Modeling enablers for building agri-food supply chain resilience: insights from a comparative analysis of Argentina and France

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Abstract

Smooth, efficient agri-food supply chain (AFSC) operations are becoming ever more difficult due to more intense and frequent natural disasters and man-made disruptions. Helping AFSCs to survive disturbances requires re-consideration of how to build their resilience. This study addresses this issue through a cross-country comparative analysis involving interviews with AFSC practitioners, thematic analysis to generate agri-food supply chain resilience (AFSCRes) capability factors, total interpretive structural modelling (TISM) to establish interrelationships among the factors, cross-impact matrix multiplication applied to classification (MICMAC) analysis to categorize the factors, and comparative analysis. The results reveal that contractual restraints regulating farmers' opportunistic behaviour and regular interactions are key factors for building AFSCRes in France and Argentina, respectively. This study also confirms the critical role of farmers' associations and coordinated activities amongst all AFSC stakeholders to build AFSCRes. For triggering AFSCRes, farmers' resilience must be particularly prioritized, as they are the least resilient point in AFSCs.

Keywords: Agri-food supply chain resilience, qualitative approach, thematic analysis, TISM, MICMAC analysis, comparative analysis

1. Introduction

Agri-food supply chains (AFSCs) comprise linked activities from farming to production/processing, testing, packaging, warehousing, transportation, trading/distribution, and marketing/consumption, spanning the process 'from field to fork' (Tsolakis et al. 2014; Zhao et al. 2020; Lu et al. 2021). Their efficient and smooth operations play a key role in driving socio-economic growth, ensuring food and nutrition security, alleviating poverty, boosting shared prosperity, and feeding a projected 9.7 billion people by 2050, thereby helping to achieve the United Nations Sustainable Development Goals (SDGs) (Food and Agriculture Organization of the United Nations. 2020; The World Bank. 2020). However, dramatic changes affecting AFSCs over the last three decades, have made it increasingly difficult for them to provide uninterrupted supplies of nutritious food for human consumption and raw materials to the textile and energy industries. First, conflicts, crises and natural disasters are increasing in number and intensity (Dong. 2021). Second, urbanization, more intensive cropping, excessive use of agrichemical products and promotion of crop monocultures have caused massive deforestation, water scarcity, serious soil depletion and high greenhouse gas emissions (Food and Agriculture Organization of the United Nations. 2017; Spanaki et al. 2021). Third, international trade has become more intense, leading to more numerous outbreaks of transboundary plant, pest and animal diseases (Bhattacharjee et al. 2020). Furthermore, agri-food products are perishable and seasonal, and annual production variations make it difficult to control the quality and quantity of outputs. All these factors pose threats to AFSCs, making distribution networks extremely vulnerable to various risks (Esteso et al. 2018; Pereira et al. 2021; Roth and Zheng. 2021). Thus, AFSCs' resilience to environmental volatility requires re-evaluation (Stone and Rahimifard. 2018; Zhao et al. 2018; Drozdibob et al. 2022).

Agri-food supply chain resilience (AFSCRes) is defined as "the capacity over time of a food supply chain and its units at multiple levels, to provide sufficient, appropriate and accessible food to all, in the face of various and even unforeseen disturbances" (Tendall et al. 2015, p.19). Resilience is considered desirable to enable supply chains to prepare for, resist, recover from and adapt to adversities (Ali et al. 2017; Linnenluecke. 2017; Shishodia et al. 2020). Supply chain resilience (SCRes) helps to reduce or avoid supply chain risks and disruptions quickly and cost-effectively, and has therefore attracted strong interest from researchers and practitioners (Purvis et al. 2016; Kochan and Nowicki. 2018; Ivanov and Dolgui. 2021). Previous studies addressed various aspects of AFSCRes, including definitions, stages, principles, capabilities, capability factors and performance measures (Kamalahmadi and Parast. 2016; Ali and Golgeci. 2019; Bak et al. 2020). However, the sparse, context-dependent and fragmented nature of extant research provides limited clarity and understanding of how to build AFSCRes (Linnenluecke. 2017; Stone and Rahimifard. 2018; Kumar and Singh. 2021). In particular, cross-country comparative analysis to identify key AFSCRes capability factors are lacking (Piprani et al. 2020). Given AFSC managers' limited budgets and scarce resources, identifying and prioritizing AFSCRes capability factors is critical. Clear consideration of key AFSCRes capability factors will reduce the time and effort spent by AFSC practitioners on recovering from disruptions and risks. Furthermore, owing to cultural and economic differences, countries may implement different measures to respond and recover from AFSC disruptions. Cross-country research provides a unique lens through which to explore AFSCRes capability factors, with the aims of identifying new resilience practices, solving non-routine problems and facilitating the development of a theoretical framework for AFSCRes (Scholten et al. 2014).

Effective use of AFSCRes capabilities requires a deeper understanding of key resilience capability factors. We address this need by conducting a cross-country analysis that provides a new perspective on AFSCRes building and opens avenues for future research. Our study aims to answer four research questions to reduce bias, error and ambiguity. First, what resilience

capability factors are used to build AFSCRes in Argentina and France? Second, how are these resilience capability factors interrelated in each country? Third, which resilience capability factors are key to building AFSCRes in Argentina and France? And fourth, what can be learned from comparison of AFSCRes between Argentina and France? In answering these questions, our study offers insights into AFSCRes building and makes several contributions: it produces a wealth of knowledge to help identify AFSCRes capability factors and their interrelationships, advances understanding of how to build AFSCRes, and provides practical guidance for AFSC practitioners on how to embed resilience in their daily operations.

In the remainder of this paper, in Section 2 we review the literature on AFSCRes, in Section 3 we explain the research methodology, and in Section 4 we outline the empirical data collection. We then present our data analysis and findings in Section 5, discuss the results in Section 6, and in Section 7 we draw conclusions, explain the implications of our findings, and suggest directions for future research.

2. Literature review

2.1 SCRes drivers, definitions and stages

Resilience is a multidisciplinary term used in a range of fields, including psychology, engineering, ecology and business and management. For example, a definition of resilience in the area of ecology is "the capacity of a system to absorb a disturbance and reorganize while undergoing change while retaining the same function, structure, identify and feedback" (Walker et al. 2004, p. 2). In the context of psychology, it is defined as "the developable capacity to rebound or bounce back from adversity, conflict, failure or even positive events, progress, and increased responsibility" (Luthans. 2002, p. 702). In supply chain management, the concept gained much-needed attention following Christopher and Peck (2004), who defined SCRes as a system's ability to return to its original state or move to a better state after being disturbed. Similarly, Datta et al. (2007) consider SCRes as the ability to maintain control over performance variability in the face of disturbance, and Klibi et al. (2010) view it as the capability to avoid disruptions and recover quickly from failures. Kim et al. (2015) define SCRes as a network-level ability to withstand disruptions, while Rajesh's (2019) definition considers it as a technological capability to manage disruptions. SCRes development has become increasingly prevalent, especially since the outbreak of COVID-19, owing to its benefits in reducing risks and uncertainties, accelerating recovery from disruptions, and increasing profits and service performance levels (Negri et al. 2021). According to those definitions, extant research views resilience simply as the capability to withstand disruptions, disturbances, uncertainties and incidents. However, SCRes enhancement requires a multi-stage approach that address the whole supply chain (Ribeiro and Barbosa-Povoa. 2018). For example, Ali et al. (2021) propose that SCRes is a supply chain's capacity to persist, adapt, transform and restore in the face of disruptions. According to Shishodia et al. (2021), three lines of defence must be established across before, during and after potential disruptions - to enhance supply chains' absorptive, adaptive and restorative capacities. Their work also highlights some supply chain perspectives that require particular attention, including the supply base, supply chain planning and network design, and SCRes assessment.

The limitations of early definitions have been addressed by defining SCRes in more detail with more variables. For example, its multiple stages include: proactively planning, responding adaptively, maintaining control and moving to a favourable state (Ponis and Kronis. 2012); readiness, response and recovery (Chowdhury and Quaddus. 2017); and anticipation, resistance, response and recovery (Kamalahmadi and Parast. 2016). Hohenstein et al. (2015) integrate speed into their SCRes definition, while Wang et al. (2016) include measures to evaluate performance. Recently, Negri et al. (2021) have suggested combining sustainability and resilience to balance supply chain effectiveness and efficiency. Some recent, more comprehensive definitions are inapplicable to this study of AFSCs, for example because they

relate mainly to general supply chains and do not reflect specific characteristics of AFSCs, or because they are outdated. Therefore, to identify AFSCRes capability factors, in this study we use Stone and Rahimifard's (2018, p.219) definition as "the collective ability of AFSC stakeholders to ensure acceptable, sufficient and stable food supplies, at the required times and locations, via accurate anticipations and the use of strategies which delay impact, aid rapid recovery and allow cumulative learning post-disruption".

2.2 SCRes principles, capabilities and strategies

Previous studies have established five principles for building SCRes: supply chain reengineering, collaboration, agility, knowledge management (KM) and a supply chain risk management culture (SCRM) (Scholten et al. 2014; Batista et al. 2019; Tan et al. 2020). In addition, flexibility, redundancy, trust, information sharing, visibility, velocity, leadership and innovation have all been highlighted as important SCRes-building capabilities (Ali et al. 2021(b); Spieske and Birkel. 2021). For example, De Sa et al.'s (2020) investigation of how resilience in different nodes of a Brazilian AFSC influenced overall AFSCRes during an extreme weather event reveals that information sharing is key. They suggest that AFSCRes can be leveraged during a disruption by intensifying information-sharing activities at the supply chain level. Manning and Soon (2016) propose value-based dynamics, supply chain dynamics, strategic decision making, strategic leadership and use of performance indicators as vital resilience capability factors enabling AFSCs to anticipate, resist, respond to and recover from supply chain disruptions. According to Hendry et al. (2019), dynamic capabilities and vertical and horizontal collaboration between stakeholders may trigger resilience, helping AFSCs to respond to threats and create opportunities for further development. Similarly, Hernandez et al. (2021) propose that collaboration among AFSC stakeholders is increasingly important for reducing costs and waste and balancing food supply and demand across the whole chain. Stone et al. (2015) identify nine essential aspects of AFSCRes: concentration, adaptability, redundancy, efficiency, awareness, anticipation, market status, security and financial readiness.

SCRes strategies have been categorized simply into proactive and reactive strategies, as some strategies may be more appropriate for dealing proactively with disruptions and risks (Hohenstein et al. 2015). Proactive strategies for dealing with supply chain disruptions include sharing valuable information and knowledge among supply chain stakeholders, running appropriate employee training sessions, maintaining safety stocks, establishing predefined contingency plans, and building multiple suppliers and slack resources into production and transport capacity (Wang et al. 2017; Ghadge et al. 2021). Other strategies may have more positive effects during reactive phases, such as flexible production systems, a multi-skilled work-force, the application of traceability technology to increase trust, interdisciplinary teams and a risk-sensitive culture (Razak et al. 2021). SCRes strategies can also be categorized based on SCRes phases (readiness, response, recovery and growth) and capabilities (e.g., agility and visibility). Various typologies have been proposed, although some key strategies, such as those relating to flexibility and redundancy, are effective before, during and after disruptions (Hohenstein et al. 2015).

AFSC practitioners use a range of resilience-building strategies to avoid or minimize the effects of disruptions. These include postponement, strategic stocks, flexible supply bases, flexible transportation, contingency planning, and relationship building between buyers and suppliers (Durach et al. 2020; Fan et al. 2020). Based on an investigation of more than 300 Australian AFSC practitioners, Ali et al. (2021) propose that deploying specific KM practices, such as knowledge dissemination during recruitment and introduction sessions, effectively mitigates AFSC risks. Leat and Revoredo-Giha (2013) state that enhancing communication between processor and retailer, in relation to product quality, animal welfare and product governance, is key for assuring AFSCRes. Recent, attention has been given to the application of industry 4.0 technologies to enhance AFSCRes (Marcucci et al. 2021; Pandey et al. 2021).

