

Original Research

Received 22 May 2026

Revised 29 June 2026

Accepted 12 July 2026

Natural Resources for Human
Health 2026, Vol. 6 (7s): 345–363

KEYWORDS:

Horticulture; Supply Chain;
Smallholder; Livelihood; Farmer
Producer Organization

Do Supply Chain and Institutional Factors Impact Smallholders' Livelihoods? An SEM Perspective

Lokesh Kumar Jena^{1*}, Debarshi Mukherjee², Subhayan Chakraborty³, Maidul Islam⁴, Pintu Majhi⁵, Seemarani Meher⁶

¹Department of Master of Business Administration, Gandhi Institute for Education and Technology (GIET), Khordha 752060, India

²Department of Commerce & Business Studies, Jamia Millia Islamia, New Delhi 110025, India

³State Panchayat Resource Centre (SPRC), Government of Tripura, Agartala 799003, India

⁴International Business Department, Keimyung Adams College, Keimyung University, Daegu 42601, Republic of Korea

⁵Assistant Professor, Hidayatullah National Law University (HNLU), Raipur, India

⁶Odisha State Open University, Sambalpur, Odisha, India

ABSTRACT: Being the second-largest producer of horticultural products, the sector in India is experiencing supply chain issues. Thus, the primary objective of this research is to use the resource curse and cluster theories to assess how the horticulture supply chain affects the smallholders' livelihoods. Independent (Horticulture Supply Chain Efficiency- HSCE), dependent (Smallholders' Livelihood Development- SLD), and moderating (Farmers Producer Organization Intervention- FPOI) variables are all included in the analysis. Using a combination of literature reviews, expert interviews, and focus groups, the researcher developed a preliminary research framework and measuring instruments for each latent construct. The instrument has been validated using face and language validation, followed by a pilot study and main study with 405 responses. Both SmartPLS 4.0 and SPSS 25.0 have been used for that purpose. This study found both HSCE and FPOI directly impacted SLD, explaining 65% of the variance, mostly by SC collaboration, followed by agricultural credit, SC infrastructure, and FPO. However, contrary to the theoretical part, the moderating effect was found to be negatively significant. This indicates the immaturity of FPOs to amplify these factors, which can draw the attention of policymakers to make necessary arrangements.

1. INTRODUCTION

India is predominantly agrarian, with 58% of rural households dependent on agriculture. Agriculture and its allied sectors contributed 20% to GDP in 2020-2021, rising in succeeding years (Kapil, 2021). Unlike the Indian horticulture industry, which contributes 33% of the total Gross Value Added to GDP (MoAFW, 2020). Data from the Directorate of Economics and Statistics' National Horticulture Database 2020-21 shows 331.048 million metric tons of horticultural produce produced on 27.586 MH (Government of India [GoI], 2021). India's diversified agroclimatic conditions allow for horticultural crop production and offer an alternative to diversifying Indian agriculture for economic, nutritional security, and poverty reduction (MoAFW, 2020; Karabari & Patil, 2015; Government of Tripura, 2021; Weinberger & Lumpkin, 2007). Horticulture, which is more labour-intensive than staple crop production, may provide more employment and markets at the producer level owing to higher market pricing (Weinberger & Lumpkin, 2007; Keatinge et al., 2018).

Similarly, Tripura, a Northeast Indian state, with 1.48962 MMT of horticulture production and 0.12681 MH of land (Government of India [GoI], 2021), produces 0.543775 MMT of fruits, 0.835183 MMT of vegetables, and 0.00058 MMT of flowers in 0.05416 MH, 0.047332 MH and 0.00029 MH of land, respectively (Government of Tripura, 2021; PNBIndia, 2015). This leads to a huge surplus of products. Based on government reports and official interviews, the state resides with 95% small and marginal farmers who produce their goods with little MSP, bargaining power, and with a focus only on production. The sector comes under three major schemes, i.e., MIDH (Mission for Integrated Development of Horticulture-Central, Pre and Post development), state plan, and RKVY (Rashtriya Krishi Vikash Yojana-Infrastructure development) (Government of Tripura, 2021; GoI MIDH, 2014; Mission for Integrated Development of Horticulture [MIDH], 2014; Reserve Bank of India [RBI], 2019) that solely focus on production and productivity only. This lowers farm-gate prices for smallholders and raises consumer costs due to a lack of cooperation and transparency among farmers and other stakeholders, which increases intermediaries, resulting in unduly lengthening and costing the SC (Jayalath et al., 2023; Islam et al., 2022). Further, it is evident from the Consumer Food Price Index (CFPI-combined) that even with 7.75% inflation of agricultural products, the producers' share of consumer pricing remains low (Dastagiri et al., 2012; PIB Delhi & NSO, 2022; RBI, 2019). This shows a significant SC gap between producers and consumers. Therefore, an efficient SC is required to reduce product loss, increase infrastructure, productivity, negotiating power, safety, quality, knowledge and skill sharing, transparency, tracking system, investments, risk sharing, productivity improvement, and customer satisfaction. These issues are very much relevant to smallholders as owing to limited resources and market access, they need additional study (Bhagat, 2012).

Horticultural crops include fruits, vegetables, ornamentals, aromatics, medicine, and herbs & spices. This doubles farmers' income compared to traditional agriculture, adding value to the sector and the country's economic growth (Kaldate et al., 2020; PIB MoAFW, 2021). India's F&V SC is inefficient and overlooked, resulting in large post-harvest losses. It is also evident that six to seven intermediaries in the SC make it more fragmented without adding value, even though they provide product transportation, ownership transfer, vendor payment, maintenance, and customer delivery (Halder & Pati, 2011; Kumar, 2020; Negi, 2018; Viswanadham, 2007).

The state of Tripura has started forming FPOs that combine private and cooperative principles to help farmers and improve their living standards by managing an efficient supply chain. Many implementing and promoting organizations use various schemes to form and operate FPOs to address common issues in agricultural services (agricultural training, advisory services, and technical support), input supply, procurement, processing, marketing, and distribution to increase farmers' bargaining power, and incomes (Government of Tripura, 2021; GoI MIDH, 2014; NAFPO, 2022).

Therefore, the study objective covers Tripura's horticultural sector, which includes fruits and vegetables, to construct a research model and instrument based on an existing literature review, focus group discussion, interviews with different stakeholders, and expert advice. Identifying these elements and how they affect smallholder livelihoods with the existing government policies and schemes. The independent variable, "Horticulture Supply Chain Efficiency", affects the dependent variable, "Smallholders' Livelihood Development". The moderating variable, "FPO Intervention," helps the SC to develop smallholders' economic and non-economic livelihoods.

2. LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

2.1. Theoretical Background

The resource curse theory posits that resource-rich countries are less likely to use their natural resources, which increases the likelihood of conflicts, authoritarianism, economic instability, and slow economic progress (Auty, 1993). Traditionally, natural resources promote economic growth, but corruption, poor governance, institutional or government policy, poor investment, lack of information, poor infrastructure, and poor collaboration have caused negative effects in a few countries (Auty, 1990; Busse & Gröning, 2013; Cappelen et al., 2021; Iimi, 2007; Kelley, 2012; Konijn, 2014; McPhail, 2008; Poncian, 2019; Wenar, 2008). Likewise, underutilized natural resources like horticulture and human resources in India could strengthen the nation's and state's economies (Shah, 2014). While cluster theory is essential for local and regional development because institutional actors work together to strengthen clusters' competitive advantage by fostering innovation (Alimov et al., 2020; Ayele et al., 2010; Porter, 1998; Swords, 2013). Unorganized markets, opportunistic middlemen, increased SC transaction costs, decreasing quality and quantity, farm gate pricing, and higher consumer purchasing prices motivate smallholders to join clusters. This

cluster has solid administration, making the resource (horticulture) curse a blessing for smallholders and the country's economic development by sharing cost and profit (Lan & Zhangliu, 2012) (Figure 1).

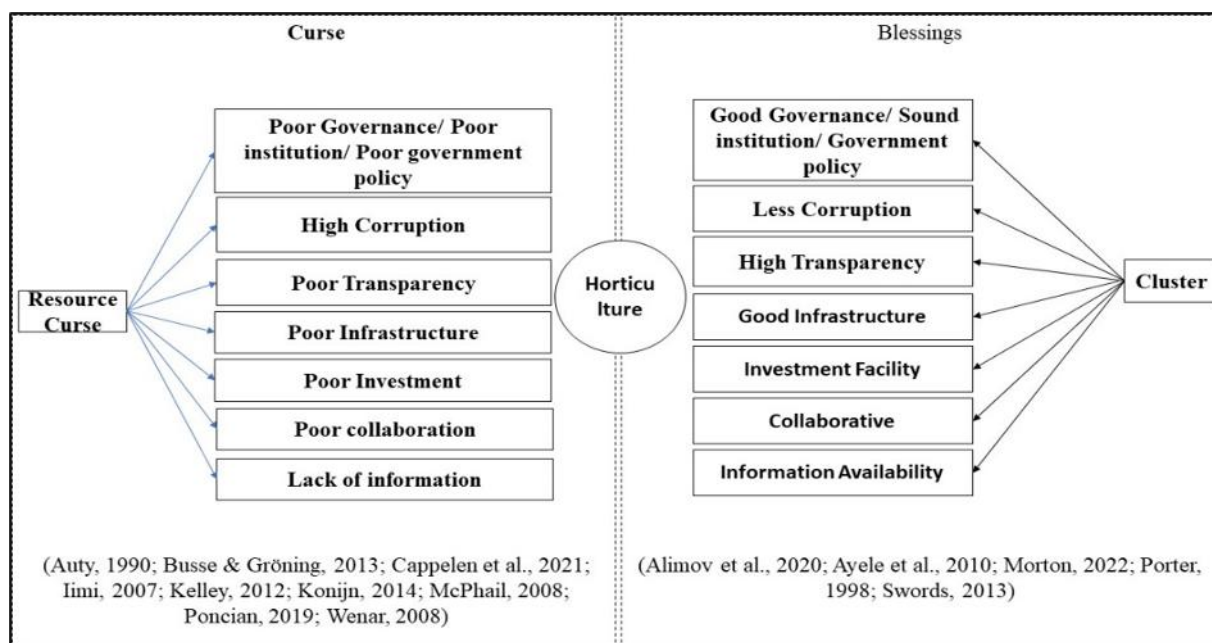


Figure 1. Resource Curse & Clustering Interpretation, Source; Self

2.2. Identification of Research Variables and Hypotheses Development

Multiple layers of interaction (Interviews, FGD & Expert advice) with Govt. officials (BDOs, ADOs, & Directorate of Agriculture), Farmers, BoD & CEOs of FPOs have been initiated to finalize the research model (see Figure 2) and its standard instrument specific to the Tripura horticultural sector. At the same time, FGD (Chambers, 2007; Merton, 1987) was conducted with farmers to understand the schemes at the ground level.

