Innovation and Cooperation in Agri-Food Value Chains in Latin American Developing Countries: Exploring the Role of Proximity Theory from Economic Geography

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Abstract

Innovation is an important strategy for enhancing the competitiveness and sustainability of agri-food value chains, especially in developing countries where it significantly contributes to rural development. Innovation is increasingly viewed as a cooperative process involving various actors. However, few studies examine cooperation within extended agri-food value chains, which include both the actors within the chains and supporting organizations. Therefore, this study explores and compares cooperation for innovation among actors in two extended value chains: one in Nicaragua (dairy milk) and another in Paraguay (corn), using proximity theory, which considers non-spatial dimensions such as institutional, cognitive, social, and organizational factors. Additionally, a method for measuring personal proximity is proposed. Data from 157 participants across the two chains are analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM). The results highlight the significant roles of social and institutional proximities in promoting cooperation and demonstrate how such collaboration accelerates innovation. The study discusses both theoretical and practical implications.

Keywords: Innovation; Technological Innovation; Agribusiness; Proximity; Value Chains; Developing Countries.

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1. Introduction

Innovation is increasingly emphasized as a strategy to address key challenges in the agri-food system, such as competitiveness, food security, and sustainability. Moreover, in agri-food value chains, which play a key role in the economic and social development of developing countries, innovation helps them respond to shifting market demands, enhances competitiveness and value addition, promotes sustainability, supports inclusive economic growth, reduces poverty, and ensures food security (Ambos et al., 2021; Barrett et al., 2022; Hidayati et al., 2021).

The analysis and promotion of innovation in agri-food value chains require a systemic approach because most innovations come from research institutions, universities, and supplier companies, rather than from farmers and agricultural firms, which often lack the resources and capabilities to innovate. Therefore, an extended value chain approach that involves chain actors (farmers, producers, aggregators, processors, and retailers) and support organizations (research and support institutions, universities, and public agencies) enables a more comprehensive analysis of innovation processes within the agri-food value chain (Barrett et al., 2022; 2022; Stanco et al., 2020).

Inter-organizational cooperation for innovation has been analyzed from various theoretical and applied perspectives (Castañer & Oliveira, 2020; Cholez et al., 2023). This article uses the theory of proximity from economic geography to explain inter-organizational cooperation in learning and innovation, an approach with less development in agri-food value chains (Gutiérrez & Macken-Walsh, 2022; León-Bravo et al., 2025; Mundler, 2022; Ouellet et al., 2020; Wilke & Pyka, 2025). According to (Boschma, 2005) *"Proximity implies more than geography. It is a broad concept that incorporates the similarities between actors and organizations, including spatial and non-spatial dimensions"*, and identifies five dimensions: geographical proximity (spatial) and non-spatial proximities: social, cognitive, organizational, and institutional. In addition, in recent years, personal proximity has been highlighted and is related to individual-level human factors. Both social and personal proximities can be considered the "glue" of inter-organizational networks (Ooms et al., 2018; Werker et al., 2016). Moreover, different authors have highlighted the need to advance proximity measurements, extend their application to agri-food value chains, and refine analytical approaches to proximity and innovation (León-Bravo et al., 2025; Maté-Sánchez-Val & Harris, 2018; Menéndez et al., 2025; Mundler, 2022).

In view of the above, an exploratory and comparative analysis is proposed. This article analyzes the dimensions of non-spatial proximity and their impact on inter-organizational cooperation for innovation in two extended agri-food value chains in Latin American developing countries: Paraguay (corn) and Nicaragua (dairy milk), both characterized by low levels of cooperation and innovation. Specifically, the contributions are to apply the proximity theory of economic geography to extended agri-food value chains in developing countries, including chain actors and support organizations. Explore a measurement scale for personal proximity, aligned with the scale proposed by Geldes et al. (2015). This allows us to answer the following questions:

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What type of proximity is relevant for inter-organizational cooperation to innovate in the extended agri-food value chain of developing countries? Does personal proximity play a significant role in fostering innovation-driven cooperation in extended agri-food value chains in developing countries? Does cooperation among different actors contribute to the development of product and process innovations in extended value chains in developing countries?

The method used is Partial Least Squares -Structural Equation Modelling (PLS-SEM) to explore and compare the relationships among proximity, cooperation, and innovation (Dash & Paul, 2021; Dennis Cook & Forzani, 2023). The data are from 157 surveys conducted in two expanded agri-food value chains in two Latin American developing countries: Nicaragua (dairy milk, 81) and Paraguay (corn, 76). The scale proposed by Geldes et al. (2015) is used to measure the non-spatial dimensions of proximity (social, organizational, cognitive, and institutional), and in this framework, a new construct of personal proximity is explored.

The following sections are the literature review, hypotheses, method, results, discussion, conclusions, and implications.

2. Literature Review and Hypotheses

In the agri-food value chains, the need to analyze innovation processes from a cooperative perspective has been increasingly emphasized (Dania et al., 2018). Specifically, Bezuidenhout et al. (2012) Indicate that many relationships in agri-food value chains are favorable to the different actors. Stability, reliability, trust, personal relationships, and communication are critical to their development. According to Geldes et al. (2017), cooperation among different actors is positively associated with non-technological innovations (marketing and organizational) and technological innovations (processes and products) in agri-food firms. For their part, Karantininis et al. (2010) argue that vertical integration, its direction, and contractual agreements are significant determinants of firms' innovative behavior in the agri-food chain. In addition, the firm's export orientation is a significant determinant of innovation, whereas the sector in which the firm operates is not. According to Kafetzopoulos & Skalkos (2019), quality orientation and process management are the two most important drivers of innovation. However, the impact of learning orientation, collaborations, and environmental dynamism on a firm's agri-food innovativeness has not yet been investigated. Stanco et al. (2020) indicate that the commitment and involvement of all actors in the agri-food chain are central to sustainable collective innovation. Moreover, its effectiveness depends on the governance model adopted.

