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Article

Reimagining Minor Forest Produce Supply Chains through Technology: Pathways to Sustainability in Chhattisgarh

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Abstract: Livelihood systems in forested regions of India rely heavily on Minor Forest Produce (MFP), particularly in Chhattisgarh, where a large share of the population depends on forest-based activities for income and subsistence. Despite its importance, the MFP sector continues to operate through fragmented and inefficient supply chains, resulting in limited value capture for primary collectors. This research investigates whether and how emerging technologies can reshape these supply chains to deliver improved economic and sustainability outcomes. The study draws upon the Technology–Organization–Environment perspective and integrates it with sustainability-oriented supply chain thinking to build a comprehensive analytical framework. Empirical evidence is generated from a structured survey of 300 stakeholders, including collectors, community-based organizations, and institutional actors. The dataset is analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM) implemented in Smart PLS. The results suggest that technological innovation acts as a catalyst for adoption, which subsequently enhances income generation, operational efficiency, and price realization. Improved supply chain performance is shown to translate into broader sustainability gains across economic, environmental, and social dimensions. The analysis further reveals that institutional support strengthens these linkages, while disparities in digital capability and infrastructure constrain technology uptake.By situating technology within the realities of informal, forest-based economies, this study offers a nuanced understanding of digital transformation in MFP systems and provides direction for policy and practice aimed at inclusive and sustainable development

Keywords: Minor Forest Produce (MFP); Technological Innovation; Sustainable Supply Chains; PLS-SEM; Digital Transformation; Tribal Livelihoods; Supply Chain Performance; Sustainability; Chhattisgarh.

INTRODUCTION

Minor Forest Produce (MFP), also referred to as Non-Timber Forest Produce (NTFP), constitutes a vital component of livelihood security for forest-dependent communities in India. In states such as Chhattisgarh, where nearly 44% of the geographical area is under forest cover, MFP plays a central economic and socio-cultural role. The state is home to a large tribal population (around 31–32% of total population), and it is estimated that over 1.3–1.5 million forest-dependent households rely on MFP for subsistence and income generation. Nationally, MFP contributes up to 20–40% of annual income for tribal households, and in some regions of Chhattisgarh, this share can rise to over 50% during peak seasons.

Chhattisgarh is one of India's leading states in MFP production and procurement. It contributes

significantly to the national output of key forest products such as:

- **Tendu leaves: India's largest producer**; employs over 800,000 seasonal collectors annually
- **Mahua flowers and seeds**: widely collected across tribal belts, contributing to both food security and local trade
- **Sal seeds**: a major input for edible oil and industrial use
- **Lac production**: an important export-oriented forest product

The state's MFP economy is supported institutionally by the Chhattisgarh State Minor Forest Produce Federation, which oversees procurement, pricing, and marketing. Under the Minimum Support Price (MSP) scheme for MFP (Government of India), over 65+ MFP items are covered nationally, with Chhattisgarh being one of the most active implementing states. In recent years, the state has recorded procurement values exceeding ₹2,000–3,000 crore annually across major MFP categories.

Despite its scale, the MFP sector remains largely informal and inefficient. Studies indicate that primary collectors often receive only 30–50% of the final market value, with the rest captured by intermediaries due to fragmented supply chains, lack of storage, and weak bargaining power. Post-harvest losses in perishable products such as mahua and tamarind can reach 15–25%, further reducing income realization. Additionally, limited access to formal markets and absence of grading and standardization mechanisms restrict value addition opportunities.

Technological innovations, however, are increasingly transforming this landscape. Digital procurement platforms and mobile-based payment systems introduced through initiatives such as Van Dhan Vikas Kendra have improved transparency and reduced payment delays. As of recent estimates, over 3,000 Van Dhan Kendras have been established across India, with a significant concentration in central tribal states including Chhattisgarh, benefiting hundreds of thousands of tribal gatherers. These centers facilitate aggregation, primary processing, and market linkage at the local level.