2.2.1. Horticultural Supply Chain Efficiency, Smallholders' Livelihood Development and Farmer Producer Organization Intervention

Horticultural product SC includes production, post-harvest, and distribution from farm to table. Low shelf-life, significant demand, price changes, food safety and quality issues make perishable food SC more complicated (Van der Vorst & Beulens, 2002). The complicated, fragmented, and intermediary-dependent F&V SC causes farmers and buyers to lose economic and non-economic benefits after harvest (Kumar, 2019). Several middlemen, a lack of policy, unorganized sectors, and a lack of cold storage are among the factors that contribute to Indian fruit SC post-harvest losses, making the SC inefficient (Dastagiri et al., 2012; Islam et al., 2022; Rais & Sheoran, 2015). HSCE can enhance smallholders' livelihoods via infrastructure, collaboration, and agricultural loans. SC infrastructure systems may help the horticulture SC save time, cost, and waste and boost production and market reach. In contrast, collaboration across horticulture SC players increases negotiating power for better pricing, shares knowledge and resources, provides training, and increases market access, maximizing efficiency. Smallholders also require accessible and timely agricultural loans to invest in their fields, buy inputs, and adopt the latest technologies to become more efficient (Fan & Gao, 2014; Johnson & Hofman, 2004; Negi, 2021; Reiner & Hofmann, 2006). SC Infrastructure (HSCE1), Agri-cultural Credit (HSCE2), and SC Collaboration (HSCE3) are important factors in HSCE that have been identified based on theory and literature review.

Similarly, livelihood security is seen as a precondition for livelihood development (Nath & Behera, 2011; Pani & Mishra, 2022). Though studies confirm horticulture's ability to strengthen farmer livelihoods (Galhena et al., 2013; Rai et al., 2019; Ulrich, 2014; Yasmin et al., 2014; Zhang et al., 2014). Low farm gate prices and limited market access (Alam & Khatun, 2021; Middendorf et al., 2022; Sibomana et al., 2016) hinder livelihood security (Nath & Behera, 2011; Pani & Mishra, 2022), which need to be addressed. Food and nutritional security (SLD1), economic security (SLD2), ecological security (SLD3), social

security (SLD4), psychological security (SLD5), and physical security (SLD6) have been identified and used to measure the outcome variable. Further, market risk mitigation (FPO1) and economies of scale (FPO2) have been used to measure FPO intervention, as a moderating variable. FPO uses efficient and effective use of common resources through technology and extension services help attain economies of scale in production, which enhances their revenue (MoAFW, 2021; Möhring, 2006). This not only empowers smallholders but also boost rural development with sustainably. Further, FPOs provide training, quality control, and marketing assistance for an effective market share, customer service, and farmer returns (Bikkina et al., 2018; Gummagolmath et al., 2022; Khushbu, 2023). FPOs reduce market risk through re-tail marketing, spot markets, futures trading, cooperative and exporter col-laboration, and direct marketing (Birthal et al., 2007; Singh, 2002; Singh & Vatta, 2019). Authorities like the World Bank and UNDP encourage FPO establishment and empowerment via policy and financial tools, acknowledging their importance. Thus, FPOs improve SC efficiency and empower farmers (Das, 2020; Gummagolmath et al., 2022; Krishnan et al., 2021).

2.2.2. SC Infrastructure and Smallholders' Livelihood Development

HSCE needs infrastructure to create livelihoods and ensure the smooth operation of the supply chain. Input, resources, and physical infrastructure increase farmers' production, productivity, and services and decrease environmental uncertainty, resulting in higher income, lower costs, and better livelihoods (Ayele et al., 2010; Minten, 1999; Satish, 2007). Thus, we can hypothesize:

H1. There is a significant relationship between HSCE1 in HSCE and SLD.

2.2.3. Agricultural Credit and Smallholders' Livelihood Development

Credit is the most significant element in all agricultural development programs. Seeds, fertilizers, pesticides, animal feed, marketing, production, and investment need financing (short, medium, and long-term). Smallholders borrowing from moneylenders or relatives at high-interest rates and with collateral may make agricultural activities unprofitable (FAO, 2022; NABARD Capital Market, 2018). Providing easy and affordable agricultural credit to is a critical factor in improving farmer livelihoods (Chandio et al., 2018; Kumar et al., 2018). Thus, we posit that:

H2. There is a significant relationship between HSCE2 in HSCE and SLD.

2.2.4. Supply Chain Collaboration and Smallholders' Livelihood Development

HSCE through SC collaboration is generally recognized in high-value food SCs, assures food quality and safety compliance, and enhances smallholder returns. Weak collaboration in the agri-food SC leads to high SC costs in developing countries. Collaboration helps in product development, planning, forecasting, procurement, information sharing, and capital expenditures (Ahoa et al., 2021; Alemu et al., 2016; Arshinder & Balaji, 2019; Arshinder et al., 2007; Dorward et al., 2009; Weaver, 2011; Widadie et al., 2022). Thus, we posit that:

H3. There is a significant relationship between HSCE3 in HSCE and SLD.

2.2.5. FPOI Moderation Effect

The efficiency of SC may be enhanced by the efforts of FPO by improving infrastructure, market intelligence, collaboration, smooth execution of government policy and procedure, credit facility, and decreasing intermediaries to boost smallholder livelihoods (Bunte, 2019; Singh & Vatta, 2019; Ton & Bijman, 2006). Thus, we can hypothesize:

H4. There is a significant relationship between FPOI and SLD.

Infrastructure development is crucial for boosting production, reducing post-harvest losses, and accessing markets (PNBIndia, 2021). FPO may help provide the infrastructure that improves their members and the agricultural community's livelihoods (IRMA-NABARD, 2022). Thus, we posit that:

H5. There is a significant moderation effect of FPOI between HSCE1 in HSCE and SLD.

Cluster-Based Business Organizations (CBBOs) promote FPOs, whereas SFAC, NAFED, NCDC, NERAMAC, NABARD, and state governments implement them. Implementing agencies help agricultural communities affiliated with FPOs to access institutional financing. Agriculture credit aids pre- and post-harvest operations, storage, processing, ripening chambers, logistics,

and marketing. The ultimate objective of these endeavours is to ensure that the agricultural communities receive satisfactory remuneration for their products, thereby leading to an enhancement in their overall livelihood (IRMA-NABARD, 2022; NABARD, 2015; NAFPO, 2022; SFAC, 2019). Thus, we can hypothesize:

H6. There is a significant moderation effect of FPOI between HSCE2 in HSCE and SLD.

The FPOs foster a sustainable and conducive environment for the farmers with strong collaborative culture with different stakeholders. This helps overcome SC challenges related to pre- and post-harvest operations. This ensures that smallholders receive equitable and holistic livelihoods (IRMA-NABARD, 2022; Krishnan et al., 2021; NABARD, 2015; NAFPO, 2022). Thus, we can hypothesize:

H7. There is a significant moderation effect of FPOI between HSCE3 in HSCE and SLD.

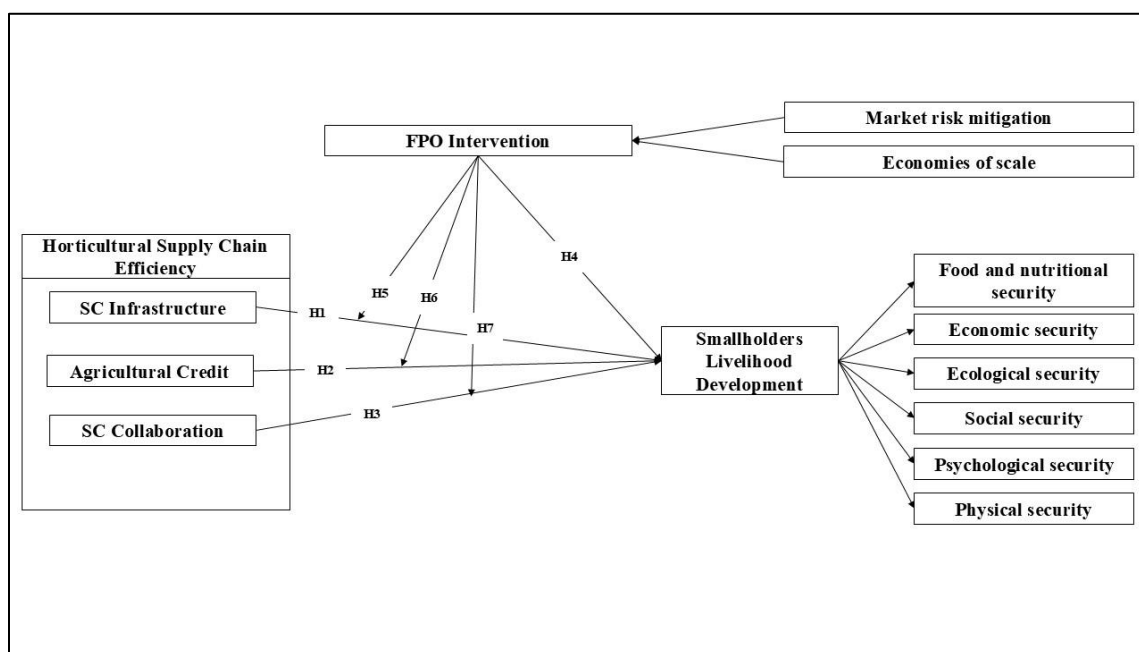


Figure 2. Proposed Research Model, Source; Self

3. RESEARCH METHODOLOGY

This cross-sectional mixed-method research collects, analyses, and interprets quantitative and qualitative data (Bougie & Sekaran, 2019; Johnson & Onwuegbuzie, 2004) from both primary and secondary sources.