In addition, Zaridis et al. (2021) state that supply chain collaboration positively impacts agri-enterprises (SMEs) performance, and provide evidence that enterprises strategize their supply chain collaboration by removing scale constraints. In the case of short food supply chains, Stoeva et al. (2024), indicate that collaborations operate as dynamic ecosystems characterized by complex interdependencies among diverse actors. Moreover, they identified seven interaction mechanisms among actors, including information sharing, decision synchronization, goal congruence, incentive alignment, resource sharing, joint knowledge creation, and collaborative communication. Those mechanisms generate relational benefits, including fair pricing, reduced transaction costs, enhanced market knowledge, technological skills, and stronger community engagement.

For the analysis of the agri-food value chain, FAO & UNIDO (2024) proposes an extended vision that includes two main types of actors: the "chain actors," which consist of producers (farmers), aggregators, processors-industry, and distributors, and "support organizations," such as financial services, suppliers, trade associations, universities and research institutions, and public agencies. This classification of actors is used in this article.

2.1. Innovation

Innovation has been the subject of substantial scholarly examination, resulting in several definitions and classifications (Crossan & Apaydin, 2010). Nevertheless, a certain degree of agreement has been reached about the concept in the Fourth Version of the Oslo Manual (OECD, 2018; p. 20)*"An innovation is a new or improved product or process (or a combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process)."* In addition, process innovation has been identified as a precursor of product innovation. Moreover, the determinants of firm innovation (internal and external) are specific to the agribusiness sector and differ according to the types of innovation (Bjerke & Johansson, 2022; Geldes, Felzensztein, et al., 2017; Geldes & Felzensztein, 2013; Kafetzopoulos & Skalkos, 2019). Specifically, in agri-food systems, most innovations come from private and public research institutions. For this reason, few farmers and firms are innovating but adopting and implementing innovations, mainly incremental and process innovations, due to their low capacities and resources to innovate (Bjerke & Johansson, 2022; Boisier et al., 2021; Läpple et al., 2015).

2.2. Proximity theory

Cooperation and collaboration for innovation and technological development among various actors have been examined from multiple theoretical and applied perspectives (Castañer & Oliveira, 2020; Cholez et al., 2023; Haus-Reve et al., 2019). This research introduces the theory of proximity from economic geography, which has been used to explain knowledge transfer, interactive learning, collaboration, and innovation among multiple actors in economic agglomerations with low levels of development in the agri-food system (Gutiérrez & Macken-Walsh, 2022; León-Bravo et al., 2025; Mundler, 2022; Ouellet et al., 2020; Wilke & Pyka, 2025).

Although different types of proximity have been identified (Knoben & Oerlemans, 2006), Boschma's (2005) classification of five types of proximity is the most widely referenced. Specifically, geographical proximity refers to the physical distance between actors (spatial dimension of proximity). The non-spatial proximities are institutional proximity with a focus on formal and informal rules and regulations in a territory; organizational proximity refers to integration, objectives, culture, and organizational regulations; cognitive proximity is related

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to learning, expertise, and experience, and social proximity allows the development of trust, and building relationships with partners is linked to social interactions and shared experiences. It is embedded in social networks and communities, as well as in knowledge fields. Moreover, in the last year, personal proximity has been highlighted as a form of micro or individual social proximity. It is related to character traits and behavioral patterns. Although social and personal proximity capture the human dimension, their distinction is recent. According to Werker et al. (2016), personal proximity has been discussed in three approaches: merged with social proximity, from a personal-acquaintance perspective, and from an organizational psychology perspective, emphasizing the personal level. In addition, Ooms et al. (2018) argue for advancing from a conceptual to an exploratory perspective to measure personal proximity. According to Romero (2018), prior personal relationships between individuals from two organizations increase the likelihood of establishing a business relationship in the biotechnology sector.

In the agri-food system, Mundler (2022) argues for advancing the application of the proximity approach. Some studies confirm the importance of geographic proximity in generating innovation in agribusiness firms (Maté-Sánchez-Val & Harris, 2018). Gerke et al. (2017) establish that geographic proximity alone is not sufficient to foster innovation; inter-organizational citizens' behavior, collaboration, and cooperation are also required. Geldes et al. (2015) state that social proximity is critical to the selection of interfirm marketing cooperation. Furthermore, Geldes et al. (2017) indicate that cognitive-organizational proximity positively determines business cooperation between organizations in an agribusiness cluster. Also, they indicate that inter-organizational cooperation favors technological (product and process) and non-technological (marketing and Organizational) innovations. According to Kabirigi et al. (2022), different proximity forms are important to incorporate into the "Agricultural Knowledge Innovation System" research. Specifically, they find that geographical proximity plays a role in the informal networks of larger villages; cognitive and social forms of proximity take over where distance is unimportant, and farmers are socially close in a smaller community where distance does not matter. León-Bravo et al. (2025), indicate that in the case of short food supply chains, the combination of different practices along the geographical, relational, and informational proximity is necessary for sustainability.

Although the need to advance in the application of the proximity approach in the food system and the need to advance in its measurement are established, there are few efforts in its measurement, within which the scale proposed by Geldes et al. (2015) measured non-spatial (social, cognitive, organizational, and institutional) and geographic proximities stands out. This scale is highlighted as one of the efforts to measure the proximity approach over the last 25 years of concept development (Torre & Talbot, 2018), and it serves as a basis for various studies (Houessou et al., 2023). Given the above, the following theoretical model and hypotheses are proposed (Figure 1):

H1: Non-spatial dimensions of proximity are positively related to cooperation with chain actors (CA) to innovate in extended agri-food value chains (H1.1 Personal proximity (PP); H1.2 Social proximity (SP); H1.3 Cognitive proximity (CP); H1.4 Organizational proximity (OP); H1.4 Institutional proximity (IP).

