationship between Integrated HR-Innovation Practices and Organizational Performance.

RESEARCH METHODOLOGY

Research Design and Sample

The study adopted a quantitative, cross-sectional survey design, appropriate for testing hypothesized relationships among innovation adoption, HR practices, and organizational performance at a single point in time. Primary data

were collected from 393 employees across six sugar factories in the Sangli-Satara belt of Western Maharashtra, India, comprising 192 respondents from cooperative-affiliated factories and 201 from private factories, which together formed the primary grouping variable for comparative analysis. A stratified approach was used to draw respondents proportionally across managerial, supervisory, and below-managerial cadres within each factory, in order to capture a representative cross-section of the factory workforce rather than a single organizational level. All 393 administered questionnaires were returned complete, yielding a 100% response rate; screening confirmed no missing values, duplicate respondent identifiers, or out-of-range Likert codes, and the full sample was retained for analysis.

Instrument

Data were collected using a structured, 120-item, five-point Likert-scale questionnaire developed for the parent doctoral study, organized into seven parts: (A) demographic profile; (B) technological innovation status, covering automation, digitalization, sustainable energy, and IT/ERP infrastructure; (C) HR practices, covering recruitment, training, performance appraisal, compensation, and employee engagement; (D) the HR-innovation relationship, covering HR support for innovation, change management, and employee readiness; (E) impact on organizational performance, covering operational efficiency, HR outcomes, financial performance, and quality outcomes; (F) challenges in technology adoption and HR management; and (G) open-ended framework questions. The present paper draws on Parts A–E as the core analytic dataset.

Reliability and Validity

Internal consistency was assessed using Cronbach's alpha for each construct and section-level composite, interpreted against Nunnally's (1978) conventional thresholds. Sampling adequacy and factorability were assessed using the Kaiser-Meyer-Olkin (KMO) measure and Bartlett's Test of Sphericity, and the internal factor structure of the predictor item pool (Parts B and C combined) was examined using Exploratory Factor Analysis (EFA) with Varimax rotation to provide convergent and discriminant validity evidence for the two predictor constructs. Results are reported in the Results section below.

Common Method Bias

Because all constructs were measured via a single self-administered instrument, the study is potentially susceptible to common method bias. Several procedural and statistical safeguards partially mitigate this concern: respondents were assured of anonymity and informed that there were no right or wrong answers, which reduces social-desirability pressure; the questionnaire's sections were separated by construct with distinct instructions, reducing the likelihood of consistency artefacts; and the EFA reported below yielded a clean two-factor structure corresponding to the a priori Part B/Part C division rather than a single dominant factor, which is inconsistent with a strong common-method-bias explanation of the results. Nonetheless, the cross-sectional, single-source design remains a limitation, discussed further below.

Data Analysis

Composite construct scores were computed by averaging items within each Likert battery. Hypotheses were tested using Pearson product-moment correlation (corroborated by Spearman's rho given the non-normal distribution of several batteries), multiple linear regression, and one-way ANOVA (corroborated by the non-parametric Kruskal-Wallis H test) to compare cooperative and private factories on the four core composite constructs. All analyses were conducted at the 5% significance level.

RESULTS

Sample Profile

Of the 393 respondents, 143 (36.4%) identified as male, 119 (30.3%) as female, and 131 (33.3%) preferred not to disclose their gender. The sample was concentrated in the early-to-mid career bands, with 131 respondents (33.3%) aged 36–45 years and 114 (29.0%) aged 25–35 years, consistent with the operative and supervisory workforce typically engaged during the sugar-crushing season. The sample comprised 192 respondents (48.9%) from cooperative factories and 201 (51.1%) from private factories.

Reliability and Validity of the Instrument

Table 1. Internal Consistency of Section-Level Composite Constructs

Construct	Items (k)	N	Cronbach's α	Verdict
Innovation Adoption	23	393	.964	Excellent
HR Practices	27	393	.965	Excellent
HR-Innovation Relationship	16	393	.942	Excellent

Construct	Items (k)	N	Cronbach's α	Verdict
Organizational Performance	19	393	.951	Excellent
Overall Instrument	100	393	.974	Excellent

Note. Verdict per Nunnally (1978): $\alpha \geq .90$ Excellent; .80–.89 Good; .70–.79 Acceptable.

