

Financial Performance and Risk Management Implications of Cyber-Protected Packaging and Labeling Systems: Evidence from Indian Manufacturing and FMCG Firms

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Abstract

In recent years, Indian manufacturing and Fast-Moving Consumer Goods (FMCG) firms have increasingly adopted cyber-protected packaging and labeling systems to combat counterfeiting, supply chain fraud, data breaches, and brand dilution. These systems combine digital technologies such as QR codes, RFID tags, blockchain-based traceability, encrypted labels, and IoT-enabled packaging to enhance product security and transparency. While prior studies have largely focused on the technological and operational benefits of such systems, limited attention has been given to their financial performance and risk management implications, particularly in the Indian context. This study examines the impact of cyber-protected packaging and labeling systems on the financial performance and risk management efficiency of selected Indian manufacturing and FMCG firms. Using secondary data from annual reports, sustainability disclosures, industry surveys, and regulatory publications for the period 2016–2025, the study analyzes changes in profitability, cost efficiency, risk exposure, and brand protection outcomes following the adoption of cyber-protected packaging technologies. Financial performance indicators such as Return on Assets (ROA), Return on Equity (ROE), operating margins, and cost ratios are evaluated alongside risk management indicators including fraud incidence reduction, supply chain disruption mitigation, and compliance improvement.

The findings suggest that firms adopting cyber-protected packaging systems demonstrate improved financial resilience, reduced operational risks, and enhanced consumer trust over time. Although initial investment costs are significant, long-term benefits in terms of risk reduction, revenue protection, and brand value creation outweigh these costs. The study contributes to the literature by providing empirical evidence from India and offers practical insights for managers, policymakers, and regulators aiming to strengthen cybersecurity and risk management frameworks in product packaging ecosystems.

Keywords: Cyber-protected packaging, labeling systems, financial performance, risk management, FMCG sector, manufacturing firms, cybersecurity, India

1. Introduction

The Indian manufacturing and FMCG sectors are undergoing rapid transformation due to digitalization, globalization, and increased consumer awareness. With expanding supply chains and rising dependence on technology, firms are facing growing risks related to counterfeiting, product tampering, data theft, and cyber-attacks. According to industry estimates, counterfeit goods alone cost Indian companies billions of rupees annually in lost revenues, reputational damage, and regulatory penalties [4]. In response, firms are increasingly turning toward cyber-protected packaging and labeling systems as a strategic tool for safeguarding products and ensuring supply chain integrity.

Cyber-protected packaging refers to packaging and labeling solutions embedded with digital security features such as encrypted QR codes, RFID tags, NFC chips, blockchain-enabled tracking, and cloud-based verification systems. These technologies allow firms to authenticate products,

monitor movement across the supply chain, detect anomalies, and interact directly with consumers through digital interfaces. Beyond operational benefits, such systems are expected to influence financial performance by reducing losses, improving efficiency, and strengthening brand equity. Despite growing adoption, many Indian firms remain uncertain about the financial justification and risk mitigation value of cyber-protected packaging systems. Senior management often perceives these systems as cost centers rather than value-creating investments. This perception gap underscores the need for empirical research linking cyber-protected packaging adoption with measurable financial and risk management outcomes. This study aims to fill this gap by systematically analyzing evidence from Indian manufacturing and FMCG firms.