H2: Non-spatial dimensions of proximity are positively related to cooperation with support organizations (SO) to innovate in extended agri-food value chains (H2.1 PP; H2.2 SP; H2.3 CP; H2.4 O; H2.4 IP).

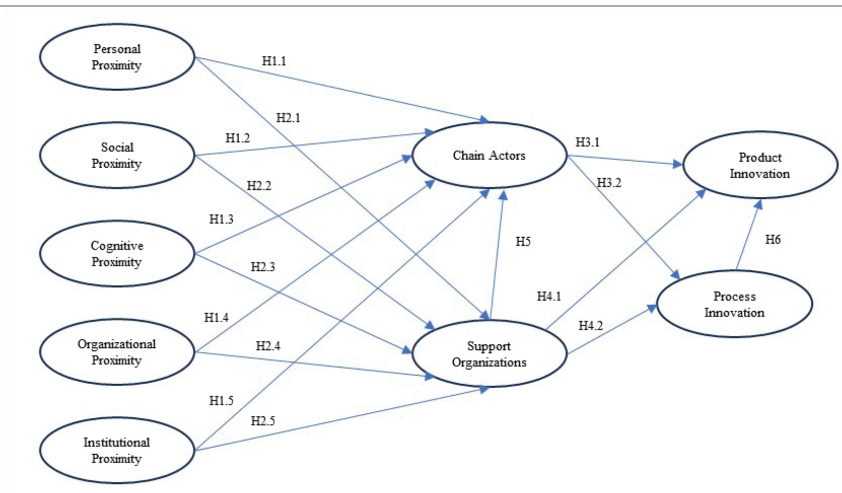
H3: Cooperation for innovation with chain actors (CA) is positively related to innovation in extended agri-food value chains (H3.1: Process innovation; H3.2: Product innovation).

H4: Cooperation with support organizations (SO) is positively related to innovation in extended agri-food value chains (H4.1 Process innovation; H4.2 Product innovation).

H5: Support organizations (SO) are positively related to chain actors (CA) that innovate in extended agri-food value chains (H5.1 Process innovation; H5.2 Product innovation).

H6: Process innovation is positively related to product innovation in extended agri-food value chains.

Figure 1. The theoretical model proposed and hypotheses (General model).



3. Method

An exploratory and comparative study of two extended agri-food value chains is selected. Specifically, dairy milk in Nicaragua and corn in Paraguay are important to local economies and rural development. Both cases belong to developing countries with GDP per capita (US$) of 6,916 and 6,929; with high levels of poverty (29.6% and 24.70%); low levels in the rankings of Global Competitiveness Index (109 and 97) and in the Global Index of Innovation (124 and 93), respectively. Moreover, Agriculture represents 17.4% and 10.6% of total GDP, and 27.7% and 17.17% of employment, respectively.

For dairy milk, the name "Milky Way" is selected; it comprises the departments of Matagalpa, Boaco, and Chontales. The "chain actors" include small- and medium-sized farmers (with 0.7 to 35 acres), collectors' centers, processors, and commercialization (internal and export). In the corn chain, the chain actors are farmers who produce dry corn for animal feed and baby corn for human consumption, both for domestic and foreign markets. The chain involves producers, collectors, and marketing companies. In both agri-food value chains, the "support organizations" are public institutions, universities, research institutions, and suppliers (products and services).

A survey was designed and validated with experts to collect data from 157 actors in two extended agri-food chains: Dairy milk (81) and corn (76). The survey included questions about the primary role or function performed by the organizations, allowing them to be classified into "chain actors" (CA) and "support organizations" (SO) (Table 1). The sampling is by "snowball", conducted by a local expert in each country, due to the limitations to obtain a representative sample, such as the lack of official registries (Barrett et al., 2022; FAO & UNIDO, 2024). To assess innovation (product and process), a dichotomous question ("yes" or "no") is used according to the Oslo Manual, which states *An innovation is a new or improved product or process (or a combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process)"*(OECD, 2018).

Table 1. Characteristics of agricultural firms in Nicaragua and Paraguay.

Characteristics of the sample	Nicaragua		Paraguay	
	Chain actors	Support organizations	Chain actors	Support organizations
Type actor	50 (62%)	31 (38%)	58 (76%)	18 (24%)
Size (employees)				
Between 1 -9	28 (35%)	7 (9%)	41 (54%)	8 (11%)
Between 10 - 50	12 (15%)	14 (17%)	12 (16%)	2 (3%)
Between 51 - 200	9 (11%)	8 (10%)	4 (5%)	3 (4%)
200 or more	1 (1%)	2 (2%)	1 (1%)	5 (7%)
Destination of production				
Domestic market	42 (52%)	23 (28%)	45 (59%)	15 (20%)
International market	3 (4%)	1 (1%)	4 (5%)	0 (0%)
Both market	5 (6%)	7 (9%)	9 (12%)	3 (4%)
Innovation	46 (57%)	30 (37%)	33 (43%)	17 (22%)
Product innovation	33 (41%)	18 (22%)	30 (39%)	13 (17%)
Process innovation	37 (46%)	29 (36%)	28 (37%)	15 (20%)
Chain actors				
Other firms	23 (28%)	18 (22%)	19 (25%)	7 (9%)
Suppliers	31 (38%)	16 (20%)	15 (20%)	7 (9%)
Buyers	10 (12%)	15 (19%)	16 (21%)	7 (9%)
Support organizations				
Trade associations	13 (16%)	20 (25%)	9 (12%)	3 (4%)
Universities	27 (33%)	22 (27%)	8 (11%)	4 (5%)
Public institutions	39 (48%)	26 (32%)	0 (0%)	2 (3%)

Percentages by country, by sample size. Nicaragua (81) and Paraguay (76).

