Unravelling the functions of knowledge communities in Spain's agri-food system: An examination of Operational Groups

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Abstract

This study analyses the functional diversity of EIP-AGRI Operational Groups (OGs) in Spain, focusing on their roles as innovation intermediaries. It seeks to identify intermediary functions and enabling conditions that support the achievement of innovative solutions in the agri-food sector. Based on a national survey of OGs, the study applies a mixed-methods design, combining hierarchical cluster analysis and Necessary Condition Analysis (NCA). The intermediary functions performed by OGs are classified into operational profiles, and key enabling factors are identified. Three distinct functional profiles emerged: Collaborative Leaders, Moderate Innovators, and Emerging Explorers. Human capital and consortium composition were identified as necessary conditions for successful innovation among advanced OGs. Moderate Innovators were characterised by the need for simplified administrative procedures and cost-effectiveness. Emerging Explorers displayed latent potential but required further capacity building. These results provide evidence for differentiated policy support, particularly for capacity building, simplification of procedures, and strategic partner selection.

Keywords*: Innovation intermediaries, Agri-food systems, Knowledge communities, Operational groups, Multi-actor programmes.*

1. Introduction

The agri-food system requires transformation to meet increasing food demand, address climate challenges and ensure the resilient rural communities (El-Nasser and Ibrahim, 2024; OCDE, 2021). Collaboration among diverse stakeholders within knowledge communities is crucial for agri-food innovation (Howells and Thomas, 2022; Oulmane *et al.*, 2024; Zhang and Liu, 2023). Through its Operational Groups (OGs), the European Innovation Partnership for Agriculture (EIP-AGRI), facilitates innovation through multi-actor alliances(Cristiano and Proietti, 2022; Fieldsend *et al.*, 2022, 2021).

These OGs are a type of knowledge community, with over 3,000 groups across the European Union with a varying composition including farmers, foresters, researchers, advisors, businesses, environmental groups, and

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NGOs, aiming at co-creating practical solutions.[1] However, their effectiveness varies by group composition, goals and funding (Kilelu *et al.*, 2013; Klerkx and Leeuwis, 2009). This variation underscores the need for innovation policy to account for the diverse nature of OGs. The EIP-AGRI initiative is grounded in the interactive model of innovation, which contrasts with linear models by emphasising co-creation, iterative feedback, and the exchange of knowledge among diverse actors within innovation systems (Klerkx *et al.*, 2012; Hekkert *et al.*, 2007)). This perspective acknowledges that innovation emerges not from a single source but through continuous interaction between producers, advisors, researchers, market actors, and policymakers. Accordingly, OGs are conceived as multi-actor platforms designed to foster collaborative problem-solving and practical innovation. The present study adopts this interactive approach as a guiding framework for examining how OGs perform intermediary functions and the extent to which these functions contribute to innovation outcomes.

Innovation policy is key when evaluating European Union (EU) rural, Agricultural Knowledge and Innovation Systems (AKIS) related policies (Fieldsend *et al.*, 2021; Giarè and Vagnozzi, 2021). In the Spanish context, this diversity is aligned with national priorities for agri-food research and innovation, which emphasise the need for sustainable production, circular economy models, and resilience under climate change (El-Nasser and Ibrahim, 2024; Rojas-Serrano *et al.*, 2024).

Further research is needed to understand how OGs perform different innovation functions and to identify the facilitating factors that are necessary for their success (Caloffi *et al.*, 2023; Cholez *et al.*, 2023; Cronin *et al.*, 2022; Ingram *et al.*, 2022; Moschitz *et al.*, 2021). Hence, the following research questions can be posed:
RQ1. Do the functions of OGs as knowledge communities uniformly influence the achievement of their objectives?
RQ2. What facilitating factors are essential to enable OGs to provide innovative solutions?

This study contributes to the literature on agricultural innovation systems by providing a functional characterisation of EIP-AGRI Operational Groups (OGs) in Spain, based on the intermediary roles they perform. Drawing on a national survey and a combined methodological approach—hierarchical cluster analysis and Necessary Condition Analysis (NCA)—the paper identifies distinct behavioral profiles among OGs and examines the conditions that facilitate the achievement of their objectives.

In addition, the study proposes an operational framework that adapts and refines existing typologies of innovation intermediary functions (e.g., Howells, 2006; Piñeiro *et al.*, 2021) to the empirical context of multi-actor innovation projects. By doing so, it provides a basis for analysing OGs not only in terms of outcomes, but also through the roles and functions that underlie their performance.

Finally, the use of NCA introduces a complementary perspective to existing analytical tools in the field, enabling the identification of non-compensatory conditions that are necessary—though not sufficient—for innovation to occur. This approach may inform future assessments of intermediary organisations and support the design of targeted policy instruments within AKIS frameworks.

2. Literature review

OGs established under the EIP-AGRI framework represent a key instrument for promoting agricultural innovation in Europe through collaborative problem-solving. These are formal consortia of farmers, advisors, researchers and firms formed to implement innovation projects. As defined in Regulation (EU) No 1305/2013, OGs are legally bound to a single innovation plan and have a limited duration. They should therefore not be understood as long-standing communities or programs, but rather as tempo-

[1] See the webpage of the EU CAP network https://eu-cap-network.ec.europa.eu/operational-groups-eu-member-states_en.

rary alliances organized around specific goals. The theoretical foundation of the EIP-AGRI initiative lies in the interactive model of innovation, which highlights the role of collaboration, mutual learning and feedback among heterogeneous actors in the innovation process (Hekkert *et al.*, 2007; Klerkx *et al.*, 2012). This model challenges linear conceptions of innovation transfer by framing it instead as a co-evolutionary process shaped by social interactions, institutional settings, and context-specific knowledge. In this view, innovation intermediaries such as OGs play a central role in linking research and practice, articulating demands, and fostering networked problem-solving. The conceptual approach adopted in this study builds upon this interactive model, which aligns with the design principles of EIP-AGRI and underpins the functions and behaviours analysed in our framework.