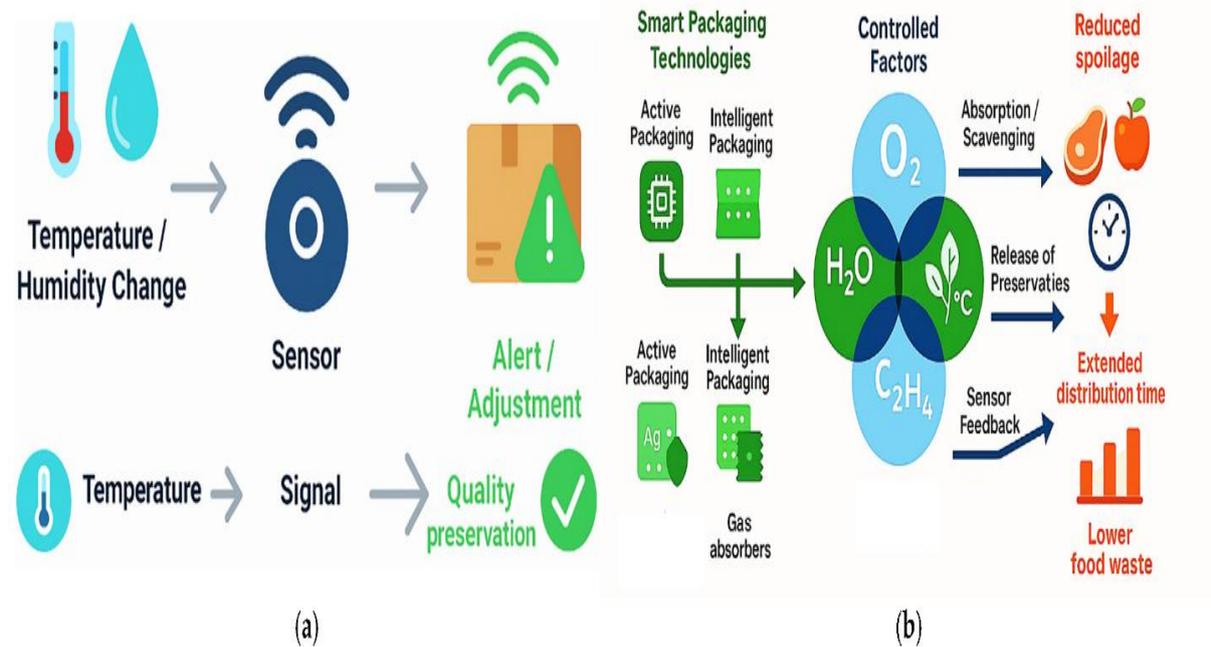


Figure 1: Conceptual illustration of cyber-protected packaging and labeling technologies

2. Background of Cyber-Protected Packaging and Labeling Systems

Traditionally, packaging served basic functions such as protection, storage, and branding. However, with the rise of sophisticated counterfeiting networks and cyber-enabled supply chain attacks, packaging has evolved into an active security interface. Cyber-protected packaging integrates physical and digital safeguards to create a secure product identity throughout its lifecycle.

Key components of cyber-protected packaging systems include unique digital identifiers, secure data storage, real-time monitoring, and authentication platforms. For example, QR codes linked to encrypted databases allow consumers and distributors to verify product authenticity instantly. RFID and IoT sensors enable real-time tracking and environmental monitoring, reducing risks related to theft, diversion, and spoilage. Blockchain-based labeling systems ensure tamper-proof records of product movement, enhancing traceability and accountability [7].

In the Indian context, regulatory initiatives such as traceability requirements in pharmaceuticals, food safety norms, and export compliance standards have further accelerated the adoption of such systems. Government agencies and industry bodies increasingly emphasize digital traceability as a means to improve transparency and consumer protection. As a result, cyber-protected packaging has emerged as a strategic investment rather than a purely operational decision.