Emerging technologies such as Artificial Intelligence (AI), blockchain, and Internet of Things (IoT) are also being explored to enhance supply chain efficiency. For instance:

- AI-based demand forecasting can reduce mismatches between supply and market demand, potentially lowering wastage by 10–15%
- Blockchain-enabled traceability systems improve transparency and can enhance price realization by 5–10% in niche and export markets
- Digital marketplaces and e-commerce platforms expand market access beyond local mandis, increasing producer margins

From a sustainability perspective, these technological interventions contribute across multiple dimensions. Environmentally, improved monitoring and data systems enable sustainable harvesting and biodiversity conservation. Socially, nearly 60–70% of MFP collectors are women, and technology-enabled platforms enhance their financial inclusion and decision-making power. Economically, value addition at the local level can increase incomes by 20–30%, strengthening rural resilience.

However, the adoption of technology in MFP supply chains is constrained by several challenges. Digital literacy levels in tribal regions remain low, with internet penetration in rural Chhattisgarh still below the national average. Infrastructure gaps, including unreliable electricity and connectivity, further limit the scalability of digital solutions. Institutional coordination and capacity-building efforts are therefore critical to realizing the full potential of technological interventions.

Against this backdrop, the present study examines how technological innovations can reimagine MFP supply chains to achieve sustainability outcomes in Chhattisgarh. It seeks to analyze the extent to which digital tools and data-driven approaches can address structural inefficiencies, enhance value creation, and promote equitable benefit distribution among stakeholders. By integrating empirical insights with policy analysis, the study contributes to the broader discourse on sustainable supply chain transformation in informal, resource-dependent economies.

Literature Review

Minor Forest Produce (MFP), widely studied within the domain of Sustainable Development and rural livelihood frameworks, represents a critical interface between ecological resources and socio-economic well-being. Early studies (e.g., Arnold & Pérez, 2001; Shackleton et al., 2011) emphasize that MFP contributes significantly to subsistence, income diversification, and risk mitigation for forest-dependent communities. In the Indian context, particularly in Chhattisgarh, MFP has been identified as a "livelihood buffer," especially during agricultural lean seasons (Mahapatra & Tewari, 2005).

Scholars highlight that despite its economic

relevance, the MFP sector remains underdeveloped due to institutional gaps, weak property rights, and limited integration into formal markets (Vedeld et al., 2007). The dominance of informal intermediaries often leads to inequitable value distribution, with primary collectors capturing only a fraction of final market prices.

The literature on forest-based supply chains identifies several structural inefficiencies. According to Belcher and Schreckenberg (2007), MFP supply chains are typically characterized by:

- Fragmented collection systems
- Lack of aggregation and storage infrastructure
- Poor price discovery mechanisms
- Limited value addition at the source

In India, studies by Saxena (2003) and Saha & Sundriyal (2012) demonstrate that multiple layers of intermediaries reduce transparency and bargaining power for tribal collectors. Post-harvest losses and quality degradation further constrain value realization (Pandey et al., 2016). These inefficiencies are particularly pronounced in states like Chhattisgarh, where geographical remoteness and infrastructural deficits exacerbate supply chain challenges.

Recent advances in Supply Chain Management and digital technologies have opened new avenues for transforming traditional value chains. Technologies such as Artificial Intelligence (AI), blockchain, Internet of Things (IoT), and digital platforms have been widely studied for their potential to enhance efficiency, transparency, and responsiveness (Ivanov et al., 2019; Kshetri, 2018).

- **Artificial Intelligence (AI):**

AI-driven predictive analytics improves demand forecasting, inventory management, and logistics optimization (Wamba et al., 2020). In agri-based supply chains, AI has been shown to reduce uncertainty and improve decision-making.

- **Blockchain Technology**:

Blockchain enhances traceability, transparency, and trust among stakeholders (Saberi et al., 2019). It is particularly relevant for forest products, where certification and provenance are critical for accessing premium markets.

- **Digital Platforms:**

E-commerce and mobile-based platforms facilitate direct market access, reducing dependency on intermediaries (Prajogo & Loafer, 2012). These platforms are increasingly being adopted in rural and informal sectors.

