Transfer VERSUS Co-production: Knowledge as "MEANS" to Sustainability as an "END"

Abstract

This study examines the relationship between sustainability performance and knowledge, as well as between innovation transfer and co-production. It moves away from evaluating processes to exploring impact by investigating how explicit and tacit knowledge archetypes are associated with sustainability performance in the agri-food sector. Applying the knowledge-based theory and the Shannon index, we rely on a database from 2013 to 2020 of two case studies selected from a Spanish research institution. At the institutional level, the results postulate that knowledge and innovation transfer tends to have a higher diversity index, mainly driven by explicit knowledge archetype. Tacit type of knowledge in both transfer and co-production mechanisms predominately relies on engagement parameters. At the case study level, as an educational toolkit, the first case study prioritizes engagement that is, transferring and transmitting knowledge to a higher number of participants—tacit knowledge transfer. As an innovative technique, the second case study prioritizes diversity that is, transferring and transmitting knowledge through various channels—explicit knowledge transfer. Regarding sustainability performance, the findings demonstrate that both explicit and tacit knowledge are associated with health and capacity building pillars in the first case study through the transfer mechanism. However, in the second one, tacit knowledge is mainly associated with economic and socioterritorial pillars through transfer and co-production mechanisms. This study sheds light on the micro level of knowledge, proposing an approach for researchers and practitioners to categorize knowledge in different proxies and evaluate their performance.

Keywords: Knowledge Transfer; Knowledge Co-production; Innovation; Societal Impact; Sustainability; Agri-food Sector

1. Introduction

The scientific community and policymakers have assessed the outcome and quality of research and innovation from multiple perspectives, relying on holistic frameworks. The assessment of academic efforts has been narrowed down to a set of indicators such as scientific output, article publication, citation count, and h-index. (Spaapen and van Drooge, 2011; D´Este et al., 2018). While the proxies of measuring academic impact are considerably well-identified in the literature, validated parameters to assess the role of research that may be related to the sustainable development goals[1] and the grand societal challenges remain deficient (Spaapen and van Drooge, 2011; Fait et al., 2019). Pedersen and Hvidtfeldt (2023) accentuated the methodological challenge faced when the evaluation of research shifts from academic impact to societal impact. Indicators and metrics are described as priority features to accommodate the instrumentality of evaluation. The debate between attribution and contribution of impact is predominant in the research evaluation domain. Attribution is perceived as a set of factors that leads to specific effects or changes in society, which is usually produced due to the synergetic mechanism between various settings such as institutions, actors, and strategies. Prior research has revealed that impact does not merely occur but is rather an "end" that needs to be cultivated through diverse "means," such as productive interactions and processes (Molas-Gallart and Tang, 2011; Olmos-Peñuela et al., 2014). As synthesized by Pedersen and Hvidtfeldt (2023), most research evaluation studies have been driven by examining the "end," that is, the impact generated, putting in shadow the "means," that is, tools to achieve the impact. Building on that, they stress the value of

The United Nation adopted the 2030 Agenda for sustainable development and defined 17 Sustainable Development Goals, recognizing that actions in one area may affect outcomes in others and that development requires a balance between social, economic, and environmental sustainability (United Nations Development Program, 2023).

investigating the productive interactions of research and its relationship with societal impact rather than focusing solely on the causal effect between research and societal impact. Therefore, this study is triggered by Pedersen and Hvidtfeldt's (2023) call and attempts to provide an evaluative approach by identifying indicators of research as a "means" and their association with sustainability as an "end." We frame these "means" as knowledge and innovation mechanisms (KIM) and distinguish them according to 1) their types of interaction (unilateral interaction: knowledge and innovation transfer (KIT) and bilateral interaction: knowledge and innovation co-production (KIP)) and 2) knowledge's nature (explicit and tacit archetypes). The study aims to investigate how explicit and tacit KIT and KIP are associated with sustainability performance in the agri-food sector.

With climate degradation and fast technological growth, the agri-food sector has been challenged in tackling both economic and sustainability practices. Due to the limited capacity of innovation absorption and limited resources for research and development, collaboration and partnerships with the scientific community are encouraged to overcome these challenges (Dezi et al., 2018). Fait et al. (2019) postulated that knowledge sharing is perceived as a key feature to enhance agri-food business performance. Cornell et al. (2013) revealed that knowledge transfer and co-production mechanisms can be anticipated as prerequisites to achieve sustainability practices. The trend of impact assessment has been recently gaining emergent attention from actors in the agri-food sector. Therefore, me scholars and practitioners are mainly engaged in understanding knowledge mechanisms and economy to demonstrate the value of science to government, stakeholders, and the public (Turner et al., 2022). In the agri-food context, there is still a resilient attitude among agri-food firms toward evaluation practices of knowledge and innovation (Guesmi and Gil, 2021). The culture of impact assessment is still considered at its infancy stage compared to the health sector. To promote this culture, first, there is the need to increase awareness of this process and facilitate methodological tools and instruments to evaluate and analyze the benefits of KIM performance.

This study outlines a potentially useful approach and indicators that might contribute to the understanding of transfer and co-production mechanisms of knowledge integrated into different types of research projects. Based on a dataset covering 2013–2020, this explanatory analysis relies on two case studies from the agri-food sector —best practices in rice cultivation (Case study 1), and genetic crossbreeding methods in the almond industry (Case study 2). Six pillars of sustainability are included in the analysis and evaluated by a group of stakeholders engaged in the selected case studies—economic, socioterritorial, environmental, health, capacity building, and political. After a preliminary test, the analysis revealed how KIT and KIP (explicit and tacit) vary in terms of diversity and engagement parameters and how they are differently associated with sustainability pillars.