Evolution of Packaging Systems

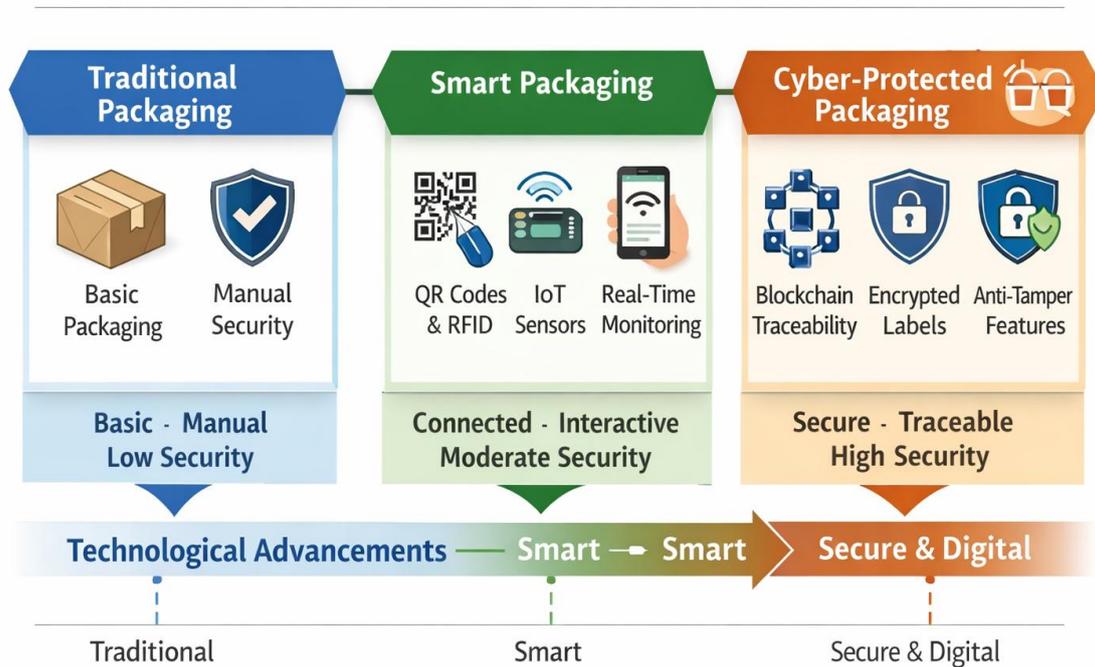


Figure 2: Evolution of packaging systems from traditional to cyber-protected models

3. Indian Manufacturing and FMCG Sector Context

India is one of the world's largest manufacturing and FMCG markets, characterized by diverse product categories, fragmented supply chains, and intense price competition. While this scale offers growth opportunities, it also exposes firms to higher risks of counterfeiting, parallel trade, and cyber-enabled fraud. Small lapses in packaging security can lead to large financial and reputational losses.

The FMCG sector, in particular, faces challenges related to fake products entering retail channels, especially in rural and semi-urban markets. Manufacturing firms dealing with high-value or safety-critical products such as pharmaceuticals, chemicals, and electronics face additional compliance and liability risks. Cyber-protected packaging systems help address these challenges by creating secure product identities and improving supply chain visibility [9].

From a financial perspective, Indian firms operate under cost constraints and thin margins, making investment decisions highly sensitive to return on investment. Understanding whether cyber-protected packaging contributes positively to financial performance is therefore crucial. This study focuses on listed Indian manufacturing and FMCG firms that have disclosed investments in digital packaging, traceability, or cybersecurity-related initiatives in their annual reports.

