

TECHNOLOGY-DRIVEN EFFICIENCY AND PERFORMANCE OF RUBBER PROCESSING UNITS: AN EMPIRICAL STRUCTURAL EQUATION MODELING APPROACH

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Abstract

The current study looks at how supply chain management and technological investment are impacted by opportunities, obstacles, and institutional support from the Rubber Board. These factors then have an impact on efficiency metrics and the overall performance of rubber processing facilities. A systematic questionnaire was used to gather primary data from 165 rubber processing facilities. The associations between the variables were investigated using Structural Equation Modelling (SEM) using AMOS. The findings show that while obstacles have a detrimental impact on supply chain management and technology investment, opportunities and institutional support have a favourable impact. Investments in technology and supply chain management greatly increase efficiency metrics, which in turn improve the assessment of rubber processing units' performance. The study emphasises how efficiency plays a mediating function in converting operational and institutional inputs into quantifiable performance results.

Keywords:- Rubber processing units, Supply Chain Management, Investment in Technology, Efficiency Parameters, Performance Evaluation, Structural Equation Modeling.

To convert raw natural rubber into industrial inputs needed for production and export, the rubber processing sector is essential. The industry makes a substantial contribution to regional economic growth, value addition, and employment in rural areas. Rubber processing facilities, however, work in a difficult environment

marked by supply unpredictability, price volatility, technological constraints, and escalating rivalry.

In this regard, increasing competitiveness and long-term sustainability now depends on operational effectiveness and technology adoption. Processing units can maximise procurement, logistics, and supplier and

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distributor cooperation with the use of efficient supply chain management. Investing in contemporary processing technologies also improves efficiency, quality, uniformity, and adherence to global standards.

Institutional groups like the Rubber Board are crucial in helping the industry by providing technical advice, financial support, market intelligence, and training. However, there hasn't been enough research done on how sectoral potential, operational difficulties, and institutional support interact to affect performance and efficiency. By creating and evaluating a structural model that explains the technology-driven performance dynamics of rubber processing units, this work fills this gap.

Need and Significance of the Study

Rubber processing facilities are progressively moving away from conventional processing techniques and toward more sophisticated operations. However, because of variations in perceived opportunities, operational difficulties, and institutional support, the rate of change differs among units. Improving performance and efficiency in the rubber processing industry requires an understanding of the connections between these variables. This study is important because it creates an integrated structural framework that connects supply chain management, technology investment, efficiency metrics, and performance results with opportunities, obstacles, and institutional support. The study offers empirical evidence on the ways that institutional and operational factors affect rubber processing units'

performance using structural equation modelling.

Statement of the Problem

Many rubber processing facilities still struggle with operational inefficiencies and low technology adoption despite the availability of institutional backing and advantageous market prospects. Modernisation and productivity gains are hampered by elements like supply chain interruptions, budgetary restrictions, and infrastructure limits. As a result, it's critical to look at how opportunities, obstacles, and institutional support affect supply chain management and technology adoption, as well as how these elements eventually impact performance and efficiency in rubber processing facilities.

Scope of the Study

Rubber processing facilities that are a part of a local rubber-producing environment are the subject of the study. It focuses on internal operational issues and external institutional consequences rather than downstream rubber product manufacturing and plantation-level production. The analysis is restricted to processing efficiency and performance results rather than export competitiveness or price behaviour.

Research Methodology

To investigate the factors that influence performance and efficiency in rubber processing facilities, the study uses a quantitative research approach. A systematic questionnaire was used to gather primary data from 165 rubber processing facilities. Prospects, obstacles, institutional support, supply chain management, technological investment, efficiency

metrics, and performance evaluation were among the constructs examined by the questionnaire. AMOS and SPSS were used to analyse the data. Skewness and kurtosis statistics were used to evaluate the data's normality. The associations between the variables were examined using Structural Equation Modelling (SEM) with Maximum Likelihood Estimation. Goodness-of-fit indices such as Chi-square, GFI, AGFI, NFI, CFI, and RMSEA were used to assess the model's adequacy.