Responses were collected using a 7-point Likert scale from four of Tripura's eight districts (West-Tripura, Dhalai, Gomati, and Sipahijala) from smallholders affiliated with FPOs registered with the "Promotion of 10000 FPOs scheme" and the "MOVCDNER (Mission Organic Value Chain Development for Northeast Region) scheme" under various implementing and promotional agencies. This study used purposive sampling in a non-probability sampling design to include people with the necessary information or meeting the researchers' criteria (Johnson & Onwuegbuzie, 2004). The minimum sample size of 405 for SEM has been calculated using a confidence interval (Daniel, 1999; Naing et al., 2006), which is considered adequate for multi-variate analysis, including regression.

3.1. Measurement Scale and Validation

The present study pertains to the development and validation of the measurement tool (see Appendix A- Table I). Developing and validating an instrument for specific contexts is a prevalent research practice, particularly when the original scale was formulated for a distinct population or environment. The constructs and measurement items were developed through an iterative process involving an extensive literature review, field interactions, expert consultation, face and language validation, pilot testing, and subsequent refinement before the final survey. Initially, the face and linguistic validation have been duly considered to address this purpose. Face validity is a researcher's subjective assessment of whether an instrument's items are

pertinent, practicable, reasonable, unambiguous, and clear (Ayodele, 2012; Field, 2005; Taherdoost & Lumpur, 2016). In contrast, Linguistic validation ensures that the instrument is conceptually and semantically identical to the source language following translation and cross-cultural adaptation (Rask et al., 2017; Wild et al., 2005). Since Bengali and Hindi speakers make up most of the state's population, English is translated into those languages. Two experts' suggestions and feedback were used at each stage to refine and develop the instrument further.

4. DATA ANALYSIS AND FINDINGS

The study uses Microsoft Excel & Word 2016, SPSS 25.0, and SmartPLS 4.0 for its tabulation, analysis, and presentation of data for both the Pilot and Main study. The pilot study used Factor Analysis, a combination of EFA (SPSS 25) and CFA (SmartPLS, PLS-SEM) for instrument development and reliability. The pilot study found all significant results within the threshold preceding the instrument's reliability, understandability, and internal consistency after removing below threshold items, i.e., HSCE2.2, HSCE2.4, HSCE3.2 and HSCE3.5 based on the rotated component matrix. However, the study didn't find any moderating effect of the FPO intervention in the model. This doesn't align with the final study, which has shown a moderation effect. This may be limited statistical power and restricted variation in the institutional context in the pilot study, which has been eliminated in the main study with a more heterogeneous study.

4.1. Final Study

4.1.1. Measurement Model

The Cronbach's alpha, factor loadings, and AVE are all above the threshold to evaluate the constructs' validity (Chin, 1998; Hair et al., 2013; Hair et al., 2010; Nunnally & Bernstein, 1994). Whereas CR and rho_A values are above the acceptable level (Hair et al., 2017a, 2017b) (See Table 1 and Figure 3).

Table 1. Construct validity, Reliability, Convergent Validity

Constructs	Items	Outer loadings	Cronbach's Alpha	rho_A	CR	AVE
SC Infrastructure	HSCE 1.1	0.683	0.665	0.710	0.798	0.505
	HSCE 1.2	0.505				
	HSCE 1.3	0.802				
	HSCE 1.4	0.811				
Agricultural Credit	HSCE 2.1	0.792	0.687	0.690	0.827	0.615
	HSCE 2.3	0.806				
	HSCE 2.5	0.753				
SC Collaboration	HSCE 3.1	0.737	0.798	0.801	0.860	0.552
	HSCE 3.3	0.756				
	HSCE 3.4	0.742				
	HSCE 3.6	0.766				
	HSCE 3.7	0.712				
FPO Intervention	FPOI1_Mean	0.920	0.733	0.775	0.880	0.786
	FPOI2_Mean	0.852				
SLD	SLD1_Mean	0.766	0.807	0.809	0.861	0.510
	SLD2_Mean	0.716				

SLD3_Mean	0.752
SLD4_Mean	0.660
SLD5_Mean	0.716
SLD6_Mean	0.667

(Note: For FPO1_Mean, FPO2_Mean, SLD1_Mean, SLD2_Mean, SLD3_Mean, SLD4_Mean, SLD5_Mean, and SLD6_Mean are taken as the mean of the item scores present under the sub-constructs FPO1, FPO2, SLD1, SLD2, SLD3, SLD4, SLD5, and SLD6, respectively)

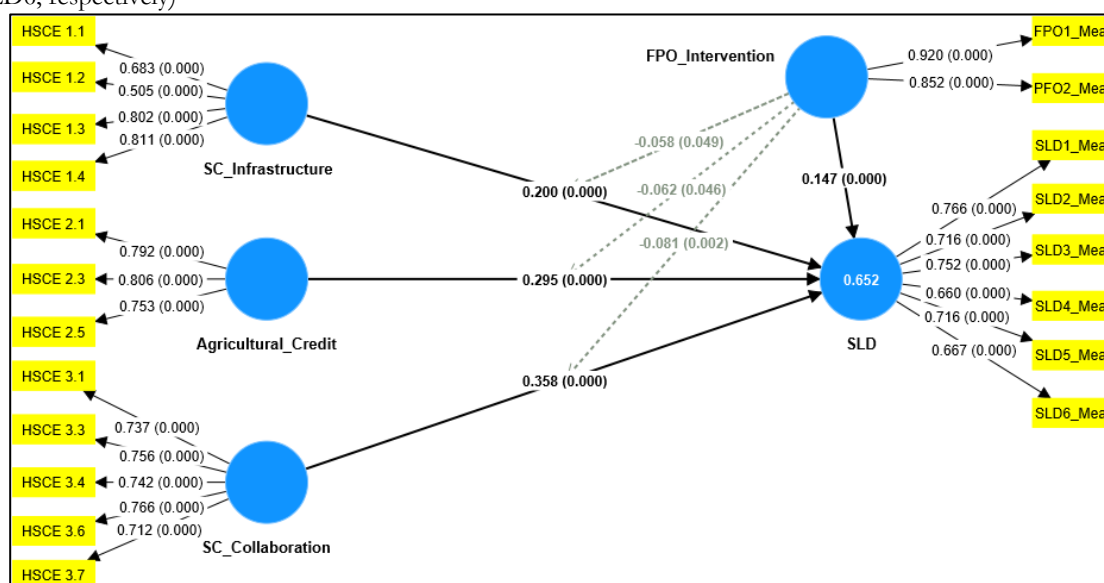


Figure 3. Measurement Model

4.1.2. Discriminate validity

To evaluate the distinctiveness of each factor, researchers may apply a standardized method called the heterotrait-monotrait ratio of correlations (HTMT) (Henseler et al., 2014, 2015). All the constructs in the current investigation had HTMT values below the cutoff of 0.85 (Kline, 2011), thereby establishing discriminant validity among the constructs (see Table 2).

Table 2. HTMT-based discriminant validity

Constructs	HSCE				
	HSCE1	2	HSCE3	FPOI	SLD
HSCE1					
HSCE2	0.564				
HSCE3	0.429	0.384			
FPOI	0.548	0.493	0.438		
SLD	0.757	0.762	0.751	0.646	
FPO Intervention x SC Infrastructure	0.609	0.279	0.217	0.352	0.456
FPO Intervention x Agricultural Credit	0.351	0.310	0.078	0.317	0.331
FPO Intervention x SC Collaboration	0.261	0.092	0.414	0.173	0.368

Found Discriminant Validity (correlation), i.e., <0.85.

4.1.3. Structural model

Each construct's VIF threshold below 5.0 shows no multi-collinearity and also used bootstrapping with 5,000 resampling iterations with a significance level of 0.05 (Hair et al., 2013; Hair et al., 2017a). The findings of the direct and moderating relationships are presented in Table 3. All direct relationships (H1–H4) were positive and significant. In contrast, the moderating effects of FPO intervention on the relationships between SC infrastructure, agricultural credit, SC collaboration, and SLD (H5–H7) were negative and significant.

