Knowledge mobilization for agri-food supply chain decisions: Identification of knowledge boundaries and categorization of boundary-spanning mechanisms

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ABSTRACT

The current world business environment is characterized by increasing uncertainties, complexities, and risks, which require agri-food supply chain (AFSC) managers to respond and act quickly in a context full of instability and unpredictability. Increasing pressure placed on AFSC managers intensifies the need to combine knowledge management (KM) and decision support that rapidly overcome knowledge boundaries. It has been recognized that the research issue related to the knowledge mobilization crossing boundaries in the AFSC needs to be addressed. This paper investigates knowledge boundaries and boundary-spanning mechanisms by collecting data from experienced AFSC practitioners. Empirical results verify that knowledge boundaries such as syntactic boundaries, semantic boundaries, and pragmatic boundaries could be effectively tackled by four specific boundary-spanning mechanisms: boundary spanners, boundary objects, boundary practices, and boundary discourses. Furthermore, an efficient knowledge mobilization process helps to increase the economic benefits and social benefits, and improves operations management and efficiency of AFSC companies. This study advances existing literature on identifying factors of knowledge boundaries and boundary-spanning mechanisms and defining the role of boundary-spanning mechanisms in tackling different knowledge boundaries. The findings from this study can help AFSC managers to tackle knowledge boundaries effectively and efficiently and to improve the performance of the AFSC companies.

Keywords: Knowledge mobilization, knowledge boundaries, boundary-spanning mechanisms, agri-food supply chains, decision making

1. Introduction

In today's turbulent business environment characterized by digitization, rapid changes, fast-changing of customer demands, exponential growth of technology, and increased interconnectedness, competition between organizations has shifted to competition between supply chains (Ketchen and Giunipero. 2004; Craighead et al. 2009; Bolivar-Ramos et al. 2012; Bhosale and Kant. 2016; Attia and Eldin. 2018). For supply chains to survive in the face of worldwide competitive rivalry and achieve superior performance, they must develop and promote their knowledge management (KM) capabilities that are congruent with the requirements of customers and markets and consistently improve their performance and competitive advantage (Weldy and Gillis. 2010; Argote and Miron-Spektor. 2011). However, it is extremely difficult for agri-food supply chain (AFSC) managers to promote their KM capabilities through learning new practices and technologies due to the involvement of different knowledge boundaries that hinder managers' decision-making (Chen et al. 2017; Liu et al. 2019). A knowledge boundary is considered the border around the specialized knowledge domain of agents (Hawkins and Rezazade. 2012).

An AFSC is a complex system responsible for the circulation of agri-food products in a "farm-to-fork" sequence from the initial stage of production to the final stage of consumption (Luo et al. 2018; Zhao et al. 2019). Additionally, stricter food quality standards, globalization, agro-sustainability, rapid industrialization of agricultural-based products, and increasing customer and government concerns over food safety have resulted in the AFSC activities becoming more complex (Zhao et al. 2020). From a process and value-adding perspective, an AFSC can be seen as a transformation system, which takes in inputs such as seeds, fertilizers, energy, and water to transform them to become desired agri-food products (Taylor and Fearne. 2006; Fischer. 2013; Dania et al. 2018). Important activities such as raw material supply, postharvest, testing, packaging, storage, distribution and marketing, are all necessary for the agri-food products' transformation (Nakandala et al. 2017; Siddh et al. 2017). Nowadays, consumers are increasingly looking for high-quality organic agri-food products that are vitamin-rich, with high-protein and low-fat content and low pesticide contamination, which requires stakeholders in the AFSC to share and combine their knowledge, and further to transform their knowledge into products' innovations (Corso et al. 2010; Cillo et al. 2019; Fait et al. 2019). Thus, KM capabilities such as exploring and exploiting available knowledge, identifying and overcoming knowledge boundaries, and sharing/transferring knowledge with AFSC stakeholders appear to be the necessary response to the continually changing and evolving customer requirements. However, most of the existing literature on supply chain KM focuses either on tools and practices that can facilitate KM in supply chains (Martin et al. 2008; Shih et al. 2012; Reyes et al. 2015) or on the barriers to the adoption of KM in supply chains (Sun and Scott. 2005; Patil and Kant. 2014; Batista et al. 2019). Only limited research has identified knowledge boundaries and corresponding boundary-spanning mechanisms in the context of AFSC (Marra et al. 2012; Cerchione and Esposito. 2016).

The aim of this study is to advance the understanding of tackling knowledge boundaries for adopting different boundary-spanning mechanisms within the context of AFSC. Accordingly, three research questions are formulated: (1) What are the knowledge boundaries and boundary-spanning mechanisms that exist in the AFSC? (2) How can boundary-spanning mechanisms be used to tackle knowledge boundaries? (3) What is the most effective element that can be used for tackling knowledge boundaries? Based on data from in-depth interviews with experienced AFSC practitioners from Chile that were analyzed using thematic analysis, total interpretive structural modeling (TISM), and Cross-Impact Matrix Multiplication Applied to Classification (MICMAC) analysis, this study provides insights into understanding knowledge boundaries and boundary-spanning mechanisms used in the AFSC, and makes the following contributions.

First, this study empirically identifies the knowledge boundaries that exist in Chileans' AFSC. Second, four boundary-spanning mechanisms to tackle knowledge boundaries have been identified; these are boundary objects, boundary spanners, boundary practices, and boundary discourses. Further, the most effective element for tackling knowledge boundaries has been identified. Finally, an integrative framework linking knowledge boundaries and boundary-spanning mechanisms has been built by serving as a foundation for AFSC practitioners to acquire knowledge and advance collaboration efforts effectively.

The structure of this study is organized as follows - section two reviews related work, followed by the research methodology in section three. Then, the empirical data collection is presented in section four. In section five, we provide the main empirical findings of the research. Further, the discussion is included in section six. Finally, conclusions are drawn in section seven.

2. Literature review

Knowledge as a construct is largely intangible, non-substitutable, imperfectly imitable, rare, and valuable; therefore, it has been considered by many scholars (e.g., Barney. 1991; Blome et al. 2014; Ogulin et al. 2020) as a critical resource for helping organizations to develop core competency, build innovative capacity, and promote competitive advantage. The knowledge-based view (KBV) of the firm postulates knowledge as an essential resource with the highest strategic value that can be created, stored, acquired and applied within and between firms (Grant and Baden-Fuller. 1995; Grant. 1996). Under the KBV, knowledge needs to be constructed, acquired, and appropriately processed and, as a result, can become a valuable and inimitable resource (Blome et al. 2014). Given the centrality of knowledge, it is not surprising that a growing body of literature has focused on the different processes of KM, including knowledge creation, knowledge storage, knowledge transfer, knowledge sharing, and knowledge application (De Vries and Brijder. 2000; Hult et al. 2004; Paton and McLaughlin. 2008; Sangari et al. 2015). However, there appears no consensus on the KM processes, despite the fact that there has been great effort in this regard (Wiig. 1993; Bukowitz and Williams. 2000; Evans et al. 2015; Liu. 2020). The KM processes (knowledge building, knowledge holding, knowledge mobilization, and knowledge utilization) provided by Liu (2020) are more suitable for this work because this study aims to explore knowledge mobilization in the boundary-spanning context. A significant effort needs to be made by the knowledge senders, receivers, and third parties to successfully share/transfer knowledge, particularly in the AFSC – a multi-objective system crossed by a variety of information and knowledge flows (Cerchione and Esposito. 2016).

