

Exploring Institutional and Operational Challenges in Global Value Chains: A Strategic Framework for Agri-Tech Startups in India

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ABSTRACT

Global Value Chains (GVCs) play a vital role in enabling agri-tech startups to access international markets, enhance technological capabilities, and improve export competitiveness. Despite the rapid growth of agri-tech startups in India, their participation in GVCs remains constrained due to multiple structural and operational challenges. This study aims to identify and analyze the critical challenges affecting GVC participation of Indian agri-tech startups and develop a hierarchical structural model illustrating their interrelationships. A comprehensive literature review has been used to identify 7 major challenges related to institutional support, technological capability, digital integration, logistics infrastructure, compliance readiness, market access, and export competitiveness. The study employs the Total Interpretive Structural Modelling methodology to develop a strategic framework. The results reveal that institutional and policy support acts as the primary driving factor influencing technological capability and operational readiness, while digital traceability and logistics infrastructure function as linkage factors enabling compliance with international standards. Market access and export competitiveness were identified as highly dependent outcome factors. The study offers valuable insights for practitioners and policymakers by highlighting the need for coordinated investments in policy support, technology adoption, infrastructure development, and certification readiness to enhance the global competitiveness of Indian agri-tech startups.

Keywords: Global Value Chains, Startups, Global Market, Technological Capability, Competitiveness

1. Introduction

GVCs have emerged as a dominant mechanism for firms to enter international markets, upgrade technological capabilities, and increase competitiveness (Nolintha & Jajri, 2016). In agriculture, GVC participation allows startups to connect local producers with global buyers, integrate advanced technologies, and improve supply chain efficiency (Montalbano & Nenci, 2022). In India, the rapid growth of agri-tech startups has transformed traditional agricultural practices with digital platforms, precision farming, and integrated supply networks (Suresh et al., 2024). Despite strong domestic growth, many Indian agri-tech startups continue to face significant challenges in integrating into global value chains, owing to infrastructural constraints, regulatory complexities, technological gaps, and limited international exposure (Tikkha et al., 2024). Previous research on GVC participation has primarily concentrated on large corporations and established exporters, emphasizing issues such as compliance standards, logistics efficiency, and institutional governance (Suresh et al., 2024; Tikkha et al., 2024). Existing literature pays little attention to early-stage agri-tech startups, particularly in emerging economies such as India, where fragmented agricultural systems and resource constraints create distinct structural barriers.

This study aims to address these gaps by identifying key challenges affecting GVC participation of Indian agri-tech startups and developing a structural framework using the Total Interpretive Structural Modelling (TISM) approach (Choudhury et al., 2021; Rajan et al., 2021). The study proposes to investigate the driving and dependent nature of the identified challenges, as well as their contextual relationships. The findings are expected to provide actionable insights for policymakers, startup founders, and ecosystem stakeholders of Indian agri-tech startups.

2. Literature Review

GVCs have played an important role in the globalization of agricultural trade by allowing firms to participate in internationally fragmented production and distribution networks (Suresh et al., 2024). In the agri-tech sector, GVC participation allows startups to connect farmers, aggregators, processors, logistics providers, and international buyers via technology-enabled platforms. The advancement of digital agriculture and smart supply chain systems has provided opportunities for emerging market startups to enter global markets (Siaw & Okorie, 2022). According to past studies, digital technologies such as the internet, blockchain, and cloud platforms promote transparency and information flow between supply chain nodes (Loonam & O'Regan, 2022). Technological readiness determines an agri-tech startup's ability to maintain product quality, increase operational efficiency, and meet the expectations of international stakeholders. However, many startups in emerging economies have limited technological resources, limiting their ability to participate in digitally coordinated value chains. Government initiatives such as export promotion, infrastructure development, certification assistance, and startup incubation significantly improve firms' ability to enter global markets (Anderson, 2009). Policy frameworks designed to support agricultural exports and startup ecosystems are being strengthened in developing economies such as India. Also, efficient storage, transportation, and packaging systems are required to ensure product quality and reduce post-harvest losses (Li et al., 2024; Suresh et al., 2024). Due to a lack of access to modern logistics networks, startups' ability to deliver perishable products to global markets within required timeframes suffers. Digital integration and traceability systems are gaining popularity in the global agricultural trade (Zhang & Sun, 2023). International buyers expect transparency in manufacturing practices, sourcing locations, and quality assurance mechanisms. Blockchain and digital tracking systems allow for traceability throughout the manufacturing process (Chen et al., 2022), which improves credibility and compliance. Compliance with international standards and certification requirements is another significant barrier to GVC participation. Certification processes necessitate financial investment, technical expertise, and documentation systems, which may be difficult for early-stage startups to maintain (Pietrobelli & Rabellotti, 2011). Market access and global buyer linkages are widely recognized as outcome-level issues influenced by a variety of structural factors (Mahutga, 2012). Establishing dependable relationships with international distributors and procurement agencies necessitates credibility, consistency in supply, and adherence to international standards. Startups that lack established networks face significant challenges in obtaining long-term export contracts. According to the literature (Zhang et al., 2022), export competitiveness emerges when technological capability, infrastructure readiness, institutional support, and compliance systems all function effectively together (Wagner, 2021). Table 1 shows the challenges affecting GVC participation of Indian agri-tech startups.