The remainder of the paper is structured as follows: Section 2presents the literature review, elaborating on the definitions of KIM proxies, identifying research gaps and challenges, and highlighting the contribution of this study. Section 3 provides a summary of the theoretical framework. The methodology, empirical design, and data collection of the study are presented in Section 4 The Section 5 consists of the results and discussion. The conclusions are drawn in the last section.

2. Literature review

2.1. Definition and conceptualization

Knowledge is perceived as a “linchpin” of innovation and value creation, which has been widely accelerated through the diffusion of communication and technologies

(Bacon et al., 2020). During the last decade, there has been an emergent concern at the global level among regulators, impact investors, and scholars regarding the evaluation of knowledge and innovation (Morton, 2015). Prins et al. (2019) advocated that the criteria of science assessment comprise three overarching benchmarks—societal quality, societal impact, and valorization of research effort. For policymakers and funders, evaluating KIM is perceived as a "milestone" when it does not only focus on its financial return but also fosters the assessment of its societal impact and sustainability performance. Various terminologies have been used interchangeably in the management literature to describe knowledge mechanisms, including diffusion, sharing, exchange, dissemination, transfer, and co-production. The assessment of these mechanisms encompasses overlapping stages. Cornell et al. (2013) summarized it in a three-stage process of knowing, learning, and implementing, which is broadly applied in research to articulate social and environmental goals. In this study, four frameworks have been adapted as follows: 1) relevance of KIM (identification of mechanisms and indicators of knowledge flow between researchers, policymakers, and end-users), 2) KIP (development and co-creation of knowledge and innovation between actors), 3) KIT (channels or activities to disseminate and transmit the knowledge produced from researchers to end-users), and 4) knowledge impact (relationship between KIM and sustainability performance). We segregate KIM into two mechanisms—knowledge transfer KIT and knowledge co-production KIP. In addition, we categorize KIT and KIP by typifying activities in two sets of knowledge from epistemological hermeneutics—explicit and tacit archetypes.

KIP versus KIT: Definition

Knowledge transfer is defined as a learning mechanism that is based on the application and dissemination of knowledge from one context or group to another. It entails a unilateral flow of knowledge from research to practical settings. We adopt the

KIT concept of Rossi et al. (2017), which refers to tailoring knowledge unidirectional from academics or researchers to stakeholders' networks. The features of the transfer mechanism are categorized into knowledge awareness, which is identifying and exploiting appropriate or accessible knowledge, and knowledge acquisition, which refers to the capability to absorb and acquire knowledge bounded to the needs and contexts of end-users. The stepping stones of integrating appropriate and effective knowledge transfer are communication, application, adaptation, and feedback loop. However, knowledge co-production is described as an interactive and bidirectional instrument of knowledge building, requiring the participation of various stakeholders. It is a collaborative tool for knowledge construction, validation, and adaptation (Brudney and England, 1983). We base our analysis on Osborne and Strokosch's (2013) definition, describing KIP as an active and participatory approach to leverage knowledge resources through collaboration and interactions among actors (Cunliffe and Scaratti, 2017). The key features to optimize its effectiveness are participatory approach, cooperation, contextual relevance, and interdisciplinarity.

The rhetorical fact of KIP and KIT as "two faces of the same coin" is the main motivation to delve deeper into this analysis. They are aspects of KIM, which are inextricably connected yet distinct. For instance, Pestoff (2014) postulated that while the outcome of knowledge transfer might be bound to the timeline of the transfer process itself, knowledge co-production outcomes could persist over time. In addition, the scope of beneficiaries might vary between the two approaches. The transfer mechanism tends to encompass direct and exclusive impact, limited to actors explicitly participating in the knowledge activities. However, the co-production mechanism may have a wider spectrum of impact, indirectly influencing actors beyond the scope of the initial process of knowledge development (Molas-Gallart and Tang, 2011).

Explicit versus Tacit: Definition

Knowledge is a complex and multidimensional process, engendering diverse typologies, tangible and intangible resources, and various characteristics of stakeholders. To facilitate its understanding and as recommended by Bacon et al. (2020), we segregate KIM into tacit and explicit types. Tacit knowledge is defined as an intuitive and unarticulated mechanism (Polanyi, 1962) that is based on experience- and observation-driven activities. The salient attributes of tacit knowledge are difficulty to be captured, codified, and diffused. Nevertheless, it is considered a valuable asset for organizations. In contrast, explicit knowledge is commonly known as an information-based approach that can be easily codified and articulated to different actors (Bacon et al., 2020). Framed by the interactionalist philosophy (Cook and Brown, 1999), explicit and tacit archetypes are not considered dichotomous conditions of knowledge but rather jointly contingent mechanisms underpinning the process of knowledge generation. The two typologies of knowledge are included in the analysis.

2.2. Research gaps and challenges

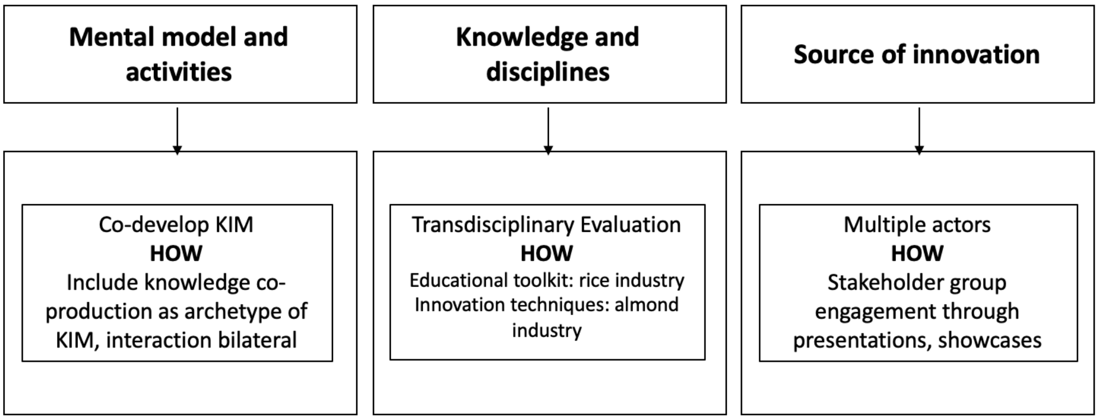
The controversy among academicians, practitioners, and funders remains on framing evaluative approaches to knowledge and its impact (Belcher et al., 2016). We sieve out three streams of research gaps from the literature and the agri-food context. The first gap is bounded to the methodological scarcity of combining both qualitative and quantitative designs, which is applying the mixed-method technique (Maslach et al., 2018), conducting in-depth longitudinal case studies (Wells and Nieuwenhuis, 2017), and considering stakeholders' perception (Wehn and Montalvo, 2018). Hence, our study could be a modest attempt to fill this methodological lacuna by blending both qualitative and quantitative data for KIM analysis from two case studies and embracing stakeholder evaluation for sustainability performance.