To evaluate proximity dimensions, the scale proposed by Geldes et al. (2015) is used. This scale is highlighted as one of the few efforts to measure the proximity approach (Torre & Talbot, 2018). Specifically, it employs a five-item Likert scale to evaluate different items for each dimension of proximity (social, cognitive, organizational, and institutional), and respondents' willingness to cooperate with other organizations. In addition, to explore the concept of personal proximity, a new construct is proposed based on the logic of belonging, and the items were obtained through a critical review of items used in publications by Romero (2018) and Torre & Gallaud (2022), listed in Table 2.

3.2 Method

The Partial Least Squares-Structural Equation Modeling (PLS-SEM) is used. It allows the simultaneous modeling and estimation of complex relationships among multiple dependent and independent variables, including both unobservable and measured indirect variables, and is increasingly used and validated in the social sciences (Dennis Cook & Forzani, 2023; Manley et al., 2021). From a Structural Equation Modeling perspective, PLS-SEM is gaining popularity because CB-SEM (Covariance-Based SEM) requires more data and produces results similar to those of PLS-SEM. Specifically, PLS-SEM does not face identification problems with small sample sizes and often reaches high statistical power with limited data; it makes no assumptions about data distribution since it is a non-parametric method; it is robust to missing values as long as they are below a reasonable threshold; it reduces the amount of unexplained variance; and it assesses the reliability and validity of measurement models using various criteria (Dash & Paul, 2021).

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The first step in applying PLS-SEM is estimating the measurement model (outer model), which assesses observed variables and the construct (composite). Items for each construct in the theoretical model are selected based on factor loadings above 0.700. For composite reliability of the constructs, Cronbach's alpha, rhoA, and rhoC values of 0.700 or higher are acceptable. Convergent validity is indicated by AVE ≥ 0.500. Discriminant validity is evaluated using the Heterotrait-Monotrait ratio (HTMT) statistic ≤ 0.9. Regarding multicollinearity, the "collinearity statistics" (VIF) are ≤ 3.0 for all variables. The second step in applying PLS-SEM is estimating the structural (or inner) model, which evaluates the relationships between the latent variables. A bootstrapping with 5,000 subsamples is performed in the structural model. The model fit indicators are evaluated. The sign and the path coefficient indicate the direction and strength of the relationship (between -1 and +1). Path coefficient significance by bootstrapping: i) signed hypotheses 1-tailed test: $p < 0.05$; CI percentile: 5% - 95% (no change of sign at the extremes), ii) unsigned hypothesis 2-tailed test: $p < 0.05$; CI percentile: 2.5% - 97.5% (no change in sign at the extremes). 97.5% (no change of sign at the extremes). Determinant Coefficient ($0 < R2 < 1$). Total effect: i) small effect $0.02 \leq f2 < 0.15$; ii) moderate effect $0.15 \leq f2 < 0.35$; iii) significant effect $f2 \geq 0.35$. The weighting scheme is PCA (Principal Components Analysis) in measurement and structural models. Then, a "general" structural model is evaluated with all data of both agri-food value chains, followed by specific structural models: "Nicaragua," "Paraguay," "Chain actors," and "Support organizations." The model fit indicators are SRMR ≤ 0.08 (0.10), and the exact fit test relies on bootstrap d_ULS ≤ HI95 ≤ HI99 and d_G d_ULS ≤ HI95 ≤ HI99 (Hair & Alamer, 2022; Manley et al., 2021).

4. Results

Table 2 shows the results of the measurement model. Items for each construct are chosen based on a Factor Loading (FL) of 0.700 or higher. For Cronbach's alpha, rhoA, and rhoC values are generally above 0.700, except for IP (Cronbach's alpha 0.677; rhoA 0.677), CA (Cronbach's alpha 0.625; rhoA 0.625), and SO (Cronbach's alpha 0.668; rhoA 0.668). These values are acceptable because all rhoCs exceed 0.7, which is a more reliable indicator when items assess different features of the underlying construct. Additionally, the constructs demonstrate discriminant validity (AVEs > 0.500) and good convergent validity (Hair & Alamer, 2022; Manley et al., 2021).

Table 2. Constructs and measurement model.

Construct	FL	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	The average variance extracted (AVE)
Social Proximity (SP)		0.789	0.789	0.904.	0.826
Friendship					
Trust					
Previous acquaintance	0.909				
Having common experiences	0.909				
Reputation					
Cognitive Proximity (CP)		0.837	0.841	0.902	0.755
Same knowledge base	0.821				
The same level of experience					
Use the same language.					
Have the same educational level	0.907				
Have the same cultural level	0.878				
Organizational Proximity (OP)		0.886	0.887	0.921	0.745
Similar organizational culture	0.835				
Similar organizational structure					
Similar inter-organizational relationships	0.853				
Use of the same technology	0.872				
The similar size of the organization	0.891				
Institutional Proximity (IP)		0.677	0.677	0.861	0.756
Possess the same cultural norms.					
Common values	0.869				
Similar habits and routines					
Compliance with laws and regulations	0.869				
Personal Proximity (PP)		0.846	0.847	0.907	0.765
Belonging to the same family					
Being schoolmates					
Being a fellow student at a university	0.888				
Belonging to the same political group	0.854				
Being part of a professional group	0.880				
Being part of the same religious group					
Being part of the same interest group					
Have worked together before					
Chain actors (CA)		0.625	0.625	0.842	0.727
Other firms					
Suppliers	0.852				
Buyers	0.854				
Support organizations (SO)		0.668	0.668	0.858	0.751
Trade associations					
Universities	0.864				
Public institutions	0.868				
Product innovation (Product inn)	1.000				
Process innovation (Process inn)	1.000				

Source: Prepared by the authors using SMART-PLS.