A knowledge boundary represents the limit, or border, of an agent's knowledge base in relation to a different domain of knowledge (Chen et al. 2017). There are three types of knowledge boundaries that have been widely cited by other scholars (Carlile. 2002; Swart and Harvey. 2011; Boshkoska et al. 2019; Liu. 2020), which are syntactic boundaries (difference in language), semantic boundaries (difference in meaning), and pragmatic boundaries (difference in practice). At each boundary, there is some level of difference, dependence and novelty.

Difference in knowledge represents a difference in the knowledge accumulated or a difference in the type of knowledge. With the increase in different forms of knowledge - for example, each AFSC practitioners has its own domain-specific knowledge - the amount of effort needed to adequately share/assess knowledge between two AFSC actors is also increasing (Carlile. 2004).

Dependence in knowledge refers to the links among different knowledge for accomplishing a task. To develop a perfect tomato product, it requires different AFSC practitioners to contribute their efforts; for example, genetic scientists provide their knowledge on gene modification for providing a seed that will produce the perfect shape, taste, and color tomato and farmers contribute their knowledge on providing a tomato seed with an appropriate humidity, temperature, and sunshine. Thus, it is not difficult to imagine that the complexities and the amount of effort involved to achieve the task are increasing with the increase in the number of dependencies between different AFSC practitioners (Boshkoska et al. 2018).

Finally, a novelty represents “a lack of common knowledge to adequately share and assess domain-specific knowledge at a boundary” (Carlile. 2004, p. 557). This is the most challenging part at the edge of a knowledge boundary because when novelty increases, a lack of common knowledge to share/assess also increases (Carlile. 2004). Only when a shared understanding or a concept between two practitioners has been built can they share knowledge and start to accumulate new knowledge (Holten and Rosenkranz. 2011). The syntactic boundary inherits the lowest ranking for novelty because in this context people share a common logic, a set of values and world view (Hislop et al. 2018). As novelty increases, people do not have a shared logic or a world view and may generate different understandings and interpretations of the same knowledge, which is regarded as a semantic boundary. Finally, further increased novelty causes partners to have different interests that impede their ability to share and assess knowledge, which is known as a pragmatic boundary (Carlile. 2004).

Knowledge boundary exists for many reasons; for example, organizational and individual characteristics, knowledge characteristics, time and space, as well as occupational, functional, disciplinary, and professional reasons (Mudambi and Swift. 2009; Cross et al. 2013; Shaw et al. 2013; Boshkoska et al. 2019). The difference in their knowledge base, the way people work, the difference in their cultural background, and the difference in their expertise are examples that may impede knowledge mobilizations (Jesiek et al. 2018; Liu. 2020). A total of 14 sources of barriers that hinder knowledge mobilization have been summarized by Sun and Scott. (2005), some of them being personality differences, trust problems, openness to ideas, organizational culture, and fear of losing competitive advantage. Patil and Kant (2014) identified that a lack of management commitment is the most important barrier. It is no doubt that knowledge boundaries can erect significant barriers to knowledge mobilization and further hinder coordination and collaboration among individuals, groups, and organizations (Carlile. 2004).

To overcome the barriers stemming from the knowledge boundaries, four specific boundary-spanning mechanisms covering human agents, presence of artefacts, practice and content of knowledge, respectively, have been deployed. Boundary spanners are human agents who use language and their cognitive power to translate knowledge across boundaries. Through promoting coordination and facilitating problem-solving between parties, knowledge is translated and cognitive gaps are bridged (Hawkins et al. 2012). Persuasion is always used by the spanners to develop legitimacy, particularly when they are outside a party’s community. While boundary spanners are effective in translating explicit knowledge, particularly fluid knowledge, boundary objects are focusing on a physical, abstract, or mental object that can be attached and transformed among organizations (Liu. 2020). The flexible nature of boundary objects provides sufficient opportunities for individuals from different communities to attach localized meaning to the object. Therefore, it is effective in facilitating coordination across knowledge communities. However, the object can only be effective in tackling knowledge boundaries after the shared meaning of the boundary object is carefully developed and strengthened. Boundary practice is generally used to tackle knowledge boundaries involving tacit knowledge that is not easily codified into explicit knowledge. It facilitates coordination by engaging experts from different domains in collective activities. There are two distinct advantages to this approach: (1) it helps to share tacit knowledge that resides in people’s minds and that cannot be expressed or one party does not fully understand; and (2) it facilitates involved parties to understand each other’s integrative framework (Hawkins and Rezazade. 2012). Thus, co-generating knowledge can be achieved. In comparison with boundary spanners and boundary objects that heavily rely on existing knowledge to be recalled and transformed, boundary practice is more active in creating new knowledge. Finally, boundary discourse is focusing on what is communicated between knowledge communities. It is suggested to be used by experts who are engaged in cross-domain collaborations.

There is also a growing interest in applying KM in supply chains due to the fragmented nature of industry sectors and fragmented knowledge across complex supply chains (Capo-Vicedo et al. 2011; Marra et al. 2012; Lim et al. 2017; Olson. 2018) (see Table 1). Based on the recent literature review on supply chain KM (Cerchione and Esposito. 2016), four topic areas have been highlighted; these are factors affecting KM, KM systems, barriers to the adoption of KM, as well as KM and performance. Furthermore, the most common areas for applying KM in supply chain management are outsourcing, construction, new product development, decision-support, risk management, procurement, and organizational performance (Marra et al. 2012).

Table 1 Research related to supply chain KM

Author(s) (year)	Topic focus				Research methods	Supply chain types
	Factors affecting KM	KM systems	Barriers to the adoption of KM	KM and performance		
Capo-Vicedo et al. (2011)		√			Case study	Construction supply chain
Samuel et al. (2011)		√			Case study	Manufacturing supply chain
Liu et al. (2013)		√			Case study	Electronic supply chain
Blome et al. (2014)	√				Hierarchical regression analysis	Procurement supply chain
Patil and Kant (2014)			√		Analytical hierarchy process	Not specified
Kim et al. (2015)	√				Hierarchical linear modeling	Not specified
Bhosale and Kant (2016)	√				Interpretive structural modeling	Manufacturing supply chain
Lim et al. (2017)				√	Total interpretive structural modeling	Textile supply chain
Batista et al. (2019)				√	Case study	Agri-food supply chain
Peng et al. (2020)				√	Structural equation modeling	Green supply chain

Based on the discussion on the supply chain KM, we summarized two research gaps that open avenues for future research:

- First, the literature review has pointed out that KM has been applied in different types of supply chains, including construction, manufacturing, textile, and green supply chains. However, the application of KM on AFSC has not attracted enough attention from academia and the agri-food industry. Considering that the agri-food industry plays a significant role in fulfilling the UN’s sustainable development goals (SDGs) in reducing hunger and ending poverty, and that more advanced technologies (e.g., Blockchain and Internet-of-Things) have been applied in the agri-food industry (Schniederjans et al. 2020). Therefore, greater focus should be given to the AFSC KM, as the agri-food industry gradually becomes more knowledge-intensive.
- Second, the recent literature reviews (Marra et al. 2012; Cerchione and Esposito. 2016) on supply chain KM have pointed out four areas that have been highlighted

(see Table 1). However, there is a lack of research that investigates the barriers to the adoption of KM; in particular a lack of studies that investigate knowledge mobilization crossing boundaries in supply chains (Liu et al. 2019). Considering most AFSC stakeholders do not receive a higher education (UNESCO. 2017), tackling knowledge boundaries may require more support and resources. Therefore, more studies focusing on knowledge mobilization crossing boundaries should be conducted.

3. Research methodology

This section describes and justifies the data collection technique, data analysis techniques, and sampling techniques used in this study. Figure 1 illustrates the research methodology employed for this study, including one data collection technique and three data analysis techniques.