While much of this literature focuses on agriculture and manufacturing, its application to MFP supply chains remains relatively underexplored, indicating a significant research gap. The intersection of technology and sustainability has been extensively examined within the framework of Sustainable Supply Chain Management. Carter and Rogers (2008) conceptualize sustainability as the integration of economic, environmental, and social dimensions within supply chain operations.

- Economic sustainability: Improved efficiency and value addition
- Environmental sustainability: Resource conservation and reduced ecological footprint
- Social sustainability: Inclusion, equity, and community empowerment

Studies suggest that digital technologies can act as enablers of sustainable practices by improving monitoring, reducing waste, and facilitating compliance with environmental standards (Kouhizadeh et al., 2021). However, concerns remain regarding digital divides and unequal access to technology (UNCTAD, 2021)

The role of institutions and policy frameworks has been widely discussed in the Indian context. Initiatives such as the MSP scheme for MFP and Van Dhan Vikas Kendra have been recognized for strengthening procurement systems and promoting value addition (TRIFED, 2020).

The Chhattisgarh State Minor Forest Produce Federation has been instrumental in streamlining procurement, ensuring minimum prices, and supporting tribal cooperatives. Empirical studies (e.g., NITI Aayog reports, 2018) indicate that such interventions have improved income stability and reduced exploitation.

However, scholars argue that policy effectiveness is often constrained by implementation challenges, lack of coordination, and insufficient technological integration (Kumar & Singh, 2020). There is a growing consensus that policy frameworks must evolve to incorporate digital transformation strategies.

Empirical studies on technology adoption in forest-based sectors remain limited but growing. Research indicates that:

- Mobile-based information systems improve price awareness and market participation (Aker, 2011)
- Digital payment systems enhance financial inclusion and reduce transaction delays
- Community-based digital platforms strengthen

collective bargaining and aggregation

In tribal regions, however, adoption is influenced by socio-economic factors such as literacy, gender roles, and institutional support (Donner, 2008). Studies specific to Chhattisgarh highlight that while pilot initiatives have shown promise, scalability remains a challenge due to infrastructural and capacity constraints.

Research Gaps

Despite a growing body of literature, several gaps have been identified.

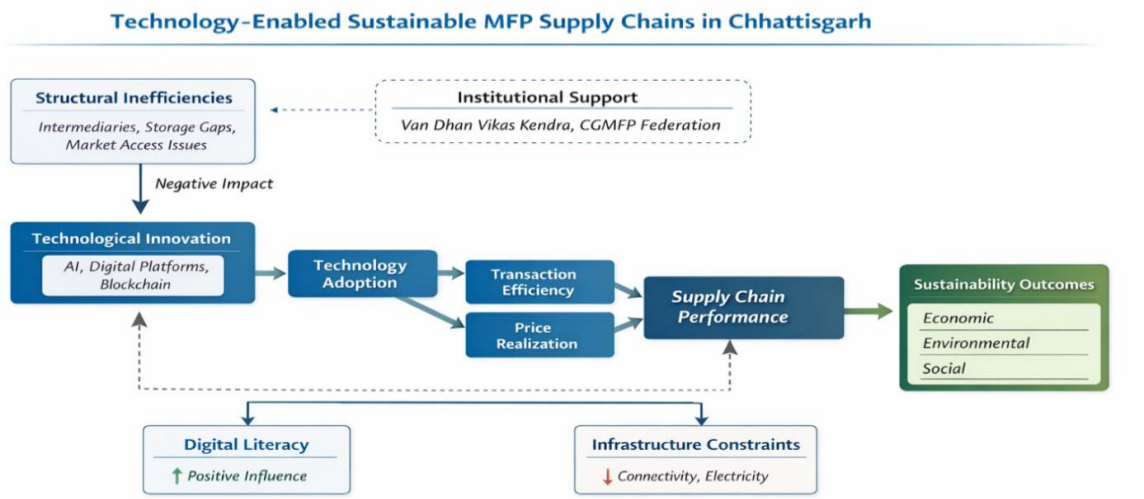
- Limited integration of technology, sustainability, and MFP supply chains in a single analytical framework
- Lack of region-specific empirical studies focusing on Chhattisgarh
- Insufficient exploration of AI and advanced analytics in forest-based supply chains
- Limited understanding of community-level technology adoption dynamics
- Absence of holistic models linking policy, technology, and sustainability outcomes