All section-level composites exceeded the .90 threshold for excellent internal consistency, and KMO values for each item set ranged from .974 to .985 (all in Kaiser's 'marvellous' band), with Bartlett's Test of Sphericity significant for every item set ($p < .001$), confirming the suitability of the data for the correlational, regression, and factor-analytic procedures reported below.

Hypothesis Testing

Table 2. Summary of Hypothesis Testing

Hypothesis	Relationship	Pearson r	r^2	p	Decision
H1	Innovation Adoption $\rightarrow$ Operational Efficiency	0.647	0.419	$< .001$	Accepted
H2	HR Practices $\rightarrow$ Innovation Adoption/Success	0.529	0.280	$< .001$	Accepted
H3	Integrated HR-Innovation Practices $\rightarrow$ Organizational Performance	0.626	0.392	$< .001$	Accepted

Note. All hypotheses were also corroborated by Spearman's rho, which produced near-identical coefficients ($\rho = .650, .525$, and $.604$, respectively; all $p < .001$).

Innovation adoption showed a strong positive relationship with operational efficiency ($r = .647$, $N = 393$, $p < .001$), statistically accounting for approximately 41.9% of the variance in operational efficiency — a magnitude broadly consistent with the strong role assigned to technological readiness in the TOE-P framework for the sugar sector (Pandey et al., 2025). HR practices showed a moderate positive relationship with innovation adoption/success ($r = .529$, $p < .001$), accounting for approximately 28.0% of its variance, echoing findings that HR-enhancing practices are positively, though not overwhelmingly, associated with innovation outcomes in other manufacturing and service settings (Alkhalaf & Al-Tabbaa, 2024; Mathushan & Shantha, 2024). Integrated HR-innovation practices showed a strong positive relationship with organizational performance ($r = .626$, $p < .001$), accounting for approximately 39.2% of its variance. All three hypotheses (H1–H3) were therefore accepted (H_0 rejected, H_1 accepted).

Regression Analysis: Predicting Organizational Performance

Table 3. Combined Regression Model — Innovation Adoption and HR Practices Predicting Organizational Performance

Predictor	B	β	t	p
Constant	0.918	—	6.924	$< .001$
Innovation Adoption	0.577	0.602	13.855	$< .001$
HR Practices	0.141	0.139	3.209	.001

Note. $R = .686$, $R^2 = .470$, Adjusted $R^2 = .467$, $F(2, 390) = 173.048$, $p < .001$.

When entered together, innovation adoption and HR practices jointly explained 47.0% of the variance in organizational performance (adjusted $R^2 = .467$), a significant improvement over either single-predictor model (innovation adoption alone: $R^2 = .456$; HR practices alone: $R^2 = .209$). Innovation adoption was the dominant predictor ($\beta = .602$), with HR practices contributing a smaller but statistically significant independent effect ($\beta = .139$), indicating that HR practices' contribution to organizational performance is only partly explained through its association with innovation adoption — it retains an independent, direct effect, consistent with the dual direct-and-indirect pathway reported by Nguyen and Dao (2023) for high-performance HRM practices and firm performance. Variance Inflation Factor values for both predictors remained below 2.0, indicating no problematic

multicollinearity. A supplementary model decomposing innovation adoption into its four sub-dimensions found that sustainable-energy practices ($\beta = .306$, $p < .001$) and IT/ERP infrastructure ($\beta = .249$, $p = .006$) were the strongest independent predictors of organizational performance, while automation and digitalization did not reach significance once the other sub-dimensions were controlled for.

Cooperative versus Private Sugar Factories

Table 4. Comparison of Composite Constructs by Type of Factory

Construct	Cooperative M (SD)	Private M (SD)	F(1,391)	p
Innovation Adoption	3.08 (0.87)	3.09 (0.88)	0.000	0.993
HR Practices	3.05 (0.79)	3.17 (0.86)	1.983	0.160
HR-Innovation Relationship	3.38 (0.80)	3.37 (0.84)	0.011	0.918
Organizational Performance	3.14 (0.79)	3.14 (0.88)	0.000	0.988

Note. All results were corroborated by the non-parametric Kruskal-Wallis H test, which produced the same non-significant conclusions.

None of the four F-tests reached statistical significance at the 5% level, indicating that employees in cooperative and private sugar factories reported statistically indistinguishable levels of innovation adoption, HR practices, HR-innovation relationship, and organizational performance. This finding qualifies the cooperative-versus-private efficiency debate reviewed above (Kapelko et al., 2019; Monteiro & Straume, 2018) as it applies specifically to workforce-level innovation and HR perceptions in this sector: whereas prior work using firm-level financial or productivity data has found ownership-related differences to be method-sensitive and context-dependent, the present employee-level evidence finds no differentiation at all on any of the four constructs central to this study.