For example, Ali and Govindan (2021) state that internet-of-things-based technologies have positive effects in mitigating the problems of supply demand misalignment, delivery delays, food waste and packaging problems. Modgil et al's (2021) investigation reveals several advantages of using artificial intelligence, such as enhancing transparency, facilitating last-mile delivery, offering personalized solutions and minimizing the impact of disruptions. Therefore, these technologies must be embedded in AFSCs.

2.3 Empirical research on AFSCRes and gaps in existing literature

Given the potentially positive effects of AFSCRes on business competitiveness and continuity, various qualitative and quantitative methods have been applied to identify and prioritize AFSCRes strategies and factors, measure and assess AFSCRes performance, build relationships between resilience strategies and vulnerabilities or risks, and examine specific factors that facilitate AFSCRes (Hendry et al. 2019; Dubey et al. 2021). Examples include single and multiple case studies, mathematical modelling, multiple-criteria decision making, and static modelling (see Table 1). Despite increasing numbers of empirical studies and quantitative modelling of AFSCRes in recent years, qualitative empirical studies of AFSCRes remain scarce (Ali et al. 2021).

Table 1 Empirical research on AFSCRes

Author(s) (year)	Topic focus	Research methodology	Country
Leat and Revoredo-Giha (2013)	Identification of resilience capability factors	Case study involving in-depth interviews	Scotland
Falkowski (2015)	Resilience of farmer-processor relationships	Case study involving in-depth interviews	Poland
Scholten and Schilder (2015)	The role of collaboration in SCRes	Case study involving in-depth interviews	Unspecified
Esteso et al. (2018)	Conceptual framework for designing AFSCs under uncertainty	Modelling	Unspecified
Moazzam et al. (2018)	Measuring AFSC performance	Case study involving in-depth interviews	New Zealand
Hendry et al. (2019)	Local AFSC resilience for responding to constitutional change	Multiple case studies	United Kingdom
De Sa et al. (2020)	The relationship between node resilience and whole SCRes	Case study involving in-depth interviews	Brazil
Ali et al. (2021)	Achieving AFSCRes by integrating knowledge management and risk management culture	Surveys and modelling	Australia
Kumar and Singh (2021)	The impact of COVID-19 on AFSC and strategies for improving AFSCRes	Case study, literature review and modelling	India
Mishra et al. (2021)	Resilience framework building	Case study involving in-depth interviews	India
Pereira et al. (2021)	Risk identification and mitigation	Case study involving in-depth interviews	Brazil

Our broad review of the literature on AFSCRes definitions, principles and capabilities and the research methods used reveals three research gaps.

First, existing research focuses on investigating AFSCRes capability factors, capabilities, principles, performance measures and resilience framework building (see Table 1), as confirmed by previous literature reviews on AFSCRes (e.g., Kamalahmadi and Parast. 2016; Stone and Rahimifard. 2018; Ali et al. 2021). However, empirical research to identify key AFSCRes capability factors and their interrelationships is lacking. More than 80% of firms in AFSCs are small and medium-sized companies (SMEs) (Tan et al. 2017), which may have limited resources to build AFSCRes. Thus, the majority of AFSC firms would benefit from

identification of key AFSCRes capability factors to enable them to build resilience, alleviate disruptions and ensure smooth operations.

Second, the extant AFSCRes literature is dominated by quantitative modelling and qualitative conceptual studies (for reviews, see Ribeiro and Barbosa-Povoa. 2018; Hosseini et al. 2019). These methods have also been widely used to investigate AFSCRes-related issues (see Table 1), whereas AFSCRes research using qualitative modelling techniques appears to be lacking (Shishodia et al. 2021). Our study begins to address this research gap through a comparative study employing a multi-method qualitative approach involving semi-structured interviews, thematic analysis, TISM, MICMAC analysis and comparative analysis.

Third, most existing studies explore AFSCRes from a single-country rather than a cross-country perspective (see Table 1). According to Linnenluecke (2017) and Kahiluoto et al. (2020), effective resilience is sensitive to organizational and national cultures. Cross-country comparative analysis will help generate clearly defined instruments to guide AFSCRes building, deepen understanding of the phenomenon, and open new avenues for AFSCRes research.

3. Research methodology

Interpretivism refers to approaches that emphasize the meaningful nature of people's character and participation in social and cultural life (Chowdhury. 2014). It assumes that people's knowledge of reality can only be interpreted through social constructions, such as language, consciousness and shared meanings (Myers. 2019). Since AFSCs involve moving food from farmer to consumer, including production, processing, distribution, retailing and consumption, thorough knowledge of AFSCRes can only be gained by taking account of the multiple viewpoints of the various individuals involved in these processes, for which interpretivism is appropriate. Interpretivism emphasizes a qualitative rather than quantitative approach (Saunders et al. 2015; Baskarada and Koronios. 2018). Accordingly, we adopted a qualitative approach to identify AFSCRes capability factors and their interrelationships, distinguish key resilience capability factors, compare the research results from Argentina and France and provide instruments for building AFSCRes. Figure 1 illustrates the methodological framework for this study.

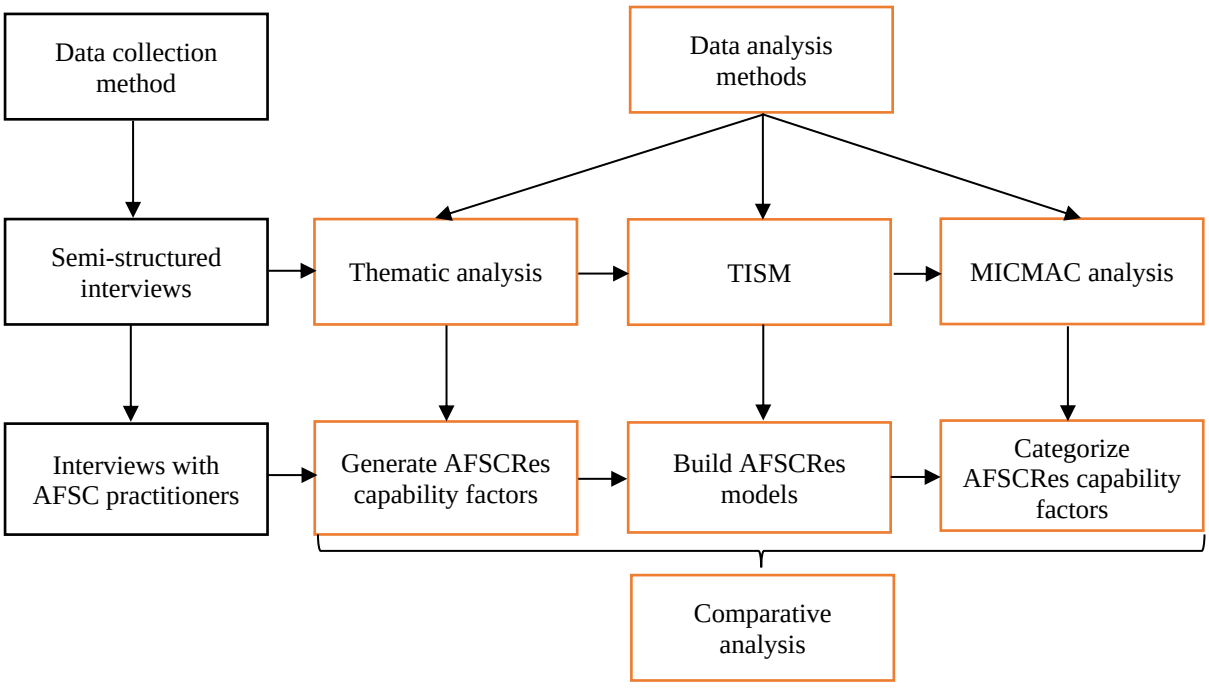

Figure 1 Research methods adopted in this study

3.1 Data collection method

Semi-structured interviews are a qualitative data collection method in which researchers ask participants predetermined but open-ended questions to delve deeply into a particular topic and explore participants' thoughts, feelings and beliefs (Dicicco-Bloom and Crabtree. 2006; Saunders et al. 2015). This method has several advantageous features, including development of an interview guide to guide the conversation and keep participants on topic, in-depth creative investigation to collect additional information through open-ended questions, encouragement of two-way communications, and allowing participants to discuss sensitive issues (Creswell. 2009; Sekaran and Bougie. 2013; Saunders et al. 2015). Other data collection methods, such as questionnaires and structured and unstructured interviews were inapplicable to this study owing to various limitations. For example, unstructured interviews lack reliability because the content and phrasing of questions may differ between participants (Corbin and Morse. 2003), making it difficult to conduct comparative analysis across data samples and generate a deep understanding of AFSCRes. Questionnaires have several limitations: some questions may be unanswered, may be unclear whether respondents have understood the questions, and whether they have provided accurate questions (Rowley. 2014). As this study aimed to generate insights and understandings of AFSCRes, semi-structured interviews were preferable to questionnaires. In structured interviews, exactly the same questions are asked in the same order, so interviewees have limited latitude in their answers. In semi-structured interviews, the order of questions is not constrained, and therefore, more novel information may emerge from asking probing questions. Furthermore, semi-structured interviews have been widely utilized to explore SCRes-related issues, such as SCRes capability factors in response to pandemic disruption (Scala and Lindsay. 2021), complex adaptive system theory for pharmaceutical SCRes (Yaroson et al. 2021) and SCRes strategies to mitigate risks (Um and Han. 2021). Therefore, semi-structured interviews were used to collect data for this study.

3.2 Data analysis methods

Four data analysis methods thematic analysis, TISM, MICMAC analysis and comparative analysis were combined in this study to analyze the data collected from the semi-structured interviews. Combining these methods alleviated their methodological limitations, and greater insights were gained by analyzing the data from different research angles (Frost et al. 2011; Clarke et al. 2015). A multiple-method approach offers several advantages, including achieving stronger results through triangulation of findings, the potential to answer broader research questions, providing a holistic understanding of the phenomenon investigated and making the investigation more convincing and comprehensive (Davis et al. 2011).

Thematic analysis, which is widely used to identify, analyze, organize, describe and report themes found in a data set (Braun and Clarke. 2006; Nowell et al. 2017), has several advantages. First, it is simpler than other qualitative data analysis techniques, as it does not require the researcher to have detailed theoretical and technical knowledge of other qualitative approaches (Saunders et al. 2015). For example, narrative analysis draws on a variety of different approaches to data analysis, such as biography, autobiography, life history, oral history, autoethnography, life narrative and the sociology of storytelling (Earthy and Cronin. 2008). Thus, may require a comprehensive understanding of different ways of producing and analyzing qualitative data, making it inapplicable to this study. Second, thematic analysis is a highly flexible, tangible and simple approach that can elicit rich and detailed accounts of data (Braun and Clarke. 2019). Other methods include discourse analysis, which has limited use in providing tangible and absolute answers to problems, and content analysis, which is extremely time-consuming (Vaismoradi et al. 2016). Thus, neither were appliable to this study. Third, thematic analysis is effective for generating unanticipated insights by summarizing, examining and highlighting similarities and differences in the data set. Finally, the results of thematic analysis are easily understood by relatively uneducated public recipients. In the European

Union, only 50% of people working in agriculture have medium levels of education, and only 8.9% have higher-level educational qualifications (European Commission. 2021). In Argentina, 80% of farmers in the Pampas region have completed secondary studies, whereas only 8% have undertaken postgraduate degrees (The World Bank. 2021). In view of its advantages, and the fact that we intended to invite AFSC practitioners to review the research results, thematic analysis was appropriate for this study.

TISM is a qualitative modelling technique widely used to build hierarchical relationships between variables (Zhao et al. 2020; Choudhury et al. 2021). It makes vague and obscure models more unambiguous and straightforward, and hence helps to answer "what", "why" and "how" questions in theory building (Jena et al. 2017; Dhir and Dhir. 2020). TISM has advantages over other multi-attribute methods. It is effective for developing a hierarchical structure of variables relatively quickly without significant expert involvement. It also illustrates the logic behind interdependencies between variables (Sushil. 2017; Yadav et al. 2020). Other methods, such as the analytical hierarchical process (AHP), the decision-making trial and evaluation laboratory (DEMATEL), the ELECTRE and PROMETHEE techniques and grey theory, can all be used for interrelationship analysis, but their limitations made them inapplicable in this study. For example, AHP may result in loss of information owing to compensation effects between good scores for some criteria and bad scores for others (Dalalah et al. 2011), whereas the process and outcomes of ELECTRE are obscure from a layman's perspective (Yu et al. 2018). DEMATEL can be used to build relationships between variables based on expert responses, but problems may occur if the information obtained is incomplete and epistemically uncertain (Aghelie et al. 2016). The PROMETHEE method is time-consuming and difficult to perform when many criteria are involved (Kabir et al. 2014), while grey theory falls short in determining the directions of relationships between variables (Garg. 2021). Thus, in this study TISM was selected to build interrelationships between AFSCRes capability factors.