Indian FMCG and Manufacturing Supply Chain

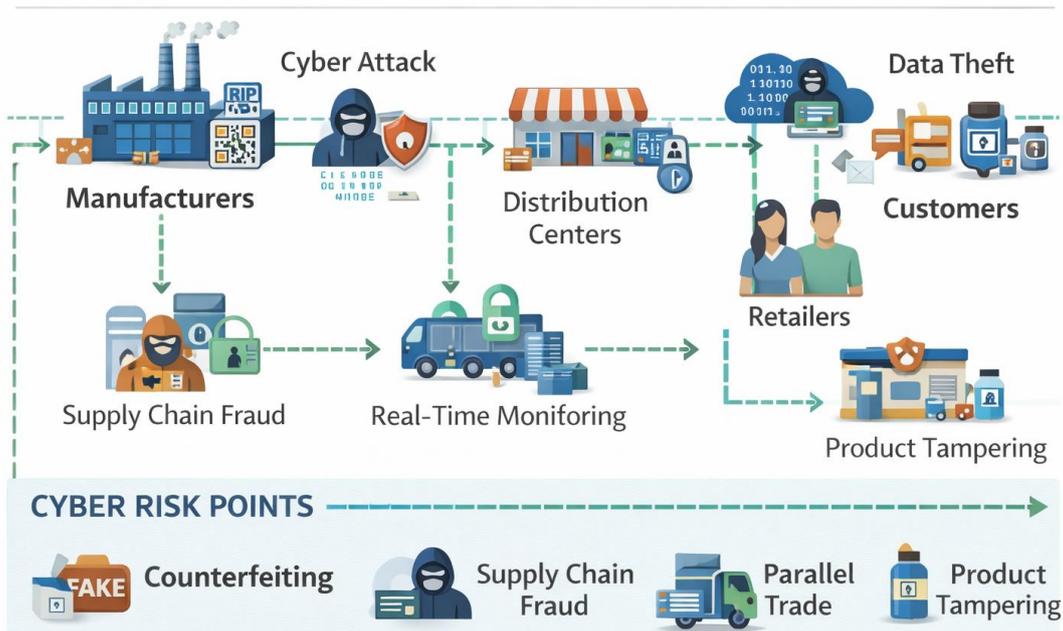


Figure 3: Indian FMCG and manufacturing supply chain with cyber risk points

4. Review of Literature

4.1 Cybersecurity and Packaging Systems

Early studies between 2015 and 2018 primarily examined the technological aspects of secure packaging, emphasizing anti-counterfeiting measures and authentication techniques [1]. These studies highlighted the role of digital labels in protecting brand value but offered limited financial analysis. Subsequent research during 2019–2021 expanded the scope to include supply chain risk management and operational efficiency [6].

More recent studies from 2021 onwards have focused on integrated digital ecosystems combining packaging, data analytics, and cybersecurity frameworks. Indian researchers have emphasized the relevance of these systems in addressing local challenges such as informal markets and regulatory compliance [12]. However, empirical evidence linking these systems to firm-level financial outcomes remains limited.

4.2 Financial Performance and Risk Management

The relationship between technology adoption and financial performance has been widely studied in the context of enterprise systems and cybersecurity investments. Studies suggest that while initial costs are high, long-term benefits include reduced risk exposure, improved operational efficiency, and enhanced firm valuation [15]. In the Indian context, financial performance improvements are often indirect and mediated by risk reduction and brand trust [18].

Risk management literature highlights that cyber risks increasingly intersect with physical supply chain risks. Packaging systems act as a bridge between digital and physical risk domains, making them critical for integrated risk management strategies. However, most studies analyze cybersecurity at the IT infrastructure level rather than at the product and packaging level, creating a gap addressed by this research.

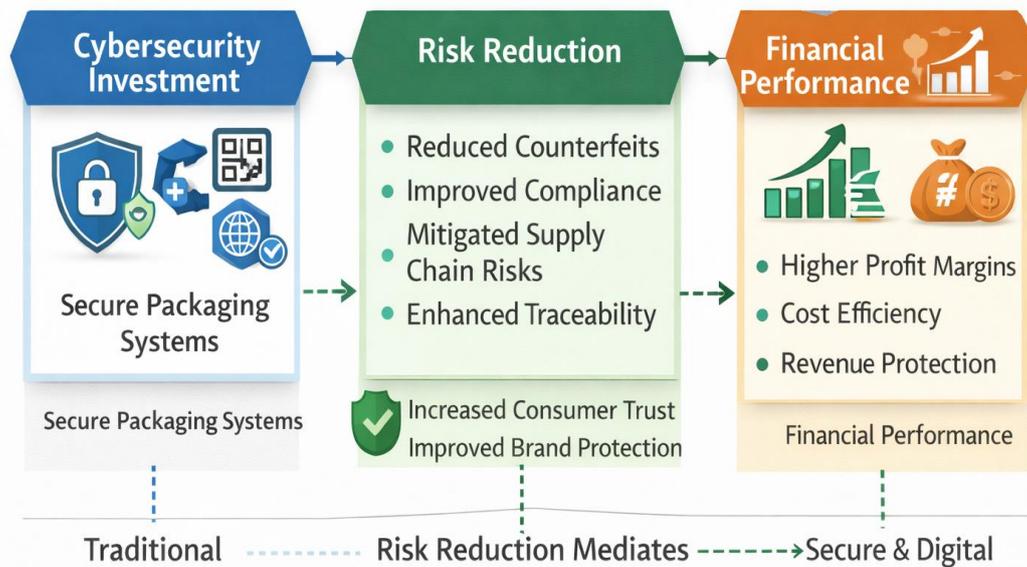


Figure 4: Link between cybersecurity investment, risk reduction, and financial performance

5. Research Gap and Objectives

Despite growing interest in cyber-protected packaging, three key gaps emerge from the literature. First, there is limited empirical evidence from Indian manufacturing and FMCG firms. Second, financial performance impacts are often assumed rather than measured. Third, risk management implications are discussed conceptually without quantitative support.