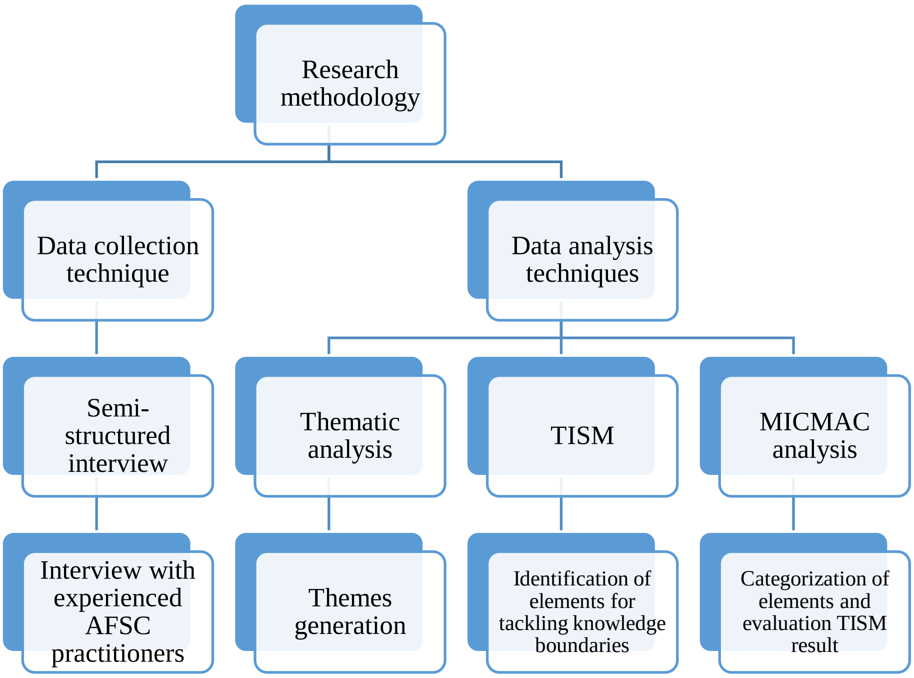

Figure 1 Research methods employed for this study

3.1 Data collection technique

The interview has been selected over other data collection techniques for the several advantages it offers. (i) a high response rate that can be achieved in comparison with the survey questionnaire (Austin. 1981); (ii) interviews are suitable for exploring the participants' attitudes, values, beliefs, and motives (Smith. 1975); (iii) interviews are useful when discussing sensitive issues through observing participants' non-verbal indicators (Gordon. 1975); (iv) it can facilitate comparability by ensuring that all questions are answered by each respondent (Bailey. 1987); and (v) interviews ensure that participants' answer all the questions without assistance from others (Bailey. 1987). Considering the variety of knowledge boundaries and boundary-spanning mechanisms, as well as the complexity of AFSC, it may be difficult for researchers to elicit the thoughts related to knowledge boundaries and boundary-spanning mechanisms that are in peoples' minds through a survey questionnaire or observation. Hence, this study's the data collection technique of this study was semi-structured interviews with AFSC practitioners with experience in knowledge boundaries and boundary-spanning mechanisms. Semi-structured interviews were selected because it offers sufficient flexibility in terms of adapting, adopting, and changing questions as the researcher proceeds with the interviews (Saunders et al. 2019).

3.2 Data analysis techniques

Three data analysis techniques have been employed for this study; these are thematic analysis, TISM, and MICMAC analysis. Thematic analysis is a foundational technique for conducting qualitative analysis, which provides a rigorous and methodical manner to yield rich and meaningful data analysis results (Saunders et al. 2019). Other qualitative data analysis techniques (e.g., content analysis, narrative analysis, and discourse analysis) all have limitations that make them unsuited to this study. For example, content analysis is time-consuming, and it is difficult to analyse the data using computers (Vaismoradi et al. 2013). Narrative analysis may only capture a limited number of experiences and may ignore broader structural influences (Earthy and Cronin. 2008). Discourse analysis has problems providing absolute and tangible answers to specific problems (Fairclough et al. 2011). Thus, thematic analysis was used as the first data analysis technique to generate themes related to knowledge boundaries and boundary-spanning mechanisms.

Then, TISM was selected to identify the most effective elements for tackling knowledge boundaries. Through arranging different elements into different levels, the elements in the lowest level are seen as the most important ones that drive the whole system (Sushil. 2012; Dubey et al. 2015; Zhao et al. 2020). There are several other techniques such as graph theory and GTMA (Matrix approach), and DEMATEL (Decision-making trial and evaluation laboratory) or fuzzy cognitive maps that could be used. Although all these techniques have the ability to depict elements/variables into one diagram with identified interrelationships among them, it may be difficult for researchers to identify the most important elements as they are depicted in one diagram in a disorderly format (Mangla et al. 2019). ISM (Interpretive structural modelling) has been widely used to build a hierarchy framework of the selected elements and identify the key elements that drive the system, but it fails in providing the transparency of the system and is limited in answering why that element is the key element of the system (Pfohl et al. 2011; Sushil. 2012; Hughes et al. 2016). Thus, TISM is selected to identify the key elements for tackling knowledge boundaries by building a hierarchy framework.

Finally, MICMAC analysis has been selected to categorize elements and evaluate TISM analysis results. MICMAC analysis has been identified as an effective technique for visualizing and judging the significance of elements/variables (Manjunatheshwara and Vinodh. 2018). Other techniques such as TOPSIS (Technique of order preference similarity to the ideal solution) and ELECTRE (Elimination and choice expressing reality) may be used to identify the key elements but have limited recognition by the scientific community (Harpulugil et al. 2011).

Thus, thematic analysis, TISM, and MICMAC analysis have been combined in this study to analyze the data from different research angles, and to further help to achieve a clearer and more holistic picture of the issues being investigated (Shaw et al. 2020).

3.3 Sampling techniques

Two sampling techniques have been used in this study, purposive sampling and snowball sampling. Purposive sampling is a non-probability sampling technique that is extremely useful when researchers need to investigate a specific phenomenon that knowledgeable experts working in this domain (Tongco. 2007). The criteria for recruiting suitable participants are set as the following: (1) the selected agri-food companies have been recognized by peers to have implemented boundary-spanning mechanisms in practice; (2) agri-food companies that have knowledge extension departments are preferred as they have more expertise in tackling knowledge boundaries; (3) the selected participants must have more than 10 years working experience in KM to ensure a high level of knowledge and experience; and (4) participants who can speak English are preferred as Chile is a Spanish-speaking country. Based on these criteria, nine participants were initially selected to be interviewed. These participants included farmers, wholesalers, retailers, exporters, and researchers. Then, snowball sampling was used to find other experts based on the recommendation of participants. Snowball sampling is effective when representation from diverse communities is needed and when it is difficult for the research team to include a representative of all communities under investigation (Sadler et al. 2010). Considering there are various actors involved in the AFSC management, the implementation of a snowball sampling technique is appropriate. At the end of each interview, we asked participants to recommend potential participants. To find the best participants, those who are frequently recommended by other participants were selected. Thus, three eligible participants that were mentioned three times by other participants and conformed to the relevant criteria were chosen to conduct further interviews with. Following these three additional interviews, no new themes emerged and the interviews did not help identify new or expand the emerging concepts, indicating we reached the data saturation point. Thus, the total sample size is 12 participants (see Table 2).

