Sustainable Agribusiness Management and Food Supply Chain Performance: A Comprehensive Review

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ABSTRACT

The article examines the existing literature concerning sustainable agribusiness management and food supply chain performance, and it uses a simulated dataset to show how the Sustainability-Performance Transmission (SPT) framework can be tested. The review indicates that the concept of sustainability in agri-food chains has evolved from one of compliance to one of capability, that perishable supply chains require performance to be measured across at least four dimensions, and that the connection between sustainable practices and performance is mainly mediated by capabilities such as information sharing, collaboration and adaptive capacity. In order to carry out the empirical analysis, a synthetic dataset consisting of 120 respondents (these having been generated by simulation and not being real respondents) was analysed using descriptive statistics, reliability analysis, chi-square tests, one-way ANOVA, correlation and OLS regression together with a bootstrapped mediation test.

The scores for sustainable practice (M = 3.15), capabilities (M = 3.24) and performance (M = 3.18) were all near the midpoint of the scale. In the simulated data, practice had a significant effect on capabilities (standardized beta = 0.55, $p < .001$, so H1 is supported) and on performance (beta = 0.56, $p < .001$, so H2 is supported); capabilities also predicted performance when practice was taken into account (beta = 0.49, $p < .001$, so H3 is supported); and the indirect effect was 0.267 (95% bootstrap CI [0.167, 0.382], so H4 is supported), which shows that there is partial mediation. There was no significant relationship between training and performance (so H5 is not supported) nor between chain role and performance (so H6 is not supported). Since these relationships were included in the simulation, they prove that the method is able to recover them and therefore do not provide any evidence about actual supply chains. Section 10 outlines what a genuine field study would need in addition. The use of artificial data is limited to showing off a complete and transparent research process, and the review and framework sections are entirely on their own.

1. Introduction

The food system has to feed an increasing population without increasing the pressure it exerts on land, water, biodiversity and the climate (Godfray et al., 2010). Poore and Nemecek (2018) found that the environmental impact of food differs greatly among producers of the same product, meaning that the choices made in terms of management are just as important as the product itself. A large amount of food is also lost before it reaches the consumers: Gustavsson et al. (2011) estimated that about one third of the food produced for human consumption is lost or wasted throughout the supply chain, and Parfitt et al. (2010) observed that losses tend to occur after harvest and during storage and transport in developing economies. The cost and sustainability of food are determined by agribusiness companies such as farmers and producer groups, aggregators, processors, logistics providers, wholesalers and retailers through the decisions they make regarding sourcing, methods of production, storage, transport, packaging, information sharing and contracting.

The disruptions caused by the COVID-19 pandemic demonstrated how swiftly food chains can break (Hobbs, 2020; Ivanov, 2020). In India the holdings are small and scattered, the supply chains are long, the cold-chain capacity is limited and market information is irregular. As Reardon et al. (2009) and Reardon and Timmer (2014) have pointed out, the transformation of agrifood systems brings with it both opportunities and a risk of exclusion for small farmers. Sustainable agribusiness management, supply chain capabilities and supply chain performance have generally been studied on their own. However sustainable practices such as loss reduction and traceability are likely to have an impact on performance by altering the way in which information, time and relationships are managed throughout the chain. In light of the above,

the current article examines the relevant literature, introduces the SPT framework, and shows, using a simulated data set and a mediation model, how the relationship between sustainable agribusiness practice and supply chain performance—capacities acting as the mediating mechanism—can be tested.

2. Review of Literature

The Brundtland Commission in 1987 described sustainable development as satisfying the needs of the present without putting at risk the ability of future generations to meet their own needs, and Elkington in 1997 interpreted it in terms of the triple bottom line comprising economic, environmental and social performance.

Seuring and Müller (2008) described sustainable supply chain management as the management of material, information and capital flows as well as of cooperation between companies, incorporating the three dimensions of sustainability and the requirements of stakeholders. Carter and Rogers (2008) put forward a framework based on risk management, transparency, strategy and culture.

Pagell and Wu (2009), in their study of individual firms, maintained that top firms regard sustainability as a design principle of the chain rather than as an extra addition.

Beske, Land and Seuring (2014) examined the literature in the field of food industry from the point of view of dynamic capabilities and maintained that collaboration, learning, integration and proactive risk management contribute to the ability to adapt within sustainable supply chains.

Beamon in 1999 and Gunasekaran, Patel and McGaughey in 2004 put forward generic frameworks for the measurement of supply chain performance. Aramyan and others in 2007 adapted performance measurement for use in agri-food chains and divided the indicators into those relating to efficiency, flexibility, responsiveness and food quality.

Ahumada and Villalobos (2009) looked at the various planning models in the agri-food chain, and Soysal et al. (2012) examined the quantitative models used in sustainable food logistics, pointing out that there had been only limited integration of environmental and social criteria. Tsolakis et al. (2014) created a hierarchical decision-making framework and a taxonomy for agrifood supply chain management.

Parfitt, together with Barthel and Macnaughton in 2010 and Gustavsson and others in 2011, measured food loss and waste and demonstrated the differences in the reasons behind them between developed and developing economies.