The second gap is mainly driven by a conceptual battle between transfer and co-production mechanisms. Argote and Fahrenkopf (2016) and Argote et al. (2022) highlighted certain challenges in knowledge transfer proxy. Due to a lack of consensus and clear-cut conceptualization, struggles in understanding and practicing knowledge transfer surfaced (Liyanage et al., 2009). As for knowledge co-production, prior studies have examined the "how" and the boundary system of co-production processes, yet keeping the analysis of its broader impact behind (Rosli and Rossi, 2016). Therefore, we aim to mitigate this flaw by distinguishing KIT and KIP measures and exploring their performance in reference to three parameters—diversity, engagement, and sustainability.

The third gap is contextually framed, zooming into the limited research tackling the intertwined connection between tools and impact (Pedersen and Hvidtfeldt, 2023), particularly in the agri-food sector (Ahmad and Karim, 2019). Few empirical studies have segregated knowledge archetypes (Yao et al., 2020) and simultaneously included transfer and co-production as pillars of knowledge mechanisms. For instance, while Hill et al. (2017) and Hindle et al. (2021) examined only knowledge transfer with qualitative and quantitative designs, respectively, Chatterjee et al. (2018) elaborated only on the co-production archetype from researchers' perspective. In the latter, the authors disaggregated co-production mechanisms into direct contact, indirect contact, and research publication, focusing on its economic impact (productivity and return) and keeping in the shadow its sustainability impact. Thus, this study concurrently examines KIT and KIP performance, piloting knowledge-based theory from the knowledge management literature to the agri-food context.

Other research challenges have been summarized as the "classical" challenges of knowledge and innovation evaluation that is, the time lapse between research output and impact on the society, attribution problem of impact on resources (Pedersen and

Hvidtfeldt, 2023), and complexity of the innovation process (Douthwaite et al., 2017). To unfold the latter, we rely on two techniques identified from the literature—temporality and participatory approach. In contrast to snapshot evaluation, the temporal factor comprises running continuous evaluation at the beginning and throughout the research project. When talking about the participatory approach, Klerkx et al. (2012) accentuated the importance of engaging various actors in the evaluation process to identify the problems faced, better understand the situation produced, and develop metrics to address it. This approach involves shifting the role of researchers from experts doing research for end-users to facilitators working with end-users. This study unshadows the complexity and time-lapse issues by 1) covering seven years of the two research projects, 2) engaging various actors in the evaluation process, and 3) including diversified proxies of KIM (researcher as an expert in KIT and researcher as a facilitator in KIP) (Figure 1). Relying on Donaldson's model, Douthwaite et al. (2017) built on the theory of change and combined two strategies—evaluation of programs based on other studies and using a prior theory. This study relies on the knowledge-based theory and combines two strategies: gathering information from staff and actors related to the project and using a prior theory (Donaldson, 2007). Although this analysis sheds light on the attribution challenge raised by Pedersen and Hvidtfeldt (2023) by investigating the relationship of KIM as a "means" and sustainability impact as an "end" and includes productive interaction as a variable, we believe that this issue remains obscured in this study due to data scarcity.



Adapted from Klerkx et al. (2012) and Douthwaite et al. (2017)

Figure 1. Characteristics of the study based on the complexity-aware framework

3. Theoretical framework

The concept of knowledge has been a prevalent theme in distinct research dogmas, remarkably in organizational learning, managerial cognition, and management of technology. First, when theorizing about knowledge at the institutional level, the resource-based view speculates that a firm is founded by a "unique bundle of idiosyncratic resources and capabilities." However, the knowledge-based view, an outgrowth of the resource-based view, extends the classic boundary of strategic management and highlights knowledge as the "most strategically important firm's resources" (Grant, 1996:110). Second, when positing knowledge at the project or impact level, various theories have been applied such as the theory-based evaluation, also known as the theory of change, logic modeling, or impact pathway analysis (Morton, 2015), and, at the micro level, the theory of planned behavior (Hill et al., 2017). As our focus is on KIM, we develop the scope of analysis following the knowledge-based theory developed by Grant (1996).

The knowledge-based theory refers to the importance of knowledge not only to its characteristics as a resource but also to its capability to be replicated, transferred, and transformed (Grant and Anupama, 2022). One of the main challenges of knowledge mechanisms is the transferability issue, which is important to be performed intra- and inter-institutionally. As conceptualized by Grant (1996), transfer requires knowledge channeling between a transmitter and recipient, mostly contingent upon absorptive capacity. Hence, we anticipate that KIT tends to apply diverse transferability channels, that is, the length and application of distinctive KIM activities, to enhance the absorptive capacity of the actors. Regarding co-production, it entails coordinated effort and specialized input of knowledge from different actors (Grant, 1996). Hence, we postulate that KIP tends to rely on engagement, that is, the number of actors participating in KIM activities, to enhance the coordination process and the knowledge input.