Table 2 Interviewees' information

Case firm	**Main duty in AFSC**	**Employees**	**Ownership**	**Interviewee**	**Collected data**	**In-site tours (Yes/No)**
A	Farmer	20-30	Privately-owned	Owner	One semi-structured interview	Yes
B	Research institution	1000-5000	Publicly-owned	Lab manager Executive Director of information technology	Three semi-structured interviews	Yes
C	Processor	80-100	Privately-owned	Owner	One semi-structured interview	Yes
D	Wholesaler	30-50	Privately-owned	Owner Director of marketing	Two semi-structured interviews	Yes
E	Retailer	800-1000	Privately-owned	Director of knowledge extension Director of operation management	Two semi-structured interviews	Yes
F	Government	15-20	Publicly-owned	Director of agriculture department	One semi-structured interview	Yes
G	Exporter	100-120	Privately-owned	Owner Director of operation management	Two semi-structured interviews	Yes

4. Empirical data collection

The empirical data collection process was conducted in November 2019 in Chile. The justifications for selecting Chile to collect data are as follows: Chile occupies a long and narrow strip of land between the Andes and the Pacific Ocean, which results in the geographical isolation of Chile from other South American countries. The unique geographical advantage has helped spare Chile from pests and diseases that spread in other South American countries.

Second, the value added by the agriculture, forestry and fishing sector to the GDP in Chile has experienced constant growth from 7.9% to 9.85% between 2010 and 2018 (Statista. 2019). In the era of the knowledge economy, economic growth cannot happen without the great contribution of knowledge (Tchamyou. 2017). Third, Chile is the longest country in the world. The diverse climate types from South to North of Chile provide us with an excellent opportunity to investigate agricultural activities. Thus, we visited Santiago in Chile in spring as agricultural knowledge-intensive activities were happening at that time. An interview guide with a predefined list of questions focusing on the knowledge mobilization model was developed, but also allowing participants to express their ideas freely and expand on the initial questions. A pilot study was organized in the form of an open round-table discussion with two experienced AFSC practitioners and one professor in KM and business decision-making. As a result, the wording of some questions was modified. We emailed the interview guide three days before the interview session in order to allow participants to have enough time to consider the questions and organize their answers. Each interview lasted between 45 and 70 minutes and all interviews were audio-recorded. During each interview, at least two research team members were presented and took notes to ensure all important information was captured. After each interview, we emailed the interview notes and transcript to the interviewees for them to check that we had interpreted their opinions correctly.

5. Data analysis and findings

The data were analyzed by three different techniques: thematic analysis, TISM, and MICMAC analysis. Thematic analysis was used to identify themes that related to boundary-spanning mechanisms and knowledge boundaries. TISM was used to identify the most effective element that could be used for tackling knowledge boundaries. Finally, MICMAC analysis was used to categorize elements and evaluate the TISM analysis results.

5.1 Thematic analysis

We began to analyze the data during the data collection process and organized our analysis in a database using NVivo 12. In this stage, thematic analysis was used to analyze the data. Initially, we transcribed the interview audio files word-by-word, immersive reading the transcript multiple times, and writing summary reports for each interview. During this process, attention was paid to how firms identified that they encountered different knowledge boundaries and how firms used their own resources to tackle these knowledge boundaries. Then, we began to code the words, sentences and paragraphs that could be used as answers to the research questions that we proposed. For example, ICT application and institution open days that can be used to tackle knowledge boundaries, and knowledge boundaries such as lack of interests were coded (Liu. 2020). After coding all the interviews, the first author shared the coding schemes with his co-authors to reach a consensus in terms of interpretation. Finally, the codes were refined, compared, grouped and categorized, resulting in first-order codes, second-order themes, and aggregation dimensions (King and Horrocks. 2010) as shown in Appendices I, II, III, and IV.

First-order codes are direct quotes from the interview transcripts, and second-order themes are the elements that lend support to build aggregate dimensions. For example, nine themes were identified to have positive effects in building boundary-spanning mechanisms (see Appendix I). The third column of support from interview cases refers to the presence or absence of evidence obtained from the interviews. A tick (√) represents the presence of weak evidence, three ticks (√√√) mean strong evidence, and no tick means no evidence.

It is interesting to note that a majority of the elements for building boundary-spanning mechanisms, identifying knowledge boundaries, identifying resources used for tackling knowledge boundaries, and identifying the benefits for tackling knowledge boundaries all gained three ticks (√√√) from the interview cases because the interviewees have a sufficient and deep understanding of the KM of the AFSC and have been working on the AFSC for more than 10 years. Therefore, they have provided sufficient details on knowledge boundaries they have met, what boundary-spanning mechanisms they have used, what resources they have used, and what benefits can be achieved after tackling knowledge boundaries. Finally, related themes were categorized into different aggregate dimensions. Based on the thematic analysis result, the knowledge mobilization model has been built, as shown in Figure 2.

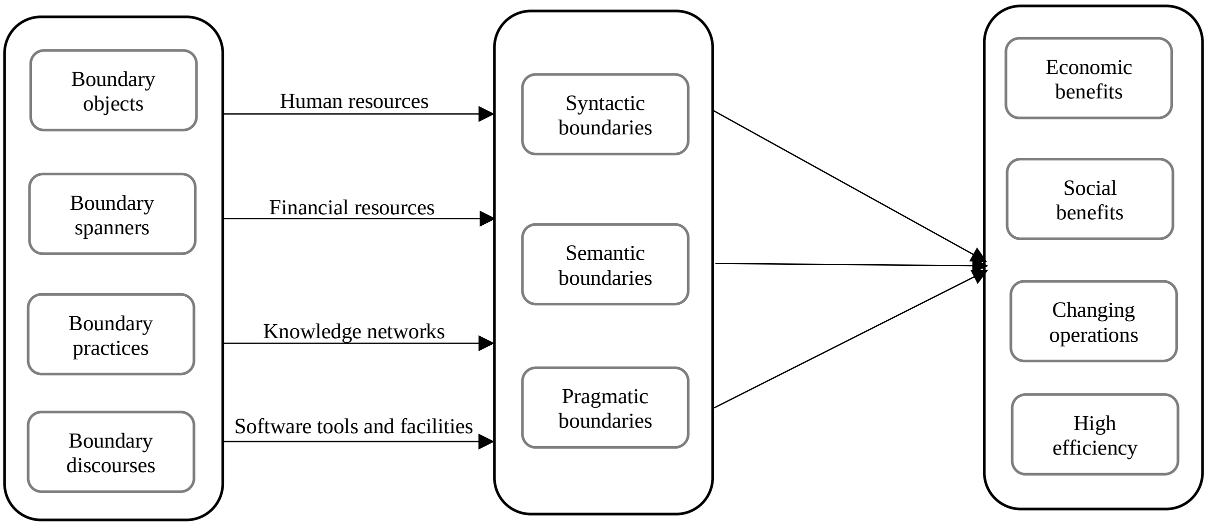

Figure 2 Knowledge mobilization model identified through thematic analysis

5.2 TISM

TISM is an effective method to identify the key element that drives the system through building hierarchical relationships among the selected elements, and it has been used by various researchers in different fields (Sushil. 2012; Singh et al. 2018; Zhao et al. 2020). The TISM process for building a hierarchical relationship among the selected elements of boundary-spanning mechanisms is discussed below.

Step I: Identification and definition of elements. This step involves identifying and defining the elements that can be used for building hierarchical relationships. Thus, the elements for modeling employed in the current study are as follows: ICT applications, open data, action protocols, public platforms, coordination, government support, supply chain collaboration, open days, and regular visits.

Step II: Define the contextual relationship. The contextual relationship identified among the elements is "element A is influencing/enhancing element B." For example, coordination is influencing/enhancing action protocols.