Trienekens and others in 2012 as well as Wognum and colleagues in 2011 looked at transparency and sustainability systems in complex food chains, highlighting their value with regard to control and assurance together as well as their costs and the problems involving data.

Kamilaris, Fonts and Prenafeta-Boldú (2019) stated that blockchain has potential in the areas of traceability and trust but is still in its early stages, while Wolfert and co-authors (2017) pointed out the issues concerning data ownership and the distribution of benefits in smart farming. Kamble, Gunasekaran and Gawankar (2020) connected data analytics to sustainable performance in agricultural supply chains.

Zhu, Sarkis and Lai in 2008 and Green et al. in 2012 linked green supply chain practices to environmental, economic and operational performance, primarily using samples from the manufacturing sector, and Paulraj in 2011 found that internal resources and capabilities have an impact on sustainable supply management and on organisational sustainability.

Christopher and Peck in 2004, together with Pettit, Fiksel and Croxton in 2010 and also Ivanov and Dolgui in 2020, developed the concepts of resilience and viability in supply chains, while Hobbs in 2020 recorded how food chains responded to the pandemic.

Reardon and Timmer (2014) as well as Reardon et al. (2009) demonstrated that the results for small farmers are influenced by standards, contracts and support. Gereffi, Humphrey and Sturgeon (2005) carried out a classification of global value chain governance, while Porter and Kramer (2011) advocated the concept of shared value.

2.1 Thematic Synthesis of the Literature

In agricultural and food sectors there are four types of sustainable practice: resource-efficient production, operations which reduce loss and are circular, responsible sourcing, and transparency and traceability (see Table 1). Initially, sustainability was seen as simply complying with regulations or with buyer requirements; later on it was viewed as a collection of practices that alter the way a supply chain plans, shares information and coordinates (Pagell & Wu, 2009; Porter & Kramer, 2011).

Practice bundle	What it includes	Key sources
Resource-efficient production	Efficient use of water, energy, fertiliser and land; soil and biodiversity protection	Poore and Nemecek (2018); Godfray et al. (2010)
Loss-reducing and circular operations	Post-harvest loss reduction, by-product use, packaging redesign	Parfitt et al. (2010); Gustavsson et al. (2011)
Responsible sourcing	Fair contracts, worker welfare, farmer training, smallholder inclusion	Reardon et al. (2009); Porter and Kramer (2011)
Transparency and traceability	Records of origin, handling and quality; information sharing	Trienekens et al. (2012); Wognum et al. (2011)

Table 1. Bundles of sustainable agribusiness practice (from the literature)

Generic performance frameworks fail to take account of three characteristics of agri-food chains: perishability (since the value decreases with both time and temperature), seasonality and biological variability, and safety exposure. The performance of perishable chains is thus organised here into four dimensions: efficiency, responsiveness and quality, resilience, and sustainability outcomes (Table 2).

Dimension	Typical indicators	Food-specific adaptation
Efficiency	Cost per delivered unit, inventory days, capacity use, yield per input	Cost per unit delivered after loss, not per unit shipped
Responsiveness and quality	Order fill rate, lead time, shelf life at delivery, recall rate	Remaining shelf life as a service measure
Resilience	Time to recover, volume kept under disruption, supplier redundancy	Weather, disease and price-shock scenarios
Sustainability outcomes	Emissions and water per unit, food loss rate, farmer income share	Loss treated as both economic and environmental indicator

Table 2. A suggested performance taxonomy for agri-food supply chains

There are five mechanisms by which sustainable management is linked to performance: information integration and traceability, collaboration and relational governance, green supply chain practices, loss reduction and circular operations, and legitimacy and market access. The evidence is classified as strong (involving several independent empirical studies with consistent results), moderate (involving some empirical support but being dependent on context) or emerging (mainly consisting of conceptual or single-study support) as shown in Table 3.

Mechanism	Dimensions most affected	Main risk	Evidence grade
Information integration and traceability	Quality, resilience	Cost burden, data ownership disputes	Moderate
Collaboration and relational governance	Efficiency, resilience	Captive governance, value capture by buyers	Moderate

Mechanism	Dimensions most affected	Main risk	Evidence grade
Green supply chain practices	Sustainability outcomes, efficiency	Limited transfer from manufacturing evidence	Moderate to emerging
Loss reduction and circular operations	Efficiency, sustainability outcomes	Capital cost, uneven access	Strong on potential
Legitimacy and market access	Efficiency (revenue), resilience	Symbolic adoption	Emerging to moderate

Table 3. The mechanisms of transmission and the grades of evidence

Four of the five mechanisms have an effect on efficiency, whereas only traceability has a major impact on quality. Loss reduction is the most direct and measurable of the mechanisms, while traceability and collaboration develop the capabilities that underpin the others (Beske et al., 2014; Trienekens et al., 2012). The strength of the link also varies according to institutional pressure, the degree of organisation among smallholders, the availability of technology and cold-chain preparedness, the type of product and the time period (Reardon et al., 2009; Reardon & Timmer, 2014; Gereffi et al., 2005).