Review of Related Literature

Prior research emphasises how crucial supply chain management and technology advancement are to raising operational effectiveness in the agro-processing sector. According to Christopher (2016), integrated supply chain systems increase productivity, decrease processing delays, and improve coordination. In a similar vein, Gunasekaran et al. (2017) contend that in resource-based businesses, supply chain integration improves organisational effectiveness. Operational efficiency has also been found to be significantly influenced by technological investment. Technology-enabled operations improve performance monitoring, quality control, and productivity, as Porter and Heppelmann (2015) show. Automation and modern machinery greatly increase productivity and output quality in agro-processing SMEs (Singh & Sharma, 2018). Sectoral performance is also influenced by institutional support systems. The Rubber Board of India (2023) states that initiatives for quality certification, financial support, and training programs all help modernise rubber processing

facilities. However, operational issues including infrastructural constraints and cost pressures still have an impact on technology adoption (Nair, 2021). While other studies have looked at each of these elements separately, few have combined opportunities, difficulties, institutional support, supply chain management, technology investment, efficiency, and performance into a thorough analytical framework. The current work uses a SEM-based methodology to close this gap.

Conceptual Model Description

The Observed, exogenous variables are Supply Chain Management, Investment in Technology, Efficiency Parameters of the Rubber Processing Units and Performance Evaluation of the Rubber Processing Units. The Observed, exogenous variables are Prospects of the Rubber Processing Units, Challenges of the Rubber Processing Units and Role of Rubber Board on the Rubber Processing Units. The Unobserved, exogenous variables are ϵ_1 to ϵ_4 . The Number of variables in the model are 11, Number of observed variables are 7, Number of unobserved variables are 4, Number of exogenous variables are 7 and Number of endogenous variables are 4.

Objectives of the Study

1. To examine the influence of prospects, challenges, and the role of the Rubber Board on supply chain management.
2. To assess the impact of prospects, challenges, and institutional support on investment in technology.

- 3. To analyze the effect of supply chain management and technology investment on efficiency parameters.
- 4. To evaluate the influence of efficiency parameters on the performance of rubber processing units.

Hypotheses

- H01: Prospects positively influence supply chain management and investment in technology.
- H02: Challenges negatively influence supply chain management and investment in technology.
- H03: The role of the Rubber Board positively influences supply chain management and investment in technology.
- H04: Supply chain management positively influences efficiency parameters.
- H05: Investment in technology positively influences efficiency parameters.

H06: Efficiency parameters positively influence the performance of rubber processing units.

The data are well-distributed and appropriate for sophisticated multivariate analysis, according to the normalcy statistics (Table 1.1) . The sufficient dispersion indicates that participants utilised the entire measurement scale. All variables’ skewness values are within the permissible range of ± 1 , suggesting very slight asymmetry. Kurtosis readings also indicate no signs of severe peakedness or flatness, falling within the acceptable range of ± 3 . The variables do not contradict the premise of univariate normality because the critical ratio (C.R.) values for both skewness and kurtosis are below the threshold of ± 2.58 .

Supply chain management ($\beta = 0.361$, $p < .001$) and technology investment ($\beta = 0.302$, $p < .001$) are significantly positively impacted by the prospects of rubber processing units, suggesting that an optimistic outlook motivates businesses

Table 1.1
Technology-Driven Efficiency and Performance of Rubber Processing Units- Normality

Variable	Min	Max	Skew	C.R.	kurtosis	C.R.
Role of Rubber Board on the Rubber Processing Units	2.080	4.680	-.091	-.622	-.519	-1.776
Challenges of the Rubber Processing Units	1.842	4.789	.091	.621	.222	.760
Prospects of the Rubber Processing Units	1.800	4.700	-.166	-1.138	-.355	-1.216
Investment in Technology	1.400	5.000	-.281	-1.921	-.453	-1.549
Supply Chain Management	1.800	5.000	.059	.401	-.486	-1.664
Efficiency Parameters of the Rubber Processing Units	1.650	5.000	-.135	-.924	-.786	-2.690
Performance Evaluation of the Rubber Processing Units	1.200	5.000	-.274	-1.876	-.468	-1.602