MICMAC analysis was used to identify key variables and validate the TISM model by categorizing the variables into four clusters, based on their relationships with and influence on each another (Mani et al. 2016). Other techniques for identifying key variables, could not be utilized in this study owing to their various limitations. For example, the analytical network process (ANP) can be used to identify decision-making priorities amongst multiple variables, but requires numerous calculations and extensive brainstorming sessions (Gu et al. 2018). The interpretive ranking process (IRP) limits the number of rankings because it requires larger numbers of comparisons as the number of variables increases (Sushil. 2019). Thus, in this study MICMAC analysis was selected to categorize AFSCRes capability factors and validate the TISM models.

Finally, comparative analysis was employed to compare the themes generated through thematic analysis, the resilience models generated through TISM and the categorizations of resilience capability factors generated through MICMAC analysis. Comparative analysis offers three advantages. First, it enhances and deepens understanding of AFSCRes by comparing resilience capability factors, resilience models and resilience categorizations across diverse settings and research contexts. Second, it provides opportunities to access a wide range of resilience options to facilitate or suggest solutions to similar dilemmas in other contexts. This study compares AFSCRes settings in Argentina and France, which will potentially serve as a guide for other countries seeking to build AFSCRes. Finally, comparative analysis contributes to developing a universally applicable theory by comparing specific phenomena and testing theory in different settings (Esser and Hanitzsch. 2017).

4. Empirical data collection

The French agri-food companies investigated are located in Brittany, France. This region is well-known for its high-quality fruit and vegetables, and is the leading region in France for

agricultural production (Invest in Bretagne. 2022). More than 1,800 farmers and 2,500 vegetable producers are coordinated by a single producers' organization, which is responsible for formulating market regulations for vegetable production, promoting members' products, lobbying EU institutions and coordinating technical support services. The producers' organization also invests heavily in production and processing facilities to enhance product quality and increase brand awareness. The Argentinian agri-food companies examined are located in Buenos Aires. Agricultural products are sold mainly in the Central Market of Buenos Aires, with few are exports owing to high and unpredictable export taxes and quantitative restrictions. Argentina's agricultural sector receives relatively little budgetary support from the government because the prices of agricultural products are below world market levels. However, the Argentinian government provides significant support for general agricultural services, such as agricultural research and development, skills training, marketing and promotion, and public stockholding. Technological and knowledge assistance is provided mainly by The National Institute of Agricultural Technology (INTA), which has more than 50 experimental research stations and 300 extension agencies across the country (OECD. 2019). The French and Argentinian AFSCs are illustrated in Figure 2.

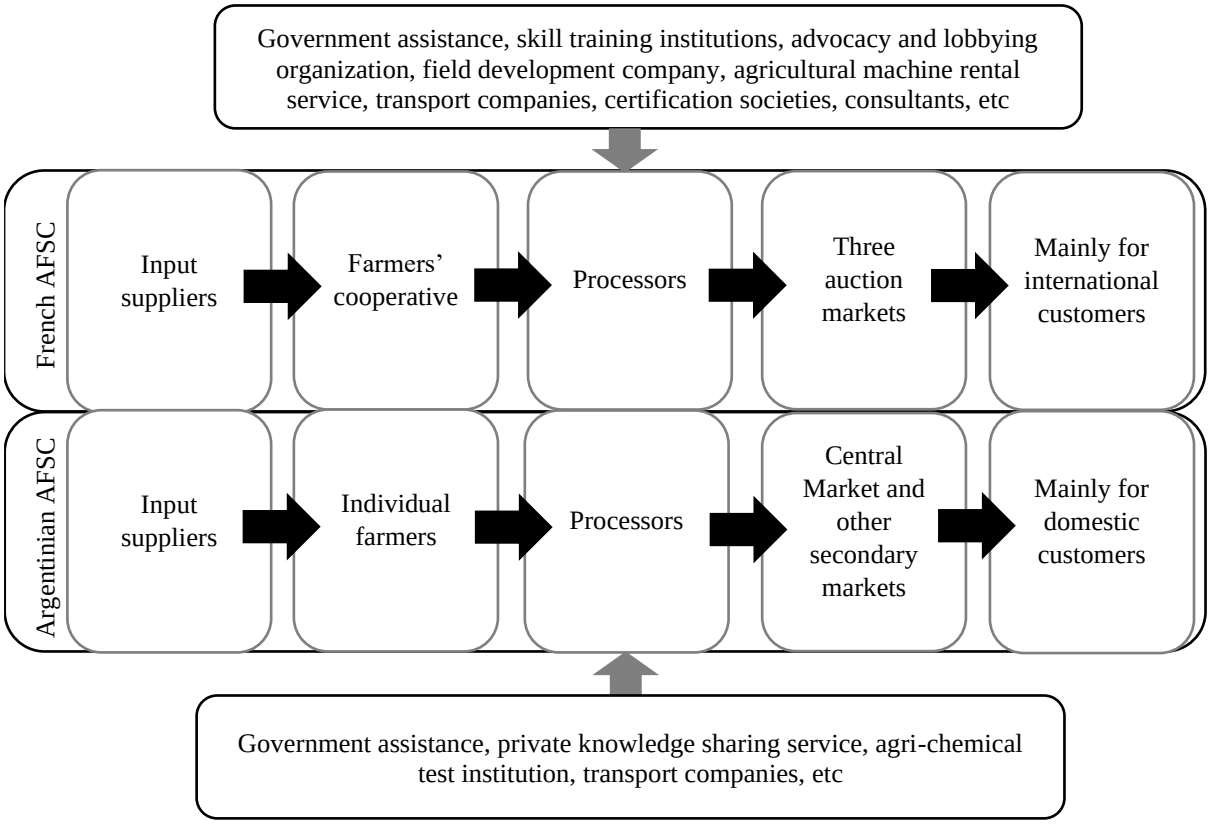

Figure 2 Analyzed French and Argentinian AFSCs

An interview protocol was developed through discussions with two professors in operations and supply chain management. The issues discussed included the ethical approval application, the participant information sheet and informed consent form, the interview approach, the interview guide design, identification and selection of key interview participants, a timeline for each key activity and the duration of each interview. In particular, we decided to conduct one-to-one interviews for their effectiveness in gaining insights into people's perceptions, understandings and experiences of a given phenomenon (Ryan et al. 2009).

Empirical data were collected in Argentina and France from April 2020 to July 2021. These two countries were selected for three reasons. First, we had extensive connections with their agri-food industries through participating in the Horizon 2020 Risk and Uncertain Conditions for Agriculture Production Systems (RUC-APS) project enabling us to find suitable AFSC practitioners to answer the research questions. Second, agriculture is a pillar industry in both Argentina and France, so comparative analysis of AFSCRes in these two countries promised to be beneficial. For example, France has the biggest utilized agricultural acreage in Europe and is the largest producer of agricultural goods (European Commission. 2021). Argentina is one of the leading food producers in South America and is among the top world exporters of soy and sunflower products, pears and lemons (International Trade Administration. 2020). Third, we visited local AFSC practitioners in Argentina and France several times between 2016 and 2020. Our familiarity with the local climate and social and cultural environments of the two countries facilitated our discovery new findings.

Purposive and snowball sampling (Saunders et al. 2015) were employed to recruit 24 experienced AFSC practitioners as suitable participants. Purposive sampling is "used to select respondents that are most likely to yield appropriate and useful information" (Kelly. 2010, p. 317). The specific criteria used to recruit suitable AFSC practitioners were, first, that the interviewees worked in the agri-food industry and were directly involved in AFSCRes management. Second, they must have at least 10 years' experience in AFSCRes management to ensure high levels of knowledge and expertise. Third, the selected companies had to be medium-sized or large, or focal companies in the AFSC, with an annual turnover of more than 50 million euros or pesos. This was because companies with these levels of annual turnover would be most likely to demonstrate resilience capabilities and be able to implement strategies to control supply chain risks (Polyviou et al. 2020). We assumed that companies with lower turnovers would have insufficient financial and human resources to apply AFSCRes strategies and would find it difficult to secure bank loans. Based on the selection criteria, nine interviewees from nine different AFSC organizations in each country were considered to be knowledgeable about AFSCRes, with extensive experience in AFSC risk/disruption management. These were selected for semi-structured interviews. The selected organizations played diverse roles in their AFSCs, with the potential to offer differing perspectives on building AFSCRes (Sullivan-Taylor and Branicki. 2011). For example, in Argentina, our selected interviewees were directors and owners of agricultural universities, research institutions, governments, farms, seed companies, wholesale distribution and agri-chemical companies. Similarly, in France, we interviewed owners, directors and managers of wholesale distribution companies, governments, research institutions, agricultural machine rental service companies and farm and seed companies. Appendix 1 provides detailed information on the interviewees. Snowball sampling was then employed to find additional participants with an interest in this research, resulting in the selection of a further three AFSC partitioners from each country. Data saturation was reached after conducting 12 interviews in each country. We identified the data saturation point by continuously analyzing the data collected. Each interview was analyzed within 24 hours in order to allow us to determine whether further interviews should be conducted. After conducting 12 interviews in each country, little or no new information was elicited to address the research questions. Thus, the total sample size was 24.

An interview guide was developed to ensure consistency between the interviewees from Argentina and France, determine what questions should be asked and their logical order, and maintain the focus of discussion (Roberts. 2020). This guide (see Appendix 2) consisted of three sections, asking general questions relating to the interviewee and the company, the risk faced by the company and the whole AFSC, and resilience strategies that might enable the company and the whole AFSC to recover from disruptions. Having developed the interview guide, pilot interviews were conducted with two professors in operations and supply chain

management and two experienced AFSC stakeholders from each country to ensure appropriate language, wording, coverage and relevance of the content of the interview guide. As a result, some questions were rephrased to avoid technical words, and additional questions relating to KM were inserted. Owing to the COVID-19 pandemic and international travel bans, the interviews were conducted and recorded through Zoom (Version 5.7.4 (804)). The interview guide was emailed to participants three days prior to their interview to ensure that they were familiar with the interview questions and structure and had sufficient time to prepare and organize their answers (James and Busher. 2006). Each interview lasted between 45 and 60 minutes, giving interviewees sufficient time to express their ideas. Probing questions were asked to explore views and ideas that required further clarification.

5. Data analysis and findings

This section presents the results of our thematic analysis, TISM and MICMAC and comparative analyses. Thematic analysis was used to generate AFSCRes capability factors, and its outputs were then used as inputs to establish TISM models that would build interrelationships among various AFSCRes capability factors and identify key AFSCRes capability factors. MICMAC analysis was applied to categorize the AFSCRes capability factors and validate the TISM models. The final stage was comparative analysis.