Table 3. Result of the structural model assessment for direct and moderating relations

H	Relationships.	Beta	Std.	T Value	P Value	BCI LL	BCI UL	Decision	F ²	VIF
H1	SCInfrastructure -> SLD	0.20	0.04	4.665	0.001	0.114	0.283	S	0.07	1.62
		0	3						1	5
H2	AgriculturalCredit -> SLD	0.29	0.03	8.043	0.000	0.222	0.366	S	0.18	1.32
		5	7						9	7
H3	SCCollaboration -> SLD	0.35	0.03	10.436	0.000	0.291	0.424	S	0.26	1.37
		8	4						7	9
H4	FPOIntervention -> SLD	0.14	0.03	4.379	0.000	0.078	0.209	S	0.04	1.36
		7	4						5	5
H5	FPOIntervention x SCInfrastructure -> SLD	-0.05	0.02	1.969	0.049	-0.114	0.000	S	0.00	1.64
		8	9						9	4
H6	FPOIntervention x AgriculturalCredit -> SLD	-0.06	0.03	1.995	0.046	-0.123	-0.001	S	0.00	1.32
		2	1						9	4
H7	FPOIntervention x SCCollaboration -> SLD	-0.08	0.02	3.055	0.002	-0.134	-0.030	S	0.01	1.28
		1	6						8	1

(Note: S-Supported, BCI LL - Confidence Intervals Bias-Corrected at Lower Limit; &BCI UL - Confidence Intervals Bias-Corrected at Upper Limit)

4.1.4. Coefficient Determination (R²) & Predictive Relevance (Q²) Analysis

The coefficient of determination (R²), with a value of 0.652, indicates that the in-dependent variables explain approximately 65% of the variance in SLD (Table 5). To ensure the construct's predictive accuracy, the values of Q² must exceed zero, as evident in the analysis (Table 4).

Table 4. Results of Coefficient of Determination (R²) and Predictive Relevance (Q²)

Construct	R ²	Adjusted R ²	Q ²
SLD	0.652	0.646	0.321

4.2. Common Method Variance (CMV)/ Common Method Bias (CMB)

Common Method Variance (CMV) is a potential threat to internal validity in research, particularly when using self-reported data like surveys. Addressing CMV is crucial to studying reliability and accuracy. Hence, “Haarman Single-Factor” test has been used for this concern, which explains variance in the data in a single underlying factor. 22.86% variance (see Appendix A- Table II) has been explained below the threshold of 50% that suggests minimum CMV (Chang et al., 2020; Cooper et al., 2020).

5. DISCUSSION

The statistical results reveal that SC Infrastructure, Agricultural Credit, SC Collaboration, and FPO intervention have direct impact on SLD, which aligns with the existing theory. SC collaboration has been found important factor in the model followed by agricultural credit and SC infrastructure. The variables stated above play a significant role in supporting the well-being of small-scale farmers by enabling them to achieve numerous forms of security, such as food and nutrition, economic, ecological, social, psychological, and physical security. These factors contribute to HSCE through product development, innovation, planning, forecasting, pre-and post-harvest activities, market access, sourcing, information sharing, and investment decisions, ensuring compliance with food quality and safety standards, and promoting increased returns and livelihoods for smallholder farmers.

Statistical analysis also demonstrates that FPO intervention has a positive and significant direct impact on SLD. However, contrary to the expected strengthening role of FPO intervention, its moderating effects on the relationships between SC infrastructure, agricultural credit, SC collaboration, and SLD were negative and significant. This lies in the fact that when FPOs are immature, they fail to pool, coordinate and leverage the infrastructure, credit and collaboration optimally. As a result, FPOs fail to amplify but rather reduce the livelihood benefits with weak financial intermediation, limited governance and coordination. The following factors, identified through literature review, expert inputs, and field interactions, may help explain why FPO intervention did not strengthen these relationships:

1. FPOs face challenges in obtaining financial resources, market access, infrastructure support, autonomy, information, training, and extension services due to their infancy, ranging from one to three years. It requires time for farmers to register with FPOs to receive equity for routine operations. Due to the low or no equity grants, financing, and credit extended by institutions, the majority of FPOs function exclusively on shareholding price money. The majority of producers obtain financing through the Kisan Credit Card (KCC).
2. Through a variety of schemes, machinery, conservatories, and polyhouses are made available to specific producers. Farmers frequently remit exorbitant charges to local leasing agencies for the basic infrastructure. Although FPOs refer to a geographical or regional aggregation, farmers and land are not more closely located in the region, which increases the cost for farmers to utilize the readily available common infrastructure. In areas with fragmented landholdings, uniting farmers into a cohesive FPO presents a hurdle. This fragmentation can hinder economies of scale, hamper collective farming practices, and weaken their bargaining power for both input costs and output prices. Although FPOs rely on various initiatives or subsidies to gain access to critical infrastructure, the majority of them possess transportation facilities but do not have cold chain facilities. Further, not all farmers have access to irrigation facilities; rather, they depend on reservoirs, rivers, or ponds.
3. Limited institutional support poses a significant challenge to FPOs to navigate complexities and achieve long-term success.
4. The limited technical acumen of FPO members concerning modern farming methods hinders the maximization of productivity.
5. The hilly terrains and locations of FPOs creates problems to access markets with increased cost.
6. Building strong, reliable market linkages and a lack of collective bargaining power in securing fair pricing for their produce remain key challenges for FPOs.
7. Mostly, FPOs don't find local organized sectors profitable, hence they sell their products at higher prices in the local unorganized market, which increases the wastage and reduces quality.
8. Most of the FPOs in Tripura operate in a supply-driven market at a lower farm gate price, instead of a demand-driven market. However, in a few instances, FPOs sell their products sometimes in foreign markets like Singapore and Dubai at twice or thrice the value of the local market.
9. FPOs have immense potential to empower farmers, but with limited governance, leadership and technical skills, it makes it vulnerable to internal conflicts. This leads to dysfunction and missing opportunities for collective growth.
10. Caste divisions can further create ingrained hierarchy with trust issues among members, leading to ineffectiveness of FPOs. Scepticism and reluctance to new technology create another level of obstacle compared to Traditional farming practices that have passed down through generations as a sign of cultural norms (Elamon, 2020; Hadley, 2023; Qureshi et al., 2023).

According to the existing literature, the FPOs moderate SC infrastructure, Agri-cultural Credit, and SC collaboration to ensure smallholders' livelihoods. In contrast, the moderating effect is optimal but rather dampening in the context. This may be due to the infancy of operational excellence in the state. The FPOs may moderate the domain in the future for SLD through inexpensive input procurement, reduced intermediary costs, equitable collective market access, and training and extension services that boost output, productivity, and economies of scale. To considerably alter the smallholder's way of life and means of subsistence, they must substantially increase their contributions. Further, there is a much-needed robust governance structure that includes transparency and good leadership, which will empower members and address conflicts constructively to unlock the true potential of FPOs.

5.1. Theoretical Implications

The data demonstrates that efficient SC helps smallholders improve their standard of living. However, the research did not discover the expected moderate effect of FPO on applying Porter's Cluster Theory, which might help smallholders overcome the resource curse. There is still confusion among FPOs about fundamental roles and responsibilities under both schemes. Important to the success of FPOs is timely and sufficient government or agency assistance. For smallholders to reap the benefits of the clusters, FPOs must exert additional effort to be seen in meaningful action. As a result, productivity and living standards among rural smallholders will improve. FPOs need institutional backing through internal capacity development and increased authority to effectively execute Cluster-based techniques. FPO intervention in the SC can enhance infrastructure, market intelligence, collaboration, government policy implementation, and credit facilities and reduce intermediaries, resulting in increased efficiency in agriculture and boosting smallholder livelihoods (Bunte, 2019; Singh & Vatta, 2019; Ton & Bijman, 2006). FPO uses efficient, cost-effective, and sustainable resource use through training and extension services to maximize income-generative production and productivity. FPOs offer members real-time demand, supply, price, location, spot markets, futures trading, and direct marketing options to reduce market risks (Birthal et al., 2007; INAFI India, 2013; MoAFW, 2021; Möhring, 2006; Singh, 2002; Singh & Vatta, 2019).

5.2. Policy Implications

FPOs are crucial for building inclusive and sustainable supply chains by connecting smallholder farmers to markets. Model selection should fit local needs, while FPOs must secure profitable market linkages and access to credit guarantee funds. The RKVY (Rashtriya Krishi Vikas Yojana) scheme's institutional reforms highlight the importance of FPOs for empowering small and marginal farmers. Government agencies SFAC and NABARD offer support alongside state-level grants, licenses, subsidies, and farm-gate sale policies. Along with the existing schemes and policies, policymakers should establish a multi-tier FPO institutional architecture that may comprise regional and central organizations for FPOs. The regional institutions would coordinate production planning, logistics, cold chain management and local market linkage, while the center would generate market intelligence, integrated demand from urban, institutional buyers, processing units and export markets. This will form a network of FPOs across regions to meet the demand-supply gaps, enhance price realization, and minimize post-harvest losses through logistics coordination. This framework at the national level will shift FPOs from isolated operational units to interconnected nodes within a demand-driven SC. This will transform the supply-driven FPOs to demand-driven institutions, which will strengthen the sustainable livelihood of smallholders. Further, an adaptive AI-based agricultural supply chain may be developed to fully automate the process efficiently and effectively. These policy measures can strengthen the institutional capacity and coordination of FPOs, improve access to shared infrastructure and logistics, and facilitate a transition towards a more market- and demand-oriented horticultural supply chain.