Source: Primary Data

to invest in technical advancements and improve logistics (Table 1.2). On the other hand, the units' difficulties have a negative impact on supply chain management ($\beta = -.0334, p < .001$) and technology investment ($\beta = -.0239, p < .001$), indicating that market, financial, and infrastructure limitations impede modernisation. The Rubber Board's role also shows up as a major enabling factor, greatly enhancing investment in

technology ($\beta = 0.392, p < .001$) and supply chain management ($\beta = 0.338, p < .001$), underscoring the significance of institutional support, policy guidance, and training in fostering structured supply networks and technology adoption.

Supply chain management ($\beta = 0.333, p < .001$) and technology investment ($\beta = 0.349, p < .001$) have a favourable impact on the efficiency parameters,

Table 1.2
Technology-Driven Efficiency and Performance of Rubber Processing Units-Relationship

Relationship			Un-Standardized Regression Estimate	S.E.	C.R.	P	Standardized Regression Estimate
Supply Chain Management	<---	Prospects of the Rubber Processing Units	.473	.061	7.748	***	.361
Investment in Technology	<---	Prospects of the Rubber Processing Units	.418	.068	6.146	***	.302
Supply Chain Management	<---	Challenges of the Rubber Processing Units	-.455	.064	-7.164	***	-.334
Investment in Technology	<---	Challenges of the Rubber Processing Units	-.344	.071	-4.867	***	-.239
Supply Chain Management	<---	Role of Rubber Board on the Rubber Processing Units	.439	.060	7.278	***	.338
Investment in Technology	<---	Role of Rubber Board on the Rubber Processing Units	.538	.067	8.005	***	.392
Efficiency Parameters of the Rubber Processing Units	<---	Supply Chain Management	.383	.051	7.454	***	.333
Efficiency Parameters of the Rubber Processing Units	<---	Investment in Technology	.379	.045	8.358	***	.349

Source: Primary Data

suggesting that coordinated supply systems and technological integration improve process optimisation, productivity, and quality control. Efficiency is also positively impacted by prospects ($\beta = 0.209$, $p < .001$), although structural restrictions continue to have a detrimental impact on problems ($\beta = -0.209$, $p < .001$). Technology investment is the best predictor of performance evaluation ($\beta = 0.349$, $p < .001$), followed by supply chain management ($\beta = 0.226$, $p < .001$) and prospects ($\beta = 0.229$, $p < .001$). The positive relationship between efficiency parameters and performance evaluation ($\beta = 0.133$, $p = .025$) indicates that efficiency partially mediates the effect of supply chain improvements and technological investments on the performance of rubber processing units, even though challenges have a negative impact on performance ($\beta = -0.146$, $p < .001$).

All the relationships are statistically significant, as the p values are lower than 5 per cent (Table 1.2.1). Hence, the null hypotheses are rejected.

All Covariance and Correlations are statistically not significant, as the p values are greater than 5 per cent (Table 1.3).

39.8 per cent of the variance in supply chain management can be explained by the squared multiple correlations resulting from the combined effects of prospects, the Rubber Board's role, and challenges (Table 1.4). This indicates that sectoral outlook, institutional support, and operational constraints significantly

influence supply chain effectiveness. In a similar vein, 33.2 per cent of the variation in technology investment represents a moderate but significant degree of explanation for businesses' choices to adopt new technologies. Additionally, a significant amount of the range in efficiency metrics (61.2 per cent) may be explained by supply chain management, technological investment, opportunities, and difficulties taken combined. Lastly, the model's combined effects of supply chain management, technology investment, efficiency characteristics, opportunities, and challenges account for 61.7 per cent of the variation in performance evaluation.