2.2 Research Gap

The studies show the individual significance of sustainable practices (Seuring & Müller, 2008; Pagell & Wu, 2009), of performance measurement that is specific to food (Aramyan et al., 2007; Beamon, 1999), of capabilities such as traceability and collaboration (Beske et al., 2014; Trienekens et al., 2012) and of loss reduction (Parfitt et al., 2010), but seldom examine practices, capabilities and performance together within a single model using a formal mediation design. Most of the evidence regarding green practices is derived from the manufacturing sector (Zhu et al., 2008; Green et al., 2012) and there is very little evidence from smallholder-based chains in emerging economies.

The article deals with this gap by introducing the SPT framework and showing, using a simulated data set and a mediation regression with bootstrapped confidence intervals, how practice, capabilities and performance can all be tested together.

3. The aims of the study

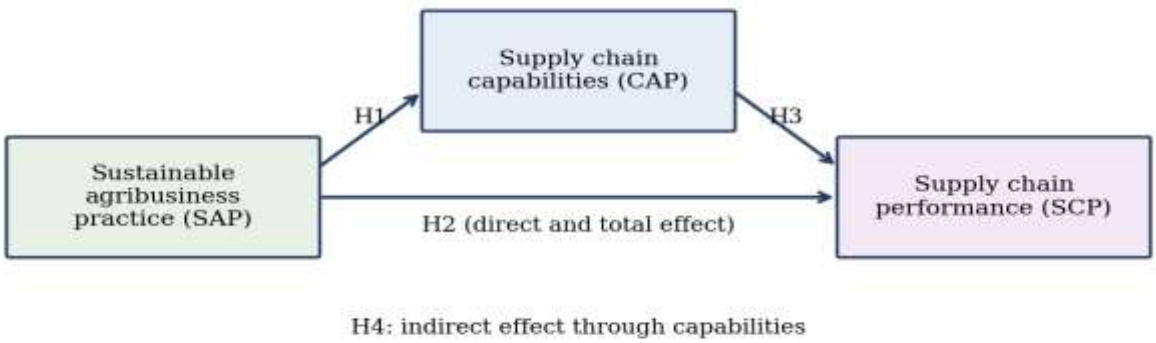
Look at the way the concept and practices of sustainable agribusiness management have developed and examine the way in which food supply chain performance should be measured

• To look at the impact of sustainable agribusiness practices on supply chain capabilities.

• To evaluate the impact of sustainable agribusiness practices on the performance of the food supply chain.

• To find out if capabilities have a mediating effect on the relationship between sustainable practice and performance.

• We are to compare the performance among the different roles in the chain and among the respondents who had training and those who did not, and to offer some practical suggestions.



4. Conceptual Framework and Hypotheses of the Study

The SPT framework holds that sustainable agribusiness practice (SAP) mainly enhances supply chain performance (SCP) by developing capabilities (CAP), specifically in the areas of information sharing and traceability, as well as collaboration and adaptive capacity.

Figure 1. Conceptual framework of the study (SAP to CAP to SCP, with direct and indirect paths).

Hypothesis	Statement
H1	Sustainable agribusiness practice has a significant positive effect on supply chain capabilities (null: no significant effect).
H2	Sustainable agribusiness practice has a significant positive effect on supply chain performance (null: no significant effect).
H3	Capabilities have a significant positive effect on performance after controlling for practice (null: no significant effect).
H4	Capabilities significantly mediate the effect of practice on performance (null: the indirect effect is zero).
H5	Receipt of training on sustainable practices is significantly associated with high performance (null: no association).
H6	Mean performance differs significantly across chain roles (null: no difference).

Table 4. Hypotheses of the study

5. Research Methodology

5.1 Research Design, Population and Simulated Sample

The study adopts a descriptive and analytical research approach. The population in terms of concept includes people who are involved in agri-food supply chains, such as farmers or members of producer organisations, aggregators and traders, processors, staff working in cold storage and logistics, and retailers or exporters. Since this article is intended to demonstrate the methodology, the sample is simulated: 120 synthetic respondents were produced using Python (with NumPy and a random seed of 2026) in order that the entire analysis can be demonstrated.

The demographic categories used in the simulation are based on fixed probabilities and standardised latent scores are produced for practice, capabilities and performance, in accordance with a predefined structure: capabilities are influenced by practice (with a loading of 0.60) and performance is influenced by both capabilities (0.50) and practice (0.22), along with noise. The questionnaire items were created from these latent scores and included random error before being rounded to the 1-5 scale. Training was generated using a logistic function of practice, with small role and scale effects also included. Since the relationships were set by the author, the fact that the hypotheses H1 to H4 in Section 6 yield significant results shows that the analysis has recovered the built-in structure; these results do not therefore reflect actual chains. The dataset can be obtained from the author upon request.

The sample size needed for an actual study was determined using a power analysis for multiple regression with three predictors (assuming a medium effect size, f-squared = 0.15, alpha = 0.05, and power = 0.80), resulting in a minimum of approximately 77 complete responses (Cohen, 1988); it is recommended to aim for at least 120.