5.1 AFSCRes capability factors generated using thematic analysis

Braun and Clarke's (2006) thematic analysis process was used to generate AFSCRes capability factors. First, the researchers familiarized themselves with the data. Digital recordings of the interviews were initially transcribed word-for-word using the professional transcription software, Otter. Immersive and repeated readings of the transcripts were then undertaken to acquire an initial understanding of the resilience strategies used to respond to disruptions in Argentina and France. Second, initial codes were generated with the assistance of NVivo 12. Two coders with a deep understanding of SCRes were involved in highlighting words, phrases, sentences and paragraphs relevant to SCRes in each country setting. Special attention was paid to measures, strategies and resources that might help to prepare for, respond to and recover from AFSC disruptions. At this stage, an iterative approach was adopted to highlight and refine codes by moving back and forth between relevant SCRes theories and data. In particular, previous theoretical research (e.g., Christopher and Peck. 2004) that had initially informed our empirical study (e.g., Ali et al. 2021) and advanced our understanding of AFSCRes was used to help identify relevant codes. Codes with similar meanings were categorized and grouped based on their relevance. This step was completed with an intercoder reliability of $k = 0.81$ (Cohen. 1960). Next, sub-themes were identified and were each assigned a code. This step was continued until two coders were in complete agreement. For example, it was identified that "training sessions" were effective in building AFSCRes in Argentina and France, but one coder had categorized them as "KM", whereas the other had categorized them as "supply chain collaboration" because collaborative activities might occur during these sessions. Subsequently, a third coder, a professor with a background in KM and supply chain management, undertook additional checking. Following this thorough review process, "training sessions" were categorized as "KM" because this was their original aim, sub-themes were then reviewed and stratified into overarching themes. Overarching themes were identified, defined, critiqued and adjusted through a roundtable discussion to ensure that they accurately represented the data. Finally, vivid examples were extracted from the data to produce an analytical report.

Throughout the thematic analysis process, themes with positive effects on building AFSCRes were identified and presented by considering first-order codes, second-order themes and aggregate dimensions (King and Horrocks. 2010). First, the transcribed data addressing the research questions were allocated descriptive codes (first-order codes); second, descriptive codes that seemed to have common meanings were grouped and allocated to an interpretive

code (second-order themes); and third, a number of overarching themes were identified that characterized key concepts in the analysis (aggregate dimensions).

The thematic analysis results for Argentina revealed 14 AFSCRes capability factors, which we categorized into four aggregate dimensions. Of these, 50% related to KM, 28.57% to supply chain collaboration, 14.29% to innovation and 7.14% to redundancy (see Table 2). This clearly shows the importance of KM in building AFSCRes in Argentina. Factors such as knowledge sharing, regular interaction, training sessions and rewards all fall into the KM category. Ali et al. (2021a) suggest that training sessions and reward system have the capability to increase employees' participation and knowledge exploitation. Previous studies of AFSCRes identify various capacity factors effective in building AFSCRes, including information sharing, regular meetings, knowledge transfer, trust, joint decision making, leadership and network complexity (Stone and Rahimifard. 2018; Zhao et al. 2018). In particular, cooperative support, collaboration between buyer and supplier, backup capacity, employee training and coordination are highlighted as key for tackling AFSC disruptions (De Sa et al. 2020; Ali et al. 2021(b)). The thematic analysis results for Argentina show that AFSCRes capability factors such as trust, decentralized knowledge networks, financial readiness and international collaborations are critical for building AFSCRes. From the thematic analysis results for France we identified 16 AFSCRes capability factors, which we categorized into four categories. Of these, 56.25% relate to supply chain collaboration, 25% to innovation, 12.5% to visibility and 6.25% to KM (see Table 3). Factors such as compensation mechanisms, loyalty, contractual restraints, protective pricing and brand sharing are all classified into supply chain collaboration, which refers to the ability to work with other entities to create mutual benefits (Pettit et al. 2010). The various mechanisms or means of supply chain collaboration include contractual and economic practices, joint practices, supply chain design, relationship management, assessment practices, technological and information-sharing practices and governance practices (Duong and Chong. 2020). Our thematic analysis results for France provide new insights into supply chain collaboration practices, including formulating compensation mechanisms, facilitating brand sharing and strengthening partners' loyalty.

Table 2 Empirical evidence from Argentina on AFSCRes capability factors

First-order codes	Second-order themes (AFSCRes capability factors)	Empirical cases from Argentina												Aggregate dimensions
		A	B	C	D	E	F	G	H	I	J	K	L	
"We shared technical knowledge and carried out research with the farmers".	**Knowledge sharing**	√√ √	√√ √	√√ √	√√ √	√√ √	√√	√	√√ √	√√ √	√√ √	√√ √		**Knowledge management**
"They feel part of the model, therefore build more trust".	**Trust**	√√ √	√√ √	√√ √	√	√√ √	√		√√ √	√√ √	√√ √	√√ √	√	
"Visit all of the farms regularly, and monthly meetings with the farmers".	**Regular interaction**	√√ √	√√ √	√√ √	√√ √	√√ √			√√ √	√√ √	√	√√ √	√√ √	
"There are some training sessions, depending on what they need. Producers may ask or demand training courses".	**Training sessions**	√√ √	√√ √	√√ √	√√ √	√√	√√ √	√√ √	√√	√√	√√	√√ √	√√ √	
"We offered certifications to the farmers if they applied the rules correctly".	**Rewards**	√	√	√	√√ √	√√ √	√	√√ √	√√ √	√√ √	√√ √		√√ √	
"A number of organizations from the Argentinian government help farmers, like SENASA".	**Decentralized knowledge network**	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	
"Quality control is much more than that, not only about visual control".	**Quality control**	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	
"Radio connection, mobile phones and WhatsApp. Now we mainly use WhatsApp".	**ICT application**	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	**Innovation**
"It is necessary to write a clear definition and disseminate to all the actors".	**Building shared understanding**	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	
"We have more international connections with Europe, Japan, Switzerland and Australia".	**Extending international collaborations**	√√ √	√√ √	√√ √		√√ √		√√ √	√√ √	√√ √	√√ √			
"In order to stand up for rights, a number of associations have been created by small farmers".	**Establishment of farmers' association**	√√	√	√√		√√ √			√√ √	√√ √	√√ √			**Supply chain collaboration**
"They already have an agreement with supermarkets on how much the supermarket will buy and at what price".	**Long-term relationship**	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	
"We got some money from the local government to fix what the weather destroyed".	**Governmental support**	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	
"We have insurance in case of accidents".	**Financial readiness**	√√ √		√√ √	√√ √					√√ √				**Redundancy**

Note: no tick = no evidence, √ = weak evidence, √√√ = strong evidence

Table 3 Empirical evidence from France on AFSCRes capability factors

First-order codes	Second-order themes (AFSC resilience capability factors)	Empirical cases from France												Aggregate dimensions
		A	B	C	D	E	F	G	H	I	J	K	L	
"We were giving solutions…through applying industry 4.0 technologies".	**Application of advanced technologies**	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	
"We got funding from the European Union and the French government".	**Multiple funding sources**	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	
"Furthermore, we participated in more projects than we have".	**Project partnership**	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	**Innovation**
"…we changed the platform with other products to sell it to other companies".	**Extension capability**	√√ √	√√ √	√	√√ √	√	√√ √	√	√√ √	√√ √	√√ √	√√ √	√√ √	
"We are always on the station to employ people and train them".	**Training sessions**	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	**Knowledge management**
"…make the link between companies and work with companies that provide solutions".	**Coordination**	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	
"Everyone knows who everyone is".	**Familiar with each other**	√√ √	√√ √	√√ √	√√ √	√	√	√	√√ √	√√ √	√	√	√	
"…farmers are all independent, so the good growers in percent pay the bad growers".	**Compensation mechanisms**	√√ √	√√	√√	√√		√	√√	√√ √	√√ √	√	√	√	
"…research to investigate the field, and growers should pay for everything including salaries".	**Joint decision-making**	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	**Supply chain collaboration**
"When they enter the organization, the farmer will buy some share".	**Loyalty**	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	
"They signed a contract stating that they will respect the rules of the auction market".	**Contractual restraints**	√√ √	√	√	√√ √	√	√√	√√ √	√√ √	√√ √	√√ √	√√	√√	
"We have minimum prices for all the products".	**Protective price**	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	
"There are quality standards for each variety of tomato".	**Strict quality standards**	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	
"All the products are equipped with the same brand, which are shared within the six organizations".	**Brand sharing**	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	
"The traceability technology that we used to let people know…"	**Traceability**	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	**Visibility**
"Anyone can see what happens, the price, who buys and everything".	**Transparency**	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	√√ √	

Note: no tick = no evidence, √ = weak evidence, √√√ = strong evidence

5.2 AFSCRes models generated through TISM

The resilience capability factors generated through the thematic analysis were used as inputs to build AFSCRes models for Argentina and France. The following steps were followed in the TISM process (Sushil. 2012; Jena et al. 2017; Zhao et al. 2021):

1) ***Identify and define AFSCRes capability factors***: the 14 and 16 AFSCRes capability factors identified for Argentina and France, respectively were utilized as inputs to build TISM AFSCRes models for the two countries.
2) ***Determine contextual relationships***: in order to model the identified AFSCRes capability factors, it was critical to identify contextual relationships between pairs of factors. A contextual relationship was defined as "AFSCRes capability factor A has effects on or enhances AFSCRes capability factor B".
3) ***Interpret relationships***: this step involved explaining relationships between AFSCRes capability factors A and B by seeking clarification from our experts. Their opinions were captured by asking whether or not "AFSCRes capability factor A effects/enhances AFSCRes capability factor B". If it did, second question was asked: "in what way does AFSCRes capability factor A affect/enhance factor B".
4) ***Interpretive logic of pair-wise comparison***: two interpretive logic knowledge bases were developed by conducting pair-wise comparisons. Each resilience capability factor was individually compared with other factor, so the total number of pair-wise comparisons for *n* identified factors would be $n\times(n-1)$. With 14 and 16 AFSCRes capability factors, respectively, there were $14\times(14-1)=182$ rows in the knowledge base for Argentina and $16\times(16-1)=240$ rows for France. Relationships between two factors were coded "Y" for yes and "N" for no, and further explanation was sought for the former.
5) ***Develop reachability matrix and conduct transitivity test***: an initial reachability matrix was developed based on the interpretive logic knowledge base by transforming each "Y" entry code into "1" and "N" into "0". The final reachability matrix was obtained after transitivity checking the initial reachability matrix, using the transitivity rule: "if factor A relates to factor B, and factor B relates to factor C, then factor A necessarily relates to factor C". Initial and final reachability matrices for Argentina and France are shown in Appendices 3(a) and 3(b), respectively.
6) ***Determine levels by partitioning reachability matrix***: the final reachability matrix was used to determine a reachability set and antecedent set for each factor. The reachability set consisted of the factor itself and other factors it would affect or influence, whereas the antecedent set consisted of the factor itself and other factors by which it would be affected or influenced. The intersection set consisted of factors common to the reachability and antecedent sets. This step was repeated until all levels of AFSCRes capability factors were determined.
7) ***Develop a digraph***: a digraph was developed by arranging the AFSCRes capability factors into levels (see Appendices 4(a) and 4(b)). Direct links, according to the relationships in the final reachability matrix, and important transitivity links were retained.
8) ***Develop an interpretive matrix***: a binary interaction matrix was developed by depicting all interactions as "1" in the respective cells (see Appendices 5(a) and 5(b)). Interpretation were taken from the interpretive logic knowledge base to match cells with "1".
9) ***Develop TISM models of AFSCRes capability factors***: two TISM models of AFSCRes capability factors were developed for the Argentinian and French AFSC contexts using the corresponding digraphs and interpretive matrices.

TISM analysis of Argentina's AFSCRes capability factors resulted in a nine-level TISM model (see Figure 3). Factors at lower levels of the TISM model have more influence on the whole system and can induce more AFSCRes capability factors, whereas factors at higher levels have less influence on the system and can induce fewer AFSCRes capability factors. The factors at levels IV to IX are F3(Regular interaction), F9(Building shared understanding), F11(Establishment of farmers' association), F13(Governmental support), F8(ICT application) and F6(Decentralized knowledge network). Resilience capability factors such as F1(Knowledge sharing), F2(Trust), F4(Training sessions), F5(Rewards), F7(Quality control), and F12(Long-term relationship) are at level III. The two remaining factors F10(Extending international collaborations) and F14(Financial readiness), are at levels II and level I, respectively. Regular interactions among farmers contribute to building farmers' associations, which are free to join. However, many farmers are migrants from Uruguay and Bolivia, with lower social status than domestic farmers. Associations aim to combine farmers' power and gain additional support from the government, such as seeking more investment in agricultural ICT application and acquiring more knowledge from government-owned institutions. However, not all farmers rely on services provided by government-owned institutions. For example, large-scale farmers prefer to use services provided by private institutions, whereas some small farmers are more likely to use services provided by non-profit organizations. These farmers have little trust in the government system because frequent party changes in central government give rise to the unsustainable agricultural policies and unstable business and economic environments. Government-owned organizations, such as INTA and the National Service of Agri-Food Health and Quality (SENASA), have been established in Argentina to provide training for and transfer knowledge to farmers. Furthermore, Argentinian farmers are eager to access the international market to acquire stable currency (e.g., US dollars) to alleviate the effects of wide fluctuations in the Argentinian pesos. However, most farmers have no opportunity to export their products owing to high-export standards and lack of associated infrastructure. Therefore, extending international collaborations is considered a resilience capability factor. Finally, financial readiness appears at the highest level of the TISM hierarchy, as AFSC practitioners' access to international market requires strong financial status in view of the risk of payment delays.

