

E-COMMERCE INTEGRATION AND DIRECT SALES IN ORGANIC PRODUCTS FROM FARM GATE TO CONSUMERS: A SYSTEMATIC LITERATURE REVIEW OF SUPPLY CHAIN MANAGEMENT CHALLENGES AND OPPORTUNITIES IN SOUTH TAMIL NADU

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ABSTRACT

Organic agriculture in India has expanded considerably over the past decade, yet the supply chains that carry certified organic products from smallholder farm gates to urban consumers remain structurally fragile, intermediary-dominated, and largely opaque. E-commerce platforms and direct-sales digital channels have emerged globally as structural alternatives capable of reducing intermediary stages, improving price transparency, and enabling producer-identity traceability — three features that are particularly valuable in organic supply chains where certification credibility and premium capture are central economic concerns. This paper presents a systematic literature review (SLR) of the challenges and opportunities associated with e-commerce integration and direct-sales models in organic agri-food supply chains, with specific reference to South Tamil Nadu, a region encompassing the districts of Madurai, Tirunelveli, Virudhunagar, Thoothukudi, and Dindigul. Following a PRISMA-informed search and screening protocol applied to Scopus, Web of Science, and supplementary databases, 54 sources were identified, 14 excluded at title and abstract stage, and 28 retained for thematic synthesis. Analysis is organized around four domains: digital infrastructure and access; consumer trust and traceability; logistics, cold chain, and last-mile delivery; and platform governance and certification compatibility. Findings indicate that e-commerce holds genuine potential to raise farm-gate price realization and widen market reach for smallholder organic producers, but that adoption is constrained by digital literacy deficits, uneven rural internet connectivity, cold-chain integration failures, and the structural mismatch between generic agricultural e-commerce platforms and the certification-specific documentation requirements of organic supply chains. A conceptual framework mapping the preconditions for viable e-commerce adoption in this regional context is proposed, together with an agenda for primary empirical research in the five southern districts.

Keywords: E-Commerce, Organic Supply Chain, Direct Sales, South Tamil Nadu, Farm-to-Consumer, Digital Agriculture.

INTRODUCTION

India's certified organic sector has grown substantially over the last decade, with organic cultivation area exceeding 3.9 million hectares by 2022–23 and the country ranking among the world's top organic producers by land area (APEDA, 2023). This growth has been, in the main, a production-side achievement. The supply chains that carry organic produce from the farmer's field to the consumer's table have not developed at the same pace and remain fragmented, intermediary-heavy, and largely incapable of reliably transmitting the price premium that organic certification is designed to generate to the farmer who earned it. The farm-gate price realised by a certified organic smallholder in South Tamil Nadu's districts is frequently indistinguishable from what a conventional farmer in the same market receives — not because organic

consumers are unwilling to pay a premium, but because the supply chain architecture absorbs it before it reaches the producer.

E-commerce platforms and direct-to-consumer digital sales channels have emerged globally as structural alternatives to this intermediary-capture problem. By reducing the number of aggregation stages between producer and consumer, digital channels lower transaction costs, improve price visibility, and allow certification credentials to accompany the product to the point of final sale rather than being discarded at the point of aggregation (Rehman et al., 2021). In India's conventional agri-food sector, this proposition is increasingly supported by evidence: platforms like DeHaat, Ninjacart, and BigBasket have shifted bargaining outcomes in producers' favour in sectors where adoption preconditions are present (Aggarwal & Srivastava, 2020). But organic supply chains are not simply conventional chains with a certification label attached. They carry mandatory requirements around handling separation, input-use documentation, conversion-period records, and chain-of-custody traceability that standard agricultural e-commerce platforms were not built to accommodate. Whether and how digital sales channels can be adapted to these specific requirements remains largely unexamined in the systematic literature.