FACTOR STRUCTURE OF THE PREDICTOR ITEM POOL

An Exploratory Factor Analysis (Varimax rotation) of the combined 50-item Innovation Adoption and HR Practices item pool confirmed excellent sampling adequacy ($KMO = .980$) and a significant Bartlett's test ($\chi^2 = 12,594.6$, $df = 1225$, $p < .001$). Applying the eigenvalue > 1 criterion, two factors were extracted, jointly explaining 52.22% of total variance. All Part C (HR Practices) items loaded saliently on Factor 1 and all Part B (Innovation Adoption) items loaded saliently on Factor 2, with no meaningful cross-loadings, providing convergent validity evidence that Innovation Adoption and HR Practices are empirically distinct yet correlated constructs — consistent with their treatment as separate but complementary predictors throughout this study, and with the two-factor structure implicit in the AMO-versus-technology distinction drawn by Bos-Nehles et al. (2023).

DISCUSSION

The findings provide robust empirical support for the theorized integration of technological innovation adoption and HR practices as complementary drivers of organizational performance in the sugar industry. Consistent with TOE-framework reasoning (Tornatzky & Fleischer, 1990) and the sugar-sector-specific TOE-P readiness model (Pandey et al., 2025), innovation adoption emerged as a strong, direct predictor of operational efficiency and the dominant predictor in the combined regression model. This underscores that, in a traditionally labour-intensive and seasonal industry, the marginal returns to automation, digitalization, sustainable-energy adoption, and IT/ERP investment on operational efficiency remain substantial — particularly for sustainable-energy and IT/ERP sub-dimensions, which retained significant independent effects even after controlling for the other innovation sub-dimensions.

At the same time, the significant, moderate relationship between HR practices and innovation adoption/success (H2) supports the AMO-theoretic proposition that innovation outcomes are not purely technological but are substantially shaped by the ability, motivation, and opportunity that HR systems create for employees (Appelbaum et al., 2000; Bos-Nehles et al., 2023). This finding parallels evidence from French manufacturing SMEs, where AMO-enhancing HR practices were found to boost innovation performance both directly and through employees' abilities, motivation, and opportunities to innovate (Alkhalaf & Al-Tabbaa, 2024), and from Sri Lankan SMEs, where HRM practices significantly predicted firm innovation (Mathushan & Shantha, 2024). It is corroborated by the combined regression model, in which HR practices retained a statistically significant independent effect on organizational performance even after accounting for innovation adoption — indicating that HR practices contribute to performance both indirectly, by enabling innovation, and directly, through their own effect on operational, HR, financial, and quality outcomes, mirroring the dual direct-and-mediated pathway reported by Nguyen and Dao (2023) for high-performance HRM practices in Vietnamese firms and consistent with the Indian banking-sector evidence that specific HR practices directly shape organizational performance (Salman et al.,

2024). This dual pathway lends empirical weight to the study's central integrative hypothesis (H3): integrated HR-innovation practices showed a strong relationship with organizational performance, larger than the relationship for HR practices alone, reinforcing the argument that HR and innovation strategies should be designed jointly rather than in isolation — a conclusion consistent with the people-centred extension of the TOE framework proposed by Mishra and Pathak (2024), in which workforce-related enablers occupy a foundational, high-driving-power position relative to purely technological enablers.

The absence of any significant difference between cooperative and private factories on all four composite constructs is a noteworthy finding that runs counter to some expectations in the governance literature. Prior firm-level research on cooperative-versus-investor-owned efficiency has generally found effects that are sensitive to estimation method and industry context: Monteiro and Straume (2018) found cooperatives significantly less productive than investor-owned firms under a standard random-effects model but inconclusive results under a more robust System-GMM approach, while Kapelko et al. (2019) similarly reported mixed, context-dependent differences. In the specific regional setting of this study, earlier work has highlighted control-rights concentration and governance weaknesses as sources of divergence between cooperative and private sugar factories in Western Maharashtra (Banerjee et al., 2001; Lalwani, 2008). Against this backdrop, the present study's employee-level finding of statistically indistinguishable innovation adoption, HR practices, HR-innovation relationship, and organizational performance scores across ownership types suggests that, at the level of individual employees' day-to-day experience — as distinct from factory-level financial or governance outcomes, which this study did not directly measure — ownership structure may be a weaker differentiator of workforce-level HR and technology practices than commonly assumed. One plausible explanation is that cooperative and private factories operating in the same regional labour market are subject to similar competitive, regulatory, and seasonal-crushing pressures that converge their day-to-day HR and technology practices, even where their boardroom-level governance and long-run financial trajectories diverge. This interpretation should be treated with some caution, however, given that several of the cooperative factories in the sample carry the 'Sahakari' (cooperative) designation in their formal names and the ownership classification was not independently verified against each factory's registered legal status; future research using factory-level financial and governance data alongside employee-level perceptions would help triangulate this result.