5.2 Research Instrument and Variables

The structured questionnaire found in Appendix A is used, Section A (questions Q1 to Q6) recording the profile; Section B (questions Q7 to Q12) assesses sustainable agribusiness practices; Section C (questions Q13 to Q17) measures capabilities; and Section D (questions Q18 to Q24) evaluates performance, using a five-point agreement scale. Three composite variables are obtained: the Sustainable Agribusiness Practice score (SAP, which is the average of questions Q7 to Q11), the Capability score (CAP, which is the average of questions Q13 to Q17) and the Supply Chain Performance score (SCP, which is the average of questions Q18 to Q24). Question Q12 (whether training has been

received, answered yes or no) is a categorical variable. Reliability is given in terms of Cronbach's alpha (Cronbach, 1951) and is considered acceptable if the value is 0.70 or higher.

5.3 Statistical Tools and Ethical Considerations

The data analysis was carried out using Python (with the use of pandas, SciPy and statsmodels) by applying methods equivalent to those used in SPSS: calculating frequencies and percentages, the mean, the median and the standard deviation, Cronbach's alpha, one-sample t-tests compared to the midpoint of the scale, chi-square tests of independence (with Fisher's exact test used as a verification), one-way ANOVA together with Levene's and Kruskal-Wallis tests and Tukey's post-hoc comparisons, Pearson correlations, and ordinary least squares (OLS) regression. To examine mediation, the stepwise approach proposed by Baron and Kenny in 1986 was used together with a percentile bootstrap of the indirect effect based on 5,000 resamples (Preacher & Hayes, 2008), and the Sobel test was also reported for comparison. The variance inflation factor (VIF) and the Durbin-Watson statistic were employed to check for multicollinearity and autocorrelation. A significance level of alpha = 0.05 was adopted. Since no actual people were involved, there are no issues concerning consent or personal data for this dataset; in the case of a real study, informed consent, anonymity and institutional ethics approval would be required.

6 The analysis and interpretation of data

The section gives a description of the simulated respondents, carries out a frequency analysis of the questionnaire items, includes the reliability and descriptive statistics, and presents the inferential tests relating to the hypotheses (the sample size is 120 throughout; percentages may not add up to exactly 100 due to rounding). All the tables and figures in this section are based on simulated data.

6.1 Demographic Profile of Simulated Respondents

Variable	Category	Frequency	Percentage
Age	Below 25 years	12	10.0%
	25-34 years	40	33.3%
	35-44 years	40	33.3%
	45-54 years	14	11.7%
	55 years and above	14	11.7%
Gender	Male	64	53.3%
	Female	49	40.8%
	Other	3	2.5%
	Prefer not to say	4	3.3%
Role in chain	Farmer / producer-organisation member	31	25.8%
	Aggregator / trader	31	25.8%
	Processor	13	10.8%
	Cold-storage / logistics	18	15.0%
	Retailer / exporter	27	22.5%
Experience	Under 3 years	21	17.5%
	3-5 years	33	27.5%
	6-10 years	32	26.7%
	Over 10 years	34	28.3%
Scale of operation	Small	49	40.8%

Variable	Category	Frequency	Percentage
	Medium	45	37.5%
	Large	26	21.7%
Education	School	14	11.7%
	Undergraduate	48	40.0%
	Postgraduate	39	32.5%
	Other	19	15.8%

Table 5. Demographic profile of simulated respondents (N = 120, simulated data)

Interpretation: The simulation includes all five roles within the chain; the biggest group of roles is that of 'Farmer / producer-organisation member' (25.8%) and the largest age group is the 25 to 34 year age bracket (33.3%). The group comprising small-scale operations is the largest scale group and this is similar to the structure of chains based on smallholder systems.

6.2 Frequency Analysis of Questionnaire Responses

Item	SD %	D %	N %	A %	SA %	Mean
Q7 Loss measurement and reduction	5.8	19.2	33.3	30.0	11.7	3.22
Q8 Resource-efficient use	9.2	20.8	40.8	17.5	11.7	3.02
Q9 Freshness-preserving handling	10.0	20.0	28.3	33.3	8.3	3.10
Q10 Responsible sourcing	6.7	20.8	27.5	33.3	11.7	3.22
Q11 Traceability records	10.8	21.7	26.7	21.7	19.2	3.17

Table 6. Section B: sustainable agribusiness practice (percentage of respondents, simulated data; SD = strongly disagree, SA = strongly agree)

Interpretation: Of the various practices, 'oss measurement and reduction' has the highest mean (3.22) and 'resource-efficient use' the lowest (3.02); means near to 3 show mixed opinions, a result that is in keeping with the way the simulation has been constructed.