The growing interest in the role of OGs has highlighted their intermediary character within AKIS. Innovation intermediaries are actors or entities that facilitate the circulation and coordination of knowledge among diverse stakeholders, often bridging research and practice. In the agricultural domain, intermediaries are critical for enabling co-innovation processes and for tackling systemic failures that prevent innovations from being adopted. Early contributions such as Howells (2006) identified key functions performed by innovation intermediaries – such as demand articulation, knowledge exchange, and network brokerage. These foundational ideas have since been expanded and contextualised in agricultural innovation systems. In particular, Piñeiro *et al.* (2021) offer a synthesis of intermediary roles adapted to the EIP-AGRI framework, drawing on both innovation systems literature (e.g. Kilelu *et al.*, 2011) and empirical studies in multi-actor settings. These functions are often informal, localised and context specific in agriculture.

From a conceptual standpoint, the role of innovation intermediaries is rooted in the systemic model of innovation, which emphasises the importance of dynamic interactions among diverse actors—such as researchers, farmers, advisors, and businesses—embedded in institutional and policy environments (Klerkx and Leeuwis, 2009; Hekkert *et al.*, 2007). This model contrasts with linear approaches by viewing innovation as a co-evolutionary process shaped by feedback loops, contextual knowledge, and coordination mechanisms. Within this framework, innovation brokers or intermediaries emerge as essential actors who facilitate connections, manage uncertainty, and enable the co-creation of solutions. The AKIS approach gives institutional form to this perspective by promoting integrated, multi-actor structures that link science, practice, and policy. In this context, OGs under the EIP-AGRI initiative represent a concrete policy instrument that operationalises the systemic and AKIS-based logic of innovation. OGs are thus designed to act as knowledge communities and innovation intermediaries, translating the principles of interaction, coordination and learning into tangible innovation outcomes.

Recent research has adapted and expanded this framework to better suit the particularities of innovation support in agriculture. For instance, Faure *et al.* (2019) and Mathé *et al.* (2016) proposed typologies of innovation support services based on empirical studies of multi-actor processes, while Cristiano and Proietti (2022) analysed the strategic roles of support actors in the Italian AKIS. These studies suggest that intermediary functions in agriculture are often distributed across multiple actors and emerge dynamically during the innovation process. In the case of OGs, such functions may be performed by different members of the consortium, especially project coordinators and advisory entities, even if not formally designated as intermediaries.

As García-Álvarez-Coque *et al.* (2020) argue, effective innovation governance in agri-food systems requires strategic directionality, well-aligned evaluation frameworks, and multi-level institutional coordination. However, as highlighted by Schebelin *et al.* (2021, 2022), this directionality is not neutral. Innovation governance involves political and normative choices that shape which actors, sectors, and knowledge systems are prioritised. In this sense, policies such as EIP-AGRI embed a deliberate orientation toward multi-actor collaboration, sustainability, and applied research, thereby influencing

the kinds of innovation that are supported and legitimised. OGs, as policy instruments grounded in this institutional logic, operate within these value-laden frameworks. Analysing their performance thus requires acknowledging the broader, non-neutral context in which their intermediary functions are enacted. Furthermore, intermediary functions are closely linked to actors' capacity to learn, adapt, and apply new knowledge. Ramos-Sandoval *et al.* (2016), in their study of small-scale agricultural holdings, demonstrated that innovation outcomes are strongly correlated with learning orientation and access to extension services. These findings suggest that intermediary roles are not only organisational but also behavioural, and that capacity-building mechanisms remain essential for enabling effective knowledge brokerage in innovation systems.

Building on this literature, the present study adopts a functional perspective that conceptualises OGs as distributed innovation intermediaries. The analysis draws on a national survey of OG representatives conducted in Spain and aims to identify distinct patterns in the way these groups perform intermediary functions. Importantly, only officially recognised OGs were surveyed; other types of innovation projects were excluded, thus ensuring consistency with the regulatory framework of the EIP-AGRI programme.

To operationalise intermediary functions within this empirical context, we use a conceptual framework adapted from the typology proposed by Piñeiro *et al.* (2021). This framework is the result of an analytical synthesis of the literature on innovation intermediaries, tailored to the specific features of EIP-AGRI Operational Groups. The functions identified in their study were translated into observable roles reported by OG members through the survey. Some of these roles preserve their theoretical labels, while others have been redefined to better capture practical realities in the Spanish implementation of EIP-AGRI. A synthesis of this conceptual alignment is presented in Table 1, which reconciles the original intermediary functions with their adapted equivalents for field application.

The intermediary roles presented in Table 1 are critical to the functional characterisation of OGs and form the foundation for the clustering analysis developed in this paper. Specifically: the Mentor provides technical guidance and knowledge transfer; the Leader ensures project coordination and drives the innovation process; the Connector builds trust and facilitates collaboration among members; the Organiser manages administrative tasks and formal requirements; the Networker promotes external visibility and establishes links beyond the OG; and the Inte-

Table 1 - Correspondence between theoretical and applied intermediary functions.