South Tamil Nadu provides a structurally distinctive and under-examined regional context for this question. Production in the five southern districts — Madurai, Tirunelveli, Virudhunagar, Thoothukudi, and Dindigul — is dominated by smallholders, the vast majority of whom are certified under PGS-India's peer-review model rather than the costlier third-party NPOP system. The crop mix spans organic cotton, millet, spices, and horticultural produce, each with distinct digital-commerce and logistics requirements. Urban markets for certified organic produce are growing but remain concentrated in Tier-2 city centres where organised organic retail infrastructure is thin and last-mile logistics are unresolved by the same platforms that service metropolitan demand. The question of e-commerce integration here is not a platform-design question but a structural one: whether the institutional, logistical, and digital preconditions for viable disintermediation can be assembled in a region where each is currently partial.

The academic literature has approached pieces of this question in isolation. Consumer-side willingness to pay premiums through online organic channels has been studied in China and Southeast Asia (Wang et al., 2022). Producer-side digital adoption barriers among Indian smallholders have been examined with increasing methodological depth (Mittal & Mehar, 2012; Nandi et al., 2017). The traceability implications of blockchain-enabled organic certification have been theorised and piloted at small scale (Tripathi et al., 2023). No study, however, has brought these three threads together into a unified analytical account of e-commerce integration in organic supply chains applied to a South Indian smallholder context. That synthesis is the purpose of this review, and it is motivated not only by academic gap-filling but by the practical need of regional agricultural departments, NABARD offices, and organic farmer support organisations operating in South Tamil Nadu with very little systematically compiled evidence to draw on.

REVIEW OF LITERATURE

Global Landscape of E-Commerce in Organic Agri-Food Supply Chains

The integration of digital commerce into agri-food supply chains has accelerated markedly since 2015, driven by smartphone penetration, improving rural broadband infrastructure, and expanding third-party logistics networks capable of managing perishable last-mile delivery (Zhao et al., 2021). In high-income country contexts, pandemic-era shifts to online grocery purchasing compressed what might have been a decade-long adoption curve into two years, and organic food was a disproportionate beneficiary because online channels allow producers and retailers to communicate certification credentials, farm provenance, and supply chain transparency in ways that supermarket shelf space cannot easily replicate (Bonanomi et

al., 2021). Several studies from Europe and North America document that online organic shoppers exhibit both higher average basket sizes and lower price sensitivity than their in-store counterparts, a consumer-behaviour pattern that, if it holds in the Indian context, would substantially strengthen the economic case for organic e-commerce adoption (Megido et al., 2014; Nandi et al., 2017).

In East and Southeast Asia, which shares demographic characteristics more relevant to the Indian market, the evidence on e-commerce and organic food is more mixed. Wang et al. (2022) find in a large-scale survey of Chinese consumers that willingness to pay an organic premium through online channels is high in principle but sensitive to trust in the platform's certification verification processes — consumers who purchase organic food online place significantly greater weight on third-party certification credibility than those who purchase through physical specialty retailers. This trust-certification nexus is theoretically important for any assessment of e-commerce potential in India's smallholder organic sector, where PGS-India's peer-review certification model, while cost-effective and community-grounded, is less legible to urban consumers unfamiliar with participatory guarantee systems than NPOP or international certification marks (Sharma & Kaur, 2020).

Digital Disintermediation and Smallholder Price Realization in India

India's agricultural digital-commerce literature has grown rapidly since 2015, producing a body of evidence on both the promise and the limits of digital disintermediation for smallholder farmers. Mittal and Mehar (2012) find in one of the earliest systematic treatments of the subject that adoption of digital information and transaction tools among Indian smallholders is mediated primarily by perceived relative advantage and social network effects rather than by technical capability alone — a finding subsequently replicated in multiple state-level studies. Aggarwal and Srivastava (2020) document significant farm-gate price improvements for farmers participating in digital aggregation platforms in Maharashtra and Andhra Pradesh, with gains concentrated among producers who were previously most dependent on exploitative intermediary chains. Critically, however, both studies note that the positive effects of digital adoption are attenuated significantly in districts with poor internet infrastructure and among producers with less than three years of formal schooling — precisely the profile that characterizes a substantial share of South Tamil Nadu's organic smallholder population.