Argentinian AFSCs

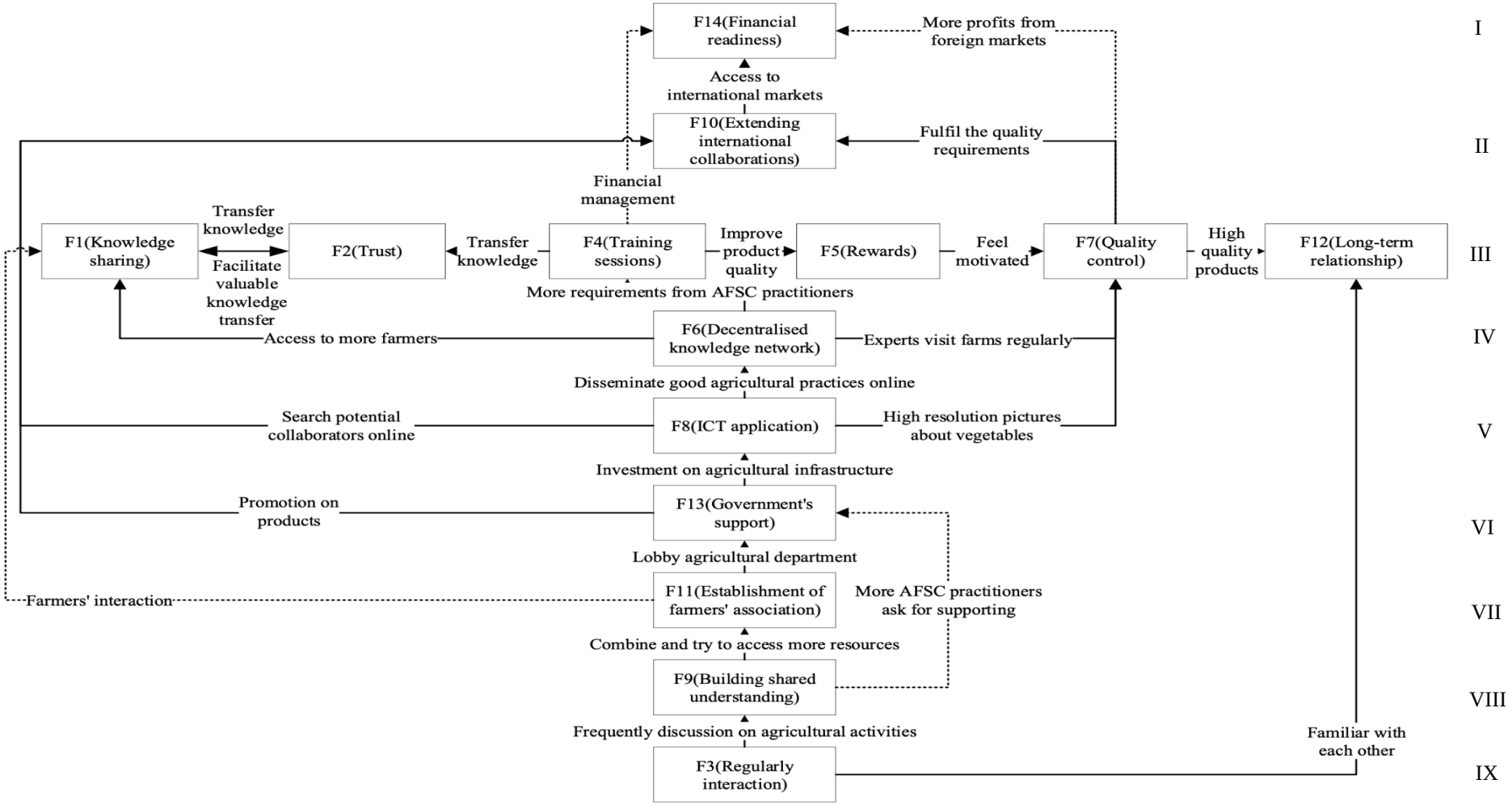

Figure 3 TISM AFSCRes model for Argentina

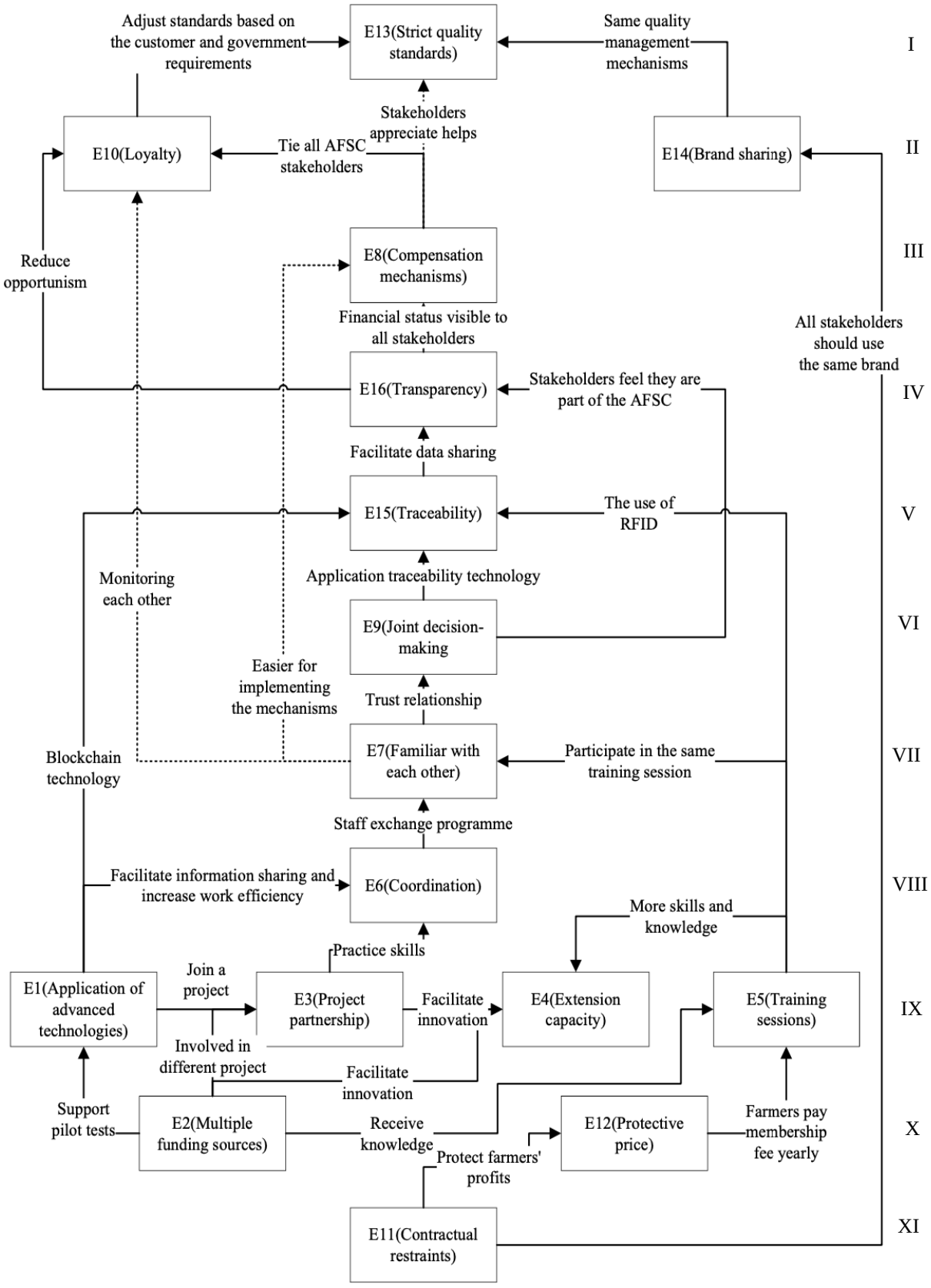

Figure 4 TISM AFSCRes model for France

TISM analysis of France's AFSCRes capability factors produced an 11-level TISM model (see Figure 4). E11(Contractual restraints) appears at the lowest level of the TISM hierarchy. Such restraints help farmers to improve their profits by setting protective prices. Contracts must be signed between farmers and the farmers' association to regulate farmers' opportunistic behaviour and increase cohesion between them. Furthermore, thousands of farmers are required to pay annual membership fees to the association to keep the whole AFSC running smoothly. Thus, training sessions are made available to all AFSC stakeholders, and an agri-tech conference is held yearly to introduce the latest agricultural technology to AFSC stakeholders. In addition, various funding sources (e.g., Horizon 2020 and European Regional Development Fund) are accessible to facilitate research and knowledge innovation, cooperation and pilot testing of technologies. This enables the application of advanced technologies (E1), building of project partnerships (E3) and extension of capabilities (E4). The farmers' association, as the focal firm of local AFSCs, must not only manage thousands of farmers, but also coordinate relationships with other AFSC stakeholders. Thus, a staff exchange programme has been launched to enable AFSC stakeholders to get to know each other. This can be considered to be an important step in increasing cohesion across the whole AFSC. To fulfil the requirements of the European Union and the French government, traceability technologies such as radio-frequency identification (RFID) and blockchain technology are applied to ensure the quality and safety of agri-food products. Thus, transparency can be improved by sharing data among all AFSC stakeholders, which also helps in implementing compensation mechanisms for farmers and other AFSC stakeholders. For example, farmers making higher profits are required to pay a certain percentage to farmers making lower or no profits, which enhances loyalty. Importantly, brand sharing can also be applied across AFSCs to ensure that all agri-food products are of high quality. Thus, the size and colour of products, packaging materials, and even package sizes are all specified through discussion among experienced farmers to ensure the highest quality products.

5.3 AFSCRes categories generated through MICMAC analysis

MICMAC analysis was implemented to validate the TISM model and categorize the AFSCRes capability factors into independent, linkage, autonomous and dependent variables. This was performed by analyzing the dependence and driving power of the AFSCRes capability factors. An entry of "1" in the rows and columns represents driving power and dependence power, respectively for each AFSCRes capability factor, as shown in Appendices 3(a) and 3(b). *Independent* variables, characterized by high driving and low dependence power, act as drivers of the system and are located at the lowest level of the TISM hierarchy. *Linkage* variables, characterized by high driving and dependence power, act as links in the system and are located in the middle of the TISM hierarchy. *Autonomous* variables have less driving and dependence power, whereas *dependent* variables have low driving and high dependence power and are located at the highest level of the TISM hierarchy. MICMAC analyses of AFSCRes capability factors for Argentina and France are illustrated in Figures 5 and 6, respectively.