Theoretical function (adapted from Piñeiro et al., 2021; based on Howells, 2006 and others)	*Applied roles in this study*	*Comments / adjustments*
Demand articulation	Prospector, Explorer, Opportunist	Adapted to reflect early-stage innovation framing in practice.
Institutional support	Advocate, Educator, Stimulator	Broadened to include awareness, mobilisation, and lobbying activities.
Network brokerage	Connector, Engager, Collaborator	Associated with engagement and network building within and beyond the OG.
Capacity building	Instructor, Mentor, Catalyst	Focused on strengthening skills and knowledge within the group.
Innovation process management	Informer, Harmoniser, Guide, Assessor	Related to planning, monitoring, and coordination of the innovation process.
Knowledge exchange	Communicator, Interpreter	Covering communication and translation between actors and systems.

**Note: The classification of functions used in this study is adapted from Piñeiro et al. (2021), who reviewed and operationalised intermediary roles in the context of EIP-AGRI Operational Groups. Their framework synthesises previous contributions, including the typology of Howells (2006) and functionalist approaches to innovation systems such as Hekkert et al. (2007).*

grator ensures coherence between goals, contributions, and expected impacts. These categories were used to design the survey and serve as the analytical basis for the behavioural profiles discussed in the results.

This approach makes it possible to categorise OGs not only by their thematic orientation but by their functional behaviour, providing new insights into how they operate as intermediaries. The correspondence between theory and practice reflects the necessity of tailoring conceptual frameworks to the complex institutional realities of innovation in agriculture. As argued by Neuberger *et al.* (2023), intermediary functions vary not only with the composition and maturity of the actors involved, but also with the policy frameworks and support instruments available.

By understanding OGs through this lens, it becomes possible to evaluate their contribution to innovation in a more nuanced way. Instead of focusing solely on outputs or success stories, this perspective allows for the identification of specific configurations of roles and functions, which in turn can inform targeted policy support.

3. Materials and methods

3.1. *Survey design and data collection*

The survey design was initially based on previous experience with a survey of OG members (Piñeiro *et al.*, 2021). This experience was used to evaluate the items selected from the literature. Once the questionnaire had been developed, it was validated by an expert panel consisting of five knowledge management researchers and innovation agents linked to existing OGs.

The questionnaire had seven sections, each with a different scope. Table 2 summarises these sections. It also includes the open access link to the questionnaire and data. Although the survey provided data to assess the performance of OGs.

The target population for the survey consisted of the 967 Operational Groups (OGs) officially recognised in Spain up to July 2022. This figure was established through the consolidation of registries from the 17 Autonomous Communities (ACs) and the Ministry of Agriculture, Fisheries and Food (MAPA). The database included basic information on the name, location, and thematic focus of each OG. Regional administrations were contacted to validate and update the available records, and they also collaborated in distributing the survey.

The survey was administered online between September and November 2022 using Google Forms. An invitation was sent by email to all OGs, addressed to the person indicated as the legal representative or technical contact. Reminder messages were sent after two and four weeks. In some cases, the survey was redirected to other members of the OG, particularly when respondents considered they were not the most suitable person to answer. Additional support was provided through phone calls to increase the response rate.

A total of 164 responses were received, of which 159 were considered valid after reviewing for consistency and completeness. This represents a valid response rate of 16.4%. The sampling error was estimated using the finite population correction formula for proportions, assuming maximum variability ($p = q = 0.5$), a confidence level of 95%, a population size of 967 OGs, and a sample of 159 valid responses. Under these conditions, the estimated sampling error is approximately ±7.1%.

Readers can use the Zenodo open platform to access the questionnaire and survey data. The questionnaire and data set are organised into sections corresponding to innovation functions and roles (Cervera *et al.*, 2023).

The final sample includes OGs from all Autonomous Communities in Spain, with representation across diverse agri-food sectors and thematic areas. Respondents mainly consisted of technical coordinators, project leaders, or representatives of the leading organisation, most of whom had been directly involved in the preparation and implementation of the innovation project. The diversity of respondent profiles and the territorial coverage of the sample provide a robust basis for analysing the intermediary functions of OGs within the EIP-AGRI framework. In terms of territorial distribution, the OGs included in the survey operate across diverse rural contexts in Spain.

Table 2 - Sections and scope of the questionary.

Questionnaire section	*Scope*
General information	Name of the OG, funding, personnel
Type and scope of innovation	Targeted type of innovation included in the Rural Development Programme 2014-2020
Achievement and scope of objectives	Likert-type scales to measure the achievement of the innovative solution and the influence of factors that facilitate and hinder innovation (7 response options ranging from 'not influential' to 'totally influential')
Innovation functions of OGs	Likert-type scales to measure the importance of innovation functions (7 response options ranging from "not at all" to "totally")
Target audience and results transfer	Likert-type scales to determine preferred audiences for communicating results and dissemination activities
Group composition	Type of organisations involved and percentage of women
Project continuity	Future of the OG

Notes: The data set is available at https://zenodo.org/records/10118180.

Although specific geolocation data were not collected, the participating OGs are formally recognised at regional or supra-regional level and predominantly rooted in rural and semi-rural environments. These include both remote or marginal rural areas and peri-urban rural zones. The thematic focus of their innovation projects—targeting primary production, value chain organisation, sustainability, or local development—further reflects their anchoring in rural territories. Additionally, the profiles of the most represented stakeholders, including farmers, cooperatives, rural associations, and public research institutions, confirm the strong rural orientation of the surveyed OGs.