Hypothesis 1 (H1): KIT tends to rely on the diversity of KIM activities

Hypothesis 2 (H2): KIP tends to rely on engagement during KIM activities

According to Bacon et al. (2020), categorizing and analyzing tacit versus explicit types of knowledge facilitate the understanding of KIM. The knowledge-based theory provides a framework to grasp how explicit or tacit knowledge is organized, presented, and utilized within a knowledge-based system. As mentioned previously, this study garners evidence to clarify the different performances of the "know about" (explicit) and "know-how" (tacit) of knowledge. Recently, a synergetic relationship between knowledge, impact, and sustainability has been revealed by scholars. Dolgonosov (2016) and Chatterjee et al. (2018) extrapolated the interconnection between knowledge and society by examining their nexus from a sustainability perspective in the agri-food sector. It is argued that due to its nature, explicit knowledge tends to have a greater ease of translation, transfer, and impact in comparison to tacit type. However, according to interactionalist philosophy (Cook and Brown, 1999), explicit and tacit knowledge has to be jointly integrated. They tend to interact (Kayes, 2002:145) to guarantee better performance and accomplish the prospected objective or impact. Therefore, we propose the following:

Hypothesis 3 (H3): Both explicit and tacit KIM are associated with sustainability performance.

4. Methodological framework and research design

4.1. Method

Alternative methodologies are proposed to evaluate KIM, comprising the mixed-method approach, comparative case studies, and multi-tiered evaluation (Bell et al., 2011). This study follows the recommendation of Hamdoun et al. (2018) and Wehn and Montlvo (2018) by combining quantitative and qualitative data and applying formative and participatory approaches for data collection. The formative evaluation provides the foundation of KIM implementation (Roux et al., 2010) and the identification of its indicators from reports, document review, and peer review. Regarding the sustainability proxies, we apply participatory design, which includes the engagement of stakeholders, to establish a bottom-up method. This tool relies on actors involved in KIM processes, both KIT and KIP, to evaluate sustainability pillars (Coombs and Meijer, 2021).

4.2. Empirical analysis

The empirical analysis relies on a micro-level approach to examine KIP and KIT activities in reference to three parameters—diversity, engagement, and impact. For the diversity parameter, we used the Shannon index to analyze the performance of explicit and tacit KIP and KIT in each case study. Alternatively, iginally developed by Shannon (1948), this index is commonly implemented to measure species' diversity in ecological research. It accommodates both the richness (number of species) and evenness (equitability of individuals) of a sample (Evert, 2012). Similar to Olmos-Peñuela et al. (2014) and Iorio et al. (2017), the diversity parameter in this study represents the number of different activities through which KIM has been employed. Therefore, the Shannon diversity index is calculated using the following equation:

$$Shannon\ diversity\ index\ = -\sum_{i=1}^{N} p_i log p_i \quad (1)$$

where $i = 1$ to N represents the number of different KIM activities realized within the project, and p_i captures the share of equivalent hours that researchers allocate to the i-th KIM activity in a regular year. p_i is calculated as the ratio of hours dedicated to each type of activity over the total hours of all KIM activities. The Shannon index ranges from zero to infinity. When one type of KIM activity predominates, the value of the Shannon index is low, indicating a high degree of task concentration. In contrast, a high value of the Shannon index occurs when various types of KIM are performed, reflecting a high degree of task diversification (Olmos-Peñuela et al., 2014; Llopis et al., 2018).

Regarding the engagement parameter, the index reflects the intensity of researcher–participant engagement in different types of KIM activities. The weighted average level of all KIM activities and participants involved in the project is computed. We start from the information at the individual level about researchers' engagement and then use this information to establish the global effort at the project level throughout the research period. The engagement index ranges from 0 to 100. A higher engagement value reveals higher researcher–participant engagement in KIM activities. The following equation has been applied:

$$Engagement = \sum_{i=1}^{N} (p_i \times RS_i/N) \times 100 \quad (2)$$

where p_i is the frequency of researcher–participant engagement within the project context in different KIM activities; RS_i is the representativeness score of participants' category i, calculated as the number of participants engaged in a specific KIM activity i; N is the total number of participants involved in the total KIM activities during the research period. Both indices defined above are constructed using the same KIM activities.

For the impact parameter, we build on the quality function deployment principle to synthesize comparative figures between KIP and KIT as weighted performance at KIM and sustainability levels, respectively. The following equations are used:

$$I = \sum(\mathrm{KIP}_i/\mathrm{KIM}_i) \times 100 \text{ and } J = \mathrm{KIP}_i \sum SI_j \quad (3a)$$

$$I = \sum(\mathrm{KIT}_i/\mathrm{KIM}_i) \times 100 \text{ and } J = \mathrm{KIT}_i \sum SI_j \quad (3b)$$

where I is the measure of performance at the KIM level, representing the weights attributed to KIP_i knowledge co-production or KIT_i knowledge transfer, calculated as the equivalent hours realized within each KIT_i or KIP_i over the total hours of KIM_i activities carried during the case study. J is the measure of the relationship between KIP_i or KIT_i and SI_j sustainability performance. It is calculated as the sum of pi multiplied by each value assigned by the stakeholders to the six sustainability pillars j (i.e., economic, socioterritorial, environmental, health, capacity building, and political).

4.3. Case study and data collection

We selected two case studies from a Spanish institute of agri-food research and technology that focuses on internal research performance evaluation (needs, audits, and formative assessment) (Turner et al., 2022). Both cases apply similar KIM activities, but they tackle different industries in the agri-food sector (rice industry versus almond industry) and exhibit distinctive inputs and outputs (educational toolkit versus innovation method). These dissimilarities represent one of the reasons for the case selection, which can demonstrate whether KIM performance varies or remains static in these two industries. The second rationale of the case choice is to build on two components of the impact model of Douthwaite et al. (2017)—the capacity development pathway (Case study 1), and the technology development and adoption pathway (Case study 2).