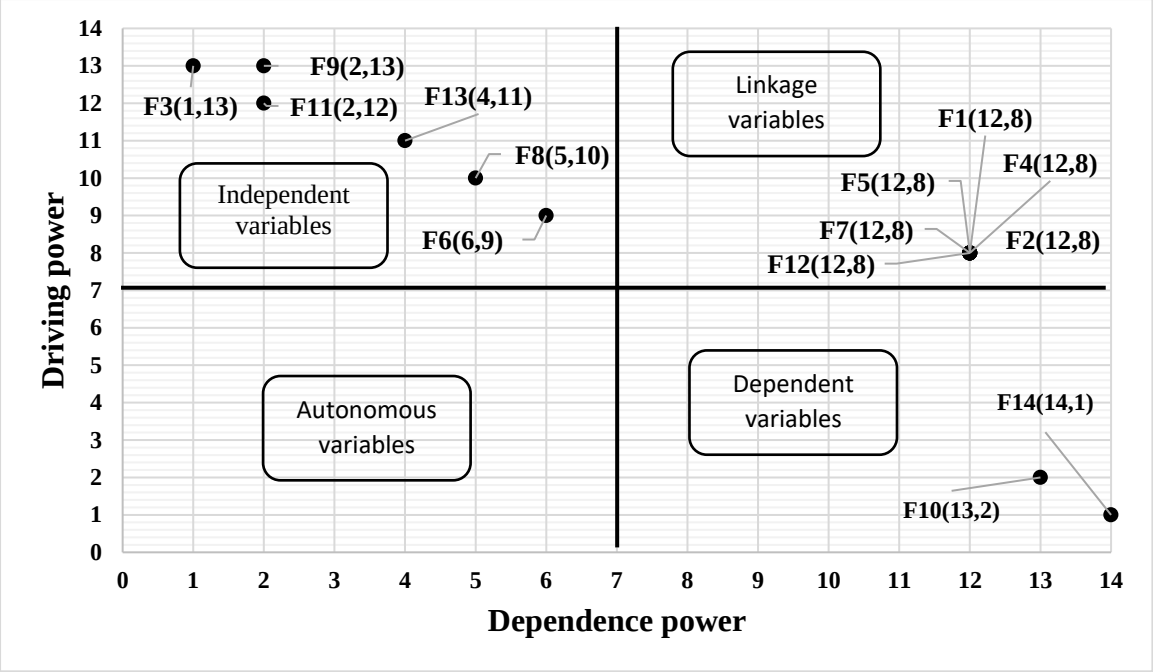

Figure 5 MICMAC analysis of Argentina's AFSCRes capability factors

The MICMAC analysis results for Argentina's AFSCRes capability factors show that all the identified factors are useful for building AFSCRes, as there are no autonomous variables. Although F3(Regular interaction), F9(Building shared understanding), F11(Establishment of farmers' association), F13(Governmental support), F8(ICT application) and F6(Decentralized knowledge network) are identified as independent variables, the key factors triggering AFSCRes in Argentina are F3(Regular interaction) and F9(Building shared understanding), as these two variables are located at the lowest level of the TISM hierarchy. For example, a decentralized knowledge network has been built to disseminate good agricultural practices, but stakeholders tend to rely on family members to acquire knowledge, as most businesses are family-run. Furthermore, most AFSC stakeholders in Argentina are reluctant to share information and knowledge for fear of divulging "business secrets". Discussion with the director of the Central Market of Buenos Aires revealed that Argentina lacks a professional database to monitor agricultural production across the whole country, including types, quantity and harvest times. Thus, the key to triggering AFSCRes in Argentina is to share information through regular interactions and build shared understandings among farmers, AFSC stakeholders and policymakers.

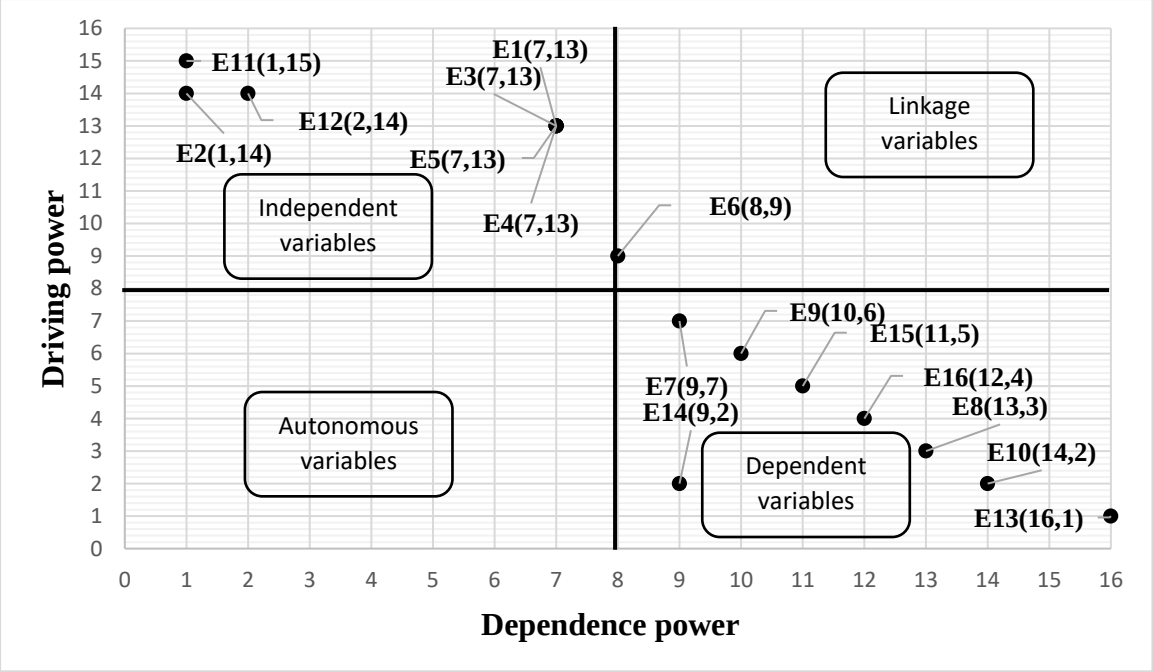

Figure 6 MICMAC analysis of France's AFSCRes capability factors

MICMAC analysis of France's AFSCRes capability factors produced interesting results. First, the combination of TISM and MICMAC analysis shows that E11(Contractual restraints) are critical to triggering AFSCRes, as farmers and other AFSC stakeholders all need mechanisms and regulations to limit their opportunistic behaviour and encourage some to contribute to the whole AFSC, for example through compensation mechanisms. Second, the MICMAC analysis shows that E6(Coordination) also plays a key role in achieving AFSCRes, as the AFSC, originating from the farmers' association, extends to the creation of an auction market, laboratory centre and field test company. The farmers' association acts as a focal entity in the supply chain, indicating that coordination activities are extremely important for the whole chain's resilience development. Third, no autonomous variables are identified, which suggests that all factors are useful for AFSCRes building in France.

5.4 Comparative analysis of research results between Argentina and France

Comparison of AFSCRes between Argentina and France highlights three AFSCRes capabilities common to the two countries: KM, innovation and supply chain collaboration. French AFSCs rely mainly on supply chain collaboration to build AFSCRes, whereas Argentinian AFSCs focus on KM. This huge difference originates from differences in cultural orientation and agricultural policies. First, Argentina has South American cultural orientation, whereas France has a Western European orientation, resulting from their geographical locations. Schwartz (2006) identifies seven cultural groups labelled as harmony, embeddedness, hierarchy, mastery, affective autonomy, intellectual autonomy and egalitarianism. France's national culture exhibits the characteristics of egalitarianism and intellectual autonomy (Schwartz. 2006). This means that individuals in France are more willing to express their rights and interests by joining voluntary organizations, and cooperate more easily with each other by formulating regulations. Thus, thousands of farmers in Brittany are connected by paying annual membership fees to the farmers' association, and farmers are regarded as owners of the association. The association has created a form of AFSC belonging to the farmers themselves, including laboratory research, a field test company, and even advocacy and lobbying institutions. The farmers' association can thus be seen as a focal entity triggering resilience across the whole AFSC. In order to manage thousands of farmers and other AFSC stakeholders, policies and mechanisms are required to make the whole AFSC run smoothly and link all

stakeholders together. For example, the compensation mechanism is designed to avoid failures by poorly performing farmers. Specific contracts and punishments are devised to convert competition among farmers into competition among customers. For instance, any farmers in the farmers' association who are discovered selling their products at prices lower than the protective price are expelled. Twenty years ago, the prices of perishable agri-food products were commonly discounted, facilitating malignant competition among farmers. Today, owing to strict rules regulating the farmers' behaviour, this practice has been eliminated, and the farmers realize that they must collaborate with other farmers in order to profit more from the markets. The TISM and MICMAC analysis results for France also indicate that contractual restraints are the "soul" of AFSCRes building. Other resilience capability factors such as brand sharing, joint decision-making, coordination and strict quality standards are adopted to inform all AFSC stakeholders that "*we are in the same boat; any failures at any points of the chain can cause devastating effects*". In contrast, Argentina belongs to the embeddedness cultural group. This kind of cultural atmosphere discourages membership of voluntary groups and does not support unnecessary involvement with people outside the ingroup (Schwartz. 2006). Thus, Argentinian farmers have weaker status than other AFSC stakeholders. Even focal firms in their AFSCs, such as supermarkets, act in their own self-interests. For example, one interviewee stated that, "*big supermarkets take advantage of their role in the supply chains, by facilitating competition among farmers to acquire the best products. To sell products, farmers even lower the product price"*. Our AFSCRes analysis results for France and Argentina supports these arguments. For example, more than 56.25% (n = 9) of AFSCRes capability factors identified for France relate to supply chain collaboration, compared with only 28.57% (n = 4) for Argentina.

Second, agricultural policy differences between these two countries result in different AFSCRes capability factors. For example, since September 2018, Argentina has used export restrictions and heavy tax on agricultural products to increase fiscal revenues and fight inflation (OECD. 2019). Export taxes account for up to 13% of all fiscal revenues in Argentina, but have not been effective in combatting food inflation. Interestingly, export restrictions are decided and implemented in an ad hoc, discretionary manner through government decrees, which have negative effects on long-term investments in the agricultural industry. Furthermore, Argentina's embeddedness cultural orientation means that individuals' to acceptance of immigrants, foreign workers and new technologies is lower than in countries in the autonomy and egalitarianism cultural groups (e.g., France) (Schwartz. 2006). In addition, one US dollar now equals over 100 Argentinian pesos, whereas 20 years agothe rate was one to one. As a result of Argentina's agricultural policies, cultural orientation and adverse peso-dollar exchange rate, AFSC practitioners are reluctant to apply new technologies and share knowledge with other partners. For example, only a few farms in Argentina have recently been able to integrate high-resolution cameras and computer technology to monitor crop status. Most Argentinian farmers rely heavily on manual labour, whereas in Brittany advanced technologies such as automated farming, soil-less and precision agriculture and robots are used in cauliflower and tomato farming. AFSC practitioners in Argentina have limited access to savings accounts and financial credit, which increases uncertainty in the agricultural industry. Thus, financial readiness is an important AFSCRes capability factor that enables AFSC practitioners in Argentina to keep their businesses running smoothly in a volatile business environment. In contrast, France's agricultural industry is mature, and the French government has formulated agricultural policies that support the development of AFSC practitioners. For example, 87% flat-rate expense deductions are available for low-income farmers with annual gross incomes below €82,800. Approximately 60% of fiscal expenditure (tax revenues foregone) is used to subsidize diesel fuel used in agriculture (OECD. 2020). AFSC stakeholders in France take advantage of the auction market and sell their products to countries around the

world. The director of the auction market said, "*We are exporting products to more than 30 countries globally. It is not a tough task for us because most of our products are exported to Germany, England and Spain*." Furthermore, France's intellectual autonomy's cultural orientation means that individuals are curious about knowledge. Widespread knowledge hubs and family farming knowledge platforms across the whole of Europe provide French farmers with easy access to knowledge. For example, there are 111 family farming knowledge platforms in Europe compared with only 35 in South America (Food and Agriculture Organization of the United Nations. 2021). In addition, an agri-tech conference, frequent training sessions and seminars are all available to enable French AFSC stakeholders to acquire knowledge. Traceability is considered a critical capability to ensure product quality and safety, and is widely applied in France. However, most AFSC stakeholders in Argentina recognize traceability only conceptually as a competitive advantage. For example, one interviewee stated, "*It is a competitive advantage if you have traceability technology… But there is no difference in the consumer's' minds when they see the products. All products look the same to them*." We presume that the "respect tradition" originating from the embeddedness cultural orientation contributes to Argentinians' reluctance to use traceability technology.

6. Discussion

Our findings make significant contributions to existing knowledge on AFSCRes building by identifying new capability factors, providing empirical evidence of the key role of contractual restraints and regular interactions, and opening up new research directions.