Multicollinearity is evaluated using the "collinearity statistics" (VIF), with all variables having values below 3,000. Table 3 examines discriminant validity using the HTMT; all values are below 0.900, satisfying the requirements for discriminant validity (Hair & Alamer, 2022).

Table 3. HTMT (discriminant validity).

Constructs	Chain actors	CP	IP	Process innovation	Product innovation	OP	PP	Support organizations
Chain actors								
CP	0.097							
IP	0.344	0.248						
Process innovation	0.308	0.092	0.020					
Product innovation	0.174	0.045	0.069	0.359				
OP	0.115	0.883	0.273	0.144	0.072			
PP	0.113	0.688	0.064	0.024	0.117	0.685		
Support organizations	0.409	0.338	0.123	0.480	0.194	0.365	0.337	
SP	0.289	0.806	0.333	0.037	0.052	0.680	0.601	0.127

Source: Prepared by the authors using SMART-PLS. HTMT statistics.

Regarding the structural model, the overall goodness-of-fit indicators, including both "General" and specific models, meet the expected thresholds. The only exception is the "Paraguay" structural model in the case of d_G (Table 4). Additionally, the R-square values are significant, with sample means of CA (0.201), SO (0.146), Process innovation (0.183), and Product innovation (0.149).

Table 4. Model fit indicators.

Indicator	Value	HI95	HI99
General model			
SRMR	0.052	0.062	0.067
d_ULS	0.574	0.801	0.954
d_G	0.470	0.549	0.592
Nicaragua			
SRMR	0.068	0.083	0.090
d_ULS	0.978	1.438	1.692
d_G	0.693	0.901	0.102
Paraguay			
SRMR	0.083	0.111	0.126
d_ULS	1.479	2.599	3.326
d_G	n/a	n/a	n/a
Chain actors			
SRMR	0.078	0.097	0.106
d_ULS	1.315	1.961	2.367
d_G	0.931	1.317	0.156
Support organizations			
SRMR	0.065	0.080	0.089
d_ULS	0.893	1.346	1.675
d_G	0.697	0.915	1.056

Source: Prepared by the authors using SMART-PLS. HTMT statistics.

The path coefficients from the structural models are shown in Table 5. For the "General" model, SP (0.153) and IP (0.082) explain cooperation with CA, supporting H1.2 and H1.5 hypotheses. Additionally, CA (0.138) indicates that Process innovation supports H3.2, and SO is significant (0.332) with Process innovation supporting H4.1. SO is significantly related to CA (0.226) (H5), and Process innovation explains Product innovation (0.367) (H6) (Figure 2).

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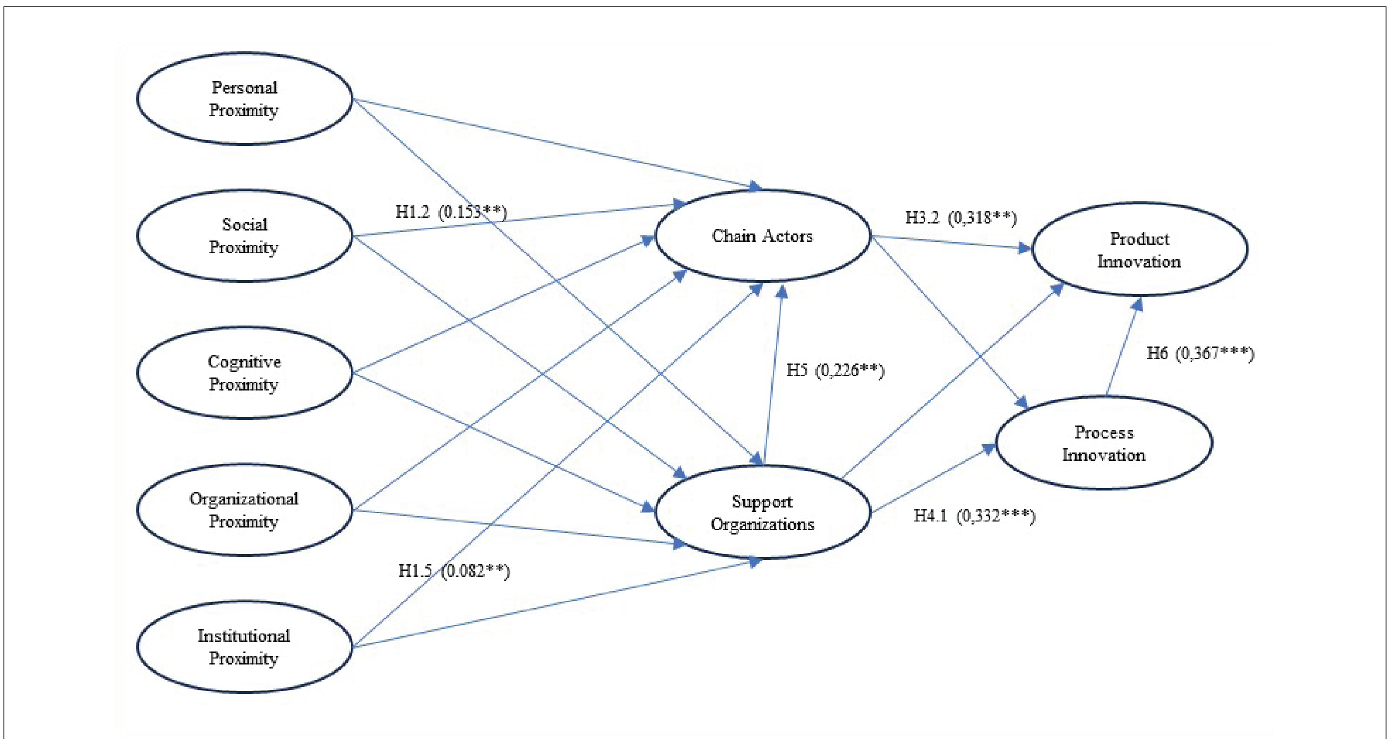
Table 5. Path coefficients in structural models.