The Rubber Board's role has a positive indirect effect on performance evaluation (0.246) and efficiency parameters (0.249), suggesting that institutional support improves performance and efficiency more through its impact on supply chain effectiveness and technology adoption than through direct pathways (Table 1.5). On the other hand, difficulties encountered by the rubber processing units have detrimental indirect effects on performance evaluation (-0.212) and efficiency metrics (-0.194). The rubber processing units' prospects demonstrate favourable indirect effects on performance (0.245) and efficiency (0.226). Furthermore, efficiency is confirmed as a crucial mediating mechanism by the small indirect contributions of supply chain management (0.044) and technology investment (0.046) to performance evaluation through efficiency metrics.

As per the model fit summary, the Chi-square test is not significant, the

Table 1.2.1
Technology-Driven Efficiency and Performance of Rubber Processing Units-
Relationship-Testing of Hypotheses

Hypotheses	Relationship	Result
H01	Prospects → SCM & Technology	Supported
H02	Challenges → SCM & Technology	Supported
H03	Role of Rubber Board → SCM & Technology	Supported
H04	SCM → Efficiency	Supported
H05	Technology → Efficiency	Supported
H06	Efficiency → Performance	Supported

Source: Primary Data

Figure 1.1
Technology-Driven Efficiency and Performance of Rubber Processing Units-
Relationship

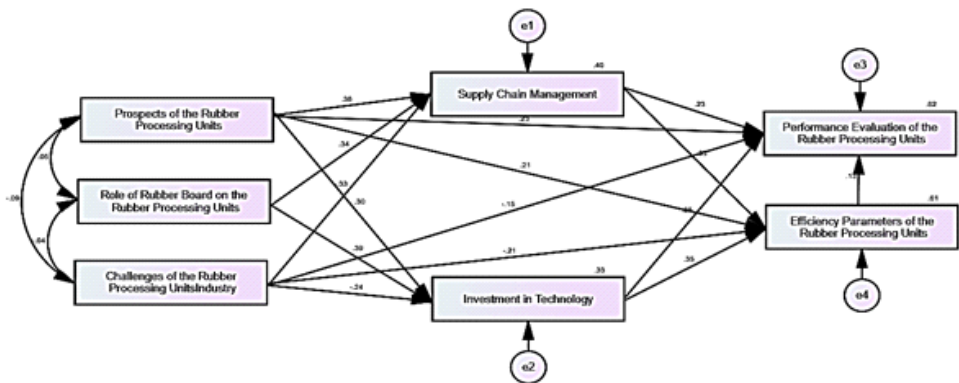


Table 1.3
Covariances & Correlations- Technology-Driven Efficiency and Performance
of Rubber Processing Units

Relationship			Covariances Estimate	S.E.	C.R.	P	Correlations Estimate
Challenges of the Rubber Processing Units	<-->	Role of Rubber Board on the Rubber Processing Units	-.010	.016	-.625	.532	-.037
Prospects of the Rubber Processing Units	<-->	Challenges of the Rubber Processing Units	-.025	.016	-1.529	.126	-.092
Prospects of the Rubber Processing Units	<-->	Role of Rubber Board on the Rubber Processing Units	.013	.017	.770	.441	.046

Source: Primary Data

Table 1.4
Squared Multiple Correlations - Technology-Driven Efficiency and Performance of Rubber Processing Units

Relationship			Estimate
Supply Chain Management	<---	Prospects of the Rubber Processing Units	.398
	<---	Role of Rubber Board on the Rubber Processing Units	
	<---	Challenges of the Rubber Processing Units	
Investment in Technology	<---	Prospects of the Rubber Processing Units	.332
	<---	Challenges of the Rubber Processing Units	
	<---	Role of Rubber Board on the Rubber Processing Units	
Efficiency Parameters of the Rubber Processing Units	<---	Supply Chain Management	.612
	<---	Investment in Technology	
	<---	Prospects of the Rubber Processing Units	
	<---	Challenges of the Rubber Processing Units	
Performance Evaluation of the Rubber Processing Units	<---	Supply Chain Management	.617
	<---	Investment in Technology	
	<---	Challenges of the Rubber Processing Units	
	<---	Prospects of the Rubber Processing Units	
	<---	Efficiency Parameters of the Rubber Processing Units	