Taken together, these findings support an integration framework in which (a) HR practices function as an enabling layer that builds workforce readiness and capability for innovation adoption, consistent with change-readiness theory (Armenakis et al., 1993; Holt et al., 2007); (b) innovation adoption, once achieved, is a strong direct driver of operational efficiency and broader organizational performance; and (c) the combined, integrated pursuit of both domains yields performance gains exceeding either domain pursued alone — a pattern that appears robust across ownership structures. For sugar-industry managers, this suggests that technology-adoption budgets should be paired with commensurate investment in recruitment, training, and change-management practices rather than treated as a purely capital-expenditure decision, and that this recommendation applies with similar force in both cooperative and private factories.

CONCLUSION, IMPLICATIONS, AND FUTURE RESEARCH

This study set out to examine the relationship between technological innovation adoption, HR practices, and organizational performance among employees of cooperative and private sugar factories in Western Maharashtra, India. All three hypotheses were supported: innovation adoption showed a strong positive relationship with operational efficiency, HR practices showed a moderate positive relationship with innovation adoption, and integrated HR-innovation practices showed a strong positive relationship with organizational performance, with a combined regression model explaining 47.0% of the variance in the latter. Ownership structure did not significantly differentiate any of these relationships.

Theoretically, the study extends TOE-framework and AMO-theoretic reasoning (Tornatzky & Fleischer, 1990; Appelbaum et al., 2000; Bos-Nehles et al., 2023) into an underexamined agro-processing context, and offers empirical support for treating HR practices and technological innovation as complementary, mutually reinforcing systems rather than independent organizational levers — echoing the people-centred TOE extension proposed by Mishra and Pathak (2024) and the dual direct/indirect HRM-performance pathway documented by Nguyen and Dao (2023). It also contributes new, worker-level evidence to the cooperative-versus-private ownership debate (Kapelko et al., 2019; Monteiro & Straume, 2018), suggesting that this debate's firm-level financial findings do not necessarily extend to employees' day-to-day perceptions of HR and innovation practices.

Practically, the findings suggest that sugar-factory managers — in both cooperative and private units — should sequence technology investment alongside targeted HR interventions (structured training, transparent recruitment aligned to digital-skill requirements, and change-management communication) to maximize returns on both fronts, consistent with practices found effective in other Indian manufacturing and service settings (Joseph et al., 2024; Salman et al., 2024). For policymakers and cooperative-sector regulators, the finding that cooperative and private factories show statistically indistinguishable innovation-HR dynamics suggests that capacity-building

initiatives need not be differentiated by ownership type, and can instead be designed around common workforce-readiness needs across the sector.

This study has several limitations. First, the cross-sectional design precludes causal inference; the observed relationships are consistent with, but do not establish, the directional pathways theorized. Second, the sample was drawn from six factories within a single regional cluster (Sangli-Satara), which may limit generalizability to sugar factories in other Indian states or agro-processing industries more broadly. Third, all measures were self-reported by employees, introducing potential common-method variance; while the study's discriminant EFA results and the theoretically coherent, non-uniform pattern of regression coefficients partially mitigate this concern, a fully independent criterion measure (e.g., factory-level productivity records) was not incorporated. Fourth, the classification of factories as cooperative or private relied on the primary grouping variable in the parent dataset and was not independently verified against each factory's registered legal and governance status. Future research could address these limitations through longitudinal designs capable of testing directional and mediating pathways (e.g., HR practices → employee readiness → innovation adoption → performance, following the mediation logic demonstrated by Nguyen & Dao, 2023, and Alkhalaf & Al-Tabbaa, 2024), multi-state or multi-industry replication, and the incorporation of factory-level financial and governance data to complement the employee-level perceptual measures used here

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