The system approach in the agri-food sector comprises a nexus between actors (organizations, institutions, and individuals) and strategies (products, processes, and policies) interacting through knowledge mechanisms (interaction, access, share, and exchange) to develop innovation. Based on the model of Faure et al. (2019), this study covers the realization phase (from 2013 to 2016), that is, the introduction, operation, and implementation stage, and the dissemination phase (from 2017 to 2020), that is, the communication and diffusion stage of Case studies 1 and 2.

Through the "sustainable practices program," Case study 1 develops sustainable strategies for the rice industry in Catalonia. The eco-friendly practices encompass land and water management and efficient application of pesticides and fertilizers. The scientific output of this project is an educational toolkit for sustainable agricultural practices. It relies on different KIM activities to enhance the skills and management capacity of rice producers. Case study 1 reveals an implicit impact of an improvement in the cost-effectiveness of rice cultivation, optimization of resource allocation, and reduction of the detrimental effects of agricultural practices on the ecosystem (waste management, water management, and pesticide usage). Based on archival data and project reports, Figure 2 displays the output, tools, outcome, and impact of Case study 1.

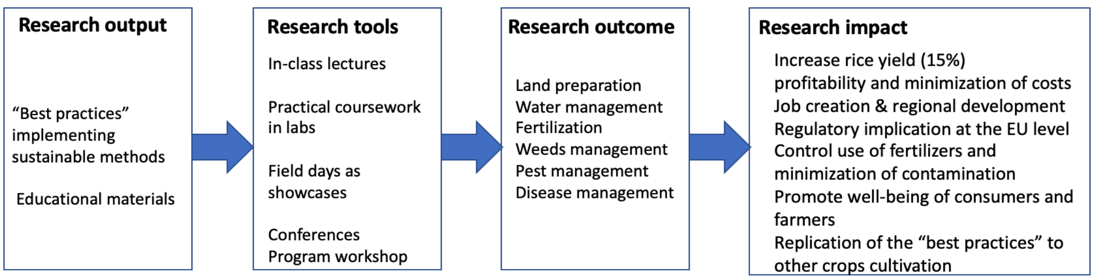


Figure. 2 Application of research impact framework to Case study 1

Through "the genetic breeding program," Case study 2 develops new crossing methods of almond cultivars. Its outcome is described as an innovative program to improve the productivity and economic sustainability of the almond industry in Catalonia. The impact of Case 2 can be summarized as quality assurance according to the European Union benchmark and enhancement of the agronomic characteristics (absence of double-kernel nuts, reducing worm and bird damage, and lower aflatoxin contamination) (Chams et al., 2023). Based on archival data and project reports, Figure 3 summarizes the output, tools, outcome, and impact of Case study 2.

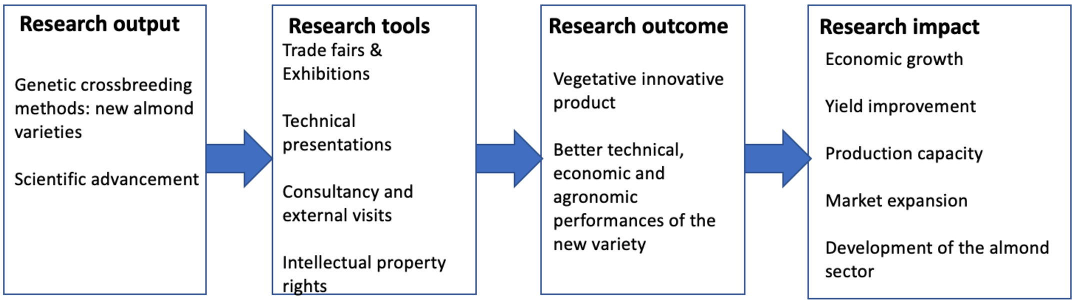


Figure. 3 Application of research impact framework to Case study 2

For KIM evaluation, we rely on a database spanning from 2013 (the realization stage of the projects) to 2020 (7 years of the projects lifetime). The rationale behind this selection is to make sure that there is sufficient data to reveal the progress of KIM performance rather than to reflect its snapshot evaluation (Douthwaite et al., 2017). In addition, to be able to conduct a comparative analysis, we opt for this timeline, which is a joint period for both case studies. The KIM indicators were identified and developed before the launch year of the projects. The data are mainly gathered from standardized questionnaires and available project documents. Structured content analysis of the project reports has been performed to collect information related to the type, number, and length of the offered activities, number of participants, and participants' valuation. We conducted three interviews with program coordinators and technology transfer managers to classify and segregate KIM mechanisms. Then, six KIM proxies were clustered in four archetypes—*explicit KIP* includes conferences (EKIP1) and technical workshops (EKIP2); *explicit KIT* comprises technical training (EKIT1) and sectorial training (EKIT2); *tacit KIP* includes external and field visits (TKIP1); and *tacit KIT* comprises consultancy (TKIT1) (Table 1). As these archetypes have idiosyncratic attributes and rely on distinct knowledge channeling, we intend to depict the difference in their performances in terms of research diversity, engagement, and sustainability.

To identify the sustainability proxies, content analysis and data reduction techniques of 32 case studies were performed in 2017. To mitigate reporting bias, we selected these case studies from different research institutions in the agri-food sector in Spain. The questionnaire is built on a set of indicators and subindicators that measure six pillars of sustainability—economic, socioterritorial, health, environmental, capacity building, and political. A standardized survey was distributed to 78 participants who were part of the stakeholder network and involved in the two case studies. To reduce self-evaluation biases and subjectivity issues, researchers and nonresearchers participated in the stakeholder survey. The final sample comprises 36 stakeholders distributed as follows: 2 project coordinators, 2 co-partners, 9 intermediary actors, 7 technical support, and 16 end-users. We asked the respondents to rate the relevance of each sustainability indicator on a Likert scale ranging from 0 (not important) to 10 (very important). The assigned score represents the average score of all the actors for each sustainability pillar.