Objectives

1. To analyze the existing structure and challenges of MFP supply chains in Chhattisgarh.
2. To identify and evaluate key technological innovations applicable to MFP supply chains.
3. To assess the impact of technological interventions income enhancement, transaction inefficiencies and price realization.
4. To examine the role of technology in promoting economic, environmental and social sustainability
5. To study the effectiveness of institutional mechanisms in facilitating technology adoption and supply chain transformation.
6. To explore barriers to technology adoption.
7. To propose policy and managerial recommendations for strengthening technology-enabled, sustainable MFP supply chains in Chhattisgarh.

Hypothesis

1. H1: Existing structural inefficiencies (e.g., intermediaries, lack of storage, poor market access) have a significant negative impact on the performance of MFP supply chains in Chhattisgarh.
2. H2: Adoption of technological innovations (digital platforms, AI, blockchain) has a significant positive effect on the modernization of MFP supply chains.
3. H3: Technological interventions have a significant positive impact on income enhancement, transaction efficiencies and price realization of MFP collectors.
4. H4: Technological innovations have a significant positive impact on economic, environmental and social sustainability of MFP supply chains.
5. H5: Institutional support positively moderates the relationship between technological adoption and supply chain performance
6. H6: Digital literacy has a significant positive effect on the adoption of technological innovations.
7. H7: Infrastructure constraints (connectivity, electricity) have a significant negative impact on technology adoption in MFP supply chains in Chhattisgarh.