Step III: Interpretation of relationships. This step is considered a critical step as it interprets the relationships between different elements. Thus, the relationship between element A and element B can be interpreted as "How element A helps to achieve element B." Experts involved in the semi-structured interviews were invited to participate in the modeling process to answer these questions.

Step IV: Pair-wise comparisons. An "Interpretive logic-knowledge base" is prepared for pair-wise comparison of the selected elements in this study. The answer for each pair-wise comparison can be Y (Yes) or N (No). If the answer is Y, a further explanation needs to be given by experts. In this study, a total of 72 rows (e.g., 9*(9-1) = 72) need to be implemented.

Step V: Construct the reachability matrix and do a transitivity check. The initial reachability matrix (see Table 3) is prepared with 1 in each cell for every Y given in the knowledge base, otherwise it is 0. Then, the initial reachability matrix is checked for transitivity rule and 1* is included to represent the transitive links. The transitivity rule is if element A relates to element B, and element B relates to element C, then the element A is necessarily related to element C.

Step VI: Level partition on the final reachability matrix. The final reachability matrix (see Table 4) obtained through previous steps is prepared for level partitioning (see Table 5). Thus, the reachability and antecedent sets for each element of the matrix are noted. The intersection of the reachability set and antecedent set is evolved. Elements with intersection set the same as the reachability sets are placed at the top level, which means a high dependency on other elements. Conversely, the elements placed in the lower levels involve a higher driving power to the whole system. The elements placed at the top level are removed from the matrix for further iterations until levels for all the elements are identified (Manjunatheshwara and Vinodh. 2018).

Table 3 The initial reachability matrix

Elements	**E1**	**E2**	**E3**	**E4**	**E5**	**E6**	**E7**	**E8**	**E9**
E1(ICT applications)	1	0	0	0	1	0	0	1	1
E2(Open data)	0	1	0	0	0	0	0	0	0
E3(Action protocols)	1	1	1	1	1	1	1	1	1
E4(Public platforms)	0	1	0	1	0	0	0	0	0
E5(Coordination)	0	1	0	1	1	1	1	1	1
E6(Government support)	1	1	0	1	0	1	1	0	0
E7(Supply chain collaboration)	0	1	0	1	0	0	1	1	1
E8(Open days)	0	0	0	0	0	0	0	1	1
E9(Regular visits)	0	0	0	0	0	0	0	0	1

Table 4 The final reachability matrix

Elements	**E1**	**E2**	**E3**	**E4**	**E5**	**E6**	**E7**	**E8**	**E9**	**Driving power**
E1(ICT applications)	1	0	0	0	1	1*	0	1	1	5
E2(Open data)	0	1	0	0	0	0	0	0	0	1
E3(Action protocols)	1	1	1	1	1	1	1	1	1	9
E4(Public platforms)	0	1	0	1	0	0	0	0	0	2
E5(Coordination)	1*	1	0	1	1	1	1	1	1	8
E6(Government support)	1	1	0	1	0	1	1	0	0	5
E7(Supply chain collaboration)	0	1	0	1	0	0	1	1	1	5
E8(Open days)	0	0	0	0	0	0	0	1	1	2
E9(Regular visits)	0	0	0	0	0	0	0	0	1	1
Dependence power	4	6	1	5	3	4	4	5	6	

Note: * represents transitive links

Table 5 Level partitioning process

Element	**Reachability set**	**Antecedent set**	**RS∩AS**	**Level**
Iteration 1				
E1	1,5,6,8,9	1,3,5,6	1,5,6	
E2	2	2,3,4,5,6,7	2	Level I
E3	1,2,3,4,5,6,7,8,9	3	1	
E4	2,4	3,4,5,6,7	4	
E5	1,2,4,5,6,7,8,9	1,3,5	1,5	
E6	1,2,4,6,7	1,3,6	1,6	
E7	2,4,7,8,9	3,5,6,7	1,6,7	
E8	8,9	1,3,5,7,8	8	
E9	9	1,3,5,7,8,9	9	Level I
Iteration 2				
E1	1,5,6,8	1,3,5,6	1,5,6	
E3	1,3,4,5,6,7,8	3	1	
E4	4	3,4,5,6,7	4	Level II
E5	1,4,5,6,7,8	1,3,5	1,5	
E6	1,4,6	1,3,5,6	1,5,6	
E7	4,7,8	3,5,6,7	7	
E8	8	1,3,5,7,8	8	Level II
Iteration 3				
E1	1,5,6	1,3,5,6	1,5,6,7	Level III
E3	1,3,5,6,7	3	1	
E5	1,5,6,7	1,3,5	1,5	
E6	1,6,7	1,3,5,6	1,5,6,7	Level III
E7	7	3,5,6,7	7	Level III
Iteration 4				
E3	3,5	3		
E5	5	1,3,5,6	5,6	Level IV
Iteration 5				
E3	3	3	3	Level V

Step VII: Developing a digraph. A digraph that illustrates the interrelationship among the elements of boundary-spanning mechanisms is developed based on the final reachability matrix. Thus, the elements, the interrelationships among the elements, and the transitive links are portrayed in the form of a directed graph (see Figure 3).

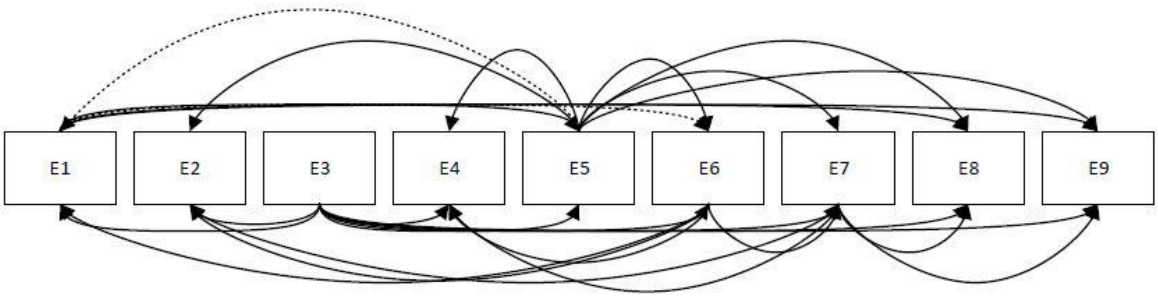

Figure 3 The digraph of boundary-spanning mechanisms

Step VIII: Prepare an interaction matrix. The interaction matrix is developed through converting a diagraph into a binary interaction matrix form by changing all the interactions by "1" entry. It is further developed as an interpretive matrix with the help of the knowledge base.

Step IX: Build a TISM model. The TISM model of boundary-spanning mechanisms is developed by using the information in the interpretive matrix and the digraph, as shown in Figure 4.