6. CONCLUSIONS AND FUTURE SCOPE

Three independent variables (HSCE1, HSCE2, and HSCE3), one dependent variable (SLD), and one moderating variable (FPOI) make up the conceptual framework for this study. According to the study's findings, HSCE and FPOI account for around 65% of SLD's explanatory power variance. Collaboration across SC has significantly influenced SLD, followed by providing agricultural credit, developing SC infrastructure, and the FPO intervention. Therefore, FPOs' smooth functioning is crucial to the continued well-being of smallholders. It may take some time for these variables to have a moderating role in further developing FPOs. Significant insights into the overall progress across various dimensions can be gained from the success stories of numerous FPOs, including Sahyadri Farmer Producer Company (FPC) in Maharashtra and DHARANI in Telangana, as well as those from Odisha, Rajasthan, Chhattisgarh, Madhya Pradesh, and other states. Leadership, farmer loyalty, efficient

internal governance, professionalism, participatory approach, vertical and horizontal integration, non-bureaucratic mode of operation, local culture of farmers, technological and infrastructure advancements, market access, branding, compliances, employee dedication, and capacity building, all these areas must be given priority in overall FPO development (Bikkina et al., 2018; Nayak, 2019; Singh, 2019). The moderating impact of FPO intervention on the association between HSCE and SLD may be further understood in future studies with broader scope utilizing a similar research approach. The horticulture SC needs a complete restructuring with the intervention of FPO for efficiency to boost profits, employment, and rural commercialization (Keatinge et al., 2018; Islam et al., 2022; von Braun et al., 2004). Policymakers may find the study useful in promoting sustainability, efficiency in SC, and equitable agricultural growth for smallholders.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge all the smallholder farmers who participated in this study and generously shared their experiences and perspectives. The authors also extend their sincere appreciation to the government officials and other relevant stakeholders for their valuable support, cooperation, and insights during the course of this research. Furthermore, the authors acknowledge the use of institutionally available AI-assisted language refinement tools to improve the language and readability of the manuscript. The authors remain fully responsible for the content, interpretations, and conclusions presented in this work.

AUTHOR CONTRIBUTIONS

Lokesh Kumar Jena and Debarshi Mukherjee: Conceptualization, Methodology, Validation.

Lokesh Kumar Jena, Subhayan Chakraborty, Pintu Majhi, and Seemarani Meher: Investigation, Data Curation.

Lokesh Kumar Jena, Pintu Majhi, and Seemarani Meher: Formal Analysis.

Lokesh Kumar Jena: Visualization, Writing—Original Draft.

Debarshi Mukherjee and Subhayan Chakraborty: Supervision.

Lokesh Kumar Jena, Debarshi Mukherjee, Maidul Islam: Writing—Review & Editing.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

ETHICS STATEMENT

Ethical approval was not required for this study, as the data was collected through proper channel.

DATA AVAILABILITY STATEMENT

Data supporting the findings of this study are available from the corresponding author upon reasonable request.

Funding Statement

Not Available

REFERENCES

- [1] Alam, G. M. M., & Khatun, M. N. (2021). Impact of COVID-19 on vegetable supply chain and food security: Empirical evidence from Bangladesh. *PLOS ONE*, 16(3), e0248120. <https://doi.org/10.1371/journal.pone.0248120>
- [2] Alemu, A. E., Maertens, M., Deckers, J., Bauer, H., & Mathijs, E. (2016). Impact of supply chain coordination on honey farmers' income in Tigray, Northern Ethiopia. *Agricultural and Food Economics*, 4(1). <https://doi.org/10.1186/s40100-016-0053-x>
- [3] Alimov, A., Boldyreva, S. B., Alimov, A. K., Adilchaev, R. T., Idzhilova, D. V., & Chadlaeva, N. E. (2020). On the development of cluster theory. *International Journal of Management*, 11(11), 749–759. <https://doi.org/10.34218/IJM.11.11.2020.070>
- [4] Amrutlal, P. A., & Sharma, M. (2010). *An in-depth comparative study of supply chain management practices at selected agriculture produce marketing committees of North Gujarat* [Doctoral dissertation, Ganpat University]. <http://hdl.handle.net/10603/39624>

- [5] Arshinder, Kanda, A., & Deshmukh, S. G. (2007). Coordination in supply chains: An evaluation using fuzzy logic. *Production Planning & Control*, 18(5), 420–435. <https://doi.org/10.1080/09537280701430994>
- [6] Arshinder, & Balaji, M. (2019). Understanding the models of Indian fruit and vegetable supply chains—A case study approach. *International Journal of Agricultural Resources, Governance and Ecology*, 15(4), 307. <https://doi.org/10.1504/IJARGE.2019.104196>
- [7] Auty, R. (1990). *Resource-based industrialisation: Sowing the oil in eight developing countries*. Clarendon Press.
- [8] Auty, R. (1993). *Sustaining development in mineral economies: The resource curse thesis*. Routledge. <https://doi.org/10.4324/9780203422595>
- [9] Ayele, G., Moorman, L., Wamisho, K., & Zhang, X. (2010). *Infrastructure and cluster development: A case study of handloom weavers in Ethiopia*. International Food Policy Research Institute. <http://www.ifpri.org>
- [10] Ayodele, J. (2012). Validity and reliability issues in educational research. *Journal of Educational and Social Research*, 2(2). <https://doi.org/10.5901/jesr.2012.v2n2.391>
- [11] Banumathi, T., & Kaliraj, S. (2013). *A study on the role of rural infrastructure in agricultural development in Kanchipuram District, Tamil Nadu* [Doctoral dissertation, University of Madras]. <http://hdl.handle.net/10603/201056>
- [12] Bhagat, D. (2012). *Some aspects concerning supply chain of high value agricultural commodities and smallholders in Garo Hills of Meghalaya* [Doctoral dissertation, Gauhati University].
- [13] Bikkina, N., Turaga, R. M. R., & Bhamoriya, V. (2018). Farmer producer organisations as farmer collectives: A case study from India. *Development Policy Review*, 36(6), 669–687. <https://doi.org/10.1111/dpr.12274>
- [14] BIRTHAL, P. S., Jha, A. K., & Singh, H. (2007). Linking farmers to markets for high-value agricultural commodities. *Agricultural Economics Research Review*, 20(2), 425–439.
- [15] Bougie, R., & Sekaran, U. (2019). *Research methods for business: A skill-building approach* (8th ed.). Wiley.
- [16] Bunte, J. (2019). *Farmer producer organisations to improve farmer livelihoods: A look at Karnataka*. Medium. <https://medium.com/s3idf/farmer-producer-organizations-to-improve-farmer-livelihood-a-look-at-karnataka-adb2938ad5d3>
- [17] Busse, M., & Gröning, S. (2013). The resource curse revisited: Governance and natural resources. *Public Choice*, 154(1), 1–20. <https://doi.org/10.1007/s11127-011-9804-0>
- [18] Cappelen, A. W., Fjeldstad, O. H., Mmari, D., Sjørnsen, I. H., & Tungodden, B. (2021). Understanding the resource curse: A large-scale experiment on corruption in Tanzania. *Journal of Economic Behavior & Organization*, 183, 129–157. <https://doi.org/10.1016/j.jebo.2020.12.027>
- [19] Chambers, R. (2007). *From PRA to PLA and pluralism: Practice and theory*. Institute of Development Studies. www.ids.ac.uk/ids/bookshop
- [20] Chandio, A. A., Jiang, Y., Wei, F., & Guangshun, X. (2018). Effects of agricultural credit on wheat productivity of small farms in Sindh, Pakistan: Are short-term loans better? *Agricultural Finance Review*, 78(5), 592–610. <https://doi.org/10.1108/AFR-02-2017-0010>
- [21] Chandran, D., & Francis, F. (2018). *A study on the problems and farmer linkage scheme of the coconut processing sector in Kerala* [Doctoral dissertation, University of Calicut]. <http://hdl.handle.net/10603/270268>
- [22] Chang, S. J., Van Witteloostuijn, A., & Eden, L. (2020). Common method variance in international business research. In *Research methods in international business* (pp. 385–398). Palgrave Macmillan.
- [23] Chin, W. W. (1998). The partial least squares approach to structural equation modeling. In G. A. Marcoulides (Ed.), *Modern methods for business research* (pp. 295–336). Lawrence Erlbaum Associates.
- [24] Cooper, B., Eva, N., Fazlelahi, F. Z., Newman, A., Lee, A., & Obschonka, M. (2020). Addressing common method variance and endogeneity in vocational behavior research: A review of the literature and suggestions for future research. *Journal of Vocational Behavior*, 121, 103472. <https://doi.org/10.1016/j.jvb.2020.103472>
- [25] Daniel, W. (1999). *Biostatistics: A foundation for analysis in the health sciences* (7th ed.). Wiley.
- [26] Das, S. (2020). Supply chain of millets: An FPO perspective (with special reference to Odisha). *Journal of Global Values*, 11(3), 234–257.
- [27] Dastagiri, M. B., Ganesh Kumar, B., Hanumanthaiah, C. V., Paramsivam, P., Sidhu, R. S., Sudha, M., Mandal, S., Singh, B., & Chand, K. (2012). Marketing efficiency of India's horticultural commodities under different supply chains. *Outlook on Agriculture*, 41(4), 271–278. <https://doi.org/10.5367/oa.2012.0103>