Item	SD %	D %	N %	A %	SA %	Mean
Q13 Information reaches us in time	8.3	17.5	35.8	25.0	13.3	3.18
Q14 Trusted long-term relationships	8.3	14.2	40.0	24.2	13.3	3.20
Q15 Coordinated planning	6.7	12.5	34.2	30.0	16.7	3.38
Q16 Quick adaptation to problems	10.0	20.8	30.0	21.7	17.5	3.16
Q17 Use of digital tools	7.5	19.2	24.2	35.0	14.2	3.29

Table 7. Section C: supply chain capabilities (percentage of respondents, simulated data)

Item	SD %	D %	N %	A %	SA %	Mean
Q18 Cost per unit improved	8.3	23.3	29.2	26.7	12.5	3.12
Q19 Produce arrives fresh	8.3	23.3	25.0	31.7	11.7	3.15
Q20 On-time, in-full delivery	7.5	19.2	35.8	25.0	12.5	3.16

Item	SD %	D %	N %	A %	SA %	Mean
Q21 Buyers satisfied with quality	8.3	20.8	22.5	33.3	15.0	3.26
Q22 Quick recovery from disruption	8.3	17.5	29.2	28.3	16.7	3.28
Q23 Waste, water, energy per unit fallen	9.2	19.2	26.7	33.3	11.7	3.19
Q24 Fair share and safe work	6.7	25.0	31.7	25.0	11.7	3.10

Table 8. Section D: supply chain performance (percentage of respondents, simulated data)

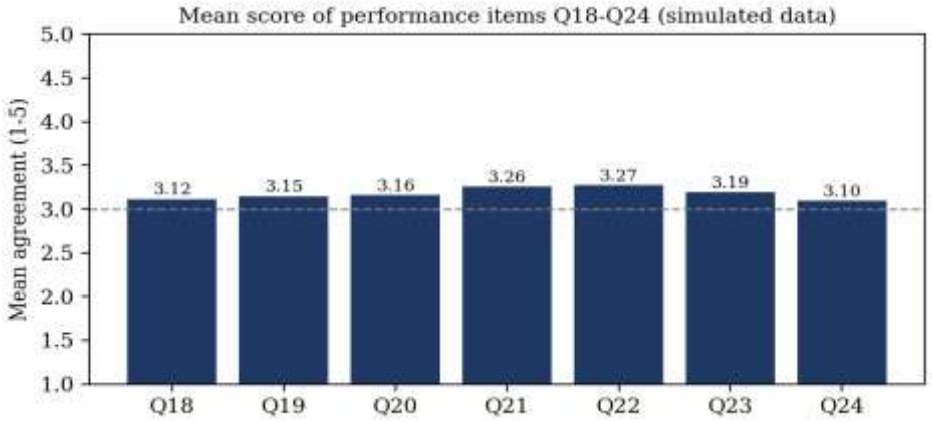


Figure 2. Mean score of the performance items Q18-Q24 (simulated data).

Training received (Q12)	Frequency	Percentage
Yes	58	48.3%
No	62	51.7%

Table 9. Receipt of training on sustainable or quality practices (simulated data)

6.3 Reliability and Descriptive Statistics

Variable	Items	Alpha	Mean	Median	SD	Min	Max	t vs 3 (p)
Sustainable practice (SAP)	Q7-Q11	0.85	3.15	3.00	0.90	1.00	5.00	1.78 (p = .077)
Capabilities (CAP)	Q13-Q17	0.87	3.24	3.20	0.93	1.00	5.00	2.84 (p = .005)
Performance (SCP)	Q18-Q24	0.90	3.18	3.29	0.90	1.14	4.86	2.17 (p = .032)

Table 10. Reliability and descriptive statistics of the scale variables (N = 120, simulated data)

Test (2 x 2)	Chi-square	df	Asymp. p	Fisher p	Result (5%)
Training (Q12) x High performance	1.23	1	0.267	0.280	ns
Gender (male / not male) x High performance	0.15	1	0.696	0.718	ns
Scale (small / medium-large) x High performance	1.52	1	0.218	0.266	ns

Interpretation: Since all three composites have a Cronbach's alpha greater than 0.70 (specifically 0.85, 0.87 and 0.90), the internal consistency is acceptable. When compared to the neutral midpoint of 3, the practice score is not significant

(p = .077), the capability score is significant (p = .005) and the performance score is also significant (p = .032); therefore, the views are almost neutral with a slight positive bias.

6.4 Chi-Square Tests (H5)

Training	Not high performance	High performance	Row total
No training	33	29	62
Received training	25	33	58
Column total	58	62	120

Table 11. Cross-tabulation: training and high performance (high = performance score at or above the median; simulated data)

Table 12. Chi-square tests of independence (simulated data)

Interpretation: Of the respondents who had training, 56.9% showed high performance as compared to 46.8% of those who did not have training. Although the difference is in the expected direction, the association is not significant (chi-square = 1.23, df = 1, p = .267) and therefore hypothesis H5 is not supported in the simulated data. There is also no significant association between high performance and gender or the scale of operation.