Table 1. Challenges affecting GVC Participation of Indian Agri-Tech Startups

Code	Identified Challenge	Support from Literature Themes	References
C1	Technological Capability Constraints	Technological readiness is essential for operational efficiency, quality management, and value chain integration.	Anderson, 2009; Wagner, 2021
C2	Limited Institutional and Policy Support	Institutional frameworks significantly influence startup development and global expansion capability.	Pietrobelli & Rabellotti, 2011; Zhang & Sun, 2023
C3	Weak Digital Integration and Traceability Systems	Traceability systems are critical for maintaining credibility and meeting international buyer expectations.	Loonam & O'Regan, 2022; Siaw & Okorie, 2022
C4	Compliance with International Standards and Certifications	Certification and compliance are mandatory requirements for entry into global markets.	Zhang & Sun, 2023
C5	Limited Access to Global Logistics and Cold Chain Infrastructure	Logistics efficiency is directly linked to product quality and timely delivery in GVCs.	Nolintha & Jajri, 2016

C6	Limited Global Market Access and Buyer Linkages	Market access is a dependent outcome influenced by infrastructure and compliance capabilities.	Mahutga, 2012; Montalbano & Nenci, 2022
C7	Low Export Competitiveness and International Positioning	Export competitiveness is considered a final performance outcome of successful GVC integration.	Zhang et al., 2022; Suresh et al., 2024; Tikkha et al., 2024

3. TISM Methodology

This study uses the TISM methodology (Rajan et al., 2021) to systematically examine the hierarchical relationships between critical challenges affecting GVC participation in Indian agri-tech startups. TISM establishes structural relationships between variables and also includes interpretive logic that explains how and why those relationships exist. The methodology begins with identifying critical challenges to GVC participation through extensive literature review (see Table 1). Seven major challenges were identified and coded as C1-C7 (see Table 1).

Following factor identification, contextual relationships between challenges were established. In this step, we determined whether one factor influences another. This step resulted in the creation of the Reachability Matrix, which depicts the direct and indirect relationships between all factors (see Table 2).

Table 2 Reachability matrix with transitivity (*Transitive links)

Challenges	C1	C2	C3	C4	C5	C6	C7
C1	1	0	1	1*	1	1*	1*
C2	1	1	1*	1*	1*	1*	1*
C3	0	0	1	1	1	1*	1*
C4	0	0	0	1	0	1	1
C5	0	0	1	1	1	1*	1*
C6	0	0	0	0	0	1	0
C7	0	0	0	0	0	0	1

Then, level partitioning was used to determine the hierarchical positions of each factor within the structural model. This process entailed determining reachability and antecedent sets for each factor, as well as identifying factors that were at the same level in the hierarchy. Iterative calculations were used to organize the factors into five hierarchical levels that represented the relative influence of each challenge. The bottom-level factor represents the most significant driving challenge, whereas the top-level factors represent outcome-level challenges that are heavily reliant on other factors (see Table 3).

Table 3 Iterations and level partitioning

Challenges	Reachability Set	Antecedent Set	Intersection Set	Level
(a): Iteration 1				
C1	1, 3, 4, 5, 6	1, 2	1	
C2	1, 2, 3, 4, 5, 6	2	2	
C3	3, 4, 5, 6	1, 2, 3, 5	3, 5	
C4	4, 6	1, 2, 3, 4, 5	4	
C5	3, 4, 5, 6	1, 2, 3, 5	3, 5	
C6	6	1, 2, 3, 4, 5, 6	6	I
C7	7	1, 2, 3, 4, 5, 7	7	I
(b): Iteration 2				
C1	1, 3, 4, 5	1, 2	1	
C2	1, 2, 3, 4, 5	2	2	
C3	3, 4, 5	1, 2, 3, 5	3, 5	
C4	4	1, 2, 3, 4, 5	4	II
C5	3, 4, 5	1, 2, 3, 5	3, 5	

(c): Iteration 3				
C1	1, 3, 5	1, 2	1	
C2	1, 2, 3, 5	2	2	
C3	3, 5	1, 2, 3, 5	3, 5	III
C5	3, 5	1, 2, 3, 5	3, 5	III
(d): Iteration 4				
C1	1	1, 2	1	IV
C2	1, 2	2	2	
(e): Iteration 5				
C2	2	2	2	V

After level partitioning, a strategic framework (directed graph) was created to visually represent the relationships between factors. These interpretive statements provide information about the mechanisms by which lower-level factors influence higher-level challenges. In this study, we developed a five-level hierarchical model that represents structural relationships between challenges affecting GVC participation of Indian agri-tech startups (see Figure 1).