First, we identify several new factors for building AFSCRes, including extending international collaborations, compensation mechanisms, extension capacity, brand sharing and loyalty. Supply chain collaboration activities, such as information sharing, collaborative communication and joint relationship efforts, are all identified as effectively improving supply chains' preparedness for, responses to and adaptation in the face of disruptions (Scholten and Schilder. 2015; Hendry et al. 2019; De Sa et al. 2020; Zaridis et al. 2021). Our study reveals that AFSC stakeholders in countries suffering from wide currency fluctuations may benefit from building international collaborations and extending their international markets to alleviate the detrimental effects of the local currency. Furthermore, our findings suggest that farmers' loyalty to the farmers' association may strengthen overall AFSCRes. Contrary to our findings, Liu et al.'s (2018) research on the liner shipping industry indicates that SCRes may be a positive factor facilitating customer loyalty, rather than the reverse. To the best of our knowledge, no previous literature on SCRes has emphasized the role of farmers' loyalty to the farmers' association in facilitating AFSCRes. Compensation mechanisms are generally used in relationship management to improve overall supply chain integration and performance. Such mechanisms are expected to exert a greater influence on integrated supply chains than on less integrated and worse performing supply chains (Li et al. 2021). Our findings provide empirical evidence that compensation mechanisms are used as a strategy to facilitate corporate integration and full supply chain integration, and hence foster loyalty and strengthen capability to respond to disruptions. An innovative practice highlighted in this study is extension capacity, which entails modifying products, services or platforms to improve performance and diversify income streams. This study expands Sharifad and Ataei's (2012) observation that innovation does not occur in a vacuum, and that it is necessary to build organization-wide shared beliefs and understanding of innovation. Our findings confirm that extension capacity can be built through training sessions and active participation in funding bids. Finally, we identify that brand sharing has positive effects on building AFSCRes. Kim and Cavusgil (2009) propose that brand sharing has positive effects on market performance and on whole supply chain integration. However, the effect of supply chain integration on brand sharing is entirely mediated by SCRes.

Second, our TISM and MICMAC analyses reveal that contractual restraints are a key factor for AFSCRes in France, whereas regular interactions are a key factor in Argentina. Previous studies identify that KM, supply chain collaboration, SCRM culture, agility and supply chain reengineering are all important for building SCRes (Kamalahmadi and Parast. 2016; Durach et al. 2020). For example, De Sa et al. (2020) observe that SCRes cannot be achieved without collaboration at the supply chain level. Jain et al. (2017) and Yadav and Samuel (2021) indicate that information sharing and an SCRM culture are key factors for building SCRes. However, most existing studies examine "what" can be used to build SCRes, but none apply system thinking about "how" to achieve resilience throughout the whole chain, nor consider how to generalize their research results. The resilience models for Argentina and France built through TISM and MICMAC analyses provide clear routes to foster AFSCRes by establishing contracts that regulate AFSC stakeholders' opportunistic behaviour and by facilitating supply chain collaboration through regular interactions.

Third, our findings open up new avenues toward achieving the AFSCRes. For example, farmers, as the weakest, most vulnerable, and least resilient point in AFSCs, should be prioritized in resilience development (De Sa et al. 2020). Much of the contemporary supply chain management literature proposes how to achieve AFSCRes from the perspective of a focal firm, typically a buyer (Kim et al. 2015; De Sa et al. 2020; Novak et al. 2021). However, few studies consider how to achieve AFSCRes from a farmer's perspective. Farmers are generally considered to lack information, visibility and support, and to be located on the supply side of supply chains, with little opportunity to become focal firms (Shukla and Jharkharia. 2013). However, the results of our comparative analysis suggest that thousands of farmers combined through a farmers' association are able to become true leaders of the whole AFSC. This finding extends current research on AFSCRes by examining the whole chain's resilience from the innovative perspective of the farmers' association.

7. Conclusions and future research directions

In this study, a multi-method qualitative approach was adopted to compare AFSCRes in Argentina and France. In each country, twelve semi-structured interviews were conducted with experienced AFSC practitioners. The transcripts were subjected to thematic analysis to generate AFSCRes capability factors. TISM was then deployed to build AFSCRes models by defining interrelationships between resilience capability factors, and MICMAC analysis was used to categorize these AFSCRes capability factors into four groups (independent, dependent, linkage and autonomous variables) according to their driving power and dependence power. Finally, comparative analysis was conducted to compare AFSCRes in Argentina and France. The results reveal useful insights to guide AFSC practitioners in building AFSCRes. First, we establish that contractual restraints and regular interactions are key factors for building AFSCRes in France and Argentina, respectively. Second, making the weakest point (e.g., farmers) stronger and even the strongest, element of AFSCs and strengthening collaborative activities to link all AFSC stakeholders together can be seen as solutions to improving AFSCRes.

7.1 Managerial and policy implications

Country-specific managerial and policy implications can be drawn from this study. For Argentina, three managerial and policy implications are identified. First, we suggest that farmers' status in AFSCs should be improved, and that farmers' associations should be made to work effectively. Chains are only as strong as the weakest link, and farmers are perceived to be the weakest link in AFSCs. Improving their status will depend not only on individuals, but also on the whole cluster of farmers in AFSCs. Thus, all farmers should pay membership fees to join the association. As more farmers join, the association will become a focal entity and the whole chain's resilience will improve. Practical measures can be taken to make the association more effective, such as negotiating with other AFSC stakeholders from the association's

perspective, and recruiting a professional management team. Second, policymakers should ease export restrictions, decrease export taxes on agricultural products, and encourage AFSC managers to participate in global trade and build trade relationships with foreign markets. This will be particularly useful for AFSC stakeholders in unstable business and economic environments. Third, we suggest that focal-firm managers should formulate strict standards to regulate AFSC practitioners' opportunistic behaviour and facilitate interactions interlinking all AFSC practitioners. Preventing opportunistic behaviour will help maintain healthy, sustainable cooperative relationships, particularly since all stakeholders rely on collaboration and cooperation to ensure that AFSCs run smoothly. More coordination and collaboration activities among all AFSC stakeholders must be implemented to bind them together. Available options include standards, punishments and knowledge-sharing activities, to inform AFSC practitioners that opportunistic behaviour may benefit their organization in the short term but have devastating long-term effects. To facilitate integration across the whole chain, staff exchange programmes and compensation mechanisms can be applied to link AFSC stakeholders together.

Our results also have managerial and policy implications for France. First, we suggest that AFSC practitioners should pay more attention to knowledge-sharing activities. In particular, industry 4.0 technologies have been widely applied in the agricultural industry to improve traceability, connectivity, transparency and knowledge representation (Zhao et al. 2019). However, KM-related AFSCRes capability factors account for only 6.25% (n = 1) of factors in France. Thus, more knowledge-sharing activities, such as university industry collaboration to upskill and reskill AFSC practitioners, may be beneficial. Second, France's cultural orientation suggests willingness to accept immigrants and foreign workers (Schwartz. 2006). Skilled workers are critical for building AFSCRes (Chmutina and Rose. 2018). Accordingly, we suggest that policy-makers should formulate preferential policies to attract skilled agricultural workers to work in the French agricultural industry.

7.2 Limitations and future research directions

This study has some limitations. First, we collected data from Argentina and France. Although Spanish- and French-speaking researchers were involved in the data collection process, knowledge may still have been lost in translation. Second, we have not established the external validity of the empirical findings. Third, we have identified resilience capability factors that are useful for building AFSCRes in Argentina and France, but have not tested whether these factors are effective over the long term. Fourth, we do not propose possible ways to generalize the findings of this study. Finally, a wide variety of practitioners (e.g., input suppliers, farmers, processors, logistics service providers, wholesalers and retailers) work for the AFSCs, which may result in differing AFSCRes capability requirements. This limits our understanding of which AFSCRes capabilities are critical for practitioners at particular stages of the supply chain, as we focus on whole AFSCs.

To tackle these limitations, we recommend the following future research directions:

(1) An integrative approach should be adopted in future research to reduce knowledge loss during the language translation process (Daghfous et al. 2013). For example, pre-tests and training sessions might be conducted to ensure that translators have sufficient understanding of AFSCRes and to find AFSC practitioners whose command of English is good enough to participate in interviews.

(2) We recommend that documents such as organizational brochures, official websites, annual reports, and even internal documents should be collected and analyzed. Fieldwork trips are also encouraged to validate the findings and achieve data triangulation (Larsen et al. 2017).

(3) Longitudinal, multi-disciplinary studies might be conducted in Argentina and France to test specific resilience capability factors. This would enable AFSC

stakeholders to assess the adaptability, profitability, generalizability and sustainability of resilience capability factors.

(4) Our research results might be evaluated by administering questionnaires in other countries with similar cultural orientations to France and Argentina to generalize our findings. We suggest choosing 7 to 10 countries for each cultural orientation group, as this number would be sufficient to support credible international generalizations (Franke and Richey. 2010).

(5) Future studies might investigate AFSCRes from specific perspectives of AFSCs, such as the perspectives of farmers and wholesalers, to deepen our understanding of key factors.

Data availability statement: The authors confirm that the data supporting the findings of this study are available within the article [and/or] its supplementary materials.

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Appendix 1 Detailed information on interviewees in Argentina and France

Country	Case firm	Role in AFSC	Products/Services	Ownership	Interviewee
Argentina	A	Agricultural university	Agricultural technology/knowledge transfer	Public	Professor
	B	Research institution	Surveillance, regulation and certification of agri-food products	Public	Director of technology transfer
	C	Agricultural university	Agricultural technology/knowledge transfer	Public	Dean of the faculty of agriculture
	D	Government	Agricultural policy-making and transfer of good agricultural practices	Public	Government officer for the agri-food minister of Buenos Aires Province
	E	Farmer	Organic vegetables	Private	Owner
	F	Input supplier	Agri-chemical products	Private	Owner
	G	Wholesaler	Central wholesale fruit market	Public	Director of the Central Market of Buenos Aires
	H	Farmer	Leaf vegetables	Private	Owner
	I	Farmer	Cereal	Private	Owner
	J	Farmer	Tomatoes	Private	Owner
	K	Input supplier	Seed farm	Private	Owner
	L	Distributor	Logistics service	Private	Owner
France	A	Wholesaler	Coordination and marketing	Union of cooperatives	Director
	B	Input supplier	Gene modification and seed selling	Private	Director
	C	Input supplier	Agricultural machine rental service	Non-profit association	Director
	D	Government	Accelerating implementation of research information systems	Public	Manager of European projects
	E	Government	Advocacy and lobbying	Non-profit association	Owner
	F	Research institution	Support for varietal creation, plant protection and innovation	Private	Director
	G	Regional government	Agricultural policy making and financial support	Public	Director of agricultural department
	H	Farmer	Vegetables	Private	Owner
	I	Farmer	Vegetable and melon farming, and crop production	Private	Owner
	J	Distributor	Cold chain logistics	Private	Owner
	K	Research institution	Generate and pass on new knowledge to support agricultural development	Public	Owner
	L	Research institution	Experimentation with fresh vegetables	Public	Owner

Appendix 2 Interview guide

A. Introductory questions

(I) Interviewee information

(1) What is your current designation?
(2) Can you give me a brief overview of your job within the company's operations?
(3) How many years have you been working in this company?
(4) How many years of your working experience have been in the same job role in total?

(II) Company information

(1) Can you give me a brief overview of the company structure, parent company, and its operations?
(2) How many employees are working for the company?
(3) What is the industry sector in which the organization operates?
(4) What is the financial status of the company?

B. Risks faced by the company and the whole AFSC

(1) How would you describe the sources of risks that affect your company?
(2) How would you describe the biggest risk that you have faced in your company?
(3) How would you describe the sources of risks that affect the whole AFSC?