6.5 One-Way ANOVA (H6)

Dependent variable by factor	F	df	p	Eta-squared	Result (5%)
Performance by Role	0.67	4, 115	0.613	0.02	ns
Performance by Scale of operation	0.63	2, 117	0.534	0.01	ns
Capabilities by Role	0.82	4, 115	0.513	0.03	ns

Table 13. Summary of one-way ANOVA results (all Levene tests non-significant; Kruskal-Wallis agrees; simulated data)

Role in chain	n	Mean performance	SD
Aggregator / trader	31	3.00	0.85
Cold-storage / logistics	18	3.33	0.98
Farmer / producer-organisation member	31	3.13	0.83
Processor	13	3.38	0.81
Retailer / exporter	27	3.24	1.05

Table 14. Mean performance score by chain role (simulated data)

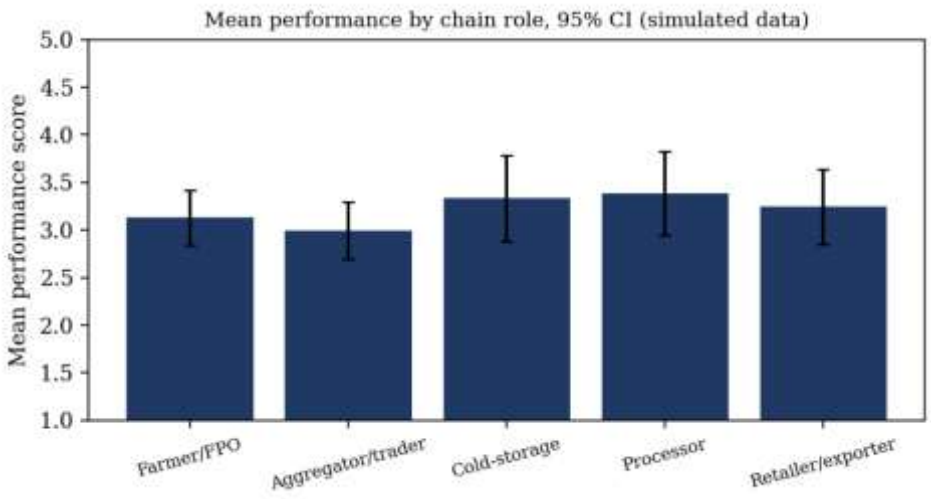


Figure 3. Mean performance by chain role with 95% confidence intervals (simulated data).

Interpretation: There is no significant difference in performance between the various roles ($F(4, 115) = 0.67$, $p = .613$, eta-squared = 0.02), and therefore H6 is not supported by the simulated data. Neither the scale of operation nor the role is significantly associated with performance or capabilities, and none of the Tukey pairwise comparisons are significant.

6.6 Correlation and Mediation Regression (H1-H4)

Correlation	Pearson r	p
SAP and CAP	0.55	$p < .001$
SAP and SCP	0.56	$p < .001$
CAP and SCP	0.65	$p < .001$

Table 15. Correlation matrix (N = 120, simulated data)

Model	R-squared	F	Sig. F	Key coefficients
Model 1: CAP on SAP (H1)	0.299	50.39	$p < .001$	B = 0.562, beta = 0.55, $p < .001$
Model 2: SCP on SAP (H2, total effect)	0.314	54.11	$p < .001$	B = 0.562, beta = 0.56, $p < .001$
Model 3: SCP on SAP and CAP (H3, direct effect)	0.481	54.16	$p < .001$	SAP beta = 0.29 ($p < .001$); CAP beta = 0.49 ($p < .001$)

Table 16. Regression models testing H1-H3 (mediation steps; VIF for Model 3 predictors = 1.43; Durbin-Watson = 1.94 to 2.07)

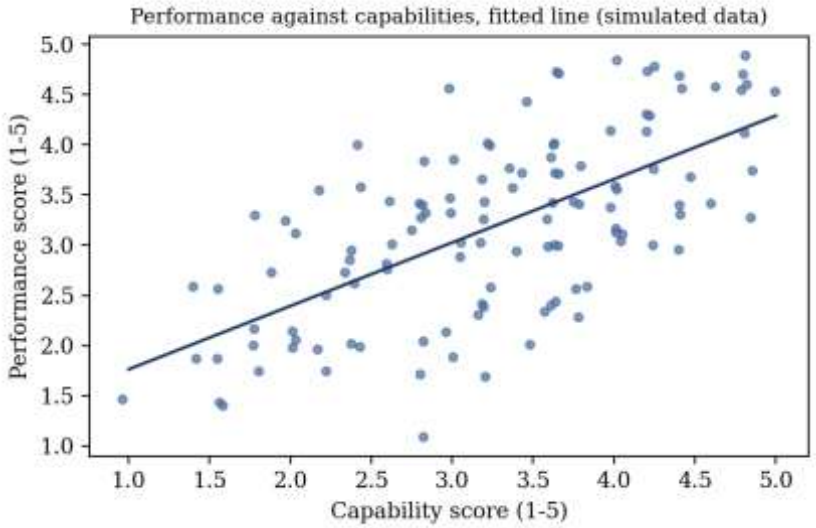


Figure 4. Performance against capabilities with fitted regression line (simulated data).