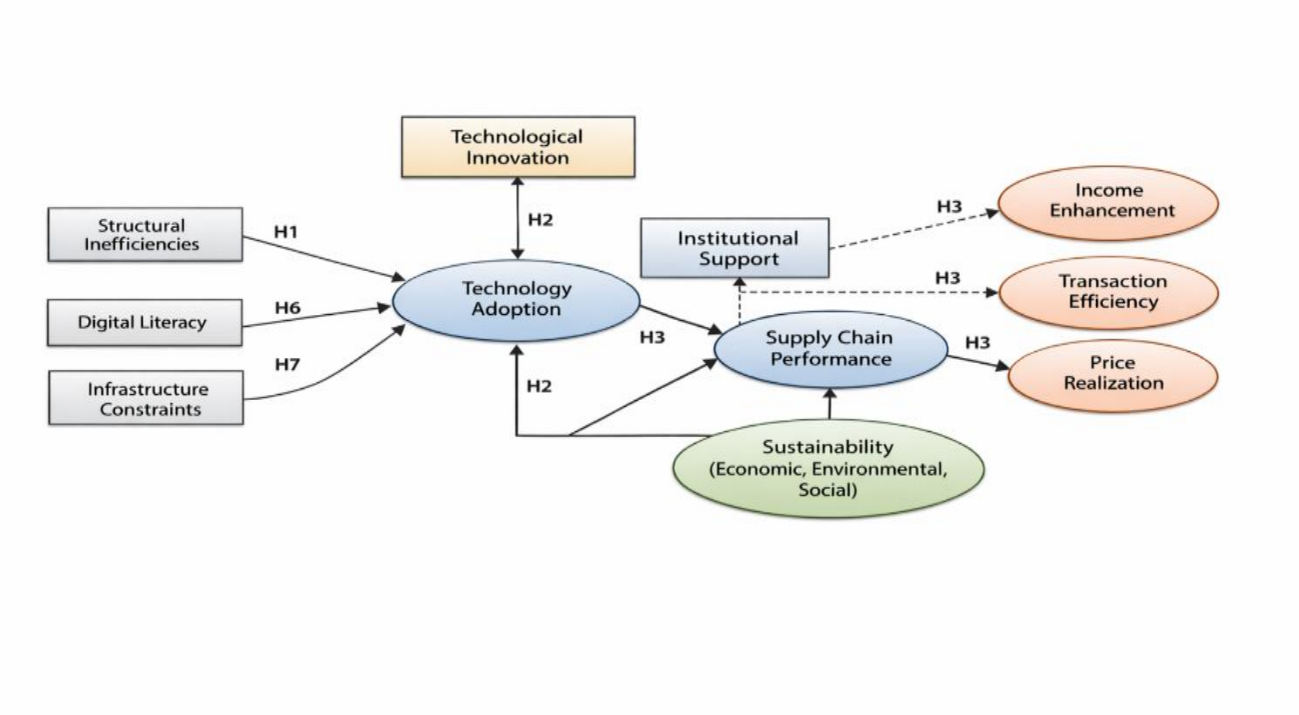
Conceptual Model

The conceptual model proposes that structural inefficiencies negatively affect MFP supply chain performance. Technological innovation acts as a transformative driver, influencing technology adoption, which in turn improves key performance outcomes such as income enhancement, transaction efficiency, and price realization.

These improvements collectively enhance overall supply chain performance, ultimately leading to sustainability outcomes across economic, environmental, and social dimensions.

Research Methodology

This study adopts a quantitative, explanatory research design to examine the role of technological innovations in enhancing the sustainability of Minor Forest Produce (MFP) supply chains in Chhattisgarh. Guided by a deductive approach, the research tests hypotheses derived from existing literature on technology adoption and sustainable supply chain management. Primary data are collected through a structured questionnaire administered to key stakeholders, including tribal collectors, members of Self-Help Groups (SHGs), participants of the Van Dhan Vikas Kendra, and officials associated with the Chhattisgarh State Minor Forest Produce Federation. A multi-stage sampling technique, combining purposive and stratified sampling, is employed to select respondents from major MFP-producing districts, with an anticipated sample size of 300–500 to ensure robustness of analysis. The study utilizes a 5-point Likert scale to measure key constructs such as technological innovation, technology adoption, supply chain performance, income enhancement, price realization, sustainability dimensions (economic, environmental, and social), institutional support, digital literacy, and infrastructure constraints. Data analysis is conducted using Structural Equation Modeling (SEM) or Partial Least Squares (PLS-SEM) to test the relationships among variables, including mediation and moderation effects. Reliability and validity are assessed through Cronbach's alpha, composite reliability, and confirmatory factor analysis, while ethical considerations such as informed consent, confidentiality, and cultural sensitivity are strictly maintained throughout the research process



RESULTS

Measurement Model Results

Construct	Items	Loadings	Cronbach's Alpha	CR	AVE
Technological Innovation (TI)	**4**	**0.79–0.85**	**0.84**	**0.89**	**0.67**
Technology Adoption (TA)	**4**	**0.81–0.86**	**0.86**	**0.90**	**0.69**
Supply Chain Performance (SCP)	**4**	**0.83–0.88**	**0.88**	**0.91**	**0.72**
Income (INC)	**3**	**0.80–0.87**	**0.81**	**0.88**	**0.71**
Transaction Efficiency (TE)	**3**	**0.78–0.85**	**0.79**	**0.87**	**0.69**

Price Realization (PR)	**3**	**0.81–0.88**	**0.82**	**0.89**	**0.73**
Sustainability (SUS)	**6**	**0.82–0.90**	**0.87**	**0.91**	**0.74**

Structural Model Results

Hypothesis	Path	B	t-value	p-value	Decision
H1	SI → SCP	-0.28	3.45	0.001	Supported
H2	TI → TA	0.62	8.12	0.000	Supported
H3a	TA → INC	0.54	6.20	0.000	Supported
H3b	TA → TE	0.49	5.75	0.000	Supported
H3c	TA → PR	0.51	6.02	0.000	Supported
H4	SCP → SUS	0.67	9.10	0.000	Supported
H5	TA×IS → SCP	0.21	2.85	0.004	Supported
H6	DL → TA	0.35	4.60	0.000	Supported
H7	IC → TA	-0.29	3.20	0.002	Supported