Table 1. KIM activities: Categorization of explicit and tacit KIT and KIP

Activity	Transfer vs Co-production			Definition
Explicit Knowledge				
Conferences	System learning approach	KIP: bidirectional	EKIP1	System/advice service for knowledge dissemination and diffusion (business and industrial sectors)
Technical Workshops	System learning approach	KIP: bidirectional	EKIP2	Activities orientated to agri-food actors that is, context application at national and international levels for best practices and sectorial advice
Technical Training	System learning approach	KIT: unidirectional	EKIT1	Learning activities such as formalized courses for professional and industrial groups
Sectorial Training	System learning approach	KIT: unidirectional	EKIT2	Specialized training formation tailored to socioeconomic agents' needs (farmers and end-users of the sector)
Tacit Knowledge				
External and field visits	Application of knowledge	KIP: bidirectional	TKIP3	Fields work and showcases targeted to the sector at national and international levels, including cluster programs, cooperatives, government delegation, and private firms
Consultancy	Application of knowledge	KIT: unidirectional	TKIT3	Meeting points as experts or references for national and international agencies and public policymakers at institutional, national, and international levels

Source: own compilation based on archival data from the research institution

5. Results and discussion

Our empirical findings accentuate the differences in the performance of KIT and KIP archetypes. These discrepancies are portrayed at three aspects—institutional, case study, and sustainability levels.

5.1. KIM at institutional level

Combining the figures of both case studies, we start first by analyzing KIM at the institutional level, examining its variation on an annual basis from 2013 to 2020. Table 2 demonstrates that the overall KIM diversity and engagement parameters are the highest in the first two years of the realization phase (2013 and 2014) and the last year of the dissemination phase (2019). During the realization stage of the projects, KIT and KIP had the same diversity score. However, driven by explicit knowledge (sectorial training EKIT2 in 2013 and technical training EKIT1 in 2019), the subscores of the archetypes of KIM and KIT mechanisms have slightly higher diversity parameters than KIP mechanisms, except for 2014 (external and field visits TKIP1). This provides partial support to H1. Regarding the engagement parameter, the analysis at the institutional level provides mixed results. While KIT had a higher engagement parameter in 2013 (realization phase), KIP scores were higher in 2014 and 2019 (realization and dissemination phases). Thus, H2 cannot be confirmed. However, we infer that whether transfer or co-production mechanisms are applied, the tacit type (consultancy TKIT1 and external and field visits TKIP1) leads in terms of engagement between the actors involved in KIM activities. From Ryle's classical philosophy, the verdict about explicit and tacit knowledge is that "know-how is a prerequisite of know-that; tacit knowledge comes first, explicit knowledge follows" (Ryle, 1949: 30). However, our results do not affirm Ryle's axiom. They rather enforce the interactionalist view, proposing that the backbones of effective tacit knowledge are grounded in direct observation, close interaction, and participation (Ribeiro and Collins, 2007) and that explicit and tacit knowledge must be used together (Cook and Brown, 1999) to optimize performance. The results shed light on the latter premise, where both types are jointly applied throughout the realization and dissemination period and a rotational superiority is observed between explicit and tacit knowledge on an annual basis, whether through diversity or engagement parameters. Confirming our inference on tacit knowledge and engagement, interactionalist scholars hold that direct interaction between actors over a specific period enhances their system learning and acquisition of knowledge (Hadjimichael and Tsoukas, 2019).

Table 2. Annual KIM diversity and engagement indices at the institutional level

	KIT				**KIP**			
	EKIT1	**EKIT2**	**TKIT1**	**Total**	**EKIP1**	**EKIP2**	**TKIP1**	**Total**
2013								
Hours	62	75	226,45	363,45	43,30	400,50	152,50	596,30
Participants	83	501	7600	8184	171	88	335	594
pi	0,24	0,38	0,21	0,23	0,23	0,57	0,10	0,25
Diversity	0,15	0,16	0,14	**0,15**	0,15	0,14	0,10	**0,15**
Engagement	0,25	2,30	19,05	**4,70**	6,55	8,39	5,75	3,19
2014								
Hours	0	42	176,45	218,45	36	74,60	669,40	780
Participants	0	85	7418	7503	174	32	399	605
pi	0	0,21	0,16	0,14	0,19	0,11	0,45	0,33
Diversity	0	0,14	0,13	0,12	0,14	0,10	0,16	**0,16**
Engagement	0	0,24	15,81	2,59	5,44	0,56	29,52	**4,25**
2015								
Hours	20	48,50	124	192,50	22	0	76,50	98,50
Participants	25	104	5462	5591	792	0	77	869
pi	0,08	0,24	0,11	0,12	0,12	0	0,05	0,04
Diversity	0,09	0,15	0,11	0,11	0,11	0	0,07	0,06
Engagement	0,04	0,45	10,98	1,70	10,54	0	0,45	0,77
2016								
Hours	4	34	150,30	188,30	4	0	33	37
Participants	50	260	4555	4865	60	0	35	95
pi	0,02	0,17	0,14	0,12	0,02	0	0,02	0,02
Diversity	0,03	0,13	0,12	0,11	0,04	0	0,04	0,03
Engagement	0,02	0,91	12,75	1,45	1,33	0	0,81	0,03
2017								
Hours	43	0	102,50	145,50	59	75	280,28	414,28
Participants	119	0	3075	3194	122	40	546	708
pi	0,17	0	0,09	0,09	0,31	0,11	0,19	0,17
Diversity	0,13	0	0,10	0,10	0,16	0,10	0,14	0,13
Engagement	0,63	0	8,94	0,73	5,34	0,60	14,45	2,64
2018								
Hours	14	0	119,85	133,85	10	37,50	99,52	147,02
Participants	91	0	4439	4530	100	6	322	428
pi	0,05	0	0,11	0,09	0,05	0,05	0,07	0,06
Diversity	0,07	0	0,10	0,09	0,07	0,07	0,08	0,07
Engagement	0,11	0	10,64	0,96	1,23	0,07	5,01	0,57
2019								
Hours	112,50	0	204,20	316,70	16	120	184,50	320,50
Participants	305	0	6442	6747	1000	100	239	1339
pi	0,44	0	0,19	0,20	0,08	0,17	0,12	0,13
Diversity	0,16	0	0,14	**0,14**	0,09	0,13	0,11	0,12
Engagement	1,99	0	17,66	3,38	6,28	1,27	2,20	**3,87**