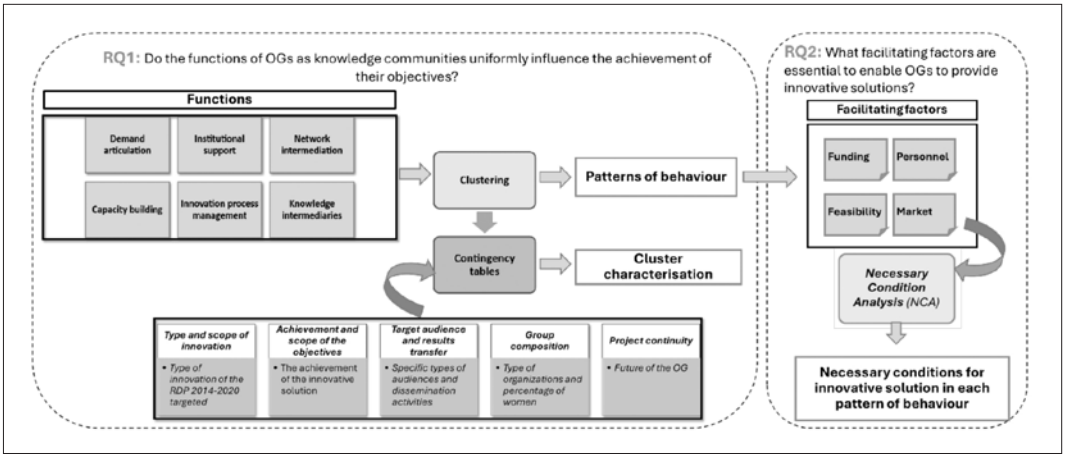
The number of respondents in Spain is larger than in previous OG assessment surveys (Fieldsend *et al.*, 2021; Knotter and Kretz, 2019). To ensure the validity of the sample and the robustness of subsequent analyses, several key statistical tests were conducted (Appendix A). The Student's t-tests for each variable indicated highly significant differences in means, with p-values less than 0.001 in all cases. This reflects remarkable consistency among the items analysed and a homogeneous distribution of the evaluated characteristics. Moreover, the Chi-square tests showed no significant associations in most variables, confirming the independence of the categories. The Cronbach's Alpha for the set of variables was 0.927, exceeding the threshold of 0.7 and

Table 3 - Facilitating factors needed to provide an innovative solution.

Dimension	*Factors*
Funding	Sufficient funding and commitment from group members
	Sufficient funding from external private sources
	Sufficient funding from public subsidies or grants
Personnel	Qualified staff among the group members
	Suitable composition of the consortium in terms of the number and characteristics of partners
	Sufficient access to external expertise
Market	Certainty regarding market demand for the innovative solution
Feasibility	Acceptable costs of the innovative solution
	Streamlined administrative procedures

Note: Terms such as "sufficient", "qualified" and "acceptable" reflect subjective assessments by OG members as reported in the survey. Definitions are provided in the main text for clarity.

Figure 1 - Methodological workflow of the present study.



demonstrating high internal consistency and excellent reliability of the scales used.

The survey addressed the facilitating factors that support OGs' efforts to provide innovative solutions (RQ2) in the section titled "Achievement and scope of objectives". This section also included Likert-type scale items, with seven options ranging from "Not influential" to "Totally influential". Table 3 shows the questionnaire items that referred to the influence of these facilitating factors.

The terms used in Table 3 reflect response categories from the survey designed to capture OG representatives' perceptions of key enabling factors. All items were measured using a seven-point Likert-type scale, ranging from "Not influential" (1) to "Totally influential" (7), based on how each factor was perceived to affect the achievement of the OG's objectives. For instance, "qualified staff among the group members" refers to the respondent's subjective evaluation of whether the consortium included personnel with the technical or scientific competencies needed to implement the project. Similarly, "sufficient funding" indicates that the available budget was perceived as adequate to meet project needs, and "acceptable institutional support" denotes a functional, if not optimal, level of administrative and policy support. These categories were developed in line with terminology used in previous AKIS-related studies (Klerkx & Leeuwis, 2009; Moschitz *et al.*, 2021).

3.2. *Methods*

Figure 1 illustrates the workflow followed to answer the research questions. In response to RQ1, cluster analysis was performed to identify patterns of OG behaviour related to the importance of OGs' innovation functions, according to respondents. Although the specific functions considered in this study are aligned with the principles and objectives of the EIP-AGRI, their implementation and particular emphasis may vary depending on the structure and specific interests of each OG.

The clustering process had three phases (Schulze Schwering *et al.*, 2022). First, a hierarchical cluster analysis was performed using the Ward method and the squared Euclidean distance to identify possible clusters. This method minimised the variance within each cluster, thereby enhancing the homogeneity of the resulting groups and ensuring a more precise classification. Second, after systematic comparison of the clustering possibilities, a dendrogram indicated the ideal number of clusters. It thus enabled identification of natural groupings and aided the decision-making process for establishing the optimal number of clusters. Finally, the Kruskal-Wallis test was applied to check whether the variables included in this study differed significantly between the clusters. It thereby provided a robust method to verify the distinctiveness of the clusters. Contingency tables were then used to examine the links

between the composition of clusters and various aspects. This step provided deeper insights into operational dynamics and potential areas for improvement for OGs.

Answering RQ2 required identification of the necessary conditions to provide innovative solutions in the clusters. To this end, NCA was employed as a set-theoretic method that identifies conditions that must be present (though not sufficient) for a desired outcome to occur (Dul, 2016). Unlike correlational approaches, NCA assumes an asymmetric relationship and focuses on non-compensatory constraints that block the outcome unless a minimum level of the condition is met.

NCA revealed the minimum levels of factors required for the desired outcome (Dul, 2016). Although the outcome of interest occurs, when necessary, conditions are satisfied, multiple necessary conditions may be required to produce the outcome. NCA examines the necessary conditions and their degree of necessity. The type of necessity indicates that a specific condition is necessary for a specific outcome. The degree of necessity describes the condition that is necessary to achieve a specific outcome.