Path	Coefficient	Std. error	95% bootstrap CI
Path a: SAP to CAP	0.562	0.079	-
Path b: CAP to SCP (controlling SAP)	0.475	0.078	-
Indirect effect (a x b)	0.267	-	[0.167, 0.382]
Direct effect (c-prime)	0.295	-	-
Total effect (c)	0.562	-	-

Table 17. Bootstrap test of the indirect effect (5,000 resamples; Sobel z = 4.64, p < .001; simulated data)

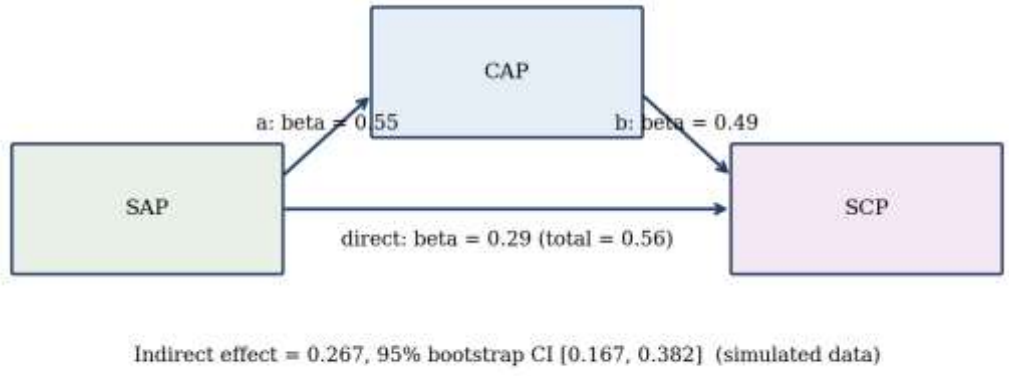


Figure 5. Standardized mediation model: SAP to CAP to SCP (simulated data).

Interpretation: Practice is a significant predictor of capabilities (Model 1, R-squared = 0.30, p < .001), thus supporting H1, and it is also a significant predictor of performance on its own (Model 2, R-squared = 0.31, p < .001), which supports H2. When capabilities are included in the model (Model 3), they still act as a strong predictor of performance (beta = 0.49, p < .001), thereby supporting H3, although the direct effect of practice drops from a beta of 0.56 to 0.29 (p < .001) and remains significant; the complete model accounts for 48.1% of the variance in performance. The bootstrap interval for the indirect effect (ranging from 0.167 to 0.382) does not include zero and the Sobel test confirms this finding,

indicating that capabilities partially mediate the relationship between practice and performance and hence H4 is supported. Since the structure was incorporated into the simulation, this result demonstrates that the method is able to detect partial mediation when it is actually present.

6.7 Summary of Hypothesis Testing

Hypothesis	Test result	Decision
H1: SAP to CAP	beta = 0.55, p < .001	Supported
H2: SAP to SCP	beta = 0.56, p < .001	Supported
H3: CAP to SCP	beta = 0.49, p < .001	Supported
H4: Indirect effect	indirect = 0.267, CI [0.167, 0.382]	Supported (partial mediation)
H5: Training and performance	chi-square = 1.23, p = .267	Not supported
H6: Performance by role	F = 0.67, p = .613	Not supported

Table 18- Summary of hypothesis tests (simulated data)

7. The results of the Study

• In the field of literature, the concept of sustainability in agri-food chains has shifted from one of compliance to one infrastructure of capability, and for perishable chains performance must be measured in terms of efficiency, responsiveness and quality, as well as resilience and sustainability outcomes.

• In the field of literature, loss reduction is the most direct approach, traceability and collaboration help to build capabilities, and the relationship relies on institutional pressure, the organisation of smallholders, and time.

• The simulated data show that the composite scores are near the midpoint of the scale (practice M = 3.15, capabilities M = 3.24, performance M = 3.18) and that all the scales are reliable (with an alpha value between 0.85 and 0.90).

• With regard to the simulated data, practice predicts both capabilities (with a beta of 0.55) and performance (with a beta of 0.56), and capabilities predict performance even after taking into account practice (with a beta of 0.49), which means that hypotheses H1 to H3 are supported.

• For the simulated data, the indirect effect via capabilities is 0.267 and its bootstrap interval does not include zero, while the direct effect remains significant, which shows that there is partial mediation (thus H4 is supported).

• With regard to the simulated data, there is no significant relationship between the training (with a chi-square p value of .267) and the chain role (with an ANOVA p value of .613) and performance, and therefore hypotheses H5 and H6 are not supported.

• The simulation has been designed so that all the important relationships between practice, capabilities and performance are included and therefore these relationships should not be taken as reflecting actual agri-food chains.

8. Discussion

The review advances a capabilities-based understanding of sustainability, on the grounds that different practices are important since they affect the way information, time and relationships are managed throughout the chain (Beske et al., 2014; Paulraj, 2011; Trienekens et al., 2012). The simulated analysis demonstrates how this kind of view can be tested; when capabilities are incorporated into the model the impact of practice on performance decreases but does not

disappear, which is an example of partial mediation since practice also operates through avenues not included in the capability variables, such as direct loss reduction (Parfitt et al., 2010).