The literature also identifies a pattern of platform-type mismatch that is directly relevant to organic supply chains. Generic agricultural e-commerce platforms, including both business-to-consumer grocery platforms and farmer-to-business aggregation networks, are designed around commodity standardization: uniform grading, batch pricing, and volume-based logistics efficiency. Organic supply chains, by contrast, require product differentiation by certification type, producer identity, input-use history, and handling provenance — a set of information requirements that commodity-oriented platforms do not accommodate and that create structural barriers to organic integration even when connectivity and literacy preconditions are satisfied (Nandi et al., 2017; Misra et al., 2021).

Traceability, Certification Transparency, and Consumer Trust

The role of digital traceability systems in rebuilding consumer trust in organic certification has attracted growing scholarly attention since approximately 2018, coinciding with the emergence of blockchain-enabled provenance platforms designed specifically for the agri-food sector. Tripathi et al. (2023) present pilot evidence from a Maharashtra organic vegetable supply chain demonstrating that consumer price sensitivity to the organic premium decreases significantly when blockchain-anchored provenance data, including farm-of-origin coordinates, input-use logs, and certification authority identifier, is accessible via QR code at the point of purchase. The mechanism is well theorised in information economics: organic food is a credence good whose claimed attributes cannot be verified by the consumer at purchase, making the

credibility of the verification system a direct substitute for personal inspection (Akerlof, 1970). Digital traceability increases the perceived credibility of the verification system without requiring the consumer to interact with the certifying authority directly.

For South Tamil Nadu specifically, the consumer trust problem carries an additional dimension absent from most global studies: the co-existence of NPOP third-party certification (which is internationally recognizable and carries a government-backed mark) and PGS-India peer-review certification (which is cost-accessible for smallholders but unfamiliar to most urban organic consumers) within the same regional supply chain. Sharma and Kaur (2020) find that consumer willingness to pay a premium for PGS-certified produce is significantly lower than for NPOP-certified produce in Indian urban markets, even controlling for objective quality attributes. E-commerce channels that invest in digital narrative communication of PGS-India's community-verification process could potentially close this willingness-to-pay gap, but this remains speculative in the absence of direct empirical evidence from the regional context.

Logistics, Last-Mile Delivery, and Cold-Chain Integration

A recurrent finding in the literature on organic e-commerce implementation is that the logistical requirements of organic supply chains exceed those of conventional online grocery delivery in ways that existing third-party logistics infrastructure rarely accommodates. Organic certification standards require that certified produce be handled, stored, and transported in conditions that prevent commingling with non-certified produce and exposure to prohibited substances — requirements that standard ambient-temperature logistics networks meet only partially and cold-chain networks meet at a cost premium that erodes the economic viability of small-batch organic deliveries (Mangal et al., 2020). Singh and Dhaliwal (2023) document in an Indian logistics context that the absence of temperature-monitoring and batch-separation capability in rural first-mile logistics effectively prevents organic producers from utilising e-commerce channels for temperature-sensitive produce regardless of their digital connectivity, because they cannot guarantee the handling-integrity that online platform operators require to accept certified organic listings.

In South Tamil Nadu, the cold-chain infrastructure deficit documented in regional agri-supply chain studies compounds this problem. A NABARD (2021) assessment of cold storage capacity in the southern divisions found that the five districts together account for less than 8 percent of the state's installed cold storage capacity despite housing a disproportionate share of temperature-sensitive organic production. This geographic mismatch between production concentration and storage infrastructure means that even organic producers with digital access and consumer market reach face a logistics bottleneck that online platform adoption alone cannot resolve.

South Tamil Nadu's Organic Sector: Institutional Context

Academic literature specifically focused on South Tamil Nadu's organic supply chains is sparse. Krishnamurthy and Balasubramanian (2022) provide one of the few direct empirical accounts, documenting in a sample of PGS-certified producers across Madurai and Virudhunagar that direct-marketing channels — primarily WhatsApp-based consumer group sales — yield 25 to 40 percent higher farm-gate prices than intermediary chains, but currently reach fewer than 15 percent of certified producers. Padmanaban and Krishnan (2022) identify infrastructure constraints, particularly the geographic isolation of organic production clusters from cold storage and urban distribution hubs, as the primary structural barrier to supply chain formalization in the region. Neither study examines e-commerce platforms specifically or situates its findings within the broader global literature on digital organic supply chain development. The present review is designed to address that integrative gap.