C. Resilience strategies

(1) How would you describe any contingency plans for dealing with the risks?
(2) How would you describe any other strategies or measures that have been used to help the organization to recover from the risks?
    - Knowledge management
    - Flexibility
    - Redundancy
    - Trust
    - Innovation
    - Visibility
    - Leadership
    - SCRM culture
    - Information sharing

Appendix 3(a) Reachability matrix for Argentina (including initial and final findings)

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	Driving power
F1	1	1	0	1	1*	0	1	0	0	1*	0	1*	0	1*	8
F2	1	1	0	1*	1*	0	1*	0	0	1*	0	1*	0	1*	8
F3	1*	1	1	1*	1*	1*	1*	1*	1	1*	0	1	1*	1*	13
F4	1	1	0	1	1	0	1	0	0	1*	0	1*	0	1*	8
F5	1	1*	0	1*	1	0	1	0	0	1*	0	1*	0	1*	8
F6	1	1*	0	1	1*	1	1	0	0	1*	0	1*	0	1*	9
F7	1*	1*	0	1*	1*	0	1	0	0	1	0	1	0	1*	8
F8	1	1*	0	1*	1*	1	1	1	0	1	0	1*	0	1*	10
F9	1	1*	0	1*	1*	1*	1*	1*	1	1*	1	1*	1*	1*	13
F10	0	0	0	0	0	0	0	0	0	1	0	0	0	1	2
F11	1*	1*	0	1*	1*	1*	1*	1*	0	1*	1	1*	1	1*	12
F12	1	1	0	1*	1*	0	1*	0	0	1*	0	1	0	1*	8
F13	1*	1*	0	1	1*	1	1	1	0	1	0	1*	1	1*	11
F14	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Dependence power	12	12	1	12	12	6	12	5	2	13	2	12	4	14	

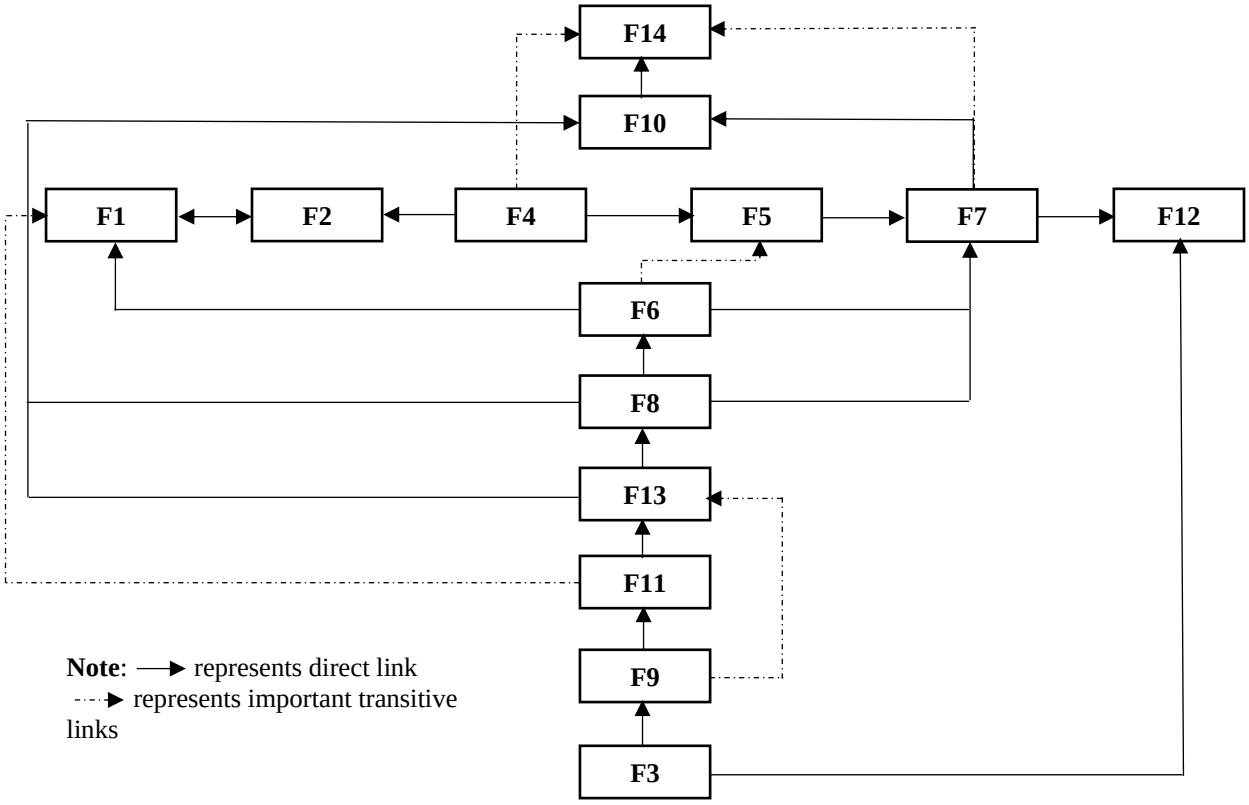
Note: * represents transitivity

Appendix 3(b) Reachability matrix for France (including initial and final findings)

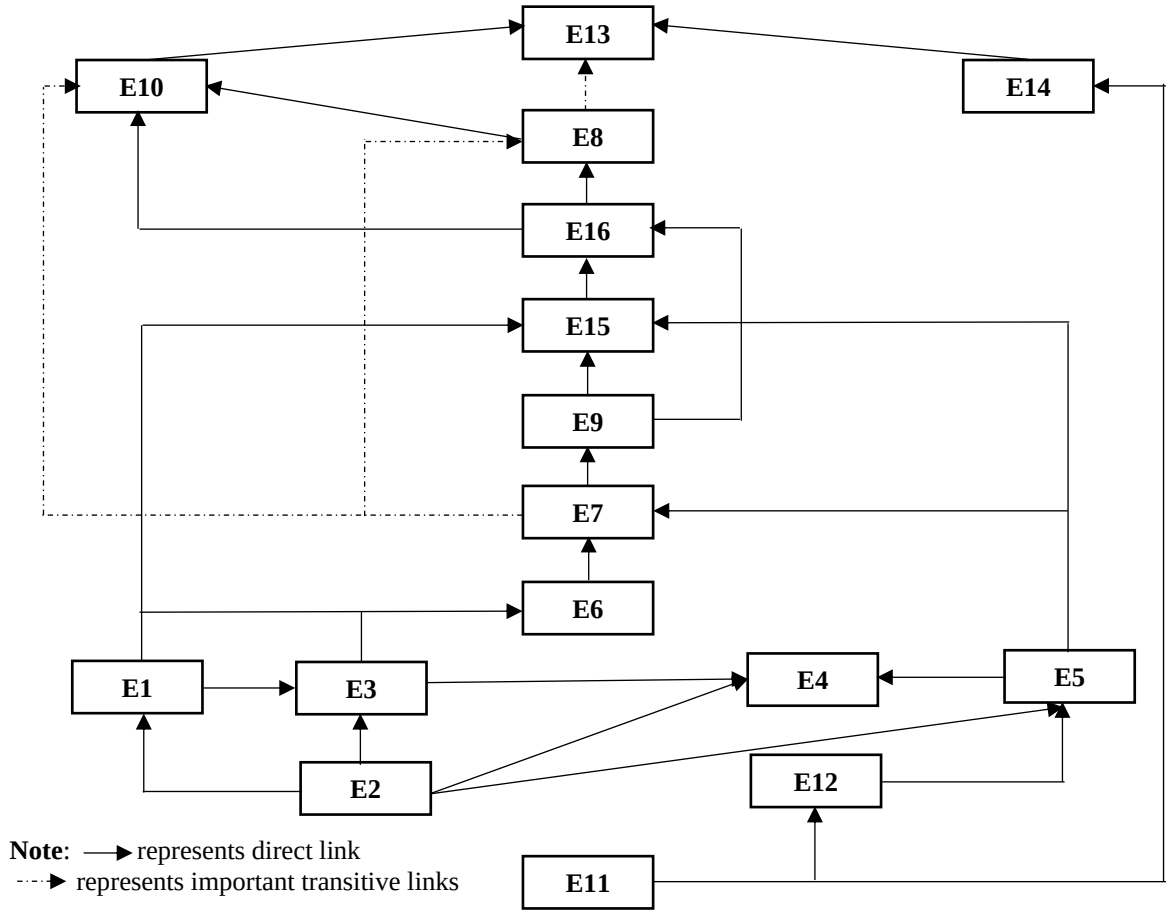
	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	E14	E15	E16	Driving power
E1	1	0	1	1*	1	1	1*	1*	1	1*	0	0	1*	1*	1	1	13
E2	1	1	1	1	1	1*	1*	1*	1*	1*	0	0	1*	1*	1*	1*	14
E3	1*	0	1	1	1*	1*	1	1*	1*	1*	0	0	1*	1*	1*	1*	13
E4	1	0	1*	1	1*	1*	1*	1*	1*	1*	0	0	1*	1*	1	1*	13
E5	1*	0	1*	1	1	1*	1	1*	1*	1*	0	0	1	1*	1	1	13
E6	0	0	0	0	0	1	1	1	1	1*	0	0	1	1	1	1	9
E7	0	0	0	0	0	0	1	1*	1	1*	0	0	1*	0	1*	1	7
E8	0	0	0	0	0	0	0	1	0	1	0	0	1*	0	0	0	3
E9	0	0	0	0	0	0	0	1	1	1*	0	0	1	0	1	1	6
E10	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	2
E11	1*	0	1*	1*	1*	1*	1*	1	1*	1	1	1	1	1	1	1	15
E12	1*	0	1*	1*	1	1*	1*	1	1*	1	0	1	1*	1*	1*	1*	14
E13	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
E14	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2
E15	0	0	0	0	0	0	0	1*	0	1*	0	0	1*	0	1	1	5
E16	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	1	4
Dependence power	7	1	7	7	7	8	9	13	10	14	1	2	16	9	11	12	

Note: * represents transitivity

Appendix 4(a) Digraph showing significant transitive links for Argentina



Appendix 4(b) Digraph showing significant transitive links for France



Appendix 5(a) Binary interaction matrix for Argentina

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14
F1	-	1	0	0	0	0	0	0	0	0	0	0	0	0
F2	1	-	0	0	0	0	0	0	0	0	0	0	0	0
F3	0	0	-	0	0	0	0	0	1	0	0	1	0	0
F4	0	1	0	-	0	0	0	0	0	0	0	0	0	1*
F5	0	0	0	0	-	0	1	0	0	0	0	0	0	0
F6	1	0	0	0	1*	-	1	0	0	0	0	0	0	0
F7	0	0	0	0	0	0	-	0	0	1	0	0	0	1*
F8	0	0	0	0	0	1	1	-	0	1	0	0	0	0
F9	0	0	0	0	0	0	0	0	-	0	1	0	1*	0
F10	0	0	0	0	0	0	0	0	0	-	0	0	0	1
F11	1*	0	0	0	0	0	0	0	0	0	-	0	1	0
F12	0	0	0	0	0	0	0	0	0	0	0	-	0	0
F13	0	0	0	0	0	0	0	1	0	1	0	0	-	0
F14	0	0	0	0	0	0	0	0	0	0	0	0	0	-

Note: * refers to important transitive linkage

Appendix 5(b) Binary interaction matrix for France

	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	E13	E14	E15	E16
E1	-	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0
E2	1	-	1	1	1	0	0	0	0	0	0	0	0	0	0	0
E3	0	0	-	0	0	1	0	0	0	0	0	0	0	0	0	0
E4	0	0	0	-	0	0	0	0	0	0	0	0	0	0	0	0
E5	0	0	0	0	-	0	1	0	0	0	0	0	0	0	1	0
E6	0	0	0	0	0	-	1	0	0	0	0	0	0	0	0	0
E7	0	0	0	0	0	0	-	1*	1	1*	0	0	0	0	0	0
E8	0	0	0	0	0	0	0	-	0	1	0	0	1*	0	0	0
E9	0	0	0	0	0	0	0	0	-	0	0	0	0	0	1	1
E10	0	0	0	0	0	0	0	0	0	-	0	0	1	0	0	0
E11	0	0	0	0	0	0	0	0	0	0	-	1	0	1	0	0
E12	0	0	0	0	1	0	0	0	0	0	0	-	0	0	0	0
E13	0	0	0	0	0	0	0	0	0	0	0	0	-	0	0	0
E14	0	0	0	0	0	0	0	0	0	0	0	0	1	-	0	0
E15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	1
E16	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	-

Note: *refers important transitive linkage