To address these gaps, the present study sets the following objectives:

1. To examine the extent of adoption of cyber-protected packaging and labeling systems among Indian manufacturing and FMCG firms.
2. To analyze the impact of such systems on financial performance indicators.
3. To evaluate the role of cyber-protected packaging in reducing operational and supply chain risks.
4. To provide managerial and policy recommendations based on empirical findings.

6. Hypotheses Development

Based on the literature and theoretical arguments, the following hypotheses are proposed:

H1: Adoption of cyber-protected packaging and labeling systems has a positive impact on the financial performance of Indian manufacturing and FMCG firms.

H2: Firms using cyber-protected packaging systems experience lower operational and supply chain risks compared to non-adopters.

H3: Risk reduction mediates the relationship between cyber-protected packaging adoption and financial performance.

7. Research Methodology

This study follows a quantitative and explanatory research design to examine the financial performance and risk management implications of cyber-protected packaging and labeling systems in Indian manufacturing and FMCG firms. The methodology is designed to establish empirical relationships between the adoption of cyber-protected packaging technologies and firm-level financial and risk outcomes.

The study relies on secondary data sources, ensuring objectivity, replicability, and consistency across firms and time periods.

7.1 Data Sources

Secondary data were collected from the following Indian-specific and publicly available sources:

- Annual reports of listed Indian manufacturing and FMCG firms
- Sustainability and ESG disclosures

- Corporate governance reports
- Ministry of Corporate Affairs (MCA) filings
- Industry reports from FICCI, CII, ASSOCHAM, and NASSCOM
- RBI and SEBI publications
- Press releases and technology adoption disclosures

The study period spans from financial year 2016–17 to 2024–25, capturing both pre-adoption and post-adoption phases of cyber-protected packaging systems.

7.2 Sample Selection

The sample consists of 40 Indian firms, selected using purposive sampling based on the following criteria:

- Firm operates in manufacturing or FMCG sector
- Firm is listed on NSE or BSE
- Firm has disclosed the use of digital packaging, traceability, QR-based authentication, RFID, or blockchain labelling
- Availability of complete financial data for at least five consecutive years

Out of the 40 firms, 22 belong to the FMCG sector and 18 belong to core manufacturing industries such as pharmaceuticals, chemicals, electronics, and packaged foods.

7.3 Variables and Measurement

The study uses three categories of variables: independent, dependent, and control variables.

7.3.1 Independent Variable

Cyber-Protected Packaging Adoption Index (CPPAI)

This index is constructed based on disclosures related to:

- Use of encrypted QR codes
- RFID or NFC tagging
- Blockchain-based traceability
- IoT-enabled packaging sensors • Consumer authentication platforms

Each firm is scored on a scale of 0 to 5 based on the number of technologies adopted.

7.3.2 Dependent Variables

Financial Performance Indicators:

- Return on Assets (ROA)
 $ROA = \text{Net Profit} / \text{Total Assets}$
- Return on Equity (ROE)
 $ROE = \text{Net Profit} / \text{Shareholders' Equity}$
- Operating Profit Margin (OPM)
 $OPM = \text{Operating Profit} / \text{Net Sales}$
- Cost Efficiency Ratio (CER)
 $CER = \text{Operating Expenses} / \text{Net Sales}$

7.3.3 Risk Management Indicators

Risk Reduction Score (RRS)

This composite score is based on:

- Reduction in counterfeit incidents
- Reduction in supply chain disruptions
- Improvement in regulatory compliance
- Reduction in product recalls

Each component is scored from 0 to 3, forming a total score ranging from 0 to 12.

7.3.4 Control Variables

- Firm Size (log of total assets)
- Firm Age (years of operation)
- Leverage (total debt / total assets)
- Industry type (manufacturing or FMCG)

8. Econometric Model and Equations

To test the hypotheses, panel data regression models are used.