- [28] Dorward, A., Kydd, J., Poulton, C., & Bezemer, D. (2009). Coordination risk and cost impacts on economic development in poor rural areas. *Journal of Development Studies*, 45(7), 1093–1112. <https://doi.org/10.1080/00220380802550277>
- [29] Elamon, J. (2020). KILA Journal of Local Governance, Vol-7 No. 1& 2, January-December 2020.
- [30] Fan, J., & Gao, L. (2014). Vegetables logistics informationization in supply chain. In *Proceedings of the 9th IEEE Conference on Industrial Electronics and Applications* (pp. 117–120). IEEE.
- [31] FAO. (2022). *FAOSTAT Analytical Brief 38: Credit to agriculture—Global and regional trends (2012–2022)*. FAO. <http://www.fao.org/faostat/en/#data/IC>
- [32] Galhena, D. H., Freed, R., & Maredia, K. M. (2013). Home gardens: A promising approach to enhance household food security and wellbeing. *Agriculture & Food Security*, 2(1), 8. <https://doi.org/10.1186/2048-7010-2-8>
- [33] Gardas, B. B., Raut, R. D., & Narkhede, B. (2018). Evaluating critical causal factors for post-harvest losses in the fruit and vegetables supply chain in India using the DEMATEL approach. *Journal of Cleaner Production*, 199, 47–61. <https://doi.org/10.1016/j.jclepro.2018.07.153>
- [34] GoI MIDH. (2014). *Mission for Integrated Development of Horticulture (MIDH) Guidelines*. Ministry of Agriculture & Farmers Welfare. [http://www.midh.gov.in/PDF/MIDH_Guidelines\(final\).pdf](http://www.midh.gov.in/PDF/MIDH_Guidelines(final).pdf)
- [35] Government of India (GoI). (2021). *Agricultural Statistics at a Glance 2021*. Ministry of Agriculture & Farmers Welfare. www.agricoop.nic.in
- [36] Government of Tripura. (2021). *Annual State Plan 2021–2022*. Planning Department, Government of Tripura.
- [37] Gummagolmath, K. C., Valamannavar, S., Darekar, A., & Lakshmi, S. B. R. (2022). *Role of Farmer Producer Organizations in empowering farmers: Case studies from India*. MANAGE.
- [38] Hadley, P. A. (2023). *Building co-operation in farmer collectives and across 'value' chains: Institutional dynamics and power relations in Central India* [Doctoral dissertation, SOAS University of London].
- [39] Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2010). *Multivariate data analysis: A global perspective* (7th ed.). Pearson.
- [40] Hair, J. F., Hult, G. T. M., Ringle, C. M., & Sarstedt, M. (2013). *A primer on partial least squares structural equation modeling (PLS-SEM)*. Sage.
- [41] Hair, J. F., Hult, G. T. M., Ringle, C. M., & Sarstedt, M. (2017). *A primer on partial least squares structural equation modeling (PLS-SEM)* (2nd ed.). Sage.
- [42] Hair, J. F., Jr., Matthews, L. M., Matthews, R. L., & Sarstedt, M. (2017). PLS-SEM or CB-SEM: Updated guidelines on which method to use. *International Journal of Multivariate Data Analysis*, 1(2), 107–123. <https://doi.org/10.1504/IJMDA.2017.087624>
- [43] Hair, J. F., Ringle, C. M., & Sarstedt, M. (2013). Partial least squares structural equation modeling: Rigorous applications, better results and higher acceptance. *Long Range Planning*, 46(1–2), 1–12. <https://doi.org/10.1016/j.lrp.2013.01.001>
- [44] Halder, P., & Pati, S. (2011). A need for paradigm shift to improve supply chain management of fruits and vegetables in India. *Asian Journal of Agriculture and Rural Development*, 1(1), 1–20.
- [45] Hamed Taherdoost, A., & Lumpur, K. (2016). Validity and reliability of the research instrument: How to test the validation of a questionnaire/survey in a research. *International Journal of Academic Research in Management*, 5(3). <https://hal.science/hal-02546799>
- [46] Henseler, J., Dijkstra, T. K., Sarstedt, M., Ringle, C. M., Diamantopoulos, A., Straub, D. W., Ketchen, D. J., Hair, J. F., Tomas, G., Hult, G. T. M., & Calantone, R. J. (2014). Common beliefs and reality about PLS: Comments on Rönkkö and Evermann (2013). *Organizational Research Methods*, 17(2), 182–209. <https://doi.org/10.1177/1094428114526928>
- [47] Henseler, J., Ringle, C. M., & Sarstedt, M. (2015). A new criterion for assessing discriminant validity in variance-based structural equation modeling. *Journal of the Academy of Marketing Science*, 43(1), 115–135. <https://doi.org/10.1007/s11747-014-0403-8>
- [48] Iimi, A. (2007). Escaping from the resource curse: Evidence from Botswana and the rest of the world. *IMF Staff Papers*, 54(4), 663–699. <https://doi.org/10.1057/palgrave.imfsp.9450020>
- [49] INAFI India. (2013). *Transforming small holders farming into agri business ventures—Role of producer companies & gendering greenpreneurship*. http://inafiindia.net/docs/Proceedings_Farmers_Producer_Companies-Madurai.pdf
- [50] IRMA-NABARD. (2022). *Handholding (Capacity Building and Facilitation) of FPOs: Framework to implementation*. Institute of Rural Management Anand; NABARD. <https://www.nabard.org/auth/writereaddata/tender/2705222930nrs-24-handholding-of-fpos-framework-to-implementation.pdf>

- [51] Islam, M., Mukherjee, D., Chatterjee, R., & Mitra, S. (2022). A self-reliant tea economy offering inclusive growth: A case of Tripureswari Tea, India. *Agronomy*, 12(12), 2935. <https://doi.org/10.3390/agronomy12122935>
- [52] Islam, M., Mukherjee, D., Jena, L. K., Chakraborty, S., Hasan, K. K., & Debnath, R. (2022). Antecedents of livelihood development using cold chains in the horticultural sector of emerging markets: A systematic literature review. *Horticulturae*, 8(12), 1196. <https://doi.org/10.3390/horticulturae8121196>
- [53] Jayalath, M. M., Ratnayake, R. C., Perera, H. N., & Thibbotuwawa, A. (2023). Waste minimization and performance improvement in vegetable supply chains: A case study from a developing economy. In *Proceedings of the 8th International Conference on Business and Industrial Research (ICBIR 2023)* (pp. 948–953). IEEE.
- [54] Johnson, G. I., & Hofman, P. J. (2004). *Agriproduct supply-chain management in developing countries*. ACIAR.
- [55] Johnson, R. B., & Onwuegbuzie, A. J. (2004). Mixed methods research: A research paradigm whose time has come. *Educational Researcher*, 33(7), 14–26. <https://www.jstor.org/stable/3700093>
- [56] Kaldate, R., Singh, S. K., Guleria, G., Soni, A., Naikwad, D., Kumar, N., Meshram, S., & Rana, M. (2020). Current approaches in horticultural crops to mitigate the effect of drought stress. In *Stress tolerance in horticultural crops* (pp. 213–240). Elsevier. <https://doi.org/10.1016/B978-0-12-822849-4.00004-8>
- [57] Kapil, S. (2021). *Agri share in GDP hit 20% after 17 years: Economic Survey*. Down To Earth. <https://www.downtoearth.org.in/news/agriculture/agri-share-in-gdp-hit-20-after-17-years-economic-survey-75271>
- [58] Karabhari, R. B., & Patil, R. M. (2015). Strengthening rural livelihood through nutrition gardening. *Indian Journal of Applied Research*, 5(4).
- [59] Keatinge, J. D. H., Virchow, D., & Schreinemachers, P. (2018). Horticulture for sustainable development: Evidence for impact of international vegetable research and development. *Acta Horticulturae*, 1205, 179–190. <https://doi.org/10.17660/ActaHortic.2018.1205.20>
- [60] Kelley, J. (2012). China in Africa: Curing the resource curse with infrastructure and modernisation. *Sustainable Development Law & Policy*, 12(3), 35–41. <http://digitalcommons.wcl.american.edu/sdlp>
- [61] Khushbu. (2023). *What are the benefits of producer company*. Vakilsearch. <https://vakilsearch.com/blog/benefits-of-producer-company/>
- [62] Kline, R. B. (2011). *Principles and practice of structural equation modeling* (3rd ed.). Guilford Press.
- [63] Konijn, P. (2014). *Chinese resources-for-infrastructure (RAI) swaps: An escape from the resource curse?* South African Institute of International Affairs. www.saiia.org.za
- [64] Krishnan, R., Yen, P., Agarwal, R., Arshinder, K., & Bajada, C. (2021). Collaborative innovation and sustainability in the food supply chain—Evidence from farmer producer organisations. *Resources, Conservation & Recycling*, 168, 105253. <https://doi.org/10.1016/j.resconrec.2020.105253>
- [65] Kumar, K. (2019). A study on supply chain management in Indian horticulture sector. *ITIHAS—The Journal of Indian Management*, 9(3), 45–53.
- [66] Kumar, K. K. (2020). A study on supply chain management in the Indian horticulture sector: Issues and challenges. *Indian Journals*, 10(2), 45–53.
- [67] Kumar, S., Kumar, S. H. I. V., Chahal, V. P., & Singh, D. R. (2018). Trends and determinants of crop diversification in Uttar Pradesh. *Indian Journal of Agricultural Sciences*, 88(11), 1704–1708.
- [68] Lan, W., & Zhangliu, W. (2012). Research on the governance of industrial clusters. In *Future wireless networks and information systems* (pp. 395–401). Springer. https://doi.org/10.1007/978-3-642-27326-1_51
- [69] MANAGE. (2017). *A case study of Sahyadri Farmer Producer Company, Nashik, Maharashtra*. National Institute of Agricultural Extension Management. <https://www.manage.gov.in/publications/reports/Sahyadri-report.pdf>
- [70] McPhail, K. (2008). Global governance challenges in industry sectors and supply chains: Contributing to sustainable development through multi-stakeholder processes—Practical steps to avoid the "resource curse". *Corporate Governance*, 8(4), 471–481. <https://doi.org/10.1108/14720700810899202>
- [71] Merton, R. K. (1987). The focused interview and focus groups: Continuities and discontinuities. *Public Opinion Quarterly*, 51(4), 550–566. <https://doi.org/10.1086/269057>
- [72] Middendorf, B. J., Traoré, H., Middendorf, G., Jha, P. K., Yonli, D., Palé, S., & Prasad, P. V. V. (2022). Impacts of the COVID-19 pandemic on vegetable production systems and livelihoods: Smallholder farmer experiences in Burkina Faso. *Food and Energy Security*, 11(1), e337. <https://doi.org/10.1002/fes3.337>