Source: Primary Data

Table 1.5
Standardized Indirect Effects- Technology-Driven Efficiency and Performance of Rubber Processing Units

	Role of Rubber Board on the Rubber Processing Units	Challenges of the Rubber Processing Units	Prospects of the Rubber Processing Units	Investment in Technology	Supply Chain Management	Efficiency Parameters of the Rubber Processing Units
Investment in Technology	.000	.000	.000	.000	.000	.000
Supply Chain Management	.000	.000	.000	.000	.000	.000
Efficiency Parameters of the Rubber Processing Units	.249	-.194	.226	.000	.000	.000
Performance Evaluation of the Rubber Processing Units	.246	-.212	.245	.046	.044	.000

Source: Primary Data

Chi-square/DF ratio of .301 falls within the acceptable threshold limit, indicating an adequate model fit. Therefore, the null hypothesis is accepted, confirming a satisfactory goodness-of-fit for the proposed model. The results demonstrate that the prospects, challenges, and the role

of the Rubber Board significantly influence supply chain management and investment in technology in rubber processing units, which in turn positively enhance efficiency parameters and subsequently improve the overall performance evaluation of rubber

processing units, with challenges exerting a negative effect and prospects and institutional support exerting positive effects. Furthermore, the Goodness of Fit Index (GFI = 0.999) and the Adjusted Goodness of Fit Index (AGFI = 0.991) exceed the recommended cutoff value of 0.90, indicating a good model fit. The Normed Fit Index (NFI = 0.999) and Comparative Fit Index (CFI = 1.000) also confirm an excellent fit of the model. Additionally, the Root Mean Square Error of Approximation (RMSEA = 0.000) falls within the acceptable limit, further supporting the adequacy of the model.

Findings

According to the survey, rubber processing companies are greatly motivated to invest in cutting-edge technology and bolster supply chain systems by promising prospects. The Rubber Board's institutional assistance is also essential for promoting technology adoption and supply chain cooperation. Both supply chain efficiency and technical investment are adversely affected by operational issues such as budgetary limitations, unstable supplies, and infrastructure constraints. Efficiency metrics like productivity, resource utilisation, and process consistency are greatly enhanced by supply chain management and technology use. By converting supply chain enhancements and technological investments into improved performance results, efficiency metrics play a significant mediating role. Overall, the model shows that better operational performance in rubber processing facilities is largely driven by institutional support and technology-driven methods.

Conclusions

The study concludes that important factors influencing performance and efficiency in rubber processing facilities are supply chain management and technology investment. These operational capacities are positively impacted by prospects and institutional support, while they are negatively impacted by obstacles. The relationship between operational strategies and performance outcomes is mediated by efficiency factors. The results emphasise the need of an integrated strategy that combines supply chain optimisation, institutional support, and technological modernisation to improve the sustainability and competitiveness of rubber processing facilities.

Suggestions

To increase operational efficiency, rubber processing facilities should prioritise investments in cutting-edge processing technologies and improve supply chain coordination. To promote modernisation, policymakers and the Rubber Board should provide support through infrastructure development, training initiatives, and technology subsidies. Reducing the infrastructure and financial obstacles that small and medium-sized processing units encounter should receive special attention. Efficiency and market competitiveness can be further improved by the use of digital supply chain platforms and cooperative networks among distributors, suppliers, and processing facilities. To enhance the overall performance and sustainability of the rubber processing industry, institutional measures should also concentrate on market information services, certification support, and capacity building.

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