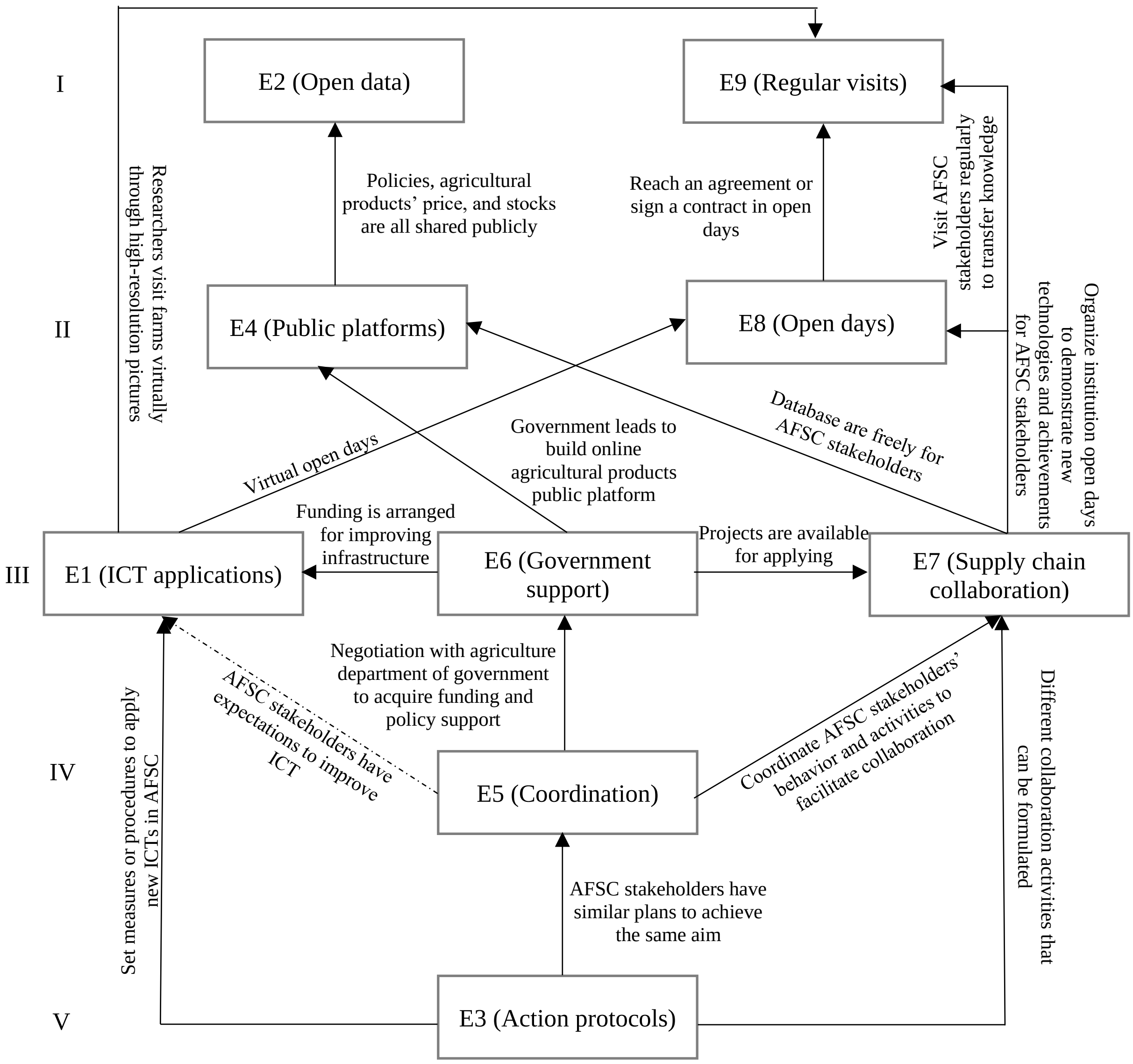

Figure 4 TISM model for elements of boundary-spanning mechanisms

From Figure 4, we can see that different elements of boundary-spanning mechanisms are deployed into five levels. Action protocols of boundary objects are identified as the key element to tackle knowledge boundaries, as it locates in the lowest level of the TISM hierarchy that has the ability to drive the whole system. Through developing the aim, setting key milestones, and regulating the behaviors of the AFSC stakeholders, an action protocol for the whole AFSC has been built. The focal company plays a critical role in helping other AFSC stakeholders to implement the action protocol, as it has sufficient financial resources, human resources, software tools and facilities, and knowledge networks. Thus, the focal company is able to coordinate the activities in the AFSC and, further, to achieve supply chain collaboration, to acquire governments' support, and to apply new ICTs in the AFSC. Collaboration activities and working for the same project helps to increase the relationship among AFSC stakeholders, whereas increased relationships contributes to tackling knowledge boundaries (Boshkoska et al. 2018). It is important to note that we visited Santiago in the November of 2019. At that time, most agricultural researchers were working at home, as civil protests took place across the whole country. AFSC stakeholders have realized the importance of applying advanced ICTs in a critical time. Thus, experts can transfer their knowledge without appearing in the field. Furthermore, governments have built online public platforms for AFSC stakeholders to download policies, timely agricultural products' prices, and agricultural products' stock to reduce the knowledge boundaries that exist between AFSC stakeholders and the government. Besides, a national vegetable network has been built under the supervision of the Chilean government, to involve more research institutions in the knowledge network and increase the efficiency of knowledge mobilization.

5.3 MICMAC analysis

MICMAC analysis categorizes different elements of boundary-spanning mechanisms into different categories (e.g., autonomous, dependent, linkage, and independent variables) based on the dependence and driving power summarized in the Table 4. Independent variables such as E3 (action protocols) and E5 (coordination) are the most effective elements for tackling knowledge boundaries as they have high driving power. Dependent variables such as E2 (open data), E4 (public platforms), E8 (open days), and E9 (regular visits) are identified as having high dependence power, which means that these elements are dependent on the driving elements of the system. No autonomous variables have been identified in this study, which indicates that all the elements have positive effects in tackling knowledge boundaries. Finally, linkage variables such as E1 (ICT applications), E6 (government support), and E7 (supply chain collaboration) having high dependence and driving power, which provide linkage between independent and dependent variables.

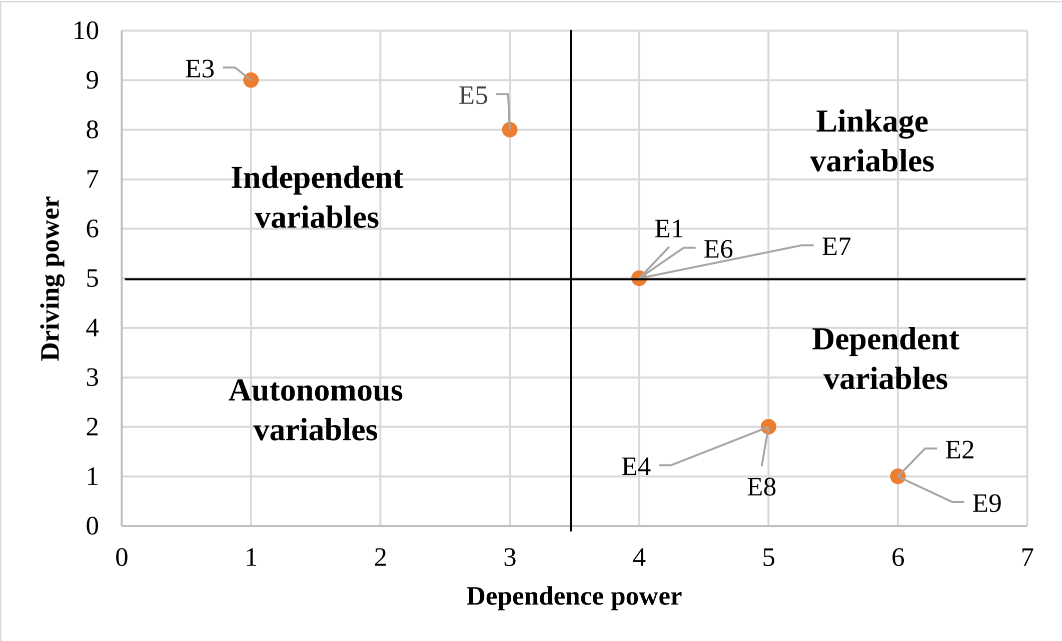

Figure 5 MICMAC analysis result for elements of boundary-spanning mechanisms

6. Discussion

This paper has investigated the effectiveness of boundary-spanning mechanisms in tackling knowledge boundaries with empirical evidence from the AFSCs of Chile. The key findings of this study have made several contributions to the existing body of knowledge while answering the three research questions outlined in the introduction. First, three knowledge boundaries (i.e. syntactic boundaries, semantic boundaries, and pragmatic boundaries) exist in the AFSC of Chile, and four specific boundary-spanning mechanisms (i.e. boundary objects, boundary spanners, boundary practices, and boundary discourses) have been used by AFSC stakeholders for tackling knowledge boundaries. Second, a framework that integrates knowledge boundaries, boundary-spanning mechanisms, resources used for tackling knowledge boundaries, and benefits for tackling knowledge boundaries has been built based on the empirical evidence, which helps to understand the interactions between knowledge boundaries and boundary-spanning mechanisms in the context of AFSC. Finally, the most effective element for tackling knowledge boundaries has been identified, which has the potential to help AFSC stakeholders' decision-making (see Figure 6) in increasing the efficiency and effectiveness of AFSC's knowledge mobilization.