- [73] Ministry of Agriculture & Farmers Welfare (MoAFW). (2020). *Horticulture overview. Government of India*. <https://www.agricoop.gov.in/en/divisiontype/horticulture>
- [74] Ministry of Agriculture & Farmers Welfare (MoAFW). (2021). *Role of Farmer Producer Organisations (FPOs) in doubling farmers' income*. Press Information Bureau. <https://pib.gov.in/PressReleasePage.aspx?PRID=1740833>
- [75] Minten, B. (1999). *Infrastructure, market access, and agricultural prices: Evidence from Madagascar*. <http://ageconsearch.umn.edu>
- [76] Möhring, J. (2006). Clusters: Definition and methodology. In *Competitive regional clusters: National policy approaches* (pp. 21–32). OECD Publishing. <https://doi.org/10.1787/9789264007116-3-en>
- [77] NABARD. (2015). *Farmer Producer Organisations: Frequently Asked Questions (FAQs)*. NABARD. <https://www.nabard.org/demo/auth/writereaddata/File/FARMER%20PRODUCER%20ORGANISATIONS.pdf>
- [78] NABARD Capital Market. (2018). *Agriculture credit to farmers*. <https://www.nabard.org/news-article.aspx?id=25&cid=552&nid=160>
- [79] NAFPO. (2022). *State of sector report: Farmer Producer Organisations in India*. NAFPO. [https://www.nafpo.in/wp-content/uploads/2022/07/SOFPO_Report_\(06-07-22\)_Hi-res_WCM.pdf](https://www.nafpo.in/wp-content/uploads/2022/07/SOFPO_Report_(06-07-22)_Hi-res_WCM.pdf)
- [80] Naing, L., Winn, T., & Rusli, B. N. (2006). Practical issues in calculating the sample size for prevalence studies. *Archives of Orofacial Sciences*, 1, 9–14.
- [81] Nath, P. K., & Behera, B. (2011). A critical review of impact of and adaptation to climate change in developed and developing economies. *Environment, Development and Sustainability*, 13(1), 141–162. <https://doi.org/10.1007/s10668-010-9253-9>
- [82] Nayak, A. (2019). *Case studies of FPOs in India*. NABARD. <https://www.nabard.org/auth/writereaddata/tender/0306220035case-studies-of-fpos-in-india-2019-21.pdf>
- [83] Negi, S. (2018). *Developing a framework to improve supply chain efficiency of fruits and vegetables sector* [Doctoral dissertation, University of Petroleum and Energy Studies].
- [84] Negi, S. (2021). Supply chain efficiency framework to improve business performance in a competitive era. *Management Research Review*, 44(3), 477–508. <https://doi.org/10.1108/MRR-05-2020-0272>
- [85] Nunnally, J. C., & Bernstein, I. H. (1994). *Psychometric theory*. McGraw-Hill.
- [86] Pandian, J., & Ganesan, M. (2021). *Sustainability factors of Farmer Producer Organisations for farmers' empowerment* [Doctoral dissertation, Anna University]. <http://hdl.handle.net/10603/427641>
- [87] Pani, B. S., & Mishra, D. (2022). Sustainable livelihood security in Odisha, India: A district level analysis. *Regional Sustainability*, 3(2), 110–121. <https://doi.org/10.1016/j.regsus.2022.07.003>
- [88] PIB Delhi, & NSO. (2022). *Consumer Price Index Numbers on base 2012 = 100 for rural, urban and combined for the month of June 2022*. <https://pib.gov.in>
- [89] PIB MoAFW. (2021). *Horticulture sector can play an important role in doubling farmers' income*. <https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1717447>
- [90] PNBIndia. (2015). *Horticulture in Tripura*. https://slbctripura.pnbindia.in/pdf/Horticulture_Tripura.pdf
- [91] PNBIndia. (2021). *Role of agricultural infrastructure. Ministry of Agriculture & Farmers Welfare*. <https://pib.gov.in/Pressreleaseshare.aspx?PRID=1783870>
- [92] Poncian, J. (2019). Extractive resource ownership and the subnational resource curse: Insights from Tanzania. *The Extractive Industries and Society*, 6(2), 332–342. <https://doi.org/10.1016/j.exis.2018.08.013>
- [93] Porter, M. E. (1998). *Clusters and the new economics of competition*. Harvard Business Review, 76(6), 77–90.
- [94] Qureshi, I., Pandey, M., Shukla, D. M., & Pillai, V. (2023). Technoficing: Reinterpretation of Gandhian perspectives on technology. In *Social entrepreneurship and Gandhian thoughts in the post-COVID world* (pp. 191–214). Springer Nature.
- [95] Rai, M. K., Paudel, B., Zhang, Y., Khanal, N. R., Nepal, P., & Koirala, H. L. (2019). Vegetable farming and farmers' livelihood: Insights from Kathmandu Valley, Nepal. *Sustainability*, 11(3), 889. <https://doi.org/10.3390/su11030889>
- [96] Rais, M., & Sheoran, A. (2015). Scope of supply chain management in fruits and vegetables in India. *Journal of Food Processing & Technology*, 6(3), 1–7.
- [97] Rask, M., Oscarsson, M., Ludwig, N., & Swahnberg, K. (2017). The Swedish translation and cross-cultural adaptation of the FACIT-CD: Linguistic validity and reliability of the Swedish version. *BMC Women's Health*, 17(1). <https://doi.org/10.1186/s12905-017-0381-3>
- [98] RBI. (2019). *Supply chain dynamics and food inflation in India*. https://www.researchgate.net/publication/348993994_Supply_Chain_Dynamics_and_Food_Inflation_in_India

- [99] Reiner, G., & Hofmann, P. (2006). Efficiency analysis of supply chain processes. *International Journal of Production Research*, 44(23), 5065–5087. <https://doi.org/10.1080/00207540500515123>
- [100] Sahoo, A. K., & Dash, S. (2022). *Issues and challenges of agricultural financing in Western Odisha for inclusive and sustainable rural development: An empirical study* [Doctoral dissertation, Gangadhar Meher University]. <http://hdl.handle.net/10603/371437>
- [101] Satish, P. (2007). Rural infrastructure and growth: An overview. *Indian Journal of Agricultural Economics*, 62(3).
- [102] SFAC. (2019). *Strategy paper for promotion of 10,000 Farmer Producer Organisations (FPOs)*. SFAC. <http://sfacindia.com/UploadFile/Statistics/Strategy-Paper-on-Promotion-of-10,000-FPOs.pdf>
- [103] Shah, A. (2014). Natural resources and chronic poverty in India: Interface and policy imperatives. In *Environment and development economics: Essays in honour of Sir Partha Dasgupta* (p. 359). Oxford University Press. <https://doi.org/10.1093/acprof:oso/9780199677856.003.0019>
- [104] Shwetha, N. V., & Shivalingaiah, Y. N. (2019). Development of scale to measure livelihood security of farmers practicing different farming systems in Southern Karnataka. *International Journal of Current Microbiology and Applied Sciences*, 8(3), 521–527. <https://doi.org/10.20546/ijcmas.2019.811.064>
- [105] Sibomana, M. S., Workneh, T. S., & Audain, K. (2016). A review of post-harvest handling and losses in the fresh tomato supply chain: A focus on Sub-Saharan Africa. *Food Security*, 8(2), 389–404. <https://doi.org/10.1007/s12571-016-0562-1>
- [106] Simatupang, T. M., & Sridharan, R. (2005). The collaboration index: A measure for supply chain collaboration. *International Journal of Physical Distribution & Logistics Management*, 35(1), 44–62. <https://doi.org/10.1108/09600030510577421>
- [107] Singh, G., & Vatta, K. (2019). Assessing the economic impacts of farmer producer organisations: A case study in Gujarat, India. *Agricultural Economics Research Review*, 32(1), 139. <https://doi.org/10.5958/0974-0279.2019.00023.5>
- [108] Singh, S. (2002). Contracting out solutions: Political economy of contract farming in the Indian Punjab. *World Development*, 30(9), 1621–1638. [https://doi.org/10.1016/S0305-750X\(02\)00059-1](https://doi.org/10.1016/S0305-750X(02)00059-1)
- [109] Singh, S. (2019). *Case study of Dharani Farmer Producer Organisation*. <http://www.apmas.org/pdf/fpo-csaestudy-long.pdf>
- [110] Strand, S. (2006). Discovering statistics using SPSS (2nd edition). Andy Field, London: Sage Publications Ltd 2005. ISBN 0-7619-4452-4. *British Journal of Educational Psychology*, 76(2), 423. <https://doi.org/10.1348/000709906X100611>
- [111] Suriyapriya, E., & Kavaskar, M. (2022). *A study on impact of Farmer Producer Organisations (FPOs) among the small and marginal farmers of Tamil Nadu* [Doctoral dissertation, Annamalai University]. <http://hdl.handle.net/10603/392087>
- [112] Swords, J. (2013). Michael Porter's cluster theory as a local and regional development tool: The rise and fall of cluster policy in the UK. *Local Economy*, 28(4), 369–383. <https://doi.org/10.1177/0269094213475855>
- [113] Ton, G., & Bijman, J. (2006). *The role of producer organisations in the process of developing an integrated supply chain: Experiences from quinoa chain development in Bolivia* (pp. 1–16).
- [114] Ulrich, A. (2014). Export-oriented horticultural production in Laikipia, Kenya: Assessing the implications for rural livelihoods. *Sustainability*, 6(1), 336–347. <https://doi.org/10.3390/su6010336>
- [115] Van der Vorst, J. G. A. J., & Beulens, A. J. M. (2002). Identifying sources of uncertainty to generate supply chain redesign strategies. *International Journal of Physical Distribution & Logistics Management*, 32(6), 409–430. <https://doi.org/10.1108/09600030210437951>
- [116] Viswanadham, N. (2007). *Can India be the food basket for the world?* (Working Paper). Indian School of Business. <https://www.csa.iisc.ac.in/~nv/Mypublications/2005-06publications/Thoughtlaedrshippapers/canIndiabethefoodbasket.pdf>
- [117] von Braun, J., Swaminathan, M. S., & Rosegrant, M. W. (2004). *Agriculture, food security, nutrition and the Millennium Development Goals*.
- [118] Weaver, B. (2011). *Coordination, co-operation, and collaboration: Defining the C3 framework*.
- [119] Weinberger, K., & Lumpkin, T. A. (2007). Diversification into horticulture and poverty reduction: A research agenda. *World Development*, 35(8), 1464–1480. <https://doi.org/10.1016/j.worlddev.2007.05.002>
- [120] Wenar, L. (2008). Property rights and the resource curse. *Philosophy & Public Affairs*, 36(1), 2–32. <https://doi.org/10.1111/j.1088-4963.2008.00122.x>
- [121] Widadie, F., Bijman, J., & Trienekens, J. (2022). Alignment between vertical and horizontal coordination for food quality and safety in Indonesian vegetable chains. *Agricultural and Food Economics*, 10(1). <https://doi.org/10.1186/s40100-022-00215-w>