Constructs	Path	General		Nicaragua		Paraguay		Chain actor		Support organization	
		Path coeff.	P values	Path coeff.	P values	Path coeff.	P values	Path coeff.	P values	Path coeff.	P values
Non spatial proximities	SP -> CA	**0.153**	**0.002**	**0.196**	**0.008**	0.022	0.712	0.098	0.188	**0.166**	**0.020**
	SP -> SO	0.077	0.152	0.121	0.155	-0.052	0.292	0.028	0.606	0.069	0.449
	CP -> CA	-0.036	0.582	0.008	0.929	-0.075	0.419	-0.075	0.488	-0.000	0.979
	CP -> SO	-0.071	0.241	-0.043	0.594	-0.016	0.667	-0.102	0.170	-0.053	0.559
	OP -> CA	-0.029	0.540	0.018	0.863	-0.000	0.953	-0.126	0.212	0.077	0.372
	OP -> SO	-0.102	0.064	-0.025	0.808	-0.016	0.826	-0.109	0.202	0.040	0.641
	IP -> CA	**0.082**	**0.049**	0.054	0.308	0.085	0.299	**0.148**	**0.040**	0.052	0.327
	IP -> SO	0.047	0.261	-0.080	0.148	0.019	0.761	**0.113**	**0.040**	-0.042	0.497
Personal proximity	PP -> CA	-0.051	0.281	-0.084	0.231	0.080	0.167	0.059	0.272	**-0.167**	**0.022**
	PP -> SO	-0.060	0.228	0.050	0.475	**0.064**	**0.020**	-0.011	0.756	-0.083	0.308
Chain actors	CA -> Inn_process	**0.138**	**0.031**	0.132	0.109	**0.242**	**0.044**	0.120	0.304	0.101	0.139
	CA -> Inn_product	0.052	0.518	0.060	0.591	0.186	0.082	0.145	0.101	0.007	0.919
Support organizations	SO -> BC	**0.226**	**0.004**	0.042	0.798	**-0.400**	**0.028**	0.094	0.528	0.136	0.234
	SO -> Inn_process	**0.332**	**0.000**	**0.230**	**0.032**	**0.717**	**0.000**	**0.401**	**0.002**	0.086	0.328
	SO -> Inn_product	0.007	0.908	0.057	0.615	**0.323**	**0.003**	**0.227**	**0.020**	-0.061	0.617
Innovation	Inn_process -> Inn_product	**0.367**	**0.000**	-0.082	0.562	**0.589**	**0.000**	**0.626**	**0.000**	-0.181	0.228

Source: Prepared by the authors using SMART-PLS. HTMT statistics.

Figure 2. General structural model: significant path (***99%; **95%) (General model).



In Nicaragua's structural model, SP is significant for CA (0.196), and SO is related to Process innovation (0.230). The structural model of Paraguay shows that PP is significantly related to SO (0.064). Moreover, SO is related to Process innovation (0.717) and Product innovation (0.323). Also, SO is negatively related to CA (-0.400). This result is possible because public support institutions are oriented only toward small agricultural producers. In addition, CA is significantly related to process innovation (0.242) and Process innovation with Product innovation (0.589). In the structural model of "Chain actors," IP is significantly related to CA (0.148) and SO (0.113). SO is related to product innovation (0.227) and process innovation (0.401), and these two innovations are significantly related (0.626). About the "Support organizations" model, SO is positively related to CA (0.166), and PP is negatively related to CA (-0.167). This can be explained by the diversity of actors and their characteristics.

Table 6 shows the total effects. In the "General" structural model, SP has a moderate effect on CA and a small effect on Process innovation. In addition, IP has a small effect on CA, and Process innovation significantly affects Product innovation. In the case of the "Nicaragua" model, SO has a moderate effect on Process innovation and SP in CA. Concerning the "Paraguay" model, SO significantly affects CA, Process innovation, and Product Innovation, and the total effect of PP on SO, Process innovation, and Product Innovation is small. Moreover, CA has a moderate effect on Process innovation and Product Innovation. In the "Chain actors" model, SO has significant effects on Process innovation and Product Innovation, and IP has a negligible effect on Process innovation, Product innovation, and SO. In the "Support organizations" model, PP has a moderate effect in CA and SP in CA.

Table 6. Total effects of structural models.