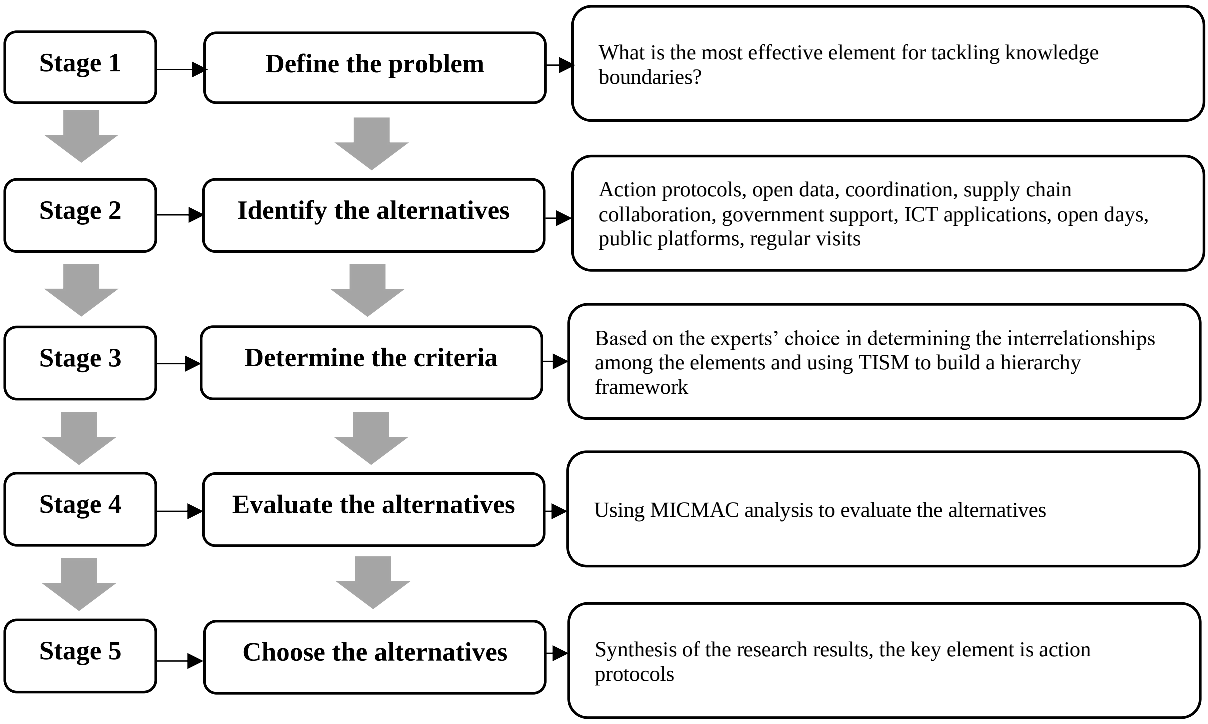

Figure 6 Decision-making process involved in this study

Among the identified boundary-spanning mechanisms and knowledge boundaries, we found that our research is consistent with previous studies. There are four boundary-spanning mechanisms that are discussed in the literature, which are boundary objects, boundary spanners, boundary practices, and boundary discourses (Akkerman and Bakker. 2011; Swart and Harvey. 2011). However, this study identifies that the only mechanisms that demand critical attention are only boundary objects and boundary spanners as they do not need to adjust an individual's knowledge base, which only needs to adjust information to fit into it (Liu. 2020). In AFSC, stakeholders are elderly and low-educated; it is relatively difficult for them to change their knowledge base. The other two boundary-spanning mechanisms are formally used in the new product recommendation or new technology application as most of the AFSC stakeholders initially lack interest. Thus, researchers or knowledge senders need to develop stakeholders' interest in it through boundary practices and boundary discourses (Hawkins et al. 2012). Previous studies prove that different types of knowledge boundaries exist in the AFSC (Sarkis. 2012; Boshkoska et al. 2019), as per the findings of this study.

Among the identified elements of boundary-spanning mechanisms and knowledge boundaries, some of them are considered new. For example, ICT application is an appreciated measure used for tackling the knowledge boundaries of supply chains (Schniederjans et al. 2020). This study holds the same view as advanced ICTs that have been applied in the AFSC of Chile. The study conducted by Boshkoska et al. (2018) illustrates that boundary-crossing education is non-existent in the AFSC of Chile. However, the empirical study identifies that open days and governments' support are used for educating AFSC stakeholders to tackle or alleviate the knowledge boundaries. The study conducted by Wong and Fang (2010) highlighted the critical role of action protocol in buyer-sell negotiations. This study has extended that critical role in tackling knowledge boundaries in the context of AFSC KM. Our study, along with Boshkoska et al.'s (2019) study, acknowledges that supply chain collaboration is an important enabler for supply chain KM. Besides, this study extends its role for knowledge mobilization crossing boundaries. Yadav et al. (2020) highlighted the most important element for improving supply chain knowledge mobilization is culture and leadership, but the findings of this study considered action protocols as the most important one.

7. Conclusions

Currently, the world business environment is characterized by increasing uncertainties and risks. There is no doubt that the business environment will exert more pressure on AFSC managers to force them to respond and act quickly, which intensifies the need to develop strategies to overcome knowledge boundaries. Therefore, having a deep understanding of knowledge boundaries and boundary-spanning mechanisms plays a key role in AFSC companies' growth. This study conducted 12 semi-structured interviews with experienced AFSC experts in Chile. Then, thematic analysis, TISM, and MICMAC analysis were used to analyze the data. The research results indicate that boundary objects, boundary spanners, boundary discourses, and boundary practices are effective in tackling syntactic boundary, semantic boundary, and a pragmatic boundary with appropriate inputs. Economic performance, knowledge networks, efficiency and operations of a company will be improved if knowledge boundaries are properly addressed. Additionally, action protocols of boundary objects should be given critical focus as it is a key element for tackling knowledge boundaries.

This paper contributes to managerial practices significantly. First, the positions of knowledge boundaries and specific boundaries in the AFSC have been identified. Thus, to help AFSC practitioners to target and deploy resources accordingly, a knowledge transfer department should be formulated in the agricultural research institutions/governments responsible for effectively transferring/sharing knowledge. Other agricultural practitioners such as farmers are advised to build relationships with experienced research institutions/universities/professional organizations to acquire knowledge, as these institutions have expertise in communicating with farmers. Second, the integrative framework of knowledge boundaries and boundary-spanning mechanisms has been constructed. Thus, AFSC practitioners would benefit from the integrative framework by replicating specific measures in a similar context to enhance collaboration efforts. For example, to strengthen the supply chain collaboration, we suggest that AFSC managers in Chile are suggested to actively participate in the open days of an agricultural research institution to acquire the latest information/knowledge about agriculture. As Chile is the longest country in the world surrounded by the Andes and the Pacific Ocean, we further suggest that AFSC practitioners use agricultural mobile applications to increase knowledge transfer efficiency. Third, key elements for tackling knowledge boundaries have been identified, which provides a guideline for the focal company in the AFSC to improve their boundary-crossing capability. Thus, formulating an action protocol for all AFSC practitioners to increase their common understanding of domain-specific knowledge is essential, particularly for the Chilean context where there is much distrust between different AFSC practitioners.