In this study, the analysis was carried out using the R package NCA (version 3.1), applying both ceiling envelopment (CE-FDH) and ceiling regression (CR-FDH) techniques. Bottleneck tables were generated to determine the minimum level of each condition needed for a specific level of the outcome. A necessary condition is considered meaningful if its effect size exceeds 0.1 (Dul *et al.*, 2020). XY scatter plots and ceiling lines help visualise the upper-bound envelope, which represents the threshold beyond which the condition must be satisfied to reach the desired outcome (Hauff *et al.*, 2021).

This methodological approach has been increasingly applied in the agri-food and sustainability domains. For instance, Chaparro-Banegas *et al.* (2024) applied NCA to identify necessary factors for eco-innovation in European agri-food SMEs. Other relevant examples include Richter *et al.* (2017), who explored sustainability strategies in small firms, and Gölz and Hofmann (2021), who used NCA to study barriers to renewable energy adoption in rural areas.

4. Results

4.1. *Operational Groups within Agricultural Knowledge and Innovation Systems*

The survey allowed OGs to assess their implemented functions. The responses collected provided detailed data on the structure and functioning of the OGs. These data enabled evaluation of OG interactions, collaborations and the integration of various actors in the innovation process. Characterising OGs was therefore the first step in answering RQ1.

Regarding types of innovation, most respondents reported having promoted process innovations (50%), product innovations (35%), organisational innovations (12%) and marketing innovations (3%). Regarding the targeted priorities of the Rural Development Programme (RDP), most respondents reported that their OGs were oriented towards innovation and knowledge transfer, viability and competitiveness and efficient and sustainable use of resources. According to the survey results, 54% of respondents reported that their OGs had achieved their objectives satisfactorily, and 12.6% reported having exceeded expectations.

Concerning the types of organisations that form part of multi-actor OGs, 88% included universities and primary sector entities, and 54% included cooperatives. A total of 41% of respondents reported that more than 50% of team members were women. Regarding continuity, 76% of respondents reported that the multi-actor group would continue to work similarly in the future and further develop the innovation project with new funding sources.

4.2. *Patterns of behaviour according to the functions of Operational Groups*

Cluster analysis resulted in the identification of three distinct groups of OGs (Kruskall-Wallis, $p < 0.05$). Table 4 presents the mean values for each cluster and for the overall sample, based on the different intermediary functions assessed through the survey. These functions include knowledge mediation, innovation development,

Table 4 - Clusters based on the roles of OGs as innovation intermediaries.

Functions	*OG roles*	*CL1 Collaborative Leaders*	*CL2 Moderate Innovators*	*CL3 Emerging Explorers*	*Mean whole sample*	*Kruskal-Wallis H(*)*
Demand articulation	Prospector	5.44	4.44	3.73	4.76	43.028
	Explorer	**6.10**	**5.44**	**4.10**	5.48	51.485
	Opportunist	**6.15**	**5.47**	**4.17**	5.53	56.986
	Enabler	5.50	4.65	3.90	4.89	32.039
Institutional support	Advocate	5.88	5.02	4.23	5.26	36.231
	Educator	5.54	4.25	2.77	4.55	71.016
	Stimulator	**6.21**	**5.23**	3.97	5.43	63.501
Network intermediation	Connector	5.65	4.54	3.00	4.75	70.000
	Engager	5.65	4.47	2.80	4.69	76.615
	Collaborator	**6.29**	**5.05**	3.70	5.36	85.968
Capacity building	Catalyst	4.63	4.05	3.10	4.13	16.720
	Instructor	5.39	4.53	3.60	4.74	30.316
	Mentor	**6.33**	**5.51**	**4.83**	5.75	37.204
Innovation process management	Informer	**6.33**	**5.28**	**4.07**	5.53	80.364
	Harmoniser	**6.33**	**5.35**	**4.23**	5.58	63.975
	Guide	6.14	4.35	3.10	4.92	88.658
	Assessor	5.71	4.32	2.90	4.68	81.910
Knowledge intermediaries	Communicator	**6.17**	**5.18**	**4.37**	5.47	45.442
	Interpreter	5.60	4.28	3.60	4.75	46.411

(*) p value = 0.000.

dissemination, demand articulation, and coordination. It is important to note that the term "Enabler" in this context does not refer to a functional role of OGs, as outlined in Table 1, but rather to an external condition or environment that facilitates their capacity to innovate. This includes aspects such as institutional support, regulatory clarity, or favourable funding frameworks.

Each cluster was characterised to reveal how the OGs in each cluster operate and their challenges and success factors. Table 5 provides a detailed characterisation of the three clusters, revealing statistically significant differences across a wide range of variables.

Cluster 1 (CL1), *Collaborative Leaders* comprised 72 OGs (45% of the sample). Respondents reported above-average values for all innovation functions. The name *Collaborative Leaders* refers to the fact that these OGs show a highly innovative mentality, shared goals and catalytic leadership. The highest scores for roles were for Mentor, Informer and Harmoniser, highlighting the importance of providing ongoing support, training and facilitating the effective transfer of knowledge and experiences that allow the group to share lessons and best practices. It contains OGs that have been highly successful (83.3%) in providing innovative solutions. They prioritise innovation, resource efficiency (76.4%) and agri-environmental issues (68.1%), particularly those linked to the Rural Development Programme priority of restoring, preserving, and improving ecosystems[2]—such as soil quality, biodiversity, and water resources. Their commu-

[2] It is important to clarify that the term 'ecosystems' is used here in line with EU policy language and does not imply the adoption of an ecosystemic analytical framework in this study.

Table 5 - Cluster characterisation.