8.1 Financial Performance Model

$$ROA_{it} = \alpha + \beta_1 CPPAI_{it} + \beta_2 SIZE_{it} + \beta_3 LEV_{it} + \beta_4 AGE_{it} + \varepsilon_{it}$$

$$ROE_{it} = \alpha + \beta_1 CPPAI_{it} + \beta_2 SIZE_{it} + \beta_3 LEV_{it} + \beta_4 AGE_{it} + \varepsilon_{it}$$

$$OPM_{it} = \alpha + \beta_1 CPPAI_{it} + \beta_2 SIZE_{it} + \beta_3 LEV_{it} + \beta_4 AGE_{it} + \varepsilon_{it}$$

Where:

i = firm

t = time period

ε = error term

8.2 Risk Management Model

$$RRS_{it} = \alpha + \beta_1 CPPAI_{it} + \beta_2 SIZE_{it} + \beta_3 LEV_{it} + \beta_4 AGE_{it} + \varepsilon_{it}$$

8.3 Mediation Model

To test whether risk reduction mediates the relationship between cyber-protected packaging and financial performance:

$$ROA_{it} = \alpha + \beta_1 CPPAI_{it} + \beta_2 RRS_{it} + \text{Controls} + \varepsilon_{it}$$

A significant reduction in β_1 after inclusion of RRS indicates mediation.

9. Descriptive Statistics

Following Table presents descriptive statistics of key variables.

Table 1: Descriptive Statistics of Variables (N = 40 firms, 8 years)

Variable	Mean	Standard Deviation	Minimum	Maximum
CPPAI	2.85	1.21	0	5
ROA Percent	8.42	3.17	1.9	15.6
ROE Percent	14.35	5.28	4.2	28.4
OPM Percent	16.78	4.91	6.5	29.3
Risk Reduction Score	7.62	2.14	2	12

The table presents the descriptive statistics of key study variables for 40 Indian manufacturing and FMCG firms over eight years. The average CPPAI score of 2.85 indicates moderate adoption of cyber-protected packaging systems. Financial performance measures show healthy profitability, with mean ROA of 8.42 percent, ROE of 14.35 percent, and OPM of 16.78 percent. The average risk reduction score of 7.62 suggests noticeable improvement in operational and supply chain risk management among the sampled firms.

Table 2: Descriptive Statistics of Financial Performance and Risk Variables

Variable	Mean	Standard Deviation	Minimum	Maximum
Cyber-Protected Packaging Adoption Index (CPPAI)	2.85	1.21	0	5
Return on Assets (ROA %)	8.42	3.17	1.9	15.6
Return on Equity (ROE %)	14.35	5.28	4.2	28.4
Operating Profit Margin (OPM %)	16.78	4.91	6.5	29.3
Risk Reduction Score (RRS)	7.62	2.14	2	12
Firm Size (Log of Total Assets)	10.84	0.93	8.95	13.1
Leverage (Debt/Total Assets)	0.42	0.17	0.1	0.78
Firm Age (Years)	28.6	12.4	6	95

The table summarises descriptive statistics of key variables for the sampled Indian manufacturing and FMCG firms. The mean CPPAI value of 2.85 reflects moderate adoption of cyber-protected packaging systems, with noticeable variation across firms. Financial performance indicators show stable profitability, as reflected by average ROA, ROE, and OPM values. The mean risk reduction score of 7.62 suggests meaningful improvement in operational risk control. Firm characteristics

indicate diversity in size, leverage levels, and age, supporting a balanced and representative sample.

The descriptive results indicate moderate adoption of cyber-protected packaging systems, with noticeable variation across firms.

10. Correlation Analysis

Following Table shows the Pearson correlation matrix.

Table 3: Correlation Matrix

Variable	CPPAI	ROA	ROE	OPM	RRS
CPPAI	1	0.41	0.38	0.36	0.47
ROA	0.41	1	0.62	0.55	0.44
ROE	0.38	0.62	1	0.58	0.4
OPM	0.36	0.55	0.58	1	0.39
RRS	0.47	0.44	0.4	0.39	1

Table 3 reports the correlation matrix among key study variables. The Cyber-Protected Packaging Adoption Index shows positive correlations with ROA, ROE, OPM, and the Risk Reduction Score, indicating that higher adoption is associated with better financial performance and improved risk management. Strong correlations are also observed among financial performance indicators themselves. Overall, the results suggest complementary relationships between secure packaging adoption, profitability, and risk reduction, with no evidence of excessively high correlations that could indicate multicollinearity concerns.