- [122] Wild, D., Grove, A., Martin, M., Eremenco, S., McElroy, S., Verjee-Lorenz, A., & Erikson, P. (2005). *Principles of good practice for the translation and cultural adaptation process for patient-reported outcomes measures: Report of the ISPOR task force.* <http://www.ispor.org>
- [123] Yasmin, T., Khattak, R., & Ngah, I. (2014). Eco-friendly kitchen gardening by Pakistani rural women developed through a farmer field school participatory approach. *Biological Agriculture & Horticulture*, 30(1), 32–41. <https://doi.org/10.1080/01448765.2013.845112>
- [124] Zhang, L., Kono, Y., & Kobayashi, S. (2014). The process of expansion in commercial banana cropping in tropical China: A case study at a Dai village, Mengla County. *Agricultural Systems*, 124, 32–38. <https://doi.org/10.1016/j.agsy.2013.10.006>

Appendix A- Instrument items

Appendix A.1

Table A1. Items of the Instrument and its sources

Variables	Item No	Items	Source (s)
Independent Variable (Horticultural Supply Chain Efficiency-HSCE)			
SC Infrastructure (HSCE1)	HSCE1.1	I have required access to input-based infrastructure (Seed, Fertilizer, pesticides, Farm Equipment, and machinery).	(Banumathi & Kaliraj, 2013)
	HSCE1.2	I am satisfied with the access to resource-based infrastructure (Irrigation, electricity).	
	HSCE1.3	I feel satisfied with my access to Physical infrastructure (Road connectivity, Transport, Storage, Processing, and Preservative).	
	HSCE1.4	My access to training and skill development centers makes me feel satisfied.	
Agricultural Credit (HSCE2)	HSCE2.1	I prefer to take a loan from institutional sources for agricultural credit.	(Sahoo & Dash, 2022)
	HSCE2.2	Getting a loan is easier from non-institutional sources than from an institutional source as agricultural credit.	
	HSCE2.3	I feel the rate of interest in Agri-finance is minimal and affordable.	
	HSCE2.4	Banks disburse the credit whenever I require it (pre and post-harvest operations).	
	HSCE2.5	I feel government policies and procedures towards agricultural credit are satisfactory.	
SC Collaboration (HSCE3)	HSCE3.1	I receive relevant information on demand, price, and place of sale through supply chain collaboration.	(Arshinder et al., 2005)
	HSCE3.2	I receive information regarding promotion events through supply chain collaboration.	
	HSCE3.3	Collaboration gives me the opportunity for a new variety of horticultural product development.	
	HSCE3.4	Collaboration helps me to access the latest agricultural technology.	
	HSCE3.5	Collaboration gives me delivery status and tracking of goods in transit.	(Arshinder et al., 2005)
	HSCE3.6	I keep myself updated with weather information.	
	HSCE3.7	I avoid crop loss using necessary technical information (latest farming equipment and other Agri-related information on time).	
Moderating Variable (FPOIntervention)			
Market risk mitigation (FPOI1)	FPOI1.1	FPO helps me increase equitable access to established markets for a fair price for my produce.	(Pandian & Ganesan, 2021)
	FPOI1.2	FPO helps me increase the bargaining power for my products in the market.	

	FPOI1.3	I am satisfied with FPO for Protecting me from the exploitation of intermediaries.	(Chandran & Francis, 2018)
	FPOI1.4	I am satisfied with FPO for Protecting me from seasonal and non-seasonal price fluctuations.	(Chandran & Francis, 2018)
	FPOI1.5	I feel satisfied when the government purchases my produce as an intermediary.	(Amrutlal & Sharma, 2010)
Economies of scale (FPOI2)	FPOI2.1	FPO helps me in attaining increased productivity in my field through training, development & extension service.	(Pandian & Ganesan, 2021)
	FPOI2.2	I am satisfied with the increased return for my product through FPO.	
	FPOI2.3	I am satisfied with FPO for lowering transportation costs.	(Chandran & Francis, 2018)
	FPOI2.4	FPO helps me in saving time.	
	FPOI2.5	FPO helps me in lowering input & production costs.	
Dependent Variable (Smallholders Livelihood Development)			
Food and nutritional security (SLD1)	SLD1.1	I feel satisfied that horticulture provides food for my family and me throughout the year.	(Shwetha & Shivalingaiah, 2019)
	SLD1.2	The quality of food available to my family and me makes me feel secure.	
	SLD1.3	I am getting an affordable, balanced diet for my family members and me.	
Economic security (SLD2)	SLD2.1	I get maximum and stabilized income through farming.	(Shwetha & Shivalingaiah, 2019)
	SLD2.2	I am able to diversify my income through horticultural production.	
	SLD2.3	I am able to save money for my family's future.	
	SLD2.4	E- The horticultural production ensures my family's employment.	
Ecological security (SLD3)	SLD3.1	I am able to use water efficiently.	(Shwetha & Shivalingaiah, 2019)
	SLD3.2	I reuse the horticultural wastage for farming.	
	SLD3.3	I use a minimum amount of chemical fertilizer and pesticides for horticultural production.	
	SLD3.4	I am able to maintain soil fertility and soil health through diversified farming.	
Social security (SLD4)	SLD4.1	Practicing horticulture production gives me good recognition in the society.	(Shwetha & Shivalingaiah, 2019)
	SLD4.2	I am able to coordinate with government or extension agencies through horticulture.	
	SLD4.3	I am satisfied with the increased coordination with other stakeholders.	
Psychological security (SLD5)	SLD5.1	I find myself improving my knowledge and skills in horticulture production.	(Shwetha & Shivalingaiah, 2019)
	SLD5.2	Experience in Horticultural production improves my confidence to try new ideas on my farm and interact with others.	
	SLD5.3	Horticulture has created demand among farmers to visit my farm and seek my advice.	
	SLD5.4	I am able to overcome my stress condition through horticultural produce with an increased return.	
Physical security (SLD6)	SLD6.1	My piece of land for horticulture practice makes me feel secure.	(Shwetha & Shivalingaiah, 2019)
	SLD6.2	My pieces of farm machinery for horticulture practice are a means of security for me.	
	SLD6.3	The availability of an irrigation facility for my land makes me feel secure.	
	SLD6.4	I feel secure in having a logistic infrastructure for marketing my horticultural produce.	

Table A2. Harman single-factor test

Component	Total Variance Explained					
	Total	Initial Eigenvalues		Extraction Total	Sums of Squared Loadings	
		% of Variance	Cumulative %		% of Variance	Cumulative %
1	20.531	22.951	22.951	20.531	22.951	22.951
2	4.861	5.434	28.385			
3	4.242	4.742	33.126			
4	3.767	4.211	37.338			
5	3.678	4.112	41.450			
6	3.407	3.808	45.258			
7	3.029	3.386	48.644			
8	2.803	3.133	51.777			
9	2.656	2.969	54.746			
10	2.327	2.602	57.348			
11	2.167	2.423	59.770			
12	2.022	2.260	62.030			
13	1.970	2.202	64.232			
14	1.857	2.076	66.308			
15	1.787	1.998	68.306			
16	1.737	1.942	70.248			
17	1.622	1.813	72.061			
18	1.580	1.766	73.827			
19	1.545	1.727	75.555			
20	1.472	1.645	77.200			
21	1.394	1.559	78.759			
22	1.356	1.516	80.275			
23	1.230	1.375	81.650			
24	1.185	1.325	82.975			
25	1.145	1.279	84.254			
26	1.096	1.225	85.480			
27	1.029	1.150	86.630			
28	1.013	1.133	87.763			
29	.996	1.113	88.876			
30	.933	1.043	89.919			
31	.878	.982	90.900			
32	.855	.956	91.856			
33	.850	.950	92.807			
34	.776	.867	93.674			
35	.739	.827	94.501			
36	.683	.763	95.264			
37	.665	.744	96.008			
38	.612	.684	96.692			
39	.574	.641	97.333			
40	.535	.598	97.931			
41	.509	.569	98.500			
42	.460	.515	99.015			
43	.448	.501	99.515			
44	.434	.485	100.000			

Extraction Method: Principal Component Analysis.