Cluster characterisation	*CL1*	*CL2*	*CL3*	*Total*	*Chi-square*	*Cont. Coeff*	*p-value*
% observations	45.28	35.85	18.87				
No. observations	72	57	30				
OG expectations achieved (%)							
Moderately/acceptably	16.7	31.6	50.0	28.3	12.066	0.266	0.002
Met satisfactorily/exceeded	83.3	68.4	50.0	71.7			
Targeted priorities of the Rural Development Programme 2014-2020 (% of highly/totally)							
Knowledge transfer and innovation	84.7	77.2	56.7	76.7	13.366	0.278	0.01
Food chain organisation and risk management	36.1	26.3	10.0	27.7	14.062	0.285	0.007
Restoring, preserving and improving ecosystems	68.1	52.6	43.3	57.9	8.877	0.230	0.065
Resource-efficient and climate-change-resilient economy	76.4	61.4	53.3	66.7	14.588	0.290	0.006
Target audience to communicate the results (% of highly/totally)							
Researchers	66.7	49.1	43.3	56.0	19.820	0.235	0.007
Professionals	95.8	93.0	66.7	89.3	32.703	0.286	0.001
Public decision makers	63.9	36.8	23.3	46.5	22.185	0.286	0.001
Agricultural and rural associations	86.1	83.5	60.0	79.9	31.132	0.269	0.003
Characteristics of the dissemination activities (% of highly/totally)							
- Multimedia content is tailored to the audience	95.8	78.9	43.3	79.9	77.888	0.471	0.000
- Complex results are communicated in a simple message	94.4	78.9	40.0	78.6	53.868	0.342	0.000
- Language is inclusive, and a gender focus is incorporated	80.6	68.4	43.3	69.2	34.420	0.310	0.000
- Knowledge products are disseminated with a social marketing vision through networks and platforms	77.8	70.2	10.0	62.3	66.495	0.255	0.002
- Results, tools and data are easily accessible and reusable	83.3	61.4	20.0	63.5	59.690	0.402	0.000
Women participating in activities (More than 30%)	83.4	61.5	56.6	70.5	12.210	0.268	0.006
Project continuity							
Similar work will continue	75.0	82.5	70.0	76.7	12.555	0.71	0.014
Will not continue, but they will have regular meetings	25.0	14.0	16.7	19.5			
Will not continue, and they will end the collaboration	0.0	3.5	13.3	3.8			

Source: Survey administered to OGs (https://zenodo.org/records/10118180).

nication strategies are innovative, accessible and gender-sensitive, with a strong commitment to continued collaboration, displaying multimedia skills. They are open innovation intermediaries (Caloffi *et al.*, 2023). High female participation (30% of OGs with >50% women) also defines this group. In total, 75% of respondents in this cluster report that their OGs will continue to collaborate in a similar manner. This result is particularly relevant considering the underrepresentation of women in agri-food innovation networks reported in the literature. For example,

Carvalho *et al.* (2020) analysed women's participation in scientific innovations in Ibero-America and found persistent gender imbalances in both visibility and leadership. Our findings are consistent with this trend, although Cluster 1 stands out positively within our sample, suggesting that collaborative environments with shared goals and inclusive communication strategies may be more conducive to female involvement. Similarly, Puertas *et al.* (2023) and Nhundu *et al.* (2023) emphasise the need for rural development policies to foster gender equality through participatory approaches.

Cluster 2 (CL2), *Moderate Innovators*, comprised 57 OGs (36%). Respondents reported below-average scores for intermediation functions that were nonetheless close to those for Collaborative Leaders. The respondents in this cluster reported that the most important roles were Mentor, Opportunist and Explorer, the priority in this group appears to be on providing expert support, identifying market opportunities and actively exploring solutions. These functions, which align with capacity building and demand articulation, reflect a more operational profile that favours internal reinforcement of capabilities over institutional engagement. In line with the work of Klerkx and Leeuwis (2009), these findings suggest that intermediaries in this cluster contribute by bridging knowledge gaps and promoting learning-by-doing dynamics, rather than acting as institutional brokers or systemic facilitators. This is further supported by Howells (2006), who highlights that technical and cognitive support roles are essential in contexts where innovation capacities are still emerging. Therefore, OGs in this group may benefit from capacity-enhancing policies that reinforce internal skills, while progressively promoting structured interaction with external stakeholders. The performance of this group reflects a mix of moderately and satisfactorily achieved expectations, indicating potential for further consolidation of their innovation capacity. It contains a mix of moderately and satisfactorily achieved expectations. OGs in this cluster prioritise knowledge transfer and innovation (77.2%), resource efficiency (61.4%) and ecosystem restoration (52.6%). Although their communication is effective, they have some shortcomings in disseminating results to researchers and policymakers. However, they show a willingness to engage in future collaboration.

Cluster 3 (CL3), *Emerging Explorers*, comprised 30 OGs (19% of the sample). The values reported by the respondents were notably below the average. The highest-scoring functions in this group had values greater than 4 and coincided with those of CL2. The most valued roles were Mentor, Opportunist, and Explorer, reflecting a profile that prioritises individual learning, opportunity recognition, and early-stage innovation exploration. Within the Institutional support function, the roles of Educator and Stimulator received the lowest scores, suggesting limited engagement in formal capacity-building or institutional reinforcement. Similarly, in the Innovation process management function, the Guide and Assessor roles were among the least valued, indicating a need for structured support in planning and evaluating innovation initiatives. These findings are consistent with a group of intermediaries that are still consolidating their innovation identity and require targeted support to transition towards more systemic and integrative roles, as discussed by Howells and Thomas (2022) and Caloffi *et al.* (2023). This cluster represents a segment with modest innovation performance but clear potential for growth, particularly if provided with mentoring and knowledge network integration. The OGs in this Cluster display varying degrees of success (50%) in innovation. OGs in this cluster prioritise knowledge transfer and innovation (56.7%), resource efficiency (53.3%) and ecosystem restoration (43.3%). According to the classification described by Caloffi *et al.* (2023), these OGs can be considered intermediaries that support innovation and competitiveness. However, they cannot be considered open innovation intermediaries or transition intermediaries because they fail to promote institutional change. Zhang and Liu (2023) position these OGs as intermediaries in a segment characterised by innovation performance and knowledge networks. These OGs require targeted support to fully exploit their potential strengths, in line with the proposals of Howells and Thomas (2022).