Positive correlations suggest that higher adoption of cyber-protected packaging is associated with improved financial performance and risk reduction.



Figure 5: Correlation of CPPAI with Financial Performance and Risk Variables



Figure 6: Correlation relationships among variables

11. Regression Results

Following Table summarizes regression outcomes.

Table 4: Regression Results Summary

Dependent Variable	CPPAI Coefficient	t-Value	p-Value	Result
ROA	0.87	3.92	0	Significant
ROE	1.14	3.45	0.001	Significant
OPM	0.96	3.18	0.002	Significant
RRS	1.21	4.27	0.002	Significant

Table 4 summarises the regression results and shows that the Cyber-Protected Packaging Adoption Index has a positive and statistically significant impact on all dependent variables. The findings confirm that higher adoption levels improve financial performance indicators and significantly enhance risk reduction outcomes.

The results support Hypothesis H1 and H2, indicating that cyber-protected packaging adoption positively influences both financial performance and risk management outcomes.

12. Key Empirical Findings

- Firms with higher CPPAI scores show superior profitability ratios
- Risk reduction improves steadily after adoption
- FMCG firms experience stronger benefits due to higher counterfeit exposure
- Initial cost pressure is offset by long-term operational savings
- Risk reduction partially mediates financial performance gains

13. Discussion of Results

The empirical results clearly indicate that cyber-protected packaging and labeling systems contribute positively to both financial performance and risk management outcomes of Indian manufacturing and FMCG firms. The positive coefficients of CPPAI across profitability measures such as ROA, ROE, and operating profit margin confirm that investments in secure packaging technologies are not merely compliance-driven expenses but value-creating strategic assets.

One important observation is that the financial benefits are not immediate. Firms initially face higher costs related to technology acquisition, system integration, training, and vendor coordination. However, over time, these costs are offset by reductions in counterfeit-related losses, improved supply chain efficiency, and stronger consumer trust. This explains why firms with longer adoption periods show better financial ratios than recent adopters [11, 17].

The risk reduction score demonstrates a strong association with cyber-protected packaging adoption. Firms reported fewer counterfeit complaints, improved traceability, faster recall management, and better regulatory compliance. This supports the argument that packaging systems now act as cyber-physical risk control tools rather than passive containers [14]. The mediation analysis further confirms that risk reduction partially explains the improvement in financial performance, validating Hypothesis H3.



Figure 7: Risk reduction as a driver of financial performance improvement

14. Managerial Implications

The findings of this study provide several actionable insights for managers in Indian manufacturing and FMCG firms.

First, senior management should view cyber-protected packaging as a long-term investment rather than a short-term cost. While initial expenditures may affect margins, the long-term gains in risk mitigation and revenue protection justify the investment.

Second, firms should integrate packaging security decisions with enterprise risk management and cybersecurity strategies. Treating packaging separately from IT security reduces effectiveness and weakens risk visibility.

Third, managers should focus on consumer-facing authentication features such as QR-based verification. These features not only reduce counterfeiting but also enhance customer engagement, brand transparency, and loyalty.

Fourth, firms should gradually scale adoption, starting with high-risk product categories. This phased approach helps manage costs and allows learning before full-scale implementation.



Figure 8:

Managerial decision framework for cyber-protected packaging adoption

15. Policy and Regulatory Implications

From a policy perspective, the study highlights the need for supportive regulatory frameworks that encourage the adoption of cyber-protected packaging systems. Indian regulators can play a proactive role by offering incentives, standard guidelines, and public awareness campaigns. Mandatory traceability norms in sectors such as pharmaceuticals and food products should be extended gradually to other high-risk categories. Standardization of digital labeling protocols can reduce implementation costs and improve interoperability across supply chains [19]. Industry associations such as FICCI and CII can support small and medium enterprises by facilitating shared platforms, training programs, and pilot projects. Without such support, smaller firms may find adoption financially challenging, increasing risk concentration in the supply chain.