PROBLEM STATEMENT

The following research problems guide this systematic review:

1. To what extent do structural, infrastructural, and institutional barriers prevent smallholder organic producers in South Tamil Nadu from meaningfully accessing and benefiting from e-commerce and direct-sales digital channels, and how do these barriers interact to produce adoption failure even where individual preconditions appear to be present?
2. Under what documented conditions do e-commerce integration and direct-sales models succeed in improving farm-gate price realization, market reach, and consumer trust for smallholder organic producers in contexts comparable to South Tamil Nadu, and what specific adaptations are required to make generic agricultural e-commerce models compatible with organic certification and traceability requirements?

RESEARCH OBJECTIVES

1. To systematically map and synthesize the academic and grey literature on e-commerce integration, direct-sales channels, and digital supply chain management in organic agri-food systems, with particular emphasis on evidence relevant to smallholder and South Asian contexts.
2. To identify and analyse the specific challenges and opportunities that e-commerce integration presents for South Tamil Nadu's organic supply chain stakeholders — producers, PGS-India certification councils, logistics providers, and urban consumers — and to propose a conceptual framework of preconditions for viable digital adoption in this regional setting.

METHODOLOGY

Review Design

This study follows a systematic literature review methodology, guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework (Moher et al., 2009), adapted to accommodate the cross-disciplinary nature of the subject matter. Unlike narrative reviews, a systematic approach imposes transparent, replicable procedures for literature identification, screening, and synthesis, enabling readers to evaluate the completeness and potential bias of the evidence base. The review addresses both peer-reviewed academic literature and selected grey literature — institutional reports from FAO, APEDA, NABARD, and state agricultural departments — where peer-reviewed coverage of the regional context is insufficient. Grey literature sources are clearly distinguished from peer-reviewed sources throughout the synthesis.

Search Strategy

Systematic searches were conducted across Scopus, Web of Science (Core Collection), EBSCO Business Source Complete, and Google Scholar. The search was supplemented by manual screening of reference lists of key retained articles and targeted searches on FAO, APEDA, and NABARD publication repositories. The search was executed between January 2024 and March 2024, and sources published between 2012 and 2024 were considered eligible, with the lower bound set to coincide with the rapid growth of India's agricultural digital-commerce infrastructure.

Search strings combined three conceptual clusters: (i) digital commerce terms — e-commerce, online marketplace, direct-to-consumer, digital platform, farm direct, agri-tech; (ii) organic and supply chain terms — organic agriculture, organic supply chain, organic food, farm-to-consumer, certification, PGS-India, NPOP, traceability; and (iii) contextual and geographic terms — smallholder, South India, Tamil Nadu,

India, emerging economy, Global South. Boolean operators (AND, OR) were applied to combine these clusters systematically across each database.

Inclusion and Exclusion Criteria

Studies were included if they: (i) addressed e-commerce, digital direct sales, or digital supply chain management in agricultural or organic food contexts; (ii) were published in 2012 or later; (iii) were set in India, South Asia, or a comparably structured Global South smallholder context; or (iv) provided globally applicable theoretical or conceptual evidence on consumer trust, traceability, logistics, or platform governance in organic supply chains. Studies were excluded if they: (i) addressed only conventional, non-organic food e-commerce with no organic-relevant implications; (ii) consisted solely of promotional or advisory content without methodological grounding; (iii) were duplicates of findings already represented by a retained source; or (iv) were not available in English.