4.3. *Discussion and policy implications*

In summary, this cluster analysis of OGs reveals that a single innovation programme can encompass a diversity of intermediaries' profiles, directly addressing RQ1, and demonstrating that OGs operate as hybrid knowledge communities. This diversity is a positive feature of the EIP-AGRI approach, reflecting the flexibility and inclusivity of the programme. These characteristics have been instrumental in fostering a range of innovation pathways adapted to the heterogeneity of actors and context within the agri-food system.

From a policy perspective, the findings offer several relevant insights. First, they highlight the need for differentiated support mechanisms in the design, implementation and evaluation of OGs. Rather than applying uniform criteria, managing authorities should adopt functional diagnostics when allocating resources and defining technical support. Second, the intermediary functions identified in this study provide a robust basis for policy evaluation, particularly in the context of the CAP Strategic Plans and the development of AKIS. The variation in functional profiles also reflects the multiplicity of needs and capacities among OGs, offering useful guidance for targeted public interventions.

Overall, this research contributes to the growing body of literature advocating a shift from output-focused evaluations toward function-oriented governance of innovation. By identifying the enabling conditions and intermediary dynamics within OGs, the study provides a foundation for more informed, context-sensitive policy design and the consolidation of support structures for agricultural innovation in Europe.

4.4. *Necessary conditions for providing innovative solutions*

The necessary facilitating factors are shown in Table 6. Appendix C provides XY scatter plots of the facilitating factors in each cluster. These results show that, in CL1 and CL3, personnel are a necessary facilitating factor for innovative solutions, with a medium effect size. Conversely, in CL2, feasibility is a necessary facilitating factor, with a medium effect size.

Personnel include qualified staff, consortium composition and external expertise; feasibility includes cost acceptability and streamlined procedure.

These facilitating factors can be assessed in detail using bottleneck tables (Table 7).

In CL1 (*Collaborative Leaders*), adequate consortium composition (understood as an appropriate configuration in terms of number and diversity of partners, including producers, cooperatives, researchers and technical advisors) gradually increases as the percentage of expectations achieved increases. It peaks in the 100% category with a value of 84.4%. These findings suggest that the appropriate consortium configuration becomes more crucial as OGs seek a higher level of achievement. These results are in line with those reported by (Molina *et al.*, 2021). In a case study of an Italian OG, they underscored the importance of the choice of members from the outset of the project, the search for synergies and the contribution of their different skills to the achievement of the common goal. In that study, Cirella and Murphy (2022) found that networking and partnering are two relevant practices for initiating collaboration.

In contrast, having qualified staff among the members of the OG does not contribute significantly to 80% to 90% achievement of expectations, and it does not apply to 100% achievement. Sufficient access to external expertise does not significantly contribute to results in any analysed category.

As in CL1, in CL3 (Emerging explorers), the adequate composition of the consortium gradually increases in relevance as the target percentage increases, peaking in the 100% category with a value of 73.3%. This finding indicates that this facilitating factor becomes more crucial as OGs seek a higher level of achievement. Qualified staff within the group and sufficient access to external expertise do not make a significant contribution until a target of 70% is reached. However, to reach a target of 100% requires all three staff-related facilitating factors, in contrast to the results for CL1.

These findings support the view that human capital is not only a structural asset, but a func-

Table 6 - Effect size (d) and significance level of the facilitating factors (CR-FDH).

Construct	*CL1*	*CL2*	*CL3*
Funding	0.07 *(0.402)*	0.07 *(0.374)*	0.07 *(0.736)*
Personnel	**0.21 (0.011)**	0.17 (0.480)	**0.26 (0.029)**
Market	0.11 (0.377)	0.10 (0.427)	0.13 (0.379)
Feasibility	0.17 (0.137)	**0.21 (0.008)**	0.06 (0.724)

Table 7 - Bottleneck table with percentages in each cluster.

EA	*CL1*			*CL3*			*CL2*	
	QS	*CC*	*EE*	*QS*	*CC*	*EE*	*AC*	*SA*
0	NN	NN	NN	NN	NN	NN	NN	NN
10	NN	NN	NN	NN	NN	NN	6.7	NN
20	NN	NN	NN	NN	8.2	NN	13.3	NN
30	NN	9.8	NN	NN	16.8	NN	20.0	NN
40	NN	20.4	NN	NN	25.5	NN	26.7	NN
50	NN	31.1	NN	NN	34.1	NN	33.3	NN
60	NN	41.8	NN	NN	42.7	NN	40.0	6.7
70	NN	52.4	NN	7.5	51.4	7.5	46.7	13.3
80	20.0	63.1	NN	30.0	60.0	30.0	53.3	20.0
90	60.0	73.8	NN	52.5	68.6	52.5	60.0	26.7
100	NA	84.4	NN	75.0	73.3	75.0	66.7	33.3

(*) EA: Expectations achieved. QS: Qualified staff. CC: Consortium composition. EE: External expertise. AC: Acceptable

tional prerequisite for success in innovation processes. This conclusion is further supported by earlier research. Ramos-Sandoval *et al.* (2016) found that, in small-scale farming contexts, farmers' learning orientation and the effective use of research and extension services are key enablers of innovation. Although their analysis focused on individual behaviour, and ours on organisational dynamics, both studies point to the same underlying mechanism: the capacity of actors to absorb, interpret and apply knowledge. The convergence of evidence across different scales underscores the strategic importance of human capital development and knowledge facilitation in innovation policy.