**pi* is calculated as the ratio of hours dedicated to each type of activity over the total hours of all KIM activities.

*Diversity and engagement indices are calculated based on the Shannon index of Equations 1 and 2, respectively.

5.2. KIM at the case study level

The second analysis comprises KIM diversity and engagement at the case study level. We conduct a segregate analysis to compare the effect of KIM in Case study 1, related to the rice industry, and Case study 2, related to the almond industry. Tables 3 and 4 display the results of the comparative analysis of KIM of the two case studies. The results indicate that explicit KIM has a higher Shannon diversity index in both case studies. The degree of diversity is slightly higher for KIM in Case study 2 than in Case study 1, mainly driven by explicit KIT mechanism (technical training EKIT2). Consistent with the finding at the institutional level, H1 is supported. Regarding the engagement indicator, tacit KIM reveals higher values in both case studies. The intensity of engagement is slightly higher in Case study 1 than in Case study 2 and is mainly driven by the tacit KIT mechanism (consultancy TKIT1). Similar to the analysis at the institutional level, the case study analysis does not provide evidence to support H2. This implies that whether through tacit or explicit knowledge, the KIT archetype is the pivotal mechanism applied in both the almond and rice industries. As an educational toolkit, Case study 1 tends to prioritize engagement that is, transferring and transmitting knowledge to a higher number of participants through tacit KIT. In this case, KIM mainly aims to transfer the "know-how" of sustainability practices to a higher number of end-users. As an innovative technique, Case study 2 tends to prioritize diversity that is, transferring and transmitting knowledge through various KIM channels via explicit KIT. In this case, KIM essentially aims to diffuse the "know about" of innovative crossbreeding methods. Ting (2023) conveyed that knowledge transfer is perceived as the stimuli of understanding, innovation, and partnership, as well as a dynamic system to build an institutional culture to enhance efficiency and performance. Similarly, scholars have revealed that transfer mechanisms are enablers of individual and institutional performances (Tsoukas, 1996;

Ambrosini and Bowman, 2001), such as Case study 1, and a facilitator of new product development (Bierly et al., 2009), such as Case study 2. Overall, the diversification strategy, that is, conveying knowledge through multiple channels, tends to be more recommendable than the concentration strategy, that is, conveying knowledge through a single channel (Landry et al., 2010).

Table 3. KIM diversity and engagement (Case study 1)

		Hours	***pi***	**Participants**	**Diversity**	**Engagement**
Explicit KIM						
Conferences	EKIP1	444	0,297	1942	−-0,361	10,275
Technical workshops	EKIP2	300	0,201	455	−0,322	1,627
Sectorial training	EKIT1	664	0,444	2671	−0,36	21,135
Technical training	EKIT2	87	0,058	545	−0,166	0,565
		1495	1	5613	1,209	33,602
Tacit KIM						
External & field visits	TKIP1	55	0,091	213	−0,218	0,129
Consultancy	TKIT1	550	0,909	14852	−0,087	89,624
		605	1	15065	0,305	**89,752**

Table 4. KIM diversity and engagement (Case study 2)

		Hours	***pi***	**Participants**	**Diversity**	**Engagement**
Explicit KIM						
Conferences	EKIP1	309	0,118	3732	−0,252	5,829
Technical workshops	EKIP2	751	0,286	304	−0,358	1,154
Sectorial training	EKIT1	417	0,159	1487	−0,292	3,134
Technical training	EKIT2	1151	0,438	2005	−0,362	11,665
		2628	1	7528	**1,263**	21,782
Tacit KIM						
External & field visits	TKIP1	1952	0,489	2486	−0,35	2,119
Consultancy	TKIT1	2038	0,511	54915	−0,343	48,866
		3990	1	57401	0,693	50,984

5.3 KIM and sustainability in a nutshell

Tables 5 and 6 reveal the relationship between "means" KIM and "end" sustainability pillars for each case study. First, we analyze our data at the KIM level and then at the sustainability level. Our empirical findings reveal that KIT activities (sectorial training EKIT1 and consultancy TKIT1) predominate the highest portion of KIM mechanisms in Case study 1. Both KIP (external and field visits TKIP1) and KIT (consultancy TKIT1) are the prevailing KIM activities applied in Case study 2. Similarly, the results demonstrate that while only tacit knowledge takes the lead in KIM mechanisms in Case study 2, both tacit and explicit types are prevalent in Case study 1. In relation to the impact model of Douthwaite et al. (2017), we conclude that both tacit and explicit archetypes tend to be applied in the capacity development pathway, that is, Case study 1. However, for the technology development and adoption pathway, that is, Case study 2, only tacit knowledge is integrated.

At the sustainability level, although KIM mechanisms are considered a complementary tool to translate scientific outcomes into societal contributions, their impact is unevenly distributed across the sustainability pillars. In Case study 1, both explicit and tacit knowledge has a higher relationship with health and capacity building pillars, through KIT channels. However, in Case study 2, tacit knowledge is mainly associated with economic and socioterritorial pillars, through KIT and KIP activities, supporting H3. In Case study 1, described as an educational toolkit for sustainable practices in the rice industry, explicit knowledge through training activity is applied as an instrumental approach to build individual competence, both internally and externally. As argued by Nguyen et al. (2023), training is a key component to initiate, adapt, and cope with change. It is an organizational process usually adapted not to coax actors to learn but rather to establish a learning culture of better performance and inclusion of technology.

In contrast, in Case study 2, classified as an innovative technique in the almond industry, tacit knowledge through consultancy services is practiced to accommodate economic growth and market expansion. The latter is confirmed by Link et al. (2007) and Grimpe and Fier (2010), who emphasized the importance of the outcomes of informal interactions, including consulting practices.

Shedding light on the debate about KIT and KIP in the knowledge management literature, we infer that "no one size fits all." De Jong et al. (2022) emphasize "productive interactions" to ameliorate societal impact assessment at the organizational level. Bilateral learning between actors (D'Este et al., 2018) and co-production (Arnott et al., 2020) improve the dynamic twist between scientific and sustainability impact. In contrast, Fini et al. (2018) revealed that the transfer mechanism influences economic development and societal challenges. Due to these mixed findings and lack of consensus, we examine KIM mechanisms by including both KIT and KIP activities. In our sample, KIT tends to slightly outperform at the KIM and sustainability levels. However, we agree with the interactionalist's notion of viewing not only explicit and tacit archetypes *in tandem* (Athanassiou and Douglas, 1999) but also KIP and KIT mechanisms. The co-occurrence of knowledge mechanisms *in bundle*, such as KIP and KIT, in this study or maybe other activities such as knowledge sharing or exchange, might enhance the evaluation approach of research as a "means" and impact as an "end."

6. Conclusion

This study investigates the performance of KIT and KIP (explicit and tacit) in terms of diversity and engagement parameters and their relationship with sustainability pillars. Combining qualitative and empirical analysis, we propose an approach to better understand KIM activities in two different types of research projects in the agri-food sector. Distinguishing between KIM proxies and knowledge archetypes, this study applies the knowledge-based theory in the knowledge management literature to agri-food research. First, the analysis reveals that, at a broader scale, the explicit KIT mechanism tends to adopt a diversification approach in learning activities. Second, the tacit type of knowledge tends to emphasize engagement between the actors to ensure the efficiency of KIM. Third, segregating knowledge channels and archetypes tends to improve the understanding and conceptualization of KIM.

To elaborate on the theoretical implication, this study builds on the knowledge-based theory and avows Grant's view on knowledge as a strategic resource for institutional capability and competitive advantage. Although distinct, tacit, and explicit knowledge is jointly performed in the two case studies and agree with the interactional premise (Hadjimichael and Tsoukas, 2019), their performance varies in terms of diversity, engagement, and sustainability, but overall they tend to complement each other. Regarding the practical implication, understanding and evaluating KIM mechanisms and their impact on society has key value for reaping public investments in the research community (Fini et al., 2018). Research institutions are encouraged to capitalize on different types of KIM activities and accommodate the inclusion of various actors. Various KIM channels tend to enhance the apprenticeship process and equip end-users in the agri-food sector with adequate capability to adjust to the changing environment and promote sustainability performances. Including diverse actors (both participants and evaluators of KIM and sustainability) is a promising strategy to convert the produced knowledge into policies and regulations.

There are some limitations of our analysis, which are mostly related to the sampling and data collection of this study. The limited participation of stakeholders' networks in the evaluation process precludes performing statistical tests to strengthen the evidence of the correlation between KIM and sustainability and to improve its external validity. Due to data scarcity, this study lacks a segregated analysis at the actor level that is, researchers, end-users, policymakers, technicians, and intermediaries. To alleviate these limitations, future research may consider replicating this analysis in different industries or sectors, incorporating more case studies. The performance of knowledge is revealed in three facets—diversity, engagement, and sustainability. Different parameters can be considered such as financial performance, innovation, and emotional or artificial intelligence. There is room to perform regression analysis with a panel dataset to understand the nexus between KIM and sustainability and to overcome the attribution challenge of impact evaluation. We recommend that knowledge evaluation and impact assessment scholars should avoid investigating knowledge mechanisms in isolation but explicitly distinguish between its channels, such as exchange, transfer, co-production, diffusion, and sharing.

Table 5. KIM and sustainability performance (Case study 1)

Sustainability Pillars	Stakeholder Evaluation	KIM		% KIM	% Sustainability
Economic	6,37	Conference	EKIP1	21,14	16,13
Socioterritorial	6,3	Technical workshops	EKIP2	14,29	15,95
Environmental	6,98	Sectorial training	**EKIT1**	**31,62**	17,67
Health	7,04	Technical training	EKIT2	4,14	**17,82**
Capacity Building	7,7	External & field visits	TKIP1	2,62	**19,49**
Political	5,11	Consultancy	**TKIT1**	**26,19**	12,94

Table 6. KIM and sustainability performance (Case study 2)

Sustainability Pillars	Stakeholder Evaluation	KIM		% KIM	% Sustainability
Economic	6,79	Conference	EKIP1	4,65	**22,08**
Socioterritorial	6,12	Technical workshops	EKIP2	11,35	**19,90**
Environmental	3,27	Sectorial training	EKIT1	6,31	10,63
Health	4,24	Technical training	EKIT2	17,40	13,79
Capacity Building	5,92	External & field visits	**TKIP1**	**29,50**	19,25
Political	4,41	Consultancy	**TKIT1**	**30,80**	14,34