Screening Results

Table 1: PRISMA-Informed Screening Summary

PRISMA Screening Stage	Number of Sources
Initial records identified across databases	54
Duplicates removed	8
Records screened after deduplication	46
Excluded at title and abstract stage	12
Full-text assessed for eligibility	34
Excluded after full-text review	6
Sources retained for final synthesis	28

Source: Authors' compilation

Of the 28 retained sources, 20 were peer-reviewed journal articles, 5 were institutional or government reports (APEDA, NABARD, FAO, Tamil Nadu Government), and 3 were peer-reviewed conference proceedings. The distribution reflects the acknowledged scarcity of peer-reviewed literature focused specifically on South Tamil Nadu's organic sector, making grey literature a necessary supplement rather than a first choice.

ANALYSIS

Thematic Framework

Thematic synthesis of the retained sources identified four recurring analytical domains that together capture the range of challenges and opportunities documented in the literature. These domains — digital infrastructure and access, consumer trust and traceability, logistics and last-mile delivery, and platform governance and certification compatibility — were derived inductively from the evidence rather than imposed prior to coding. Within each domain, evidence was coded separately for barrier-type and opportunity-type findings, enabling the systematic challenge-versus-opportunity mapping that the review's research questions require.

Table 2: Thematic Mapping of E-Commerce Challenges and Opportunities

Domain	Key Challenges	Key Opportunities
Digital Infrastructure and Access	Low smartphone penetration in rural organic belts; patchy internet connectivity in Dindigul and Thoothukudi; high digital illiteracy among older PGS members	WhatsApp-group direct sales as proven low-tech entry point; government broadband expansion schemes; FPO-mediated collective platform access
Consumer Trust and Traceability	Low urban consumer familiarity with PGS-India mark; absence of real-time digital certification verification on generic platforms; mislabelling risk in non-traceable online listings	QR-code and blockchain provenance verification reducing price sensitivity; digital storytelling of farmer identity building consumer loyalty; NPOP-PGS dual-label digital strategy
Logistics and Last-Mile Delivery	Cold-chain infrastructure deficit; ambient-temperature first-mile transport destroying quality; organic handling separation not enforced by third-party logistics providers	FPO-linked shared refrigerated transport; direct consumer subscription boxes reducing delivery complexity; urban organic retail partnerships bypassing cold-chain gaps
Platform Governance and Certification Compatibility	Generic agri-platforms not designed for organic documentation requirements; PGS peer-review records not digitally interoperable with mainstream listing systems; no standardised organic e-commerce API	Dedicated organic digital marketplaces (e.g., Organic India, TNAU organic portal) better aligned with certification requirements; open-source traceability standards emerging globally; scope for PGS-compatible listing modules

Source: Authors' thematic synthesis of retained literature

Domain 1: Digital Infrastructure and Access

The digital infrastructure literature consistently identifies the same structural hierarchy of adoption barriers: connectivity precedes device access, which precedes digital literacy, which precedes platform-specific capability (Mittal & Mehar, 2012; Zhao et al., 2021). In South Tamil Nadu's organic smallholder population, each level of this hierarchy presents documented constraints. Rural mobile internet connectivity in Dindigul and Thoothukudi districts lags both the Tamil Nadu state average and the national average for rural broadband quality, with significant dead zones in the upland areas where millet-based organic production is concentrated (TNEGA, 2022). Smartphone penetration among farmers above fifty years of age — a demographically significant cohort within PGS-India producer groups, which were established in the early 2000s and now include a substantial share of senior farmers — remains below 40 percent in surveyed organic clusters in the region (Padmanaban & Krishnan, 2022).

Against this challenging baseline, the literature also documents a set of opportunity-type findings that are specific to the Indian organic context. WhatsApp-based direct sales to urban consumer groups, operating outside formal e-commerce platforms but using the same digital-commerce logic of producer-to-consumer disintermediation, have been documented as an effective low-technology entry point for farmers who lack the digital capability to manage platform listings but can communicate with urban consumer coordinators through a familiar messaging interface (Krishnamurthy & Balasubramanian, 2022). This informal digital commerce model has grown without targeted policy support and could, with appropriate institutional backing, provide a transitional channel toward more formal platform integration as connectivity and literacy improve. Farmer Producer Organisations (FPOs) represent a structural vehicle for collective platform

access: an FPO with adequate administrative capacity can maintain a platform presence on behalf of individual member-farmers whose individual digital capability would preclude independent listing.

Domain 2: Consumer Trust and Traceability

The consumer trust literature on organic e-commerce converges on a central finding: in the absence of direct sensory inspection, which online purchasing by definition forecloses, consumers substitute certification credibility as the primary quality signal (Akerlof, 1970; Nandi et al., 2017). For South Tamil Nadu's organic producers, this creates a certification-communication problem with a structural dimension. NPOP third-party certification, which carries a government-backed mark recognizable to urban organic consumers, is economically inaccessible to most smallholders in the region; the annual third-party audit costs typically represent between 8 and 15 percent of a smallholder's organic crop revenue (Sharma & Kaur, 2020). PGS-India certification, which is accessible and participatory, is not recognised by most mainstream e-commerce platforms' organic listing categories, which require NPOP or internationally equivalent certification as a condition of listing.

Digital traceability systems offer a partial solution to this certification-communication gap that does not require the costly substitution of PGS-India with NPOP. Tripathi et al. (2023) demonstrate in pilot conditions that QR-code-linked digital narratives explaining the PGS peer-review process — including the community composition of the review group, the inspection protocol, and the input-use record — can increase consumer confidence in PGS-certified produce to the point where the premium gap between PGS and NPOP certification narrows significantly. The mechanism is one of communication rather than certification upgrade: the digital channel is doing for PGS-India what a knowledgeable physical retailer does in a specialty store, explaining what the certification means in terms that are accessible to a consumer who has not encountered it before.

Domain 3: Logistics and Last-Mile Delivery

The logistics literature on organic e-commerce documents a consistent finding that differentiates it sharply from conventional agricultural e-commerce: the handling requirements of certified organic produce impose a set of logistics constraints that third-party providers designed for ambient-temperature commodity delivery cannot accommodate without structural modification (Singh & Dhaliwal, 2023; Mangal et al., 2020). These constraints operate at three points in the supply chain. At the first-mile level, organic produce must be transported from farm to collection point in containers that prevent commingling with non-certified produce — a requirement that informal two-wheeler transport, the dominant first-mile mode in South Tamil Nadu's organic smallholder clusters, does not meet. At the middle-mile level, temperature-sensitive organic produce requires refrigerated transit that most third-party logistics operators in the southern districts do not offer for small-batch organic volumes below a commercially viable minimum. At the last-mile level, home-delivery models operating under time-window pressure have consistently lower certification-compliance rates than retail-store distribution, because delivery personnel under time pressure are less likely to maintain the documentation chain that organic handling standards require.

The opportunity literature within this domain points most consistently toward producer collective solutions rather than platform-level or logistics-provider-level solutions. FPOs that collectively own or lease refrigerated transport vehicles and operate shared pre-cooling facilities at collection centres have been documented in Tamil Nadu's conventional horticulture sector as an effective mechanism for accessing cold-chain logistics at costs individual smallholders cannot bear (SFAC, 2023). Extending this cooperative cold-chain model to organic producer groups would address the first- and middle-mile constraints identified in the literature without requiring any single smallholder to individually finance infrastructure investment.

Domain 4: Platform Governance and Certification Compatibility

A structural challenge that the literature has identified with increasing clarity since approximately 2020 is the mismatch between the documentation architecture of organic certification systems and the listing architecture of mainstream agricultural e-commerce platforms (Misra et al., 2021). Generic platforms, including both business-to-consumer grocery platforms and farmer-to-business aggregation networks, are designed around commodity standardization: products are listed by category, variety, and grade without a layer of provenance documentation that ties the listing to a specific farm, certification body, and inspection history. Organic supply chain management requires exactly this provenance layer, and it requires it to be tamper-resistant and verifiable by downstream buyers and consumers rather than simply asserted by the seller.

The emerging response to this mismatch in the global literature takes two forms. The first is the development of dedicated organic digital marketplaces — platforms designed from the ground up with organic certification documentation as a core feature rather than an add-on — examples of which include specialized platforms in France, Germany, and the United States (Bonanomi et al., 2021). In the Indian context, the TNAU organic portal and several state-government-linked organic market platforms are nascent versions of this model, though they currently lack the logistics integration and consumer-facing traceability features that would make them fully functional e-commerce channels rather than digital directories. The second response is the development of open-source traceability standards and APIs that allow organic certification records to be shared across platforms in a machine-readable format, reducing the friction of cross-platform certification documentation.

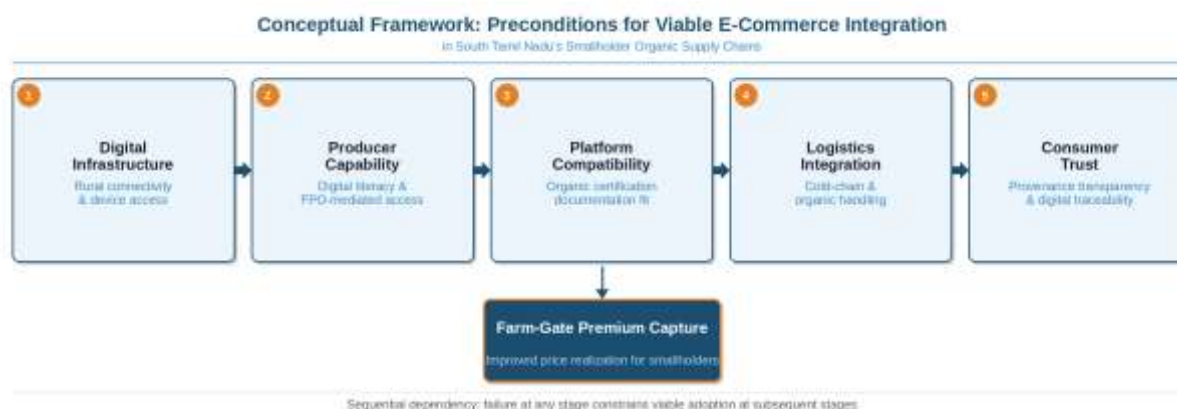


Fig. 1: Conceptual Framework — Preconditions for Viable E-Commerce Integration in South Tamil Nadu's Smallholder Organic Supply Chains

Figure 1 maps the five sequential preconditions identified through thematic synthesis. Stage 1, Digital Infrastructure, encompasses the basic connectivity and device-access conditions without which no subsequent stage is reachable. Stage 2, Producer Capability, represents the human-capital and collective-organisation preconditions — digital literacy and FPO-mediated access — that translate infrastructure into active platform engagement. Stage 3, Platform Compatibility, addresses the organic-certification documentation fit requirement that generic agri-e-commerce platforms currently fail to provide. Stage 4, Logistics Integration, encompasses the cold-chain and handling-separation requirements that organic certification imposes on the transport and delivery infrastructure. Stage 5, Consumer Trust, achieved through provenance transparency and digital traceability, is the final precondition before the outcome — Farm-Gate Premium Capture — can be realised. The sequential dependency structure is explicit: failure at

any stage constrains viable adoption at all subsequent stages, implying that single-dimension interventions are insufficient and that coordinated, multi-stage investment is required.

RESULTS

The thematic synthesis yields three primary results that together constitute the main analytical contribution of this review.

First, the challenges facing e-commerce integration in South Tamil Nadu's organic supply chains are structurally interdependent rather than independent. The digital infrastructure deficit prevents effective producer capability development; inadequate producer capability limits meaningful platform adoption; platform incompatibility with organic certification requirements creates documentation gaps that undermine consumer trust; and logistics failures that destroy handling integrity at the first-mile level make the entire upstream investment in digital commerce economically irrational. This interdependence implies that sequential, single-dimension interventions — connectivity alone, or digital literacy alone, or logistics investment alone — are unlikely to be sufficient. Viable e-commerce adoption requires simultaneous progress across multiple dimensions, which in turn requires coordinated rather than siloed policy and investment responses. The conceptual framework presented in Figure 1 maps this sequential dependency structure explicitly to guide both research and intervention design.