In CL2 (Moderate Innovators), the relevance of the costs of innovative solutions increases steadily as the target percentage increases. It reaches a maximum in the 100% category with a value of 66.7%. This finding indicates that this facilitating factor becomes more crucial as OGs seek a higher level of achievement. Additionally, streamlining administrative procedures increases in relevance as the target percentage increases, reaching a maximum in the 100% category with a value of 33.3%.

In CL2, these factors support goal achievement. This finding highlights their importance when seeking higher levels of expectation achievement. Turner *et al.* (2023) reported similar findings. Furthermore, the absence of data in the "Not Necessary" ("NN") category suggests that these variables are significant for all analysed categories of achievement of expectations.

These findings address RQ2 and confirm the importance of tailored support for each cluster. It thus contributes to meeting the overall objectives of the EIP-AGRI programme. These findings provide empirical support for the strategic differentiation of innovation support services in AKIS, as recommended by Proietti & Cristiano (2022) and Neuberger *et al.* (2023). The profile-specific

bottlenecks identified herein could guide targeted interventions in the CAP Strategic Plans.

NCA adds precision by identifying non-compensatory factors by identifying non-compensatory factors that constrain innovation outcomes. Cluster analysis revealed intermediary profiles, and NCA the structural prerequisites without which innovation cannot occur, regardless of the strengths in other project components. Applying this logic helps anticipate weaknesses and better allocate support.

5. Conclusions

This study examined OGs acting as knowledge communities. It explored their internal management differences and their functions as innovation intermediaries. After assessing these differences, the facilitating factors that are necessary to provide innovative solutions were identified.

The study's findings address RQ1 by showing that the intermediary functions of OGs do not uniformly influence the achievement of their objectives. Instead, the influence varies across the three functional profiles identified through cluster analysis. For instance, OGs classified as Collaborative Leaders perform consistently high across all innovation functions and report the highest levels of success in achieving or exceeding their objectives (83.3%). In contrast, Emerging Explorers show lower engagement in intermediary roles and more modest outcomes (50%), while Moderate Innovators fall in between. This confirms a heterogeneous, context-dependent influence of intermediary functions rather than a uniform one.

These findings highlight the functional diversity of OGs within the EIP-AGRI programme, positioning them as a hybrid category of knowledge communities. As networks, OGs foster direct collaboration among stakeholders and support the co-creation and dissemination of innovations. As intermediaries, they facilitate connections and provide support services, catalysing the innovation process both within and beyond the group. This research illustrates the variety of functions and strategic orientations among Spanish OGs and supports the need for differentiated policy tools adapted to their operational realities.

These findings are particularly relevant in the context of the EIP-AGRI framework and its articulation through the EU Rural Development Programme (2014-2020) and the new CAP Strategic Plans. The diversity of intermediary profiles identified suggests that innovation support measures should be adapted to the specific capacities and needs of each OG type. This includes reinforcing targeted capacity-building for less mature groups (e.g., Emerging Explorers), simplifying administrative procedures to support Moderate Innovators, and incentivising collaborative practices among well-performing consortia. Therefore, rural innovation policies should adopt a function-oriented approach that complements the current project-based funding schemes with long-term strategies for strengthening multi-actor partnerships.

Regarding RQ2, the facilitating factors for providing innovative solutions vary significantly between groups. For OGs acting as Collaborative Leaders, selecting partners with qualified personnel is crucial from the outset. External experts play a pivotal role in helping OGs achieve ambitious innovation goals, particularly for Emerging Explorers. In contrast, Moderate Innovators prioritise reducing the costs of innovative solutions and facilitating administrative procedures.

Developing innovative initiatives that effectively address complex challenges requires the support of knowledge communities tailored to the unique characteristics and needs of different types of innovation groups. This recognises the different capacities and improvement areas of each cluster. The success of innovation programmes hinges on policymakers' ability to recognise and accommodate beneficiaries' varied interests, ensuring inclusivity and adaptability to diverse needs. Farm advisors and innovation agents should be ready to recognise and respond to the diverse interests and functions of participant groups within the same innovation programme.

In the context of the EU's new programming period for the Common Agricultural Policy and National Strategic Plans, these findings provide valuable guidance for fostering collaborative and efficient environments. Tailoring strategies to the strengths and weaknesses of each OG cluster can enhance synergies and knowledge

exchange, maximising innovation benefits. Policies should support collaboration, especially in catalyst groups.

Rural innovation policies should be flexible and adaptive, tailored to address the specific roles and functions identified within OGs. For Collaborative Leader OGs, ongoing support is crucial to maintain a holistic approach. OGs in the Moderate Innovators cluster require additional resources to manage costs and streamline administrative processes effectively. Emerging Explorer OGs would benefit from strategies that emphasise early consortium building and the incorporation of external experts to bolster innovation capabilities.

One potential limitation of this study is the response rate of 16.4%. Although this figure aligns with accepted standards in organisational research using online surveys (Baruch & Holtom, 2008), it may limit the generalisability of the findings. While the diversity of OGs represented and their alignment with regional distribution patterns provides some reassurance, future research should aim to confirm these behavioural profiles using larger and more representative samples.

This study's main limitations are its geographic scope and qualitative methods. Future research could employ quantitative approaches such as partial least squares structural equation modelling (PLS-SEM) to provide quantitative validation of necessary conditions and causal relationships. Exploring the nuances of innovation intermediaries in different contexts would also be valuable.

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