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LONG ABSTRACT

Building resilient agrifood supply chains in the era of shocks: an ANP-ADAM approach

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The resilience of supply chains received considerable attention over the last decades (Koufteros and Lu, 2017). Several shocks and negative unexpected events (e.g., the COVID-19 pandemic and the war between Russia and Ukraine) affected the global economy with consequences on the markets both in the short- and long-term (Zakeri et al., 2022). The Russian-Ukrainian war, in particular, caused rising energy prices and the interruptions of some fuel supply channel with relevant implications in terms of energy price increases, while the pandemic had already generated significant variations in goods and services demand, supply chain interruptions, and difficulties with energy investments.

Studies in the field of supply chain resilience were carried out by scholars over the years and trace back to the 2000s. The existing literature already identified transport infrastructure endowment (Agnusdei et al., 2022a), contingency plans, coordination and financial support, human resource management, use of information technology, trust and satisfaction (Das et al., 2022), as drivers for building sustainable and resilient supply chains (Agnusdei and Coluccia, 2022).

Despite the several outbreaks and emergencies that occurred in the past, companies are still not able to mitigate these risks, mainly due to the lack of long-term strategies for building up resilient supply chains. The latter may not be the cheapest, but they are certainly capable of coping with uncertainties and disruptions, because they anticipate, identify, adapt to, and recover from unexpected and unpredictable events (Karbassi Yazdi et al., 2023).

Evaluating the supply chain has become most crucial to overcome the recent shocks, to mitigate the risk of the unforeseeable events, and to help managers and policymakers to develop shared plans for achieving resilience (Johnson et al. 2013; Vanpoucke and Ellis, 2019; Krstić et al., 2023).

Furthermore, population growth, changing consumption habits and trade globalization made the supply chain more complex (Katsikouli et al., 2021), implying the risk that agrifood demand will not be met with negative consequences on security (McGuire et al., 2022).

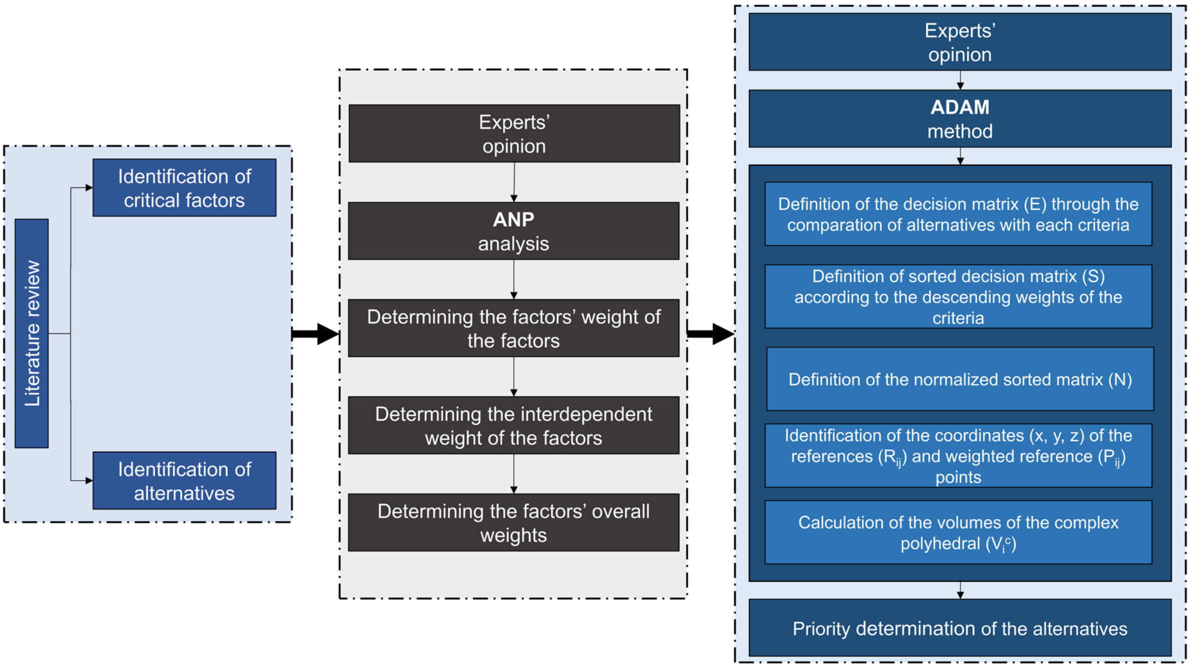
In the current context, characterized by several and increasingly frequent shocks, the present study aims at exploring the critical factors which allow for the identification of the best resilience approach to be adopted within the agrifood supply chains among alternatives. Based on this, the research questions are:

RQ1. *Which are the most critical factors affecting the resilience of agrifood supply chains in the era of shocks?*

RQ2. *Which is the best resilience approach to be adopted in the agrifood supply chains based on the identified critical factors?*

An integrated ANP-ADAM analysis is performed to accomplish the abovementioned aims, following a two-stage approach to answer the research questions. The methodology structure is illustrated in Figure 1.

Figure 1. Methodology structure of the study



In the ***first stage***, critical factors affecting the resilience of agrifood supply chains in the era of shocks and the type of resilience approaches adoptable by the companies are identified from the literature (Das et al., 2022). Based on the judgements expressed by a panel of experts, critical factors are weighted and ranked through the Analytic Network Process (ANP), one of the most popular methods of multi-criteria decision making (MCDM), which generalizes the Analytic Hierarchical Process (AHP) by replacing hierarchies with networks (Chung et al., 2005).

In the ***second stage***, a priority determination of the alternatives is performed through the ADAM method, a new class of MCDM techniques, known as geometric MCDM (Krstić et al., 2023; Agnusdei et al., 2023), which rates alternatives by computing the volumes of complex polyhedra made up of points (vertices) in a three-dimensional coordinate system as an aggregate measurement.
Table 2 shows a synthetic visualization and description of the critical factors affecting the resilience of agrifood supply chains in the era of shocks identified based on the literature.

Table 1. Critical factors affecting the resilience of agrifood supply chains

Criteria	Description
(C1) *Process automation and artificial intelligence*	It helps to carefully assess the situation and timely actions that helps to mitigate the risk and to deal with asymmetric information and capability to deal with an uncertain environment which cannot be anticipated wholly, with the help of learning and adoption (Legg and Hutter, 2007).
(C2) *Inventory management*	It enables to adequately manage the inventories of multiple products, to reduce the risk of pilling of the inventory and to optimize the holding cost (Kristianto et al., 2012; Rajesh, 2017).

(C3) *Outsourcing of business operations*	It helps to consider economies of scale, to optimize the cost of production, to increase profit margins (Mani et al., 2010) and hence to derive competitive advantage during crises or emergencies (Kroes and Ghosh, 2010).
(C4) *Geographical integration of supply chain agents*	Since the integration of supply chain agents operating in a certain geographical area can eliminate the information asymmetry and trade barriers while improving collaborative relationships, it helps agents to take appropriate decisions at the time of disruptions (Yu et al. 2013).
(C5) *Quality assurance*	It enables to create brand image, establish new customer base, attain customer loyalty, and establish competitive advantage from their counterparts (Cai et al. 2013).
(C6) *Monitoring unethical pricing practices*	It unavoidably increases the tangible costs due to inspecting the supply chain agents and it is essential to consciously check on strategic decisions in order to maintain or increase customer base during the times of shocks (Simangunsong et al. 2016).
(C7) *Service quality and customer satisfaction*	It leads to improved customer satisfaction and helps in maintaining a sustainable competitive advantage (Politis et al. 2014).
(C8) *Human resource management*	It allows for the co-development and co-production of products or services and the sharing of information among supply chain partners (Ragatz et al. 2002; Lee et al. 2000).
(C9) *Government support*	Through the implementation of business-friendly policies and financial incentives at the time of disruption events, it stimulates the industrial growth and stabilizes the economy (Dube et al. 2016), encouraging to recover from economic crisis and revive their supply chain production.
(C10) *Cