Analysis of factors affecting cross-boundary knowledge mobilization in agri-food supply chains: An integrated approach

Abstract Agri-food supply chains (AFSCs) link produce from farm-to-fork. Over 80% of businesses operating in AFSCs are small and medium-sized enterprises (SMEs) that lack the necessary resources to make knowledge accessible and usable to other stakeholders. To enhance AFSCs' performance, we adopt an integrated approach to analyze factors affecting knowledge mobilization (KMob) across boundaries. Thematic analysis of data collected from interviews reveals 11 KMob factors. We apply total interpretive structural modeling (TISM) to identify influential relationships among these factors, and fuzzy cross-impact matrix multiplication applied to classification (MICMAC) to distinguish each factor's role in the system. Our results complement previous studies in showing that power and national culture are critical KMob factors with the greatest ability to elicit other factors. Our study has implications for SME management teams, focal companies of AFSCs and governments.

Keywords: Knowledge mobilization, boundary-crossing mechanisms, knowledge boundaries, total interpretive structural modeling, fuzzy MICMAC analysis, agri-food supply chains

1. Introduction

Sir Francis Bacon (1597) proposed that - "knowledge is power", and more than 400 years later, knowledge has become one of the most critical resources for business improvement, competitive advantage, productivity and flexibility (Zheng et al. 2010; Liu. 2020; Vaio et al. 2021; Zhao et al. 2021). Knowledge related strategic concepts, such as tacit, explicit and organizational knowledge and its management, spillover, mobilization and application, have also attracted significant scholarly attention as elements enabling organizations to survive in competitive environments (Gaviria-Marin et al. 2019; Oliva and Kotabe. 2019). In the knowledge economy era, businesses need to leverage the value of knowledge through a range of KMob activities (Oyemomi et al. 2019), for example by building partnerships with external knowledge generation centres to increase their innovation potential, or forming communities of practice to facilitate KMob (Ivcovici et al. 2022).

The concept of KMob originates from the idea that a range of methods must be used to build stronger connections between research, policy and practice (Van Biljon. 2020; Olan et al. 2021; Zhao et al. 2023). The various organizational roles responsible for fostering communication and collaboration between teams, which further enable KMob, include knowledge mentors, brokers, taxonomists, content editors and gatekeepers (Venkitachalam and Bosua. 2014). In a supply chain ecosystem, KMob between organizations depends on a range of factors, such as intra- and inter-organizational social capital, trust, power and technology adoption (Olan et al. 2022a). KMob is a process of building relationships to make knowledge accessible and usable by people who need particular knowledge to inform their practice (Handoko et al. 2018). Gosain (2007, p. 255-256) describes it as "the extent to which people needing knowledge for specific tasks can be efficiently matched with counter-parties possessing that knowledge". Effective cross-boundary KMob, which is a prerequisite for effective organization management, requires continuous investment in KMob practices (Chen et al. 2018). At the individual level, interpersonal trust, reciprocal relationships and motivation and intention to share knowledge may influence KMob practices; at the organizational level, management support, organizational culture and structure and rewards affect KMob practices; at the technological level, software and technological applications at both individual and organizational levels are critical factors to KMob performance (Ali et al. 2019; Singh et al. 2021). As competition has developed between supply chains rather than between companies, companies' ability to create and mobilize knowledge within networks of interconnected companies can enhance the performance not only of individual companies but also of the whole supply chain (Cai et al. 2013; Wang and Hu. 2020).

Agri-food supply chains (AFSCs) are interconnected networks of individuals and organizations involved in the production, transportation, distribution and consumption of agri-food products (Zhao et al. 2020; Toorajipour et al. 2021; Gebhardt et al. 2022). Companies in AFSCs rely on efficient KMob and coordination to create value. This is because agri-food products are perishable, seasonal, and vary in quality and quantity, placing additional pressure on AFSC managers seeking to deliver healthy, nutritious and high-quality food to final consumers (Olan et al. 2022b). Facilities such as cold storage, refrigerated trucks and traceability technology must be deployed to ensure food security; relationships need to be built with agri-food institutes, charity organizations, and supermarkets to reduce food waste and losses; and the latest knowledge on agri-technology and farming must be mobilized by various AFSC stakeholders. These factors make AFSCs even more complex. Therefore, organizations involved in the flows of materials, finance and knowledge within AFSCs must not only build close relationships with other network members, but must also acquire tacit and explicit knowledge from interactions with other AFSC partners (Marra et al. 2012; Cerchione and Esposito. 2016). In this respect, Boshkoska et al. (2019) have developed a decision support framework to improve cross-boundary KMob, and Gardeazabal et al.'s (2021) agricultural knowledge management (KM) system aims to distribute explicit and tacit knowledge among AFSC stakeholders. Thus, KMob is important for AFSCs and associated organizations, as it facilitates organizational growth and reduces costs by circulating knowledge among partners, and increases the whole AFSC's capacity for innovation (Bhosale and Kant. 2016a). Consequently, it is critical to understand the factors shaping the KMob performance of organizations within AFSCs (Handoko et al. 2018). Previous studies have analyzed managerial, relational, environmental and social-political factors influencing supply chains' KMob activities (Cerchione and Esposito. 2016; Perez-Salazar et al. 2019). However, other types of factors, such as human, technical, and cultural factors (Nisar et al. 2019), which also play a crucial role in KMob within supply chains (Breite and Koskinen. 2014; Hock-Doepgen et al. 2021). Furthermore, existing research on KMob in supply chains focuses mainly on manufacturing and engineering industries, with relatively little focus on agri-food industries (Bhosale and Kant. 2016b; Schniederjans et al. 2020). Advanced mathematical models, simulation techniques, and fuzzy set theory are needed to analyze KM issues in AFSCs (Bhosale and Kant. 2016b; Perez-Salazar et al. 2019). Our investigation helps to address these gaps in the literature.

This study uses fuzzy modeling techniques to analyze factors influencing KMob crossing boundaries by SMEs involved in AFSCs. In the agri-food sector, SMEs, which account for more than 80% of businesses, are characterized by a lack of financial and human resources (Chen et al. 2017; McDougall et al. 2022). However, the increasingly interconnected and interdependent business environment requires them to strengthen their KMob in order to maintain competitive advantage (Ali et al. 2019). Our study has three main objectives: (1) to identify factors that influence KMob crossing boundaries by SMEs within AFSCs; (2) to explore interactions between the identified factors; and (3) to define key factors with the greatest ability to elicit other factors in the system. To address the first objective, we comprehensively reviewed the literature on factors affecting KMob crossing boundaries, and consulted relevant experts from the agri-food industry. To address the second objective, we adopted TISM, which has been widely used to build interrelationships among elements, factors, enablers, or barriers by allocating them to different layers of a framework and linking them with experts' interpretations (Mathivathanan et al. 2022; Zhao et al. 2022). The third objective was addressed using fuzzy MICMAC analysis, which may enhance sensitivity analyses compared with non-fuzzy MICMAC (Zhao et al. 2020).

This study makes several contributions to theory and managerial practice. In relation to theory, we identify 11 KMob factors that contribute to KMob crossing boundaries, including rarely mentioned factors such as financial resources and continuous improvement. Existing studies, including reviews of the literature on knowledge-sharing enablers and inhibitors (Anwar et al. 2019; Rahman et al. 2020) and empirical studies of factors influencing knowledge and information sharing (Fu et al. 2017; Maskey et al. 2020), neglect the role of continuous improvement and financial resources in improving KMob crossing boundaries. Continuous monitoring and evaluation of KMob practices adopted by individuals, organizations and AFSC stakeholders improves the effectiveness of KMob crossing boundaries. We also provide insights into interrelationships between the 11 identified KMob factors, and find that the key factors are power and national culture. Previous studies prioritizing enablers, factors and elements of knowledge and information sharing similarly identify organizational culture and top management support as key facilitators of KMob (Anantatmula and Kanungo. 2010; Ali et al. 2019; Meher and Mishra. 2019). However, our study goes further in proposing that national culture also influences KMob. Third, we categorize the 11 KMob factors according to their roles in the system. For example, trust and collaboration act as links, and financial resources and government support act as drivers of the system. This study also has implications for the top management teams of agricultural SMEs, focal companies of AFSCs, and regional and national governments in identifying the importance of boundary brokers, marginal actors and collective practices at organizational and supply-chain levels.

In the remainder of this article, in Section 2, we review the literature on definitions of KMob, knowledge boundary types and factors influencing KMob crossing boundaries was conducted. In Section 3, we explain our research methodology, including two data collection methods and three data analysis methods. In Section 4, we present the results of thematic analysis, TISM and fuzzy MICMAC analysis, and in Section 5 we discuss our contributions to theory and managerial practices, before drawing some conclusions and discussing some limitations and future research directions in Section 6.

2. Literature review

In this section reviewing recent developments relevant to KMob, we examine characteristics of agriculture and AFSCs, the literature on KMob models, knowledge boundary types and boundary-crossing mechanisms, factors influencing KMob crossing boundaries, and decision-making methods applied to investigate KMob issues. A theoretical framework is then built to link knowledge boundary types, boundary-crossing mechanisms, KMob factors and AFSCs, and identify current research gaps.

2.1 Characteristics of agriculture and AFSCs

AFSCs differ from other types of supply chains in several respects. First, agriculture integrates science, practical applications and social processes, and thus requires mobilization knowledge and experience across different AFSC stakeholders. For example, agricultural knowledge hubs have been widely deployed to foster partnerships and knowledge exchange among participants (FAO. 2023). Second, the world's farming population is growing older, as younger generations increasingly choose to work in cities. This hinders KMob, as the elderly are recognized as being less likely to absorb new knowledge. Third, more than 80% of businesses in AFSCs are SMEs, who often lack the human and financial resources necessary to deploy technologies to mobilize knowledge. Finally, AFSCs are becoming more complex owing to the need to prioritize food security, safety and traceability for agri-food products. Knowledge is an intangible resource, so its benefits for agri-food production, organization, and AFSCs cannot be evidenced as quickly as deploying technology directly.

2.2 KMob models, knowledge boundary types and boundary-crossing mechanisms

KMob can be simply defined in terms of "four rights": transferring the right information to the right people in the right format at the right time (Levin. 2008; Olan et al. 2022a; Zhao et al.

2023). It is used to facilitate multidimensional, longer-term and purposeful knowledge exchange to link research with practice and policy (Sa et al. 2011). For example, according to Kusumowardani et al. (2022), KMob is critical in enabling AFSC stakeholders to address food waste and losses, especially by sharing knowledge between growers and retailers, and between distributors and retailers. The World Health Organization (WHO) estimates that more than 828 million people worldwide are affected by hunger, a rise of 18% since the outbreak of COVID-19 (WHO. 2022). Similarly, Kayikci et al. (2022b) suggest that blockchain-enabled KMob might help to tackle trust, traceability and accountability challenges of AFSCs. Sharma et al. (2022) address the impact of the COVID-19 pandemic on perishable AFSCs from a KMob perspective. Their results indicate that KMob among AFSC stakeholders positively influences visibility, which in turn accelerates adoption of sustainable practices, and thus further positively affects AFSCs' performance. Facilitating KMob would therefore help to achieve the United Nations Sustainable Development Goal 2 of ending hunger, achieving food security, improving nutrition and promoting sustainable agriculture. Previous research on KMob focusing on linear or one-directional approaches to transform knowledge into action has proved problematic in practice, especially in the context of supply chains involving a range of interacting stakeholders (Chen et al. 2018). Thus, models and frameworks have been proposed to tackle the complexity of KMob in different contexts and settings. For example, Jacobson et al. (2003) propose an understanding-user-context framework to help researchers and others to engage in the KMob process. Graham et al.'s (2006) knowledge-to-action process framework aims to enhance use of research knowledge by practitioners, the public and policymakers. Other models have been developed to increase the effectiveness of KMob across different stages of KM (e.g., knowledge creation, storage, dissemination and implementation) and tackle KMob challenges from the perspectives of various stakeholders, including researchers and policymakers (Sudsawad. 2007). These include a model of knowledge translation developed by the Canadian Institutes of Health Research, the Ottawa model of research use, and the coordinated implementation model. However, the effectiveness of KMob is challenged by knowledge boundaries.

These are barriers, gaps or differences that impede effective knowledge sharing across functions and among experts (Hsu et al. 2014). They arise from various sources, such as sociocultural differences, lack of motivation, weak absorptive capacity or lack of transfer channels (Ferreira et al. 2022). Knowledge boundaries exist between different stages of AFSCs (e.g., farming, processing, distributing and retailing), as participants may lack interest in learning new knowledge, fear innovation, be resistant to change, or lack knowledge of public regulations and policies (Liu et al. 2021). Carlile (2002) classifies knowledge boundaries into three categories based on novelty, specialization and dependence: (1) a *syntactic boundary* refers to absence of a shared syntax, such as lack of a common language, vocabulary or lexicon; (2) a *semantic boundary* refers to lack of common understanding or interpretation, where different interpretations of a common syntax make communication and collaboration difficult; and (3) a *pragmatic boundary* refers to lack of common interests among participants, in terms of scope, consequences and conflicts in knowledge delivery. These knowledge boundaries exist widely among individuals, teams, organizations and communities, posing significant barriers to KMob and hindering coordination and problem solving.

To alleviate problems caused by knowledge boundaries, four boundary-crossing mechanisms (boundary objects, spanners, practice and discourse) have proved effective in improving information processing and developing shared meanings (Carlile. 2004; Belitski et al. 2021). *Boundary objects* are knowledge common to several actors that can be used to improve participants' understanding, thereby facilitating negotiation and knowledge transformation (Carlile. 2002; Carlile. 2004). For example, knowledge repositories, standardized forms and methods, shared artefacts or models (e.g., drawings and prototypes) and maps of interdependence are all widely used as focal points to facilitate shared meanings across different parties (Liu et al. 2021). Kansou et al. (2022) propose three ways to improve KMob effectiveness between AFSC stakeholders: embedding digital objects on the web as a scientific asset, collaboratively developing transferable software by involving experts and AFSC stakeholders, and reskilling food engineers using food models and software in education and training. *Boundary spanners* are middlemen, intermediaries or agents who act as interfaces between individuals, groups and organizations from different domains (Keszey. 2018). They are categorized based on their membership status (Neal et al. 2022): boundary translators have membership of only one party, boundary brokers have membership of two parties involved in the KMob process, and marginal people have membership of multiple parties. Boundary spanners enable knowledge exchange and bridge cognitive gaps between different domains, thereby facilitating evidence-based decision making (Glegg and Hoens. 2016). Practical examples include a university's knowledge extension group, the FAO's agroecology knowledge hub, and the European Commission's knowledge hub on water and agriculture, all of which link researchers, professionals and farmers and foresters. Another means of improving KMob is *boundary practice*, an effective boundary-spanning mechanism that engages agents from different knowledge domains in collective activities (Hawkins and Rezazade M. 2012). Practical examples in the context of AFSCs include social farming and agricultural research institutes' open days. Finally, *boundary discourse* refers to "the content of knowledge that shapes the dialogue among the experts from distinct domains" (Hawkins and Rezazade M. 2012, p. 1807).

2.3 Factors influencing KMob crossing boundaries

Facilitating KMob crossing boundaries should be a priority for supply chain managers. Circulating knowledge cross-functionally enhances inter-organizational connectivity, evidence-based decision-making and coordinated problem-solving for organizations involved in supply chains, and improves supply chains' overall performance (Song et al. 2016). Given the positive effects of KMob crossing boundaries, research has focused on tacit versus explicit knowledge, enablers or barriers, organizational performance, and mobilization of knowledge in different types of relationship such as dyadic relationships (Cerchione and Esposito. 2016; Song et al. 2020). Ali et al. (2019) argue that managers should focus on three dimensions to improve KMob performance: individual, organizational, and technological. Cerchione and Esposito's (2016) detailed framework of managerial, relational, environmental, socio-political, human and cultural, technical and firm-specific factors categorizes factors that influence KM development. Finally, Maskey et al. (2020) propose a typology for categorizing relationship factors, intra- and inter-organizational and environmental factors affecting KMob in supply chains. Relationship factors are important because the effectiveness of KMob depends largely on relationships between supply chain partners (Lee et al. 2010). Trust, commitment and power are frequently mentioned as critical relationship factors (Perez et al. 2010; Costa et al. 2020). Organizational behaviours affecting the KMob process arise internally from activities between departments and divisions (Maskey et al. 2020). Thus, intra-organizational factors including education and training, are considered to be important. Factors such as supply network structures, collaboration and technology deployment are amongst the inter-organizational factors that may facilitate KMob. Environmental factors include government support and national culture (Shah and Ganji. 2017). In clustering factors affecting KMob in supply chains, we follow Maskey et al.'s (2020) recent work on KMob, which takes account of supply chain characteristics such as inter-connected structure into consideration (see Table 1).

Table 1 Factors influencing KMob crossing boundaries

Categorizations	Specific factors	Description	Sources
Relationship factors	Power	Senior manager's involvement, interest and leadership of the process (top-down implementation)	Busse et al. (2017); Amentae et al. (2018); Ali and Gurd (2020)
	Trust	Willingness to share knowledge and information Willingness to accept suggestions, acquire knowledge and act as requested	Amentae et al. (2018); Marques et al. (2020)
	Commitment	Agreement to specific requests or requirements (e.g., confidential information, purchasing agreements).	Taylor (2006); Scholten and Schilder (2015); Solano et al. (2020)
Intra-organizational factors	Training and education	Process of learning and understanding specific skills, technology, knowledge and information	Pearce et al. (2018); Umar et al. (2021)
Inter-organizational factors	Supply network structure	Relationships between stakeholders (personal, vertical or horizontal) Links between stakeholders in the supply chain/community	Busse et al. (2017); Amentae et al. (2018); Umar et al. (2021)
	Collaboration	Cooperation on specific tasks or processes Information sharing and exchange between stakeholders	Wolfert et al. (2010); Kumar (2014); Scholten and Schilder (2015); Marques (2019)
	Technology deployment	Taking advantage of ICT to achieve specific functions or improve effectiveness and efficiency	Lubell et al. (2014); Sener et al. (2019); Serazetdinova et al. (2019)
Environmental factors	National culture	Local culture.	Maskey et al. (2020)
	Governmental support	National or local government providing support in terms of KMob.	Pearce et al. (2018); Maskey et al. (2020)

2.4 Decision-making methods used to investigate KMob issues

Since SMEs have limited access to finance, low research and development expenditure, and low levels of financial inclusion (Yoshino and Taghizadeh-Hesary. 2016), they lack resources to support activities relating to KMob crossing boundaries. In this context, various decision-making methods may be used to investigate KMob issues. For example, structural equation modeling (SEM) has been used to explore the impact of trust on technical exchange and technology transfer in dyadic buyer-supplier relationships (Cai et al. 2013); fuzzy interpretive structural modeling (ISM) has been employed to prioritize supply chain knowledge flow enablers (Bhosale and Kant. 2016a); the fuzzy analytic hierarchy process – technique for order preference by similarity to ideal solution (AHP-TOPSIS) has been used to rank solutions to KM adoption in supply chains (Patil and Kant. 2014); and TISM has been applied to analyze enablers of KM in improving logistics capabilities (Yadav et al. 2020). Table 2 presents analysis of relevant literature.

Table 2 Decision-making methods for exploring KMob issues

Author(s)(year)	Topic	Decision-making methods	Industry
Percin (2010)	Selecting KM strategies that are difficult to imitate	Analytic network process (ANP)	Manufacturing
Kant and Jeenger (2013)	Identification and prioritization of knowledge-sharing barriers	Fuzzy AHP	Not specified
Sharma and Singh (2013)	Modeling individual/group knowledge-sharing barriers	Combination of AHP, ISM and similarity coefficient approach	Engineering
Liu et al. (2014)	Identification and prioritization of critical knowledge to support integrated decisions of global supply chains	ANP	Manufacturing
Patil and Kant (2014)	Identification and prioritization of solutions to KM adoption in supply chains	Fuzzy AHP-TOPSIS	Manufacturing
Bhosale and Kant (2016)	Establishment of interrelationships among supply chain knowledge flow enablers	Fuzzy ISM-MICMAC	Manufacturing
Chen et al. (2017)	Evaluation of KMob framework for lean supply chain management	AHP	Agri-food
Lim et al. (2017)	Exploration of KM in sustainable supply chains	ISM-MICMAC	Textile
Philsoophian et al. (2022)	Examination of the impact of blockchain technology on knowledge sharing in supply chains	SEM	Multiple industries

2.5 Theoretical framework development and identification of research gaps

Based on our literature review, we propose a theoretical framework. Figure 1 for relationships between KMob factors, knowledge boundaries and boundary-crossing mechanisms in the context of AFSCs. KMob across AFSC stakeholders is impeded by three types of knowledge boundaries: syntactic, semantic and pragmatic. Four boundary-crossing mechanisms are deployed by AFSC stakeholders to enhance the effectiveness and efficiency of KMob: boundary spanners, objects, practices and discourses. Successful implementation of boundary-crossing mechanisms depends on various factors in AFSCs that may contribute to KMob, including relationship, intra- and inter-organizational, and environmental factors. Finally, knowledge boundaries and boundary-crossing mechanisms are linked in our framework because the latter can be used to tackle the former.

Based on the detailed analysis of the relevant literature, we identified several research gaps to the research context, research methods adopted and major KMob issues.

First, most existing work on KMob focuses on tacit and explicit knowledge conversion, KMob models, KM process stages and factors influencing KMob within the same organization or communities (Liu et al. 2021). However, few studies address KMob crossing boundaries in heterogeneous contexts, especially in AFSCs involving various stakeholders with different interests and cultural backgrounds. Further research is needed to investigate issues of KMob crossing boundaries in AFSC to overcome barriers between agribusinesses, governments and research institutes.

Second, most existing studies explore supply chain KMob issues using data from manufacturing and engineering industries (see Table 2), both of which play critical roles in the global economy, as confirmed by several literature reviews on supply chain KM. For example, Bhosale and Kant (2016b) show that 36.36% of the articles on the topic investigate issues relating to manufacturing industries, whereas only 3.41% focus on the agri-food industry. Although increasing attention was given to the agri-food industry between 2010 and 2018, Schniederjans et al. (2020) estimate that no more than 2.04% of scholarly publications in this period concentrate on AFSCs' KM issues. Our study aims to fill this gap.

Third, the extant supply chain KM literature is dominated by AHP, SEM, ANP, TOPSIS, ISM and other decision-making techniques (see Table 2). Bhosale and Kant's (2016b) review of 176 peer-reviewed articles on supply chain KM reveals that most analysis has used traditional data analysis techniques, such as SEM, AHP and regression analysis. Other methods, such as TISM, fuzzy set theory and thematic analysis, account for only 1.71% of their selected peer-reviewed articles, indicating another clear research gap. Thus, in our study we adopt an integrated approach to analyze factors influencing KMob crossing boundaries, including semi-structured interviews, thematic analysis, TISM and fuzzy MICMAC analysis.

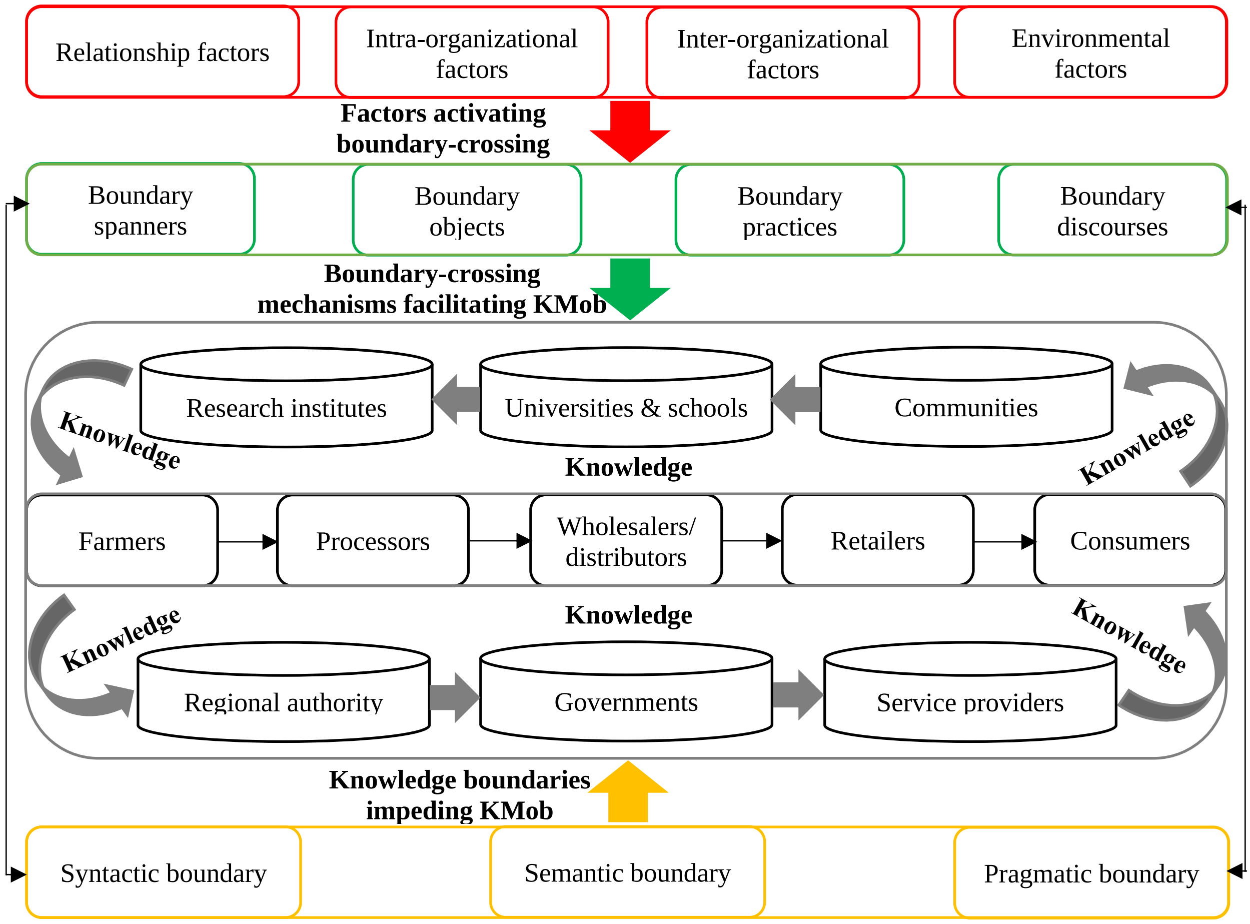

Figure 1 Theoretical framework

3. Research methodology

We employed an integrated approach to analyze factors influencing KMob crossing boundaries by SMEs involved in AFSCs (see Figure 2). This approach has the advantages of allowing data and results triangulation by combining various data sources and methods, and uncovering new insights to stimulate further work (Tashakkori and Teddlie. 2003). Thus, data were collected from multiple sources using different methods to broaden the range, confirm related information, and verify the reliability of data (Eisenhardt. 1989). Data reliability, referring to consistency of data from different resources (Golafshani. 2003), was achieved by conducting a literature review to identify relevant KMob factors, and then interviewing experts from the agri-food industry. These two methods enabled us to identify KMob factors commonly accepted by industry experts. The data collected were then analyzed using three complementary analysis methods: thematic analysis, TISM and fuzzy MICMAC analysis. These methods were employed to produce more convincing results than using a single data analysis method, to gain a better understanding of the investigated issues and obtain more complete evidence, and to alleviate the weakness of each individual method (Shorten and Smith. 2017).

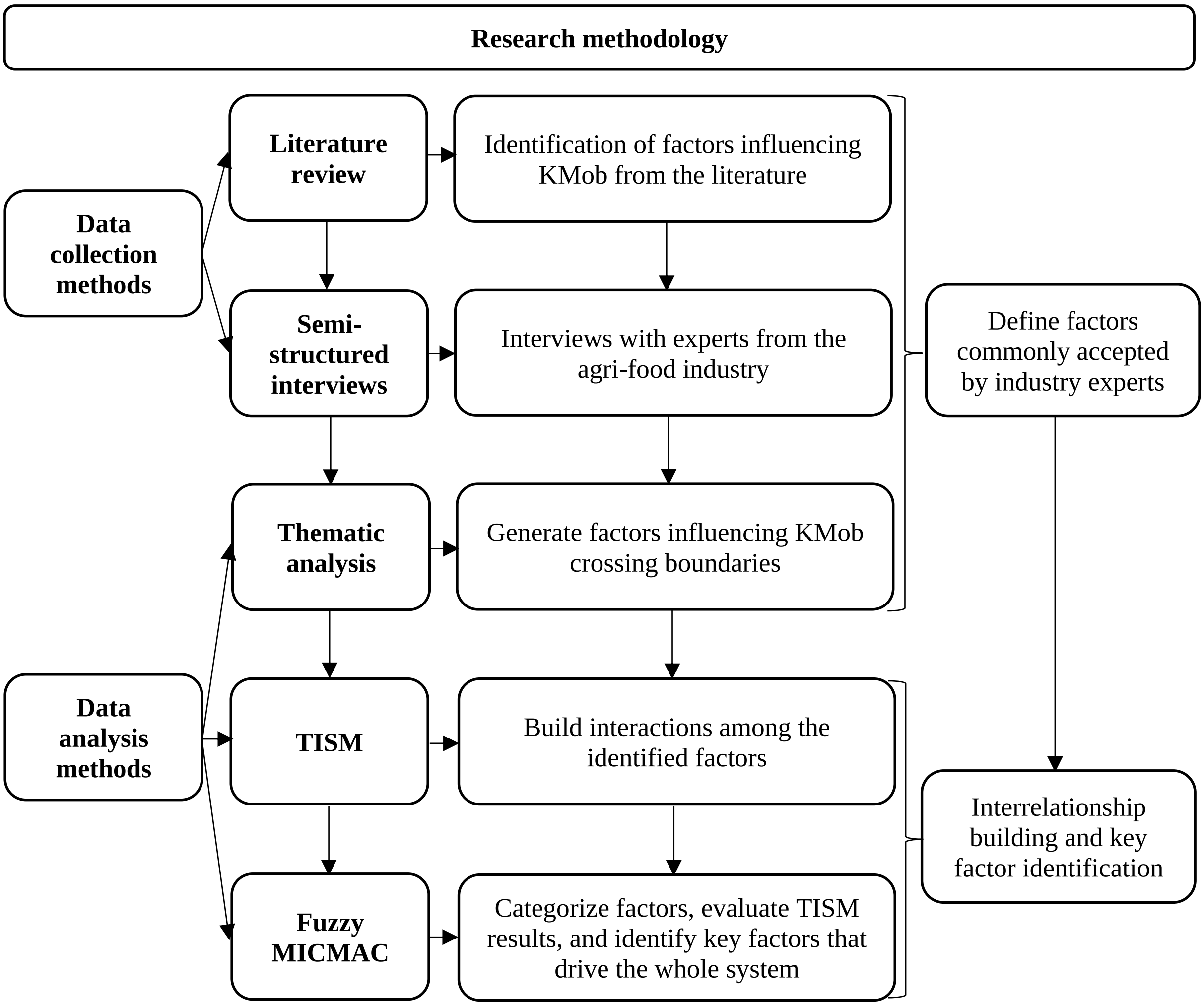

Figure 2 Research methodology framework

3.1 Data collection methods

We collected data from two different sources to achieve data triangulation. Having conducted a comprehensive literature review to identify and categorize factors that might influence KMob crossing boundaries. We then asked experts from the agri-food industry to evaluate those factors. We conducted semi-structured interviews give participants flexibility in their responses using open-ended questions to probe the experts' relevant knowledge and experience (Barriball and While. 1994). Structured or unstructured interviews would have been inappropriate, as the former lack flexibility, while the latter do not constrain participants' responses (McIntosh and Morse. 2015). Furthermore, semi-structured interviews achieve higher response rates than questionnaire surveys, and are more suitable for situations where there is sufficient objective knowledge relating to a particular phenomenon or experience but subjective knowledge is lacking, as in the case of factors influencing KMob crossing boundaries in the agri-food industry (Nisar et al. 2019).

We developed an interview guide (see Appendix 1) to help interviewers and interviewees to focus on the topics and issues under investigation (Zhao et al. 2022). Based on our review of the literature, our guide consisted of five sections, covering participants' backgrounds, factors impacting on successful implementation of KMob, understanding of who can frame and translate knowledge from one domain to another, measures to store and mobilize knowledge, and identification of boundary interactions for KMob. We then conducted pilot interviews with two practitioners from the agri-food industry and two professors in operations and supply chain management (OSCM) to check appropriate topic coverage, language and the schedule of questions. As a result, we made minor modifications to the interview guide to avoid using professional jargon (e.g., boundary objects and boundary spanners) and explain specialist terminology.

Both purposive and snowball sampling were used to collect empirical data. Purposive sampling was initially used to select participants, who met three criteria: respondents had to have over five years' experience of working in the agri-food industry to ensure that they had a deep understanding of agribusinesses; they should have practical experience of participating in or leading knowledge extension or mobilization activities, such as knowledge transfer partnerships; and they should be based in an agri-food SME. SMEs normally have a staff headcount of between 10 and 249, a turnover of between €10 and €50 million, or a balance sheet total of between €10 and €43 million (European Commission. 2003). We interviewed 26 respondents from countries in Europe (France and Italy) and South America (Chile and Argentina). Respondents from these countries were interviewed because we had previously participated in a Horizon 2020 project, and had thereby accumulated social capital in the agri-food industry across these four countries. Our established trusting relationships with AFSC practitioners in these countries enabled us to obtain in-depth knowledge more easily. The respondents covered various roles in AFSCs and were from different backgrounds, with diverse knowledge and insights relating to KMob crossing boundaries, enabling us to have a deep understanding of the phenomenon investigated by asking probing questions. The interviews were recorded with permission. On average, they lasted over 1.5 hours to give respondents enough time to explain their ideas. We analyzed the data within 24 hours, relying on rapid data analysis to identify the data saturation point and determine whether further interviews should be conducted. At the end of each interview, we conducted snowball sampling by asking respondents, "Do you know any other potential respondents who may be interested in participating in this research?" This produced a further three respondents. After conducting 26 interviews, we identified from the transcripts that phrases such as "trust", "training and education", "collaboration and "government support" occurred frequently, and we decided not to conduct further interviews. Detailed information on the SMEs and participants is given in Appendix 2.

3.2 Data analysis methods

We employed three complementary data analysis methods: thematic analysis, TISM and fuzzy MICMAC analysis.

Thematic analysis is a qualitative data analysis method (Braun and Clarke. 2006) widely used in business and management to analyze, identify, describe, cluster and report themes found in data sets (Nowell et al. 2017). It was chosen for this study for several reasons. First, it is particularly useful for generating unanticipated insights by examining different perspectives and highlighting similarities and differences across a data set (King. 2004). Second, it is more flexible than other qualitative analytic methods. For example, conversion analysis and interpretive phenomenological analysis are both tied to specific theoretical frameworks (Braun and Clarke. 2006). Finally, thematic analysis is helpful for summarizing key features of a large data set (Kiger and Varpio. 2020). We used this method to identify themes potentially influencing KMob crossing boundaries from our agri-food industry data.

TISM was then applied to identify influential relationships between the factors that might contribute to KMob crossing boundaries. TISM was chosen over other modeling techniques because it enabled us to produce a hierarchical model of factors and take account of experts' interpretations of links between factors (Jena et al. 2017). Other modeling techniques, such as ISM, SEM and graph theory, can be used to build relationships between constituents of a system, but were inapplicable in this study. For example, ISM and SEM do not explain why relationships exist between elements (Kayikci et al. 2022a), and graph theory has limitations in determining directions between elements (Mangla et al. 2018). We also chose TISM because fewer experts are required to build a TISM model compared with other techniques, such as ANP which relies heavily on experts' explanations (Agarwal et al. 2022).

Finally, we introduced fuzzy MICMAC analysis to evaluate the TISM model, cluster factors based on their driving and dependence power, and identify key factors with the largest effect in facilitating KMob crossing boundaries. Fuzzy set theory was employed to increase the sensitivity analysis of MICMAC, which analyzes binary relationships between factors (Bhosale and Kant. 2016a). The combination of fuzzy set theory and MICMAC analysis increased the accuracy of our results by taking account of the strength of relationships between factors.

4. Data analysis and findings

We used thematic analysis to identify KMob factors, TISM to determine interactions between the identified factors, and fuzzy MICMAC analysis to identify driving and dependent forces in the system.

4.1 Thematic analysis to identify factors impacting KMob crossing boundaries

We employed thematic analysis to analyze the qualitative data collected from semi-structured interviews. Having transcribed the interviews verbatim, we read each transcript several times to gain familiarity with the data, and highlighted sentences and paragraphs that might contribute to KMob crossing boundaries using qualitative data analysis software *NVivo 13*. Next, we categorized and linked sentences and paragraphs with similar meanings, and devised titles or themes to represent them. After adopting an iterative approach to refine the codes and themes, moving back and forth between relevant theory and literature, we grouped codes into overarching themes using King and Horrocks's (2010) framework to illustrate our data analysis results (see Table 3). More specifically, prior theoretical research formed the foundation of KMob (Carlile. 2002; Carlile. 2004) and empirical works shed light on the knowledge boundary-spanning process (Hawkins and Rezazade M. 2012; Maskey et al. 2020) were utilized in this study.

Based on the thematic analysis, we identified 11 factors across four categories that might contribute to KMob crossing boundaries by SMEs involved in AFSCs. Some of these are mentioned in previous literature (see Table 1), while others are new to the KMob literature. For example, continuous improvement has been identified by Perez et al. (2010) as a critical enabler in creating lean supply chains. However, its effective role in facilitating KMob crossing boundaries in the context of AFSCs is seldom mentioned. The KMob process must be continuously monitored and reviewed by KM managers to provide tailored support for other organizational/supply-chain members to tackle knowledge boundaries (Liu et al. 2021). SMEs' ability to access physical and financial resources has previously been identified as critical for building agricultural knowledge systems (Rao. 2007). Similarly, our study reveals that financial resources are essential in enabling SMEs to engage in KMob.

Table 3 Empirical evidence on factors influencing KMob crossing boundaries

First-order codes	Second-order themes	Support from cases																										Aggregate dimensions
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	
"The knowledge leader must establish an environment in which employees may easily develop their knowledge manipulation abilities."	**Power (F1)**	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	**Relationship factors**
		√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	
		√	√	√					√	√			√		√	√	√	√				√		√	√	√	√	
"My organization has a knowledge worker team to share knowledge and all employees trust each other."	**Trust (F2)**	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	
		√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	
		√	√	√	√	√					√	√			√	√	√	√	√		√	√				√	√	
"Several elements of commitment, such as loyalty, identification and participation, are very important in an agricultural organization."	**Commitment (F3)**	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	
		√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	
					√	√	√	√	√	√	√	√				√	√	√		√				√	√	√	√	
"All employees are given adequate training internally in the organization."	**Training and education (F4)**	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	
		√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	
		√	√	√	√		√	√		√	√	√		√		√	√	√		√	√	√		√		√	√	
"Government offers a wide range of grants and funding to support local farming."	**Financial resources (F5)**	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	**Intra-organizational factors**
		√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	
		√		√		√		√	√	√			√		√	√	√	√	√		√	√	√		√	√	√	
"Farmers will often try something new on a smaller scale on their farm, such as using a modern farm practice to improve an area."	**Continuous improvement (F6)**	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	
		√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	
						√	√	√	√	√		√		√		√	√	√	√		√	√		√		√	√	
"The hierarchical depth of organization is positively related to KMob performance."	**Supply network structure (F7)**	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	
		√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	
		√	√	√			√	√	√	√	√	√	√			√	√	√	√	√				√	√	√	√	

"Our supervisor encourages the staff to work as a team."	**Collaboration (F8)**	√√√	√√√	√√	√√	√√√	√√	√√√	√√	√√	√√	√√√	√√√	√√	√√√	√√√	√√√	√√√	√√√	√√√	√√√	√√√	√√√	√√√	√√√	√√√	√√√	**Inter-organizational factors**
"The technological know-how in our network is easily transferable."	**Technology deployment (F9)**	√√√	√√	√√	√√√	√√√	√√	√√	√√√	√√	√√√	√√	√√	√√√	√√√	√√√	√√√	√√√	√√	√√√	√√√	√√	√√√	√√	√√	√√√	√√√	
"All organizations conduct annual performance appraisals of the employees."	**National culture (F10)**	√√√	√√	√√	√√	√√	√√	√√√	√√√	√√√	√√√	√√√	√√√	√√√	√√√	√√√	√√√	√√√	√√	√√√	√√	√√√	√√√	√√	√√	√√√	√√√	**Environmental factors**
"Organizations are highly dependent on government, for instance they are more likely to with heavy cost burdens imposed by public policy."	**Government support (F11)**	√√√	√√	√√	√√	√√√	√√√	√√√	√√	√√	√√	√√	√√√	√√	√√√	√√√	√√√	√√√	√√	√√√	√√√	√√	√√√	√√√	√√√	√√√	√√√	

Notes: √√√ indicates strong evidence, √ indicates weak evidence, and no ticks indicates no evidence

4.2 TISM employed to build a KMob hierarchical framework

TISM was used to build a KMob hierarchical framework based on the factors generated by thematic analysis. The 11 factors were allocated to different layers of the framework, and the experts were consulted about their interrelationships. Nine steps were implemented to build a TISM model (Sushil. 2012; Jena et al. 2017):

1) Identification and definition of KMob factors: This step involved identifying and defining factors or elements to be modeled. The 11 factors impacting on KMob crossing boundaries identified from our thematic analysis (see Table 3) were used as inputs to build a TISM hierarchical model.
2) Determination of contextual relationships between KMob factors: One of our research objectives was to understand interrelationships between the identified KMob factors. Contextual relationships between two KMob factors were defined as "KMob factor A will enhance/help to achieve KMob factor B."
3) Interpretation of relationships between pairs of KMob factors: Two experts' opinions were captured to understand relationships between pairs of KMob factors. These experts were professors in OSCM who had been working for AFSCs for over 15 years. Their opinions were initially used to understand whether or not "KMob factor A will enhance/help to achieve KMob factor B". If yes, we followed up by asking them, "In what way will KMob factor A enhance/help to achieve KMob factor B?" We gained an in-depth understanding of interrelationships between pairs of KMob factors from the experts' interpretations.
4) Interpretive logic of pair-wise comparisons among the 11 KMob factors: This step involved developing an "interpretive logic-knowledge base" based on pair-wise comparisons of the 11 identified KMob factors. Each KMob factor was individually compared with each remaining factor to judge which acted as a driver. Thus, the knowledge base consisted of $n \times (n-1) = 11 \times (11-1) = 110$ rows, where n represents the number of elements.
5) Reachability matrix and transitivity test: This step involved developing initial and final reachability matrices. An initial reachability matrix was developed based on the interpretive logic-knowledge base by entering "1" for "Y" and "0" for "No" (see Appendix 3), with "Y" indicating the presence of a relationship between two KMob factors, and "N" indicating no relationship. This was then transformed into a final reachability matrix by checking for transability, whereby if KMob factor A related to KMob factor B and KMob factor B related to KMob factor C, then KMob factor A necessarily related to KMob factor C (see Appendix 4).
6) Level determination by partitioning the reachability matrix: This step involved allocating the 11 KMob factors to different layers of the framework. The final reachability matrix was used to determine the level of each KMob factor, based on the reachability and antecedent sets of each factor through a series of iterations. The reachability set for a specific KMob factor consisted of the factor itself and the other KMob factors that it would achieve/enhance, whereas the antecedent set consisted of the factor itself and the other KMob factors that would enhance/achieve it. The intersection set comprised common KMob factors determined by the reachability and antecedent sets. The detailed iteration process is shown in Appendix 5.
7) Digraph development: A digraph (see Appendix 6) was developed to illustrate interrelationships between the 11 KMob factors by drawing direct and transitive links according to the relationships revealed in the final reachability matrix. Only important transitive links were retained in the digraph, based on the experts' recommendations.
8) Interpretive matrix: This step involved developing a binary interaction matrix (see Appendix 7) by translating all interactions (direct and transitive links) in the digraph

into 1 in the respective cells. Appropriate interpretations were drawn from the interpretive logic-knowledge base to interpret relationships between pairs of KMob factors, as shown in the binary interaction matrix.

9) Total interpretive structural model: Finally, a total interpretive structural model was developed to illustrate interrelationships among the KMob factors (see Figure 3).

The analysis of KMob factors crossing boundaries resulted in a TISM model with eight levels. Power (F1) and National culture (F10) comprise level VIII, Commitment (F3) and Supply network structure (F7) constitute level I, whereas the remaining seven factors dispersed from levels II to VII. KMob factors located in the lower levels of the TISM model (towards the bottom of Figure 3) can elicit more KMob factors in the system, whereas those at higher levels of the TISM model (towards the top of Figure 3) can elicit fewer KMob factors. The TISM model of KMob factors demonstrates that Power (F1) and National culture (F10) are critical in enabling SMEs in AFSCs to overcome knowledge boundaries. For example, some SME participants in this research were from Argentina, where has a cultural value orientation pertains to embeddedness (Schwartz. 2006). This makes it more difficult to mobilize knowledge crossing boundaries because cultural embeddedness discourages unnecessary involvement with people outside the broad ingroup. For SMEs from Europe, France's intellectual autonomy orientation and Italy's egalitarianism orientation encourage individuals to pursue their own ideas and join voluntary organizations, which facilitates KMob. Support from the top management team is also necessary to foster employees' knowledge manipulation abilities and inter-organizational networks. For example, a sustainable economic AFSC was established in southern France by linking organizations providing a range of specialist functions (laboratory research, field research and maritime transport), as well as an advocacy and lobbying organization. This enabled AFSC practitioners to acquire Government support (F11) through lobbying, and regional and national governments increased their budgets for agricultural and rural development. Financial resources (F5) acquired by SMEs could be used for Training and education (F4), short mobilizations between different organizations, and formulation of knowledge transfer partnerships. These collective activities increased Trust (F2) and Collaboration (F8) among AFSC practitioners, facilitated advanced Technology deployment (F9) and applications for funding to support Continuous development (F6). For example, SMEs can apply to the European Regional Development Fund (ERDF) and the Horizon 2020 Programme for funding to extend relationships and trial the latest technology at their farms and laboratories. All these activities enhance Commitment (F3) and the Supply network structure (F7).

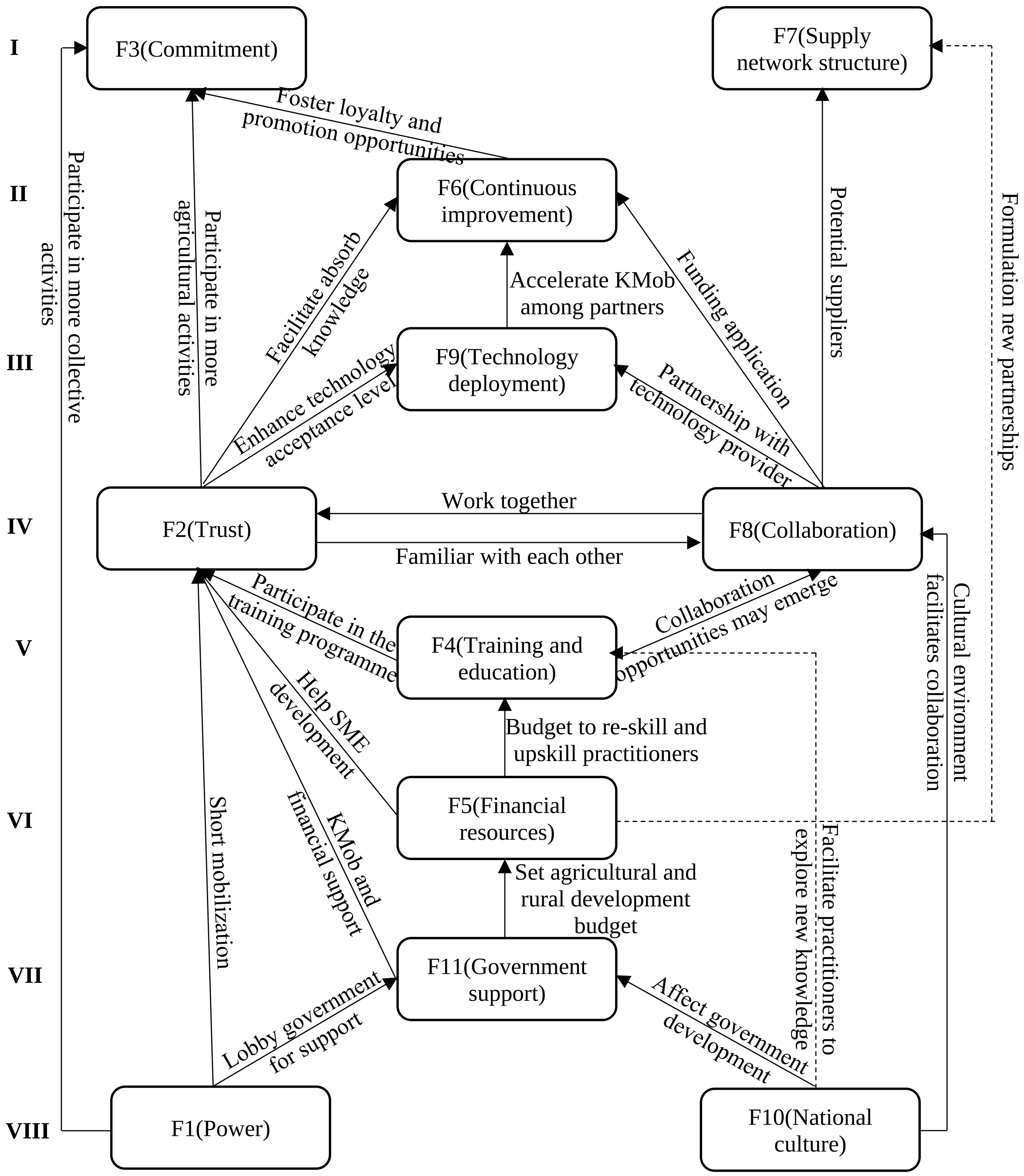

Figure 3 TISM model of KMob factors crossing boundaries

4.3 Fuzzy MICMAC analysis to cluster KMob factors and evaluate the TISM model

We constructed a TISM hierarchical model of KMob factors by considering binary relationships between pairs of factors. The presence of a relationship between two KMob factors was denoted with “1”, and absence of a relationship was denoted with “0”. A drawback of TISM is that it offers no scope to determine the relative strength of binary relationships. To overcome this weakness, we utilized fuzzy set theory and MICMAC analysis. Using the outputs from the TISM framework, fuzzy MICMAC analysis was used to cluster the KMob factors and evaluate the TISM hierarchical model based on each factor’s driving and dependence power. Three steps were implemented to perform fuzzy MICMAC analysis:

1) Binary direct relationship matrix (BDRM): A BDRM was developed from the initial reachability matrix by converting the diagonal entries to “0” (see Appendix 8).

2) Development of fuzzy direct relationship matrix (FDRM): Two professors of OSCM involved in interpreting the relationships between pairs of KMob factors in TISM were asked to re-rate these relationships. A critical advantage of fuzzy MICMAC is that it allows consideration of potential interactions between pairs of factors. The strengths of relationships between KMob factors were given numerical values of 0 for no relationship, 0.1 for very low, 0.3 for low, 0.5 for medium, 0.7 for high, 0.9 for very high, and 1 for an absolute relationship. To obtain the FDRM, these values were superimposed on the BDRM.
3) Fuzzy MICMAC stabilized matrix (FMSM): A fuzzy MICMAC stabilized matrix was developed to obtain the driving power and dependence power of each KMob factor. According to fuzzy set theory, when two fuzzy matrices are multiplied, the outcome is still a fuzzy matrix, as shown in the following equation. The matrix multiplication process was repeated until the driving and dependence power of each KMob factor were constant. The FMSM is shown in Appendix 10.

$$C = A,B = [\max k(\min(a_{ik}, b_{kj}))], \text{ where } A = [a_{ik}] \text{ and } b = [b_{kj}]$$

We obtained the driving and dependence power of each KMob factor by summing the numbers in a column and row, as shown in Appendix 10. KMob factor with higher driving power are more likely to elicit other KMob factors in the system, and those with higher dependence power are more likely to be elicited by other KMob factors. Based on these values, we plotted and categorized the 11 KMob factors into four clusters of independent, dependent, linkage, and autonomous factors, as shown in Figure 4.

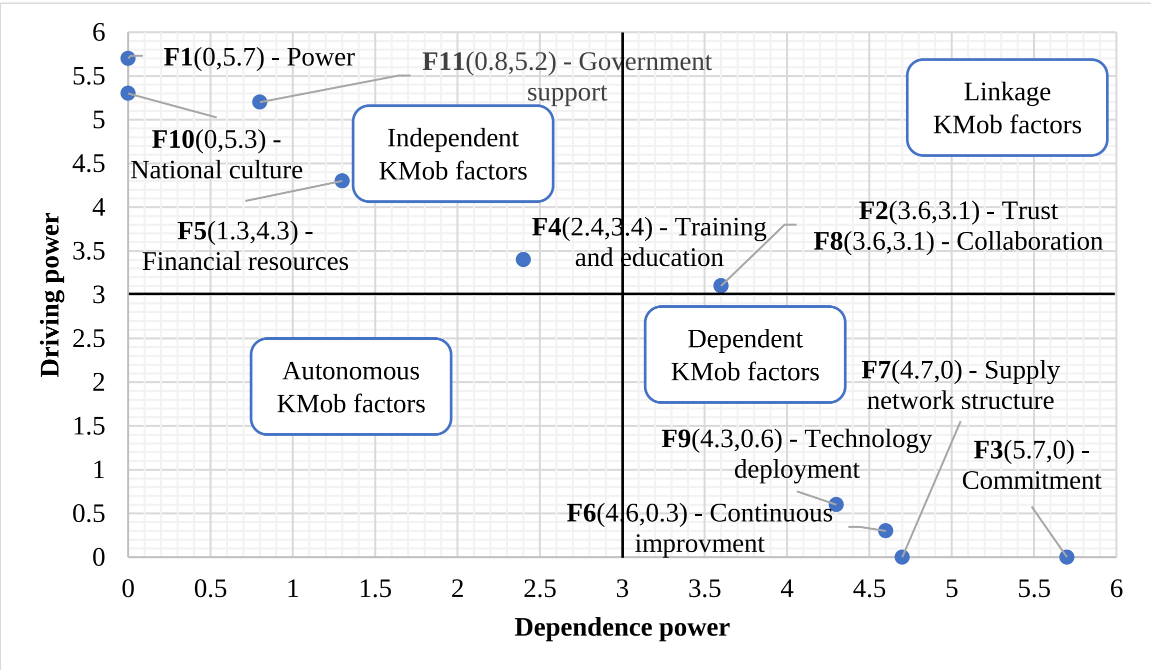

Figure 4 Cluster of KMob factors

1) Independent KMob factors are characterized by strong driving power and weak dependence power and are the driving forces of the system. They include Power (F1), Training and education (F4), Financial resources (F5), National culture (F10) and Government support (F11). As Power (F1) has the highest driving power and acts as the primary force eliciting other KMob factors, it should receive strategic focus. As one of our interviewees stated, the knowledge leader of an SME "*must be able to establish an environment in which employees may easily develop their knowledge manipulation abilities, add their own personal knowledge resources to the organization's pool of information, and have easy access to appropriate knowledge resources*".

2) Dependent KMob factors have weak driving power and strong dependence power were clustered as dependent KMob factors, relying on other factors for their achievement. These include Commitment (F3), Continuous improvement (F6), Supply network structure (F7), and Technology deployment (F9). For example, deploying technologies such as blockchain and the internet of things (IoT) to facilitate KMob requires not only financial resources, but also support from regional governments and the organization's top management team. Additional governmental financial resources, such as from the industrial transformation fund and the European agricultural fund, are especially important in enabling agricultural SMEs to deploy the latest technologies.
3) Linkage KMob factors, characterized by strong driving and strong dependence power, act as linkages in the system. These include Trust (F2) and Collaboration (F8). Any alteration in the system that affects other KMob factors will also impact on these two factors. Previous studies have identified that trust and collaboration as critical enablers of KMob (Rutten et al. 2016; Alshwayat et al. 2021). However, it is not easy to build trusting and collaborative relationships with other stakeholders in AFSCs. For example, in Abrams et al.'s (2003) proposed KMob framework, trust is influenced by ten factors across four categories.
4) Autonomous KMob factors have weak driving and dependence power. None was identified in this study because such factors are relatively disconnected from the system. They neither affect KMob crossing boundaries, nor are influenced by other KMob factors.

4.4 Synthesis of findings and establishment of KMob framework

Based on the findings of this study, we devised a KMob framework that links KMob factors, boundary-crossing mechanisms and knowledge boundaries in the context of AFSCs (see Figure 5). KMob factors can be used to activate various boundary-crossing mechanisms, such as repositories (e.g., systems for storing good agricultural practices), standardized forms and methods (e.g., food safety standards, packaging standards, and international food labelling standards), artifacts and models (e.g., profit model for food production) and agricultural workshops and seminars. Such mechanisms can be used to tackle knowledge boundaries through knowledge transfer, translation and transformation.

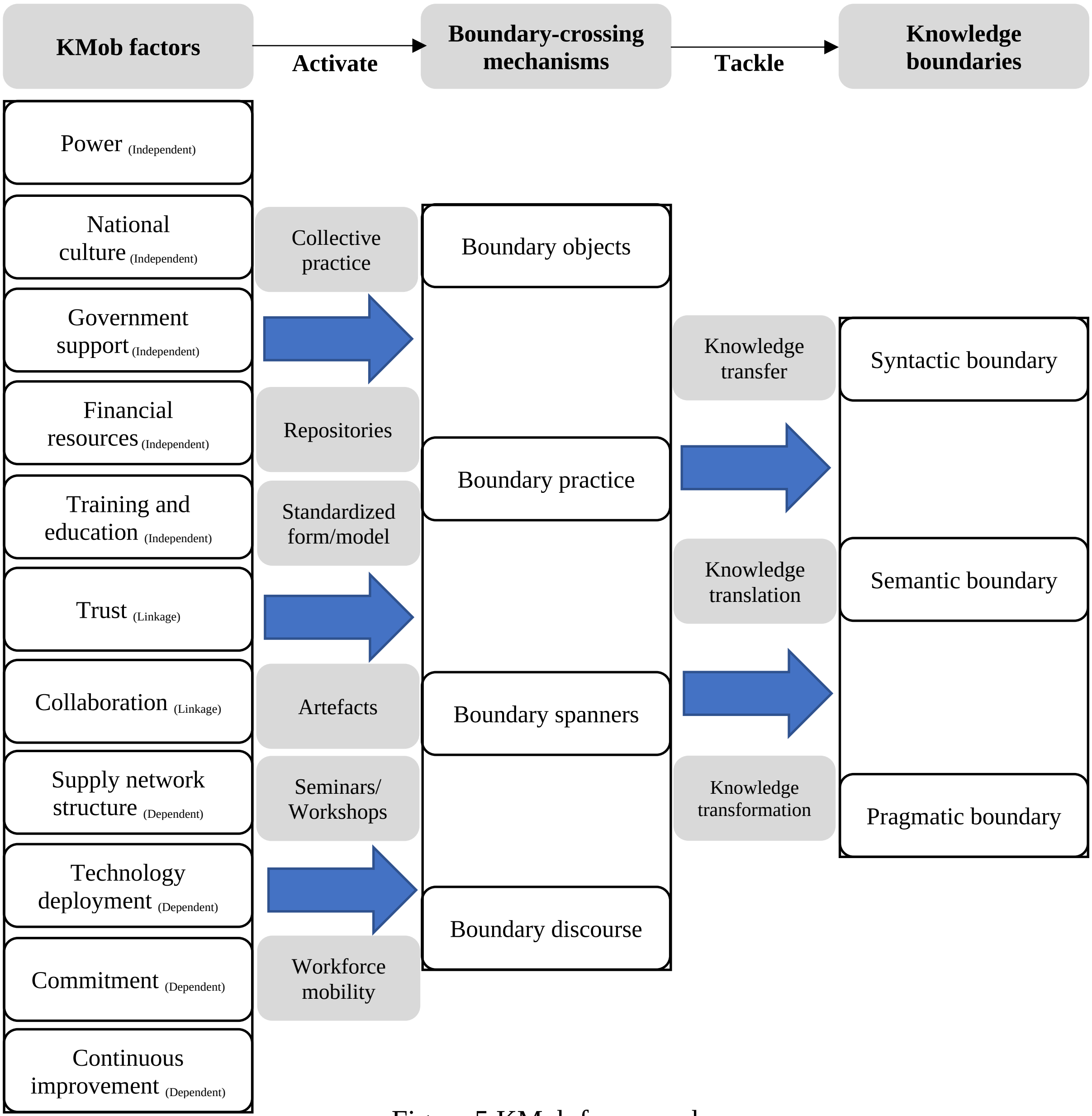

Figure 5 KMob framework

5. Discussion and implications

Based on our literature review and empirical data collected from Europe and South America, we identify 11 factors that may contribute to KMob crossing boundaries (see Table 3). Our empirical findings indicate that KMob factors frequently mentioned in the literature (see Table 1) are effective in leveraging boundary-crossing mechanisms. These include trust, collaboration, commitment, power, technology deployment, government support, national culture and supply network structure (Li et al. 2014; Ali et al. 2019; Rajabion et al. 2019). For example, Lilleoere and Hansen (2011) suggest that work involvement and interests, social relations and networks, and meetings and information spaces are enablers of knowledge sharing in research and development. Our findings indicate that commitment and collaboration are useful for triggering boundary-crossing mechanisms, thereby facilitating KMob. Hussein et al. (2016) show that top management support has a positive impact on knowledge sharing. Our study similarly reveals that power contributes to KMob, because knowledge leaders may help employees to develop their knowledge manipulation abilities. Maskey et al. (2020) identify 21 factors critical to supply chain KMob, including partnerships, top management commitment and personal connections. Our findings partially support their results by confirming these factors' roles in influencing KMob crossing boundaries. Owusu-Manu et al. (2018) reveal that knowledge strategy, information technology and knowledge leadership are enablers of KMob in the construction industry, and our findings extend their role to the agri-food industry. Although previous research has identified some factors that contribute to knowledge transfer, sharing and mobilization, we identify several other factors that are less often mentioned in this context, such as continuous improvement and financial resources. For example, Lin et al. (2022) highlight the important role of continuous improvement in employees' learning and knowledge capability to enhance the performance of information systems. In contrast, our study shows that continuous improvement mechanisms should be embedded at individual, organizational, and supply chain levels to monitor and review KMob practices and measures, and thereby increase their KMob effectiveness and efficiency. Boundary objects used to increase shared meanings across different parties and boundary practices used to involve different parties in collective activities, these measures must be constantly monitored, reviewed and improved to optimize KMob. Several previous studies (e.g., Fu et al. 2017; Lyu and Zhang. 2017; Maskey et al. 2020) confirm the important role of incentives, legal contracts, market orientation, interaction routines and farmers' dependence on agri-food companies to enable KMob. However, they neglect the role of financial resources in activating boundary-crossing mechanisms. In particular, financial resource are critical in enabling SMEs to conduct short visits to other AFSC organizations, participate in KMob activities and circulate shared meanings across all supply chain stakeholders.

Based on the TISM and fuzzy MICMAC analysis results, we identify that power and national culture are key drivers that elicit other KMob factors in the system. In previous studies, Yadav et al. (2020) demonstrate that organizational culture and leadership are two key enablers of KM to improve logistics capabilities, Bhosale and Kant (2016a) reveal the critical role of top management support in circulating knowledge flows among supply chain stakeholders, and Anantatmula and Kanungo (2010) highlight the importance of organizational culture, KM leadership and top management involvement for successful KM implementation. Similarly, our results indicate that KM leaders have power to build environments in which supply chain stakeholders will share knowledge, have resources to build knowledge repositories and develop capabilities to facilitate KMob. However, unlike previous studies, we identify that national culture, rather than organizational culture, may influence KMob crossing boundaries. For example, with Argentina's cultural value orientation of embeddedness, people are encouraged to respect tradition and participate in a shared way of life. Thus, most farmers in Argentina running family businesses, receive agricultural knowledge from their family members, and are reluctant to share knowledge with people outside their group. To tackle this knowledge boundary, the Argentinian government developed the National Agricultural Technology Institute (INTA), a KMob agency at the federal level, responsible for agricultural technology and knowledge generation, adaptation and diffusion. INTA currently has at least 44 experimental stations and 240 KMob units nationwide. France's cultural environment intellectual autonomy encourages people to express their own ideas, cooperate and join voluntary organizations (Schwartz. 2006). Thus, thousands of farmers in southern France have built a farmer's association and developed a whole AFSC based on their own requirements. Although France also has a national agricultural research institute, the Institut National de la Recherche Agronomique (INRAE), this kind of organization concentrates on research rather than KMob. Differences in national cultural value orientations foster different attitudes to KMob, which give rise to differing knowledge boundaries that impede KMob, and induce different boundary-crossing mechanisms embedded at national, supply-chain, and organizational levels.

Our study also contributes to identifying the role of each KMob factor in KMob crossing boundaries. For example, we find that trust and collaboration act as linkages between driving and dependent KMob factors. In previous studies, Bhosale and Kant (2016a) find no linkage enablers amongst their 34 selected supply-chain knowledge flow enablers, whereas Zhao et al. (2018) argue that trust and collaboration in terms of joint decision making and regular meetings, act as linkages between their nine supply chain resilience factors. The mediating role of trust and collaboration in KMob development has been highlighted in various contexts (Wang et al. 2014; Lee et al. 2020) and is confirmed in our study. Anantatmula and Kanungo (2010) have previously modelled enablers of KM support. We categorize culture, KM leadership and top management involvement as the main drivers of KMob, and cluster collaboration, content quality, measurement of results and strategic focus as the main dependents. Our results indicate that AFSC practitioners in Argentina, Chile, France and Italy all need more government support, financial resources, and training and education. Most SMEs in this study had recently survived from the COVID-19 pandemic, and therefore, required more resources, supports and training to leverage KMob.

5.1 Managerial implications

This study has implications for the top management teams of SMEs, focal companies of AFSCs, and local and national governments.

For top management teams, first, internal knowledge repositories should be built to share definitions, meanings and experiences, in order to solve problems such as crop management and integrated pest management. These are effective way to de-contextualize and de-personalize knowledge (Liu et al. 2021), enabling knowledge to be transformed and transferred from one domain to another. Second, collective activities such as training to improving employees' knowledge and skills, should be conducted regularly to facilitate communication between employees. Third, SMEs should join associations (e.g., farmers' association, processors' association) to lobby governments for more support.

For focal companies of AFSCs, first, they should organize regular supply-chain-wide collective activities to facilitate KMob. These might include annual conferences on agricultural technologies, annual agricultural equipment trade shows, and seminars on good agricultural practices. Second, focal companies should set up knowledge extension departments and act as coordinators to facilitate chain-wide funding applications, new technology deployment and workforce mobility. Cross-organizational workforce mobility, especially, would help employees to become "boundary brokers" as members of two organizations (Hayes and Fitzgerald. 2009), and even "marginal people" as members of multiple organizations (Star and Griesemer. 1989). These are extremely useful for KMob crossing boundaries.

Finally, we suggest that regional and national governments should establish sufficient budgets for agricultural and rural development. This would enable SMEs to apply for funding to support their development, and reskill and upskill their employees. Knowledge extension agencies should also be set up at national, state and district levels to ensure knowledge and technology generation, extension and diffusion.

5.2 Implications for knowledge

This study also has implications for knowledge. First, unlike previous research, we find that continuous improvement and financial resources may contribute to KMob crossing boundaries. Continuous improvement means continuously monitoring, reviewing and adapting KMob practices to optimize performance, while financial resources are necessary to finance KMob activities. Previous studies have simply identified that monitoring and incentives have positive effects on KMob (Maskey et al. 2020; Wang et al. 2023). Second, we allocate our 11 KMob factors to different layers of our framework to elucidate their interrelationships. Third, we cluster the KMob factors into four categories (independent, linkage, autonomous and dependent) to enhance understanding of the role of each KMob factor in the system.

6. Conclusions, limitations and future research directions

In this study, we aimed to identify factors influencing KMob crossing boundaries by SMEs involved in the AFSCs, explore interactions between these factors, and investigate of the key KMob factors driving the system. We developed an integrated approach to achieve these three research objectives. In relation to the first objective, we conducted semi-structured interviews to collect data from 26 AFSC practitioners in Europe and South America, and employed thematic analysis to identify various KMob factors. For the second objective, we used TISM to build interrelationships between the identified KMob factors, and to meet the third objective, we utilized fuzzy MICMAC analysis to categorize the factors into independent, linkage, autonomous and dependent KMob factors.

This study contributes significantly to theory and managerial practice by identifying KMob factors, building interactions between them, and revealing key KMob factors driving other factors in the system. For example, we identify 11 KMob factors that may influence KMob crossing boundaries. Of these, continuous improvement and financial resources have seldom been mentioned in previous research. By combining the results of TISM and fuzzy MICMAC analysis, we identify that power and national culture should be prioritized in designing, developing, and implementing relevant strategies to facilitate KMob crossing boundaries. A clearly understanding of the role of each KMob factor in the system and their position in a multi-layered framework may also help agri-food SMEs to use resources efficiently and effectively.

6.1 Limitations and future research directions

This study has some limitations that open up avenues for future research.

First, our framework (see Figure 5) links KMob factors, boundary-crossing mechanisms and knowledge boundaries, showing how KMob factors can be used to activate boundary-crossing mechanisms, and boundary-crossing mechanisms can be used to tackle knowledge boundaries. However, we do not identify any key performance indicators (KPIs) that might be used to evaluate performance after implementing these KMob factors. Thus, future studies might investigate KMob performance evaluation and integrate it into our framework.

Second, our study sheds light on resources, elements and factors that may activate various boundary-crossing mechanisms. However, we are unable to quantify relationships between KMob factors and boundary-crossing mechanisms, such as how much specific KMob factors or groups of factors contribute to particular boundary-crossing mechanisms (e.g., boundary objects and boundary discourse). To tackle this limitation, we suggested using SEM in future studies to test and evaluate the effects of different KMob factors on boundary-crossing mechanisms. SEM is a powerful modeling technique for testing and evaluating multivariable causal relationships (Asparouhov et al. 2018).

Third, our study confirms that national culture (cultural value orientation) affects individuals' behaviour and has positive or negative effects on KMob crossing boundaries. Future studies might conduct comparative analyses of countries with different cultural value orientations to evaluate the effects on KMob crossing boundaries.

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Appendix 1 Interview guide

Part 1: This part asks questions about your general background

1) What is your organization's role in the agri-food supply chain? (e.g., farmer, food processor, distributor, retailer, interest group, education/research institute, consultancy/advisory agency, other)
2) What is the size of your company? e.g., micro – (fewer than 10 employees), small – (10 to 49 employees), and medium – (50 to 249 employees)
3) What is the geographic location of your organization? (e.g., Europe, South America, Asia, North America, Oceania)
4) What is the main functional area of your work in the organization? (e.g., production, sales and marketing, procurement/buying, finance and accounting, logistics, research and development, other)
5) What is your role/position in your organization? (e.g., farmer, specialist, administrator, supervisor, senior manager, director/executive, scientist, academic, and others)
6) How many years working experience in relevant areas do you have? (e.g., 6-10 years, 11-15 years, 16-20 years, and more than 20 years)

Part 2: In this part, we are interested in identifying factors impacting on successful implementation of knowledge mobilization

(1) What factors help to increase the effectiveness of knowledge mobilization? (e.g., power, trust, commitment, training and education, supply network structure, collaboration, technology deployment, national culture, government support)

Part 3: In this part, we are interested in knowing who can frame and translate knowledge from one domain to another. We use the term "boundary spanners", meaning human agents who use language and cognitive power to translate knowledge across boundaries.

(1) Based on the membership status of the spanners, what types of boundary spanners are used in your organization?
(2) What other boundary spanners do you think can create collaborative relationships between members and develop more inclusive economies, societies and institutions of governance?

Part 4: In this part, we are interested in knowing how you store and share knowledge that is important to running your organization. We use the term "boundary objects", meaning objects or items in which knowledge can be stored or embedded and so mobilized.

(1) What are the main types of boundary objects used in your organization?
(2) What other boundary objects do you think can or should be used in your organization, and why are they not being used?

Part 5: In this part, we are interested in identifying boundary interactions used for knowledge mobilization.

(1) What boundary interactions are used in your organization to share knowledge?
(2) What other boundary interactions do you think your organization could benefit from but has no access to? Please explain.

Appendix 2 Background of participants and SMEs

No	Role in AFSC	Number of interviewees	Country	Interviewee's position	Working experience
A	Farmer	10 - 49 employees	Argentina	Director/ executive	Over 20 years
B	Farmer	10 - 49 employees	Argentina	Director/ executive	Over 20 years
C	Farmer	10 - 49 employees	France	Production manager	Over 10 years
D	Farmer	10 - 49 employees	Italy	Owner	16 - 20 years
E	Farmer	10 - 49 employees	Chile	Owner	11 - 15 years
F	Processor	50 - 249 employees	France	Director/ executive	6 - 10 years
G	Processor	50 - 249 employees	France	IT service manager	11 - 15 years
H	Processor	50 - 249 employees	Italy	Planning manager	6 - 10 years
I	Research institute	50 - 249 employees	Italy	Marketing manager	6 - 10 years
J	Wholesaler	50 - 249 employees	Argentina	Managing director	16 - 20 years
K	Wholesaler	50 - 249 employees	Italy	Managing director	16 - 20 years
L	Retailer	10 - 49 employees	Chile	Project manager	11 - 15 years
M	Retailer	10 - 49 employees	France	Technology director	11 - 15 years
N	Research institute	10 - 49 employees	France	Gene modification scientist	6 - 10 years
O	Research institute	10 - 49 employees	Italy	Agri-chemical scientist	6 - 10 years
P	Research institute	50 - 249 employees	Chile	Agro-economic scientist	6 - 10 years
Q	Research institute	50 - 249 employees	Argentina	Pest management scientist	16 - 20 years
R	Seed nursey	10 - 49 employees	Argentina	Director/ executive	6 - 10 years
S	Farm equipment provider	Fewer than 10 employees	France	Senior manager	11 - 15 years
T	Agri-chemical provider	50 - 249 employees	Argentina	Director/ executive	11 - 15 years
U	Packing service	50 - 249 employees	Chile	Marketing manager	11 - 15 years
V	Logistic service	50 - 249 employees	Italy	Director	11 - 15 years
W	Regional government	10 - 49 employees	Argentina	Director/ Executive	11 - 15 years
X	Regional government	10 - 49 employees	Chile	Director of agricultural department	11 - 15 years
Y	Regional government	10 - 49 employees	Italy	Director of rural development	6 - 10 years
Z	Regional government	10 - 49 employees	France	Managing director	16 - 20 years

Appendix 3 Initial reachability matrix of factors impacting on KMob crossing boundaries

KMob factors	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11
F1	1	1	1	1	1	1	1	1	1	0	1
F2	0	1	1	0	0	1	1	1	1	0	0
F3	0	0	1	0	0	0	0	0	0	0	0
F4	0	1	1	1	0	1	1	1	1	0	0
F5	0	1	1	1	1	1	0	1	1	0	0
F6	0	0	1	0	0	1	0	0	0	0	0
F7	0	0	0	0	0	0	1	0	0	0	0
F8	0	1	1	0	0	1	1	1	1	0	0
F9	0	0	1	0	0	1	0	0	1	0	0
F10	0	1	1	0	0	1	1	1	1	1	1
F11	0	1	1	1	1	1	1	1	1	0	1

Appendix 4 Final reachability matrix of factors impacting on KMob crossing boundaries

KMob factors	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11
F1	1	1	1	1	1	1	1	1	1	0	1
F2	0	1	1	0	0	1	1	1	1	0	0
F3	0	0	1	0	0	0	0	0	0	0	0
F4	0	1	1	1	0	1	1	1	1	0	0
F5	0	1	1	1	1	1	1*	1	1	0	0
F6	0	0	1	0	0	1	0	0	0	0	0
F7	0	0	0	0	0	0	1	0	0	0	0
F8	0	1	1	0	0	1	1	1	1	0	0
F9	0	0	1	0	0	1	0	0	1	0	0
F10	0	1	1	1*	0	1	1	1	1	1	1
F11	0	1	1	1	1	1	1	1	1	0	1

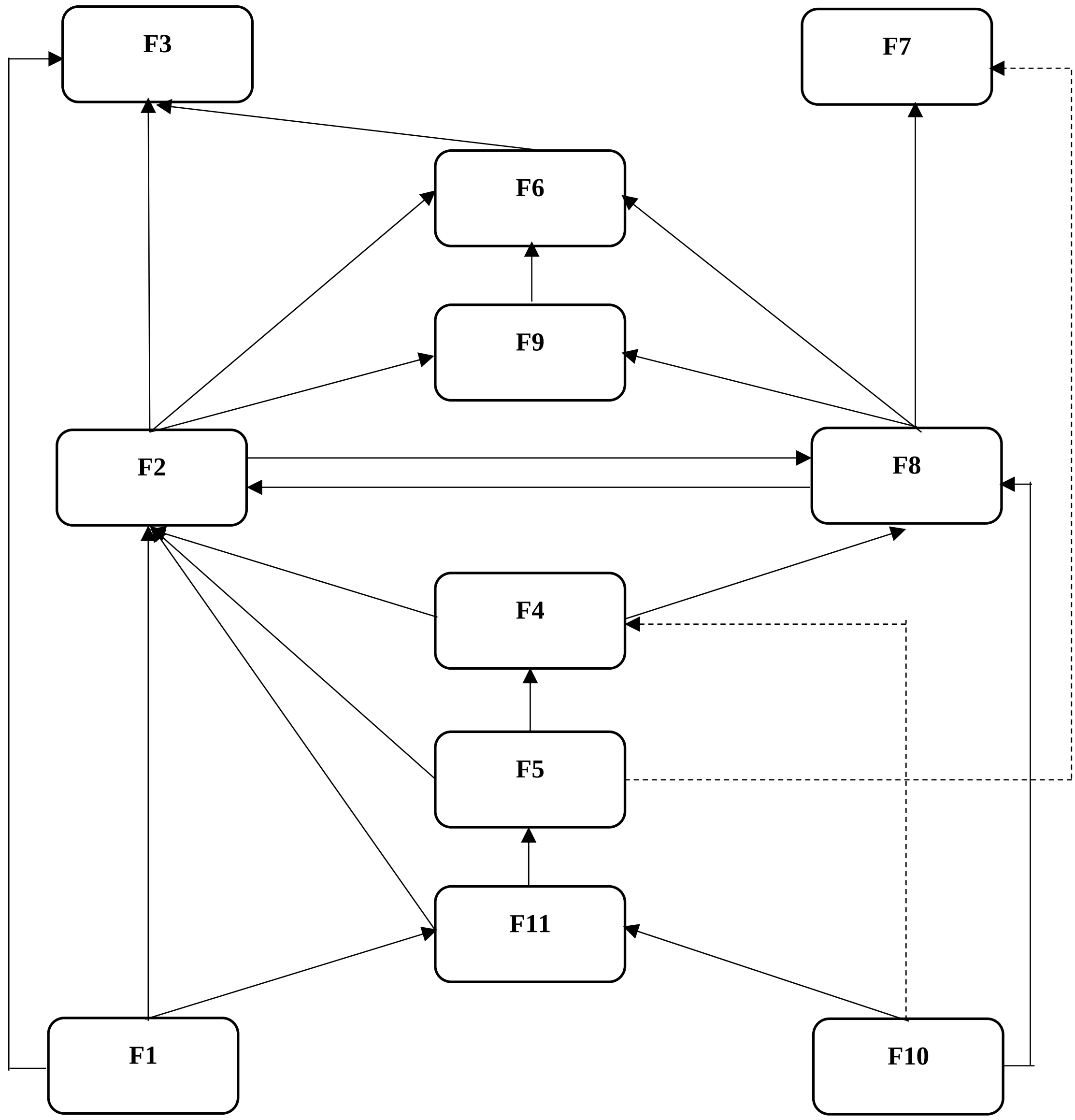
Note: * represents transitivity

Appendix 5 Partitioning of the reachability matrix into different levels

Variable	Reachability set (RS)	Antecedent set (AS)	RS∩AS	Level
Iteration 1				
E1	1,2,3,4,5,6,7,8,9,11	1	1	
E2	2,3,6,7,8,9	1,2,4,5,8,10,11	2,8	
E3	3	1,2,3,4,5,6,8,9,10,11	3	**Level I**
E4	2,3,4,6,7,8,9	1,4,5,10,11	4	
E5	2,3,4,5,6,7,8,9	1,5,11	5	
E6	3,6	1,2,4,5,6,8,9,10,11	6	
E7	7	1,2,4,5,7,8,10,11	7	**Level I**
E8	2,3,6,7,8,9	1,2,4,5,8,10,11	2,8	
E9	3,6,9	1,2,4,5,8,9,10,11	9	
E10	2,3,4,6,7,8,9,10,11	10	10	
E11	2,3,4,5,6,7,8,9,11	1,10,11	11	
Iteration 2				
E1	1,2,4,5,6,8,9,11	1	1	
E2	2,6,8,9	1,2,4,5,8,10,11	2,8	
E4	2,4,6,8,9	1,4,5,10,11	4	
E5	2,4,5,6,8,9	1,5,11	5	
E6	6	1,2,4,5,6,8,9,10,11	6	**Level II**
E8	2,6,8,9	1,2,4,5,8,10,11	2,8	
E9	6,9	1,2,4,5,8,9,10,11	9	
E10	2,4,6,8,9,10,11	10	10	
E11	2,4,5,6,8,9,11	1,10,11	11	
Iteration 3				
E1	1,2,4,5,8,9,11	1	1	
E2	2,8,9	1,2,4,5,8,10,11	2,8	

E4	2,4,8,9	1,4,5,10,11	4	
E5	2,4,5,8,9	1,5,11	5	
E8	2,8,9	1,2,4,5,8,10,11	2,8	
E9	9	1,2,4,5,8,9,10,11	9	**Level III**
E10	2,4,8,9,10,11	10	10	
E11	2,4,5,8,9,11	1,10,11	11	
Iteration 4				
E1	1,2,4,5,8,11	1	1	
E2	2,8	1,2,4,5,8,10,11	2,8	**Level IV**
E4	2,4,8	1,4,5,10,11	4	
E5	2,4,5,8	1,5,11	5	
E8	2,8	1,2,4,5,8,10,11	2,8	**Level IV**
E10	2,4,8,10,11	10	10	
E11	2,4,5,8,11	1,10,11	11	
Iteration 5				
E1	1,4,5,11	1	1	
E4	4	1,4,5,10,11	4	**Level V**
E5	4,5	1,5,11	5	
E10	4,10,11	10	10	
E11	4,5,11	1,10,11	11	
Iteration 6				
E1	1,5,11	1	1	
E5	5	1,5,11	5	**Level VI**
E10	10,11	10	10	
E11	5,11	1,10,11	11	
Iteration 7				
E1	1,11	1	1	
E10	10,11	10	10	
E11	11	1,10,11	11	**Level VII**
Iteration 8				
E1	1	1	1	**Level VIII**
E10	10	10	10	**Level VIII**

Appendix 6 Digraph showing interrelationships between KMob factors



Appendix 7 Binary interaction matrix

KMob factors	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11
F1	0	1	1	1	1	1	1	1	1	0	1
F2	0	0	1	0	0	1	1	1	1	0	0
F3	0	0	0	0	0	0	0	0	0	0	0
F4	0	1	1	0	0	1	1	1	1	0	0
F5	0	1	1	1	0	1	1*	1	1	0	0
F6	0	0	1	0	0	0	0	0	0	0	0
F7	0	0	0	0	0	0	0	0	0	0	0
F8	0	1	1	0	0	1	1	0	1	0	0
F9	0	0	1	0	0	1	0	0	0	0	0
F10	0	1	1	1*	0	1	1	1	1	0	1
F11	0	1	1	1	1	1	1	1	1	0	0

Appendix 8 Binary direct relationship matrix (BDRM)

KMob factors	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11
F1	0	1	1	1	1	1	1	1	1	0	1
F2	0	0	1	0	0	1	1	1	1	0	0
F3	0	0	0	0	0	0	0	0	0	0	0
F4	0	1	1	0	0	1	1	1	1	0	0
F5	0	1	1	1	0	1	0	1	1	0	0
F6	0	0	1	0	0	0	0	0	0	0	0
F7	0	0	0	0	0	0	0	0	0	0	0
F8	0	1	1	0	0	1	1	0	1	0	0
F9	0	0	1	0	0	1	0	0	0	0	0
F10	0	1	1	0	0	1	1	1	1	0	1
F11	0	1	1	1	1	1	1	1	1	0	0

Appendix 9 Fuzzy direct relationship matrix (FDRM)

KMob factors	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11
F1	0	0.3	0.7	0.9	0.3	0.1	0.7	0.5	0.3	0	0.3
F2	0	0	0.7	0	0	0.1	0.3	0.9	0.3	0	0
F3	0	0	0	0	0	0	0	0	0	0	0
F4	0	0.3	0.7	0	0	0.9	0.3	0.3	0.9	0	0
F5	0	0.3	0.3	0.3	0	0.5	0	0.7	0.7	0	0
F6	0	0	0.3	0	0	0	0	0	0	0	0
F7	0	0	0	0	0	0	0	0	0	0	0
F8	0	0.9	0.3	0	0	0.5	0.7	0	0.1	0	0
F9	0	0	0.5	0	0	0.1	0	0	0	0	0
F10	0	0.7	0.7	0	0	0.5	0.7	0.5	0.3	0	0.5
F11	0	0.5	0.5	0.7	0.5	0.1	0.9	0.3	0.3	0	0

Appendix 10 Fuzzy MICMAC stabilized matrix (FMSM)

KMob factors	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	Driving power
F1	0	0.5	0.7	0.9	0.3	0.9	0.7	0.5	0.9	0	0.3	**5.7**
F2	0	0	0.7	0	0	0.5	0.7	0.9	0.3	0	0	**3.1**
F3	0	0	0	0	0	0	0	0	0	0	0	**0**
F4	0	0.3	0.7	0	0	0.9	0.3	0.3	0.9	0	0	**3.4**
F5	0	0.7	0.7	0.3	0	0.5	0.7	0.7	0.7	0	0	**4.3**
F6	0	0	0.3	0	0	0	0	0	0	0	0	**0.3**
F7	0	0	0	0	0	0	0	0	0	0	0	**0**
F8	0	0.9	0.7	0	0	0.5	0.7	0	0.3	0	0	**3.1**
F9	0	0	0.5	0	0	0.1	0	0	0	0	0	**0.6**
F10	0	0.7	0.7	0.5	0.5	0.5	0.7	0.7	0.5	0	0.5	**5.3**
F11	0	0.5	0.7	0.7	0.5	0.7	0.9	0.5	0.7	0	0	**5.2**
Dependence power	**0**	**3.6**	**5.7**	**2.4**	**1.3**	**4.6**	**4.7**	**3.6**	**4.3**	**0**	**0.8**	