This study also has several limitations. First, this study focuses on the AFSC of Chile. It is necessary for researchers to test the generalizability of this study results. Second, this study identifies the elements for tackling knowledge boundaries, but we do not know which elements are effective for tackling each knowledge boundary. Thus, we proposed several future research directions that have the potential to cover the limits of this study. First, structured interviews should be conducted in future research to evaluate the research results in other South American countries, as they have a similar cultural environment. Second, to check which elements are effective to tackle each knowledge boundary, we suggest that fsQCA (Fuzzy-set qualitative comparative analysis) is used in future research, as it has the capability to build relationships between an outcome and all binary combinations of the independent variables (Kraus et al. 2018).

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Appendix I Empirical evidence for supporting boundary-spanning mechanisms

First-order codes	Second-order themes	Support from interview cases												Aggregate dimensions
		1	2	3	4	5	6	7	8	9	10	11	12	
"Mobile applications with specific agricultural information".	**ICT applications**	√ √ √	√ √	√ √ √	√ √ √	√	√ √ √	√ √	√ √ √	√ √	√ √ √	√ √ √	√	
"Documents related to food safety and public regulations and policies are available for free download on the related website".	**Open data**	√ √ √	√ √ √	√ √	√ √	√ √ √	√ √ √	√ √ √	√ √	√ √	√ √	√ √ √	√ √ √	**Boundary objects**
"Action protocols for all AFSC stakeholders".	**Action protocols**	√ √	√ √	√ √ √	√ √ √	√ √	√ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √	√ √ √	
"Generation of public platforms of companies that provide different supplies for the horticultural sector".	**Public platforms**	√ √ √	√ √ √	√ √	√ √ √	√ √	√ √ √	√ √	√ √ √	√ √	√ √ √	√ √ √	√ √ √	
"Coordinate with knowledge extension agents to transfer knowledge".	**Coordination**	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	**Boundary spanners**
"Joint work with the Agricultural and Livestock Service of Chile (SAG) and exporters on agri-food products safety".	**Government support**	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	
"Establishments of collaboration agreements and internships among different institutions".	**Supply chain collaboration**	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	**Boundary practices**
"Research institutions' open days for other AFSC stakeholders".	**Open days**	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	
"Interview with AFSC practitioners regularly to acquire knowledge".	**Regular visits**	√ √ √	√ √ √	√ √ √		√ √ √	√ √ √	√	√ √ √	√	√ √ √	√	√ √ √	**Boundary discourses**

Appendix II Empirical evidence for identifying knowledge boundaries

Identify where knowledge boundaries exist		First-order codes	Second-order themes	Support from interview cases 1	2	3	4	5	6	7	8	9	10	11	12	Aggregate dimensions
Research institution	Farmers' cooperative	"Low associativity among farmers in the cooperative association".	**Lack of common lexicon**	√	√	√	√	√	√	√	√	√	√	√	√	**Syntactic boundaries**
	Research institution	"Low inter-institutional relationship between different research institutions".		√	√	√	√	√	√	√	√	√	√	√	√	
	Wholesalers	"Communication media, use of simple but incorrect language".		√	√	√	√	√	√	√	√	√	√	√	√	
Research institution	Farmers	"Sometimes, farmers cannot use the knowledge I share with them".	**Lack of common meaning**	√	√	√	√	√	√	√	√	√	√		√	**Semantic boundaries**
	Retailers	"Lack of technical information to understand product differentiation".		√	√	√	√	√		√	√		√		√	
Farmers	Wholesalers	"They do not value quality but only differentiation by production costs".		√	√		√			√	√		√		√	
Research institution	Farmers	"Fear to be innovative and resistance to change".	**Lack of common interests**	√	√	√	√	√	√	√	√	√	√	√	√	**Pragmatic boundaries**
Processors	Government	"High costs in machinery and regularization of production systems under current phytosanitary regulations".		√	√	√	√	√	√	√	√	√	√	√	√	
Farmers	Wholesalers	"There is no clarity of the suppliers of inputs for the horticultural sector in the Araucania region of Chile".		√	√	√	√	√	√	√	√	√	√	√	√	
	Exporters	"Export information is unfriendly and without free access".														
Retailers	Consumers	"Lack of information on the benefit of consuming functional products".														

Appendix III Empirical evidence for identifying resources used for tackling knowledge boundaries

First-order codes	Second-order themes	Support from interview cases												Aggregate dimensions
		1	2	3	4	5	6	7	8	9	10	11	12	
"We have built a collaborative relationship with research institutions. Thus, we can get greater access to the knowledge they have".	**Supply chain collaboration**	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √		√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	**Knowledge networks (social)**
"There are early warning programs in Chile for us to identify pests and diseases".	**Computer-based software**	√	√ √ √	√ √ √	√ √ √	√ √	√ √	√ √ √	√ √ √		√ √ √	√ √	√ √ √	**Software tools and facilities (technological)**
"Mobile applications helped us a lot in getting timely information about the weather".	**Mobile-based software**	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	
"Human resources with programming and informatics knowledge to look for new alternatives to improve and food production efficient".	**Experts in computer science**	√ √ √	√ √ √	√ √ √	√ √		√ √ √	√ √ √		√ √	√ √	√ √ √	√ √ √	**Human resources**
"Human resource informed and empowered to manage sources of financing".	**Experts of financing**	√ √ √	√ √ √	√ √ √	√ √	√ √ √	√ √ √	√	√ √ √	√	√ √ √	√ √ √	√ √ √	
"More funds from private companies and the government".	**Public and private funding**	√ √	√ √	√ √	√ √ √	√	√ √ √	√	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	**Financial resources**
"There are international projects available for application".	**Project funding**	√ √ √	√ √ √	√ √	√ √	√ √ √	√ √	√ √ √	√ √ √	√ √ √	√ √	√ √	√ √ √	

Appendix IV Empirical evidence for identifying the benefits of tackling knowledge boundaries

First-order codes	Second-order themes	Support from interview cases												Aggregate dimensions
		1	2	3	4	5	6	7	8	9	10	11	12	
"…to increase competitiveness because it is necessary to reduce cost or apply for niche markets".	**Cost reduction**	√ √ √	√ √ √	√ √ √	√ √	√ √ √	√ √	√ √ √	√ √ √	√ √ √	√ √	√ √	√ √ √	**Economic benefits**
"Budget planning more efficient in terms of time and money".	**Budget planning**	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	
"Knowledge mobilization helps us to reduce uncertainty and reduce the negative effects on the environment and human health".	**Uncertainty reduction**	√ √ √	√ √ √		√ √ √	√ √ √	√ √ √	√ √	√ √	√	√ √ √	√ √ √	√ √ √	**Social benefits**
"It allows carrying out activities to reduce operation process reduction and adoption of new knowledge".	**Process reduction**	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√	√ √ √	√ √ √	√	√ √ √	√ √ √	√ √ √	**Changing operations**
"Knowledge helps us to increase efficiency as new knowledge has been applied in production and processing".	**Increase efficiency**	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	√ √ √	**Efficiency**