The fact that the results for training and for role show how a real study might also fail to support a hypothesis, and how such a failure should be reported, means that in an actual sample a null result for training has to be interpreted with care since it might indicate that training is not effective, that the quality of training varies, or that the sample is too small to pick up a small difference. Similarly, the fact that the performance was similar across roles should be regarded in the light of the argument that smallholders and processors face different constraints (Reardon et al., 2009; Trienekens et al., 2012) and would require larger subgroups of role to be tested properly.

It also gives a reason for the fact that mixed results are frequent in this area: models which examine only the direct effects, combine different contexts or consider a single point in time for an investment that pays off over a period of time will yield inconsistent results (Gereffi et al., 2005; Reardon & Timmer, 2014); the SPTframework and the mediation design deal with the first of these issues and identify the other two as areas where real data is needed.

9. Suggestions and Recommendations

We should start by developing our ability to gather information and ensure traceability, since this makes losses, quality issues and claims measurable and enables the implementation of other practices.

Make an investment in collaboration and in fair contracting so as to share risks and stabilise supply, and keep a close eye on any arrangements that shift the risk onto small suppliers.

• Focus on the stage that has the greatest decay—for example, transport or storage—since upgrades to the cold chain are most likely to pay off there.

• Symbolic adoption should be avoided since certificates without any actual changes in practice result in extra costs without improving capability.

Policymakers ought to support shared cold-chain and storage facilities, producer organisations and aggregators, as well as open data standards in order to keep traceability affordable for small suppliers.

• The researchers ought to use actual survey or chain data rather than the simulated dataset, employing the instrument and analysis plan set out in this article.

10. Limitations and Scope for Further Research

The main limitation is that the dataset is simulated. Although the analysis covers the entire research process (including the formulation of objectives, the development of hypotheses, the methodology, data analysis, interpretation and reporting), it is unable to provide any real-world evidence regarding the sustainability of agribusiness practices, capabilities or performance. If a submission were to claim to have arrived at empirical findings it would need to:

- Collect data from a population that is clearly defined and has enough people in it using a way to choose people that gives each a chance to be selected or divides them into groups.
- Use scales that have been checked to make sure they work well show how reliable they are (Cronbachs alpha, reliability) and how valid they are (convergent and discriminant) and check for common-method bias.
- Use structural equation modelling with bootstrapped intervals and check for things that might change the results such as smallholder organisation, infrastructure and institutional pressure.
- Use real data about the chain (loss rates cost per delivered unit, delivery performance) along with what people think.
- Use term or quasi-experimental designs to prove cause and effect and to see effects that happen later.

- The literature review includes English-language peer-reviewed and selected institutional sources and the quality of evidence is described in words.

11. Conclusion

This article looked at the research on agribusiness management and food supply chain performance introduced the SPT framework and showed with a simulated dataset how practice, capabilities and performance can be tested together. In the simulated data practice predicted capabilities and performance capabilities predicted performance and capabilities had some effect on the relationship between practice and performance while training and role were not linked to performance. These results were part of the simulation. Show the method, not the real world. The main message from the review is that sustainability investments should go with building capabilities and not be seen as following rules. The next step is to use the tools and analysis plan on real data from agri-food supply chains in countries that are developing such as India.

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APPENDIX A. Questionnaire

Section A, Profile: Q1 Age group; Q2 Gender; Q3 Role in chain; Q4 Experience in the agri-food chain; Q5 Scale of operation; Q6 Education. Sections B to D use a five-point scale: 1 = strongly disagree to 5 = strongly agree.

No.	Item	Variable
Q7	We actively measure and try to reduce losses during harvest, handling and storage.	SAP
Q8	We use water, energy and inputs efficiently and keep track of their use.	SAP
Q9	We use storage, packaging or handling methods that keep produce fresh for longer.	SAP
Q10	We follow responsible sourcing practices (fair prices or contracts, safe working conditions).	SAP
Q11	We keep records that let us trace produce back to its source.	SAP
Q12	Have you received training or support on sustainable or quality practices? (Yes / No)	Training
Q13	Information on prices, demand and quality reaches us, or is shared by us, in time.	CAP
Q14	We have trusted, long-term relationships with our main buyers or suppliers.	CAP
Q15	We coordinate quantities and timing with our chain partners.	CAP
Q16	We can change sourcing, routes or products quickly when problems occur.	CAP
Q17	We use digital tools (apps, records, online platforms) for orders, prices or tracking.	CAP
Q18	Our cost per unit of produce delivered has improved over the last two years.	SCP
Q19	Our produce reaches buyers fresh, with little spoilage.	SCP
Q20	We deliver orders on time and in full.	SCP
Q21	Buyers are satisfied with the quality of our produce.	SCP
Q22	We recovered quickly from the last major disruption (weather, price fall, transport problem).	SCP
Q23	Our waste, water and energy use per unit of produce has fallen.	SCP
Q24	Farmers and workers in our chain earn a fair share and work safely.	SCP

Table A1. Questionnaire items and variable coding