Path	General			Nicaragua			Paraguay			Chain actors			Support organizations		
	Path coeff.	P values	Effect	Path coeff.	P values	Effect	Path coeff.	P values	Effect	Path coeff.	P values	Effect	Path coeff.	P values	Effect
CA -> Inn_process	0.138	0.031		0.132	0.109		**0.242**	**0.044**	M	0.120	0.304		0.101	0.139	
CA -> Inn_product	0.103	0.206		0.049	0.649		**0.329**	**0.005**	M	**0.221**	**0.050**	M	-0.009	0.941	
CP -> CAC	-0.052	0.431		0.005	0.940		-0.070	0.462		-0.082	0.416		-0.007	0.962	
CP -> Inn_process	-0.031	0.224		-0.011	0.688		-0.025	0.436		-0.054	0.201		-0.004	0.760	
CP -> Inn_product	-0.014	0.318		-0.003	0.915		-0.030	0.408		-0.070	0.176		0.006	0.822	
CP -> SO	-0.071	0.241		-0.043	0.594		-0.016	0.667		-0.102	0.170		-0.053	0.559	
IP -> CA	**0.093**	**0.026**	S	0.050	0.307		0.073	0.331		**0.160**	**0.019**	M	0.047	0.369	
IP -> Inn_process	0.028	0.106		-0.013	0.532		0.032	0.463		0.063	**0.041**	S	0.000	0.905	
IP -> Inn_product	0.016	0.193		-0.000	0.952		0.038	0.408		**0.089**	**0.019**	S	0.003	0.836	
IP -> SO	0.047	0.261		-0.080	0.148		0.019	0.761		**0.113**	**0.040**	S	-0.042	0.497	
Inn_process -> Inn_product	0.367	0.000	Sig	-0.082	0.562		**0.589**	**0.000**	Sig	**0.626**	**0.000**	Sig	-0.181	0.228	
OP -> CA	-0.053	0.309		0.017	0.864		0.009	0.918		-0.138	0.168		0.082	0.327	
OP -> Inn_process	-0.041	0.077		-0.002	0.884		-0.011	0.886		-0.058	0.140		0.012	0.487	
OP -> Inn_product	-0.020	0.233		-0.001	0.979		-0.011	0.909		-0.081	0.087		-0.006	0.844	
OP -> SO	-0.102	0.064		-0.025	0.808		-0.016	0.826		-0.109	0.202		0.040	0.641	
PP -> CA	-0.065	0.158		-0.083	0.221		0.053	0.352		0.057	0.273		**-0.178**	**0.010**	M
PP -> Inn_process	-0.028	0.112		-0.002	0.965		**0.061**	**0.029**	S	0.005	0.964		-0.024	0.157	
PP -> Inn_product	-0.013	0.166		-0.003	0.908		**0.067**	**0.026**	S	0.009	0.830		0.010	0.769	
PP -> SO	-0.060	0.228		0.050	0.475		**0.064**	**0.020**	S	-0.011	0.756		-0.083	0.308	
SO -> CA	**0.226**	**0.004**	M	0.042	0.798		**-0.400**	**0.028**	Sig	0.094	0.528		0.136	0.234	
SO -> Inn_process	0.363	0.000		**0.235**	**0.034**	M	**0.616**	**0.000**	Sig	**0.416**	**0.001**	Sig	0.099	0.277	
SO -> Inn_product	0.154	0.055		0.044	0.703		**0.612**	**0.000**	Sig	**0.505**	**0.000**	Sig	-0.073	0.510	
SP -> CA	**0.171**	**0.000**	M	**0.204**	**0.004**	M	0.045	0.492		0.100	0.173		**0.176**	**0.011**	M
SP -> Inn_process	**0.049**	**0.040**	S	0.056	0.100		-0.030	0.430		0.022	0.458		0.023	0.227	
SP -> Inn_product	0.027	0.110		0.017	0.584		-0.025	0.509		0.036	0.374		-0.007	0.807	
SP -> SO	0.077	0.152		0.121	0.155		-0.052	0.292		0.028	0.606		0.069	0.449	

Source: Prepared by the authors using SMART-PLS. HTMT statistics. Effect: S: small; M: moderate; Sig: significant.

5. Discussion

First, this study contributes to the development of proximity theory in economic geography in three ways. First, it applies the proximity approach to analyzing innovation cooperation in extended agri-food value chains (León-Bravo et al., 2025; Mundler, 2022). Secondly, the study compares two international cases of agri-food value chains in developing Latin American countries with low levels of interorganizational cooperation for innovation (Edelmann et al., 2020; León-Bravo et al., 2025; Leonhardt, 2024). Third, it contributes to exploring a way of measuring personal proximity, enhancing and validating the scale proposed by Geldes et al. (2015). Regarding the measure of personal proximity, eight items were evaluated using factor analysis, and three were selected (being a fellow student at a university, belonging to the same political group, and being part of a professional group). These items align with a logic of belonging that is more related to the proposal by Romero (2018) and complementary to the approach, as merged with the social proximity measure. It differs from the logic of similarity proposed by Werker et al. (2016) and Ooms et al. (2018), which is more closely related to personal ties and psychological approaches.

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Additionally, this study contributes to innovation in the agri-food system, particularly in agri-food value chains, with few studies examining cooperation for innovation through an extended value chain approach that encompasses chain actors and support organizations. With respect to the sample, a high proportion of firms and farmers engage in innovation, for example, in chain actors in Nicaragua (57%) and in Paraguay (43%). For example, in Chile, according to the National Innovation Survey (2021-2022), which follows the Oslo Manual guidelines, only 9.3% of small, medium, and large agricultural firms engage in innovation. These results can be explained by the fact that most chain actors sampled consider that incorporating improvements or new technologies constitutes innovation. This is consistent with the technological improvements of recent years across both the agri-food value chains studied. Moreover, this aligns with the Oslo Manual's guidelines. That considers three types of innovations according to the type of novelty: 1) innovation can be new to the firm/farm, 2) new to the market, and 3) new to the world (OECD, 2018).