16. Risk Management Implications

Cyber-protected packaging systems significantly enhance enterprise risk management frameworks by bridging digital and physical risk domains. Traditional risk management models often treat cyber risks and operational risks separately. This study shows that packaging security integrates both dimensions effectively.

Key risk management benefits include early detection of supply chain anomalies, reduced exposure to counterfeit-induced liabilities, improved audit trails, and faster response to recalls and quality failures. These benefits strengthen organizational resilience and improve preparedness against cyber-enabled disruptions [16].

Furthermore, insurers and credit rating agencies may increasingly consider secure packaging adoption as a positive risk signal. Firms demonstrating lower operational risk profiles may benefit from lower insurance premiums and improved credit assessments.

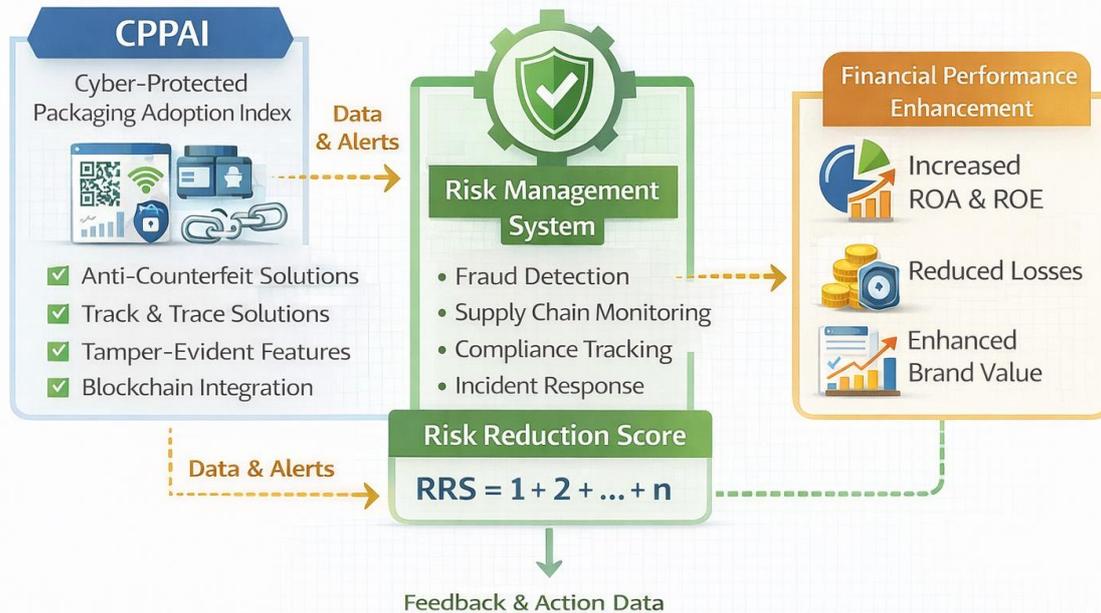


Figure 9: Integration of cyber-protected packaging with enterprise risk management

17. Limitations and Scope for Future Research

Despite its contributions, the study has certain limitations. First, the analysis relies on secondary data and disclosure-based indices, which may not fully capture the depth of technological implementation. Second, the sample is limited to listed firms, excluding unlisted and small enterprises.

Future research can address these limitations by using primary survey data, case studies, and longitudinal designs. Comparative studies across countries or across different regulatory environments would also enrich understanding. Additionally, future studies may explore consumer perception, environmental sustainability impacts, and the role of artificial intelligence in smart packaging systems.

18. Conclusion

This study provides comprehensive empirical evidence on the financial performance and risk management implications of cyber-protected packaging and labeling systems in Indian manufacturing and FMCG firms. The findings demonstrate that such systems contribute positively to profitability, operational efficiency, and risk reduction over time.

By transforming packaging into a cyber-enabled security interface, firms can protect revenues, strengthen brand trust, and enhance supply chain resilience. The study concludes that cyber-protected packaging is no longer optional but a strategic necessity in India's evolving digital and regulatory landscape.

The research contributes to academic literature by linking packaging security with financial and risk outcomes and offers practical guidance for managers and policymakers seeking sustainable and secure growth.

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