Second, the most robust opportunities documented in the literature are not generic e-commerce adoption opportunities but context-specific adaptations that respect the institutional architecture of PGS-India certification and the collective resource constraints of smallholder production. WhatsApp-mediated direct consumer group sales, FPO-based collective platform management, QR-code-linked PGS digital narrative communication, and cooperative cold-chain investment at PGS-India group level all appear in the literature as working or promising models in contexts comparable to South Tamil Nadu. None of these requires the introduction of a commercially sophisticated e-commerce platform; all of them build incrementally on institutional structures — peer-review groups, farmer collectives, community trust — that PGS-India has already established. This suggests a phased adoption logic that begins with formalization and digital documentation of the informal direct-sales channels already operating in the region before attempting to integrate producers into mainstream platform ecosystems.

Third, the consumer trust and certification compatibility findings together identify a specific structural opportunity for South Tamil Nadu's PGS-certified organic producers that has not been fully exploited in the regional context. The evidence from Tripathi et al. (2023) and the broader consumer trust literature indicates that digital traceability communication of the PGS peer-review process can narrow the willingness-to-pay gap between PGS and NPOP certification — a gap that is currently a significant structural disadvantage for smallholder producers who cannot afford NPOP certification. A regional e-commerce strategy that invested in high-quality digital narrative content explaining PGS-India's verification process, linked to producer-specific QR codes on packaging, could address both the consumer trust deficit and the certification-communication gap simultaneously, without requiring any change to the certification system itself.

CONCLUSION

This systematic literature review has synthesized 28 sources to characterize the challenges and opportunities of e-commerce integration and direct-sales models in organic agri-food supply chains, with particular reference to South Tamil Nadu's smallholder organic sector. The review finds that e-commerce holds genuine potential to raise farm-gate price realization and improve market reach for the region's organic producers — potential that is not merely theoretical but is grounded in documented evidence from

comparable contexts in India and internationally. The realization of this potential, however, is conditional on progress across five interdependent preconditions: digital infrastructure, producer capability, platform compatibility, logistics integration, and consumer trust. The five-stage conceptual framework proposed here maps these preconditions explicitly and argues that phased, institutionally grounded adoption — beginning with the formalization of existing WhatsApp-based direct-sales channels and FPO-mediated collective platform access — is a more viable pathway for this region than the direct implementation of mainstream e-commerce platforms designed for different structural contexts.

The practical implications of these findings are direct. For NABARD and state agricultural departments considering digital market-linkage investments in South Tamil Nadu's organic sector, the evidence suggests that infrastructure investment (rural connectivity, pre-cooling units at collection centres) and institutional capacity building (FPO formation, PGS-India digital documentation systems) are sequentially prior to platform adoption investments. For organic consumer advocacy and marketing organizations, the evidence suggests that digital traceability communication of PGS-India's peer-review process, rather than expensive upgrading to NPOP certification, is the most cost-effective route to narrowing the consumer trust and willingness-to-pay gap that currently limits the organic premium that smallholders capture.

For future research, the review identifies three priorities. The most urgent is primary, field-based empirical work in the five southern districts: structured producer surveys documenting current digital channel use, income effects of direct-sales channels, and barriers to platform adoption; consumer surveys in Madurai and Tirunelveli urban markets measuring familiarity with PGS-India and responsiveness to digital traceability communication; and case studies of the WhatsApp-based direct-sales networks already operating in the region, which represent a natural experiment in low-technology digital disintermediation whose outcomes have not been systematically studied. The second priority is experimental or quasi-experimental evaluation of QR-code and blockchain traceability pilots in PGS-certified supply chains, to test the consumer trust and premium-capture propositions that this review derives from comparable but not identical contexts. The third priority is a systematic comparative study of the organic e-commerce models operating in different Indian states — including TNAU's organic portal, state-government digital marketplaces, and FPO-managed online channels — to identify what organizational and institutional features are associated with successful scaling in the smallholder organic context. These three research directions together would convert the evidence base that this review has mapped into the primary empirical grounding that regional policy and investment decisions currently lack.

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