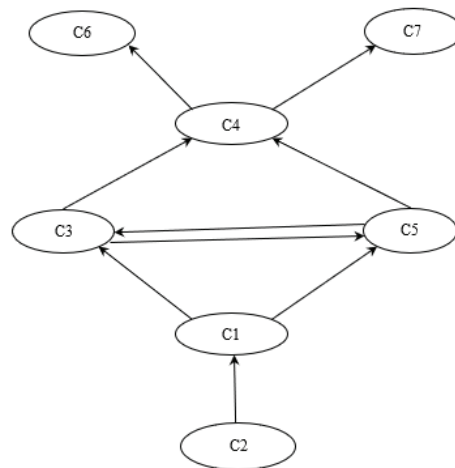


Figure 1. Strategic Framework of Challenges affecting GVC participation of Indian Agri-tech Startups

4. Results and Discussion

The TISM analysis produced a strategic framework that depicted the interdependence of the 7 identified challenges to GVC participation of Indian agri-tech startups. The level partitioning revealed that Limited Institutional and Policy Support (C2) emerged as the most powerful driving factor at Level 5, indicating its fundamental role in shaping technological and operational readiness. This finding suggests that policy facilitation, export incentives, and institutional support mechanisms have a significant impact on the availability of resources needed for global integration (see Table 4).

Table 4. Classification of Challenges based on Characteristics

Identified Challenge	Category Classification	Role
Limited Institutional and Policy Support	Driving Factor	Foundational policy and ecosystem driver influencing all other factors
Technological Capability Constraints	Driving Factor	Enables adoption of digital and operational systems
Weak Digital Integration and Traceability Systems	Linkage Factor	Connects technological readiness with compliance requirements
Limited Access to Global Logistics and Cold Chain Infrastructure	Linkage Factor	Supports quality preservation and supply chain efficiency

Compliance with International Standards and Certifications	Dependent-Linkage Factor	Acts as a gateway enabling global participation
Limited Global Market Access and Buyer Linkages	Dependent Factor	Reflects accessibility to international trade networks
Low Export Competitiveness and International Positioning	Dependent Factor	Represents final performance outcome in global markets

At Level 4, technological capability constraints (C1) were identified as a significant driver influenced by institutional frameworks. This shows that technological readiness, such as digital adoption and automation capability, is critical for improving supply chain operations. At Level 3, Weak Digital Integration and Traceability Systems (C3) and Limited Access to Global Logistics and Cold Chain Infrastructure (C5) were identified as linkage challenges, emphasizing their dual roles as both drivers and dependent factors. These operational challenges have a direct impact on compliance readiness. At Level 2, Compliance with International Standards and Certifications (C4) was identified as a critical intermediary factor for gaining access to international markets. Finally, at Level 1, Limited Global Market Access and Buyer Linkages (C6) and Low Export Competitiveness and International Positioning (C7) were identified as output factors, representing the ultimate outcomes influenced by previous structural and operational factors.

Driving factors, particularly institutional support (C2) and technological capability (C1), have a significant impact on the entire system and thus require priority attention from policymakers and ecosystem stakeholders. Linkage factors, such as digital integration (C3) and logistics infrastructure (C5), are sensitive components of the system because they both influence and rely on other variables. These factors necessitate coordinated development strategies, such as digital supply chain integration and investment in cold chain infrastructure.

5. Conclusions, Limitations and Future Research

The TISM approach was used in this study to create a hierarchical framework for investigating the critical challenges affecting GVC participation in Indian agri-tech startups. The findings showed that institutional and policy support is the primary driving force behind technological capability, digital integration, logistics infrastructure, and compliance readiness. The findings also showed that operational capabilities like traceability systems and cold chain infrastructure play an important role in enabling compliance with international standards. Finally, market-level outcomes such as global market access and export competitiveness were identified as highly dependent variables, implying that successful global integration necessitates systematic strengthening of foundational and intermediate capabilities. The study adds to the growing literature on agri-tech and GVC participation by offering a structured understanding of interconnected challenges in emerging startup ecosystems. Future research could validate the proposed framework by testing causal relationships between variables using quantitative techniques such as Structural Equation Modelling (SEM) or PLS-SEM (Kurniawan & Dachyar, 2021). Comparative studies across sectors, and case-based validation can provide more detailed insights into the dynamic evolution of GVC participation among startups.

6. Recommendations and Implications for Practice and Policy

The study's findings include several practical recommendations for agri-tech practitioners, startup founders, and ecosystem stakeholders looking to increase GVC participation. Since institutional and policy support emerged as the most powerful motivator, practitioners should actively engage with government schemes, export facilitation programs, and incubation platforms to maximize available incentives and technical assistance. Startup founders are encouraged to maintain ongoing communication with export promotion agencies, certification bodies, and agricultural development institutions in order to stay current on regulatory changes and market requirements. Practitioners should invest in digital technologies like traceability platforms, farm-level data systems, and automated quality monitoring tools. Collaboration with technology providers and digital service platforms can help startups overcome resource constraints and accelerate their digital transformation. To reduce transportation costs and product losses, practitioners should form partnerships with reputable logistics providers and look into shared infrastructure models. Policymakers should prioritize simplifying certification procedures and providing targeted financial support for technology adoption and infrastructure development. Capacity-building initiatives such as export compliance training, digital supply chain management, and international marketing strategies will help practitioners compete more effectively on a global scale..

7. References

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