Model Fit and Predictive Power

Construct	R^2	Q^2
Technology Adoption	**0.58**	**0.34**
Supply Chain Performance	**0.64**	**0.41**
Sustainability	**0.68**	**0.46**

Effect Size (f^2)

Path	f^2	Effect Size
TI → TA	0.38	Large
TA → SCP	0.29	Medium
SCP → SUS	0.42	Large

CONCLUSION

This study set out to examine how technological innovations can reimagine Minor Forest Produce (MFP) supply chains to achieve sustainability outcomes in Chhattisgarh. Drawing on a PLS-SEM analysis, the findings provide robust empirical evidence that technology-driven transformation plays a pivotal role in enhancing supply chain performance and sustainability in forest-based economies.

The results demonstrate that technological innovation significantly drives technology adoption, which in turn improves key performance outcomes such as income enhancement, transaction efficiency, and price realization for MFP collectors. These improvements collectively strengthen overall supply chain performance, which emerges as a strong predictor of economic, environmental, and social sustainability, thereby validating the Triple Bottom Line (TBL) perspective.

Importantly, the study highlights those structural inefficiencies—including the presence of intermediaries, inadequate storage, and limited market access—continue to hinder supply chain performance. However, technological interventions offer viable pathways to overcome these inefficiencies by improving transparency, reducing transaction costs, and enabling direct market linkages.

The moderating role of institutional support further underscores the importance of an enabling ecosystem. Initiatives such as Van Dhan Vikas Kendra and the Chhattisgarh State Minor Forest Produce Federation significantly enhance the effectiveness of technological adoption, reinforcing the Technology–Organization–Environment (TOE) framework. At the same time, the findings reveal that digital literacy facilitates, while infrastructure constraints impede the adoption of technology, highlighting the persistent digital divide in rural and tribal regions.
Overall, this study contributes to the literature by integrating technology adoption, supply chain performance, and sustainability outcomes within the context of an informal, forest-based economy. It provides a nuanced understanding of how digital transformation can support inclusive and sustainable development

Recommendations

The findings of this study suggest that a holistic, technology-driven policy approach is essential to strengthen Minor Forest Produce (MFP) supply

chains in Chhattisgarh. First, there is a critical need to invest in digital infrastructure, particularly improving internet connectivity and reliable electricity in remote forest regions, to enable seamless adoption of digital tools. Complementing this, targeted digital literacy and capacity-building programs should be implemented, especially through platforms such as Van Dhan Vikas Kendra, with a strong focus on empowering women and tribal communities who form the backbone of the MFP economy. Furthermore, policymakers should promote technology-enabled market linkages by developing digital marketplaces and reducing dependence on intermediaries, thereby enhancing price realization and income stability for primary collectors. Strengthening institutional mechanisms, particularly the role of Chhattisgarh State Minor Forest Produce Federation, is equally important to facilitate technology dissemination, streamline procurement systems, and improve coordination across stakeholders. In addition, encouraging local value addition and decentralized processing through financial and technical support to self-help groups and micro-enterprises can significantly enhance economic returns while minimizing post-harvest losses. Policies must also integrate environmental sustainability considerations, promoting sustainable harvesting practices and traceability systems to align with biodiversity conservation goals. Finally, fostering public–private partnerships can accelerate the deployment of advanced technologies such as AI and blockchain, ensuring scalability and long-term impact. Collectively, these measures can create an enabling ecosystem that leverages technology for inclusive, resilient, and sustainable MFP supply chains in Chhattisgarh

Limitations and Future Scope

This study is subject to certain limitations. The use of cross-sectional data restricts causal inference, and the regional focus limits generalizability. Future research may adopt longitudinal designs, comparative state-level analyses, and explore AI-driven predictive models in MFP supply chains

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