Regarding the proximities that explain inter-organizational cooperation to innovate in the extended agri-food value chains. It is observed that SP is positive and statistically significant in explaining cooperation between Chain actors (CA) in the "General," "Nicaragua," and "Support chain organizations" models. Complementarily, in the "Paraguay model," PP is positive and significant for collaboration with Support organizations (SO) (universities and public institutions). These results confirm the importance of social and personal proximity as the "glue" of cooperation to innovate and that they can be understood as two complementary proximity dimensions (Ooms et al., 2018; Werker et al., 2016). Also, it is highlighted that in the case of the "Support organizations" model, the PP has a significant negative effect; this could be explained by differences between the people who compose these organizations in the areas of belonging to the same university, political group, and professional group, which are significant items in the construct. Moreover, it can be explained as the negative effect of proximity, named "lock-in," due to previous negative experiences among actors (Torre & Gallaud, 2022; Torre & Talbot, 2018). It is also observed that PO and PC are not significant. On the other hand, IP is positive and significant with CA in "General" and "Chain actor" models. This differs from the cooperation of agribusiness firms with other organizations within a cluster (Geldes et al., 2017).

The different results of the roles of non-spatial dimensions in explaining cooperation to innovate in agri-food value chains generate background on the need to deepen the application of this approach to explain inter-organizational cooperation to innovate and not to generalize its results, as they could be explained by differences in country and economic sector contexts, levels of social capital, characteristics of the chains and their actors, as well as the focus to innovate, with whom one collaborate to innovate and changes in the innovation dynamics (Leonhardt, 2024; Mundler, 2022; Torre & Gallaud, 2022).

It also explores the effects of inter-organizational cooperation to innovate between two types of actors grouped into CA and SO. The results of the "General," "Nicaragua," "Paraguay," and "Chain actor" models show the positive effect of collaboration with SO to innovate in process innovation and product innovation in the case of "Paraguay" and "Chain actor." These results support the need for further analysis of "support organizations" and their interactions with other organizations for innovation in extended agri-food chains. There is also a need to analyze approaches, policies, programs, and instruments to support companies and farmers in innovating, especially in developing countries. (Boisier et al., 2021; Castillo-Vergara & Torres Aranibar, 2019; Rodrigo Fuentes et al., 2019). CA positively affects process innovation in the "General" and "Paraguay" models. This can be explained under co-creation and collaborative innovation. It is also observed that SO has a positive effect on CA in the "General" model but a negative relationship in the "Paraguay" model, which may be because, in this country, public institutions focus on small agricultural producers. It can be explained as an institutional mismatch, a focus for future studies. On the other hand, it has been seen that the effects of cooperation for innovation have different results depending on the type of partners with whom it is innovated (Castillo-Vergara & Torres, 2019; Fuentes et al., 2019). It is also observed that process innovation precedes product innovation in the "General" and "Chain actors" models. This is consistent with previous precedents (Geldes et al., 2017). It indicates the need to initially strengthen innovation processes. In sum, the cooperation among heterogeneous stakeholders and relations based on interest and trust is essential to achieve innovation and sustainability in agri-food supply chains (Dania et al., 2018; Gutiérrez & Macken-Walsh, 2022), and the need to make progress in systemic approaches as an innovation ecosystem, collaborative innovation, and extended value (FAO & UNIDO, 2024; Oh et al., 2016).

6. Conclusions and implications

This exploratory and comparative study contributes to the general discussion about innovation in agri-food value chains. Specifically, focusing on cooperation among the various actors in extended value chains in developing countries, which are highly important for sustainable rural development.

The proximity theory of economic geography helps explain the phenomenon of inter-organizational cooperation for innovation in the extended agri-food value chains of developing countries. This perspective has received less attention in the literature. It is also concluded that the effects of proximity, the interrelations between chain actors and support organizations to innovate, and the types of innovation that are developed are specific to each extended value chain and each country, demonstrating that the results in the study of cooperation to innovate are particular to each agri-food chain. More studies are needed, including representative samples.

It is also concluded that the scale proposed by Geldes et al. (2015) and the exploratory measure for "personal proximity" represent an advance in quantifying analyses of proximities and collaboration to innovate extended agri-food chains. According to the general model, social and institutional proximities are positively and significantly related to chain actors to innovate. In addition, chain actors favor process innovation, cooperation favors process innovation, and chain actors themselves favor process innovation. Moreover, it is observed that

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process innovation is a significant and positive antecedent of product innovation. Personal proximity is a significant and positive predictor of cooperation with support organizations in Paraguay. In general, inter-organizational cooperation favors process and product innovations. The effects of chain actors and support organizations differ depending on the extended chain actors. Process innovation is also positively significant in the "General," "Paraguay," and "Chain actors" models, with antecedents of product innovation.

These implications highlight the need to strengthen innovative agri-food development policies that take a systemic approach and encourage inter-organizational cooperation for innovation, including all actors in the extended agri-food chains, rather than focusing public policies and programs solely on small-scale agricultural producers. Particular attention should be paid to understanding the phenomena behind the low levels of inter-organizational cooperation for innovation in developing countries. Innovation can be a strategy for developing an agri-food system, which is essential to the economy, employment, food security, and sustainable development. Governance and planning for the agri-food chain development should guide this. In addition, relationships within agri-food chains should be strengthened, as they favor innovation. It is also noted that advancing cooperation in agri-food chains requires developing and improving the quality of social and personal relationships among stakeholders.

From a theoretical point of view, the proximity theory of economic geography in the agri-food system, specifically in agri-food value chains, contributes to the analysis of the process of cooperation for innovation between chain actors and supporting organizations. Moreover, the dimensions of proximity as determinants of cooperation between chain actors and support organizations vary across agri-food value chains, industries, and institutional contexts, especially in less developed countries. This is a crucial aspect of various theoretical approaches to systematic innovation, including clusters, sectoral innovation systems, technological innovation systems, and innovation ecosystems. This means it is necessary to explore and extend this type of study using both qualitative and quantitative approaches to understand the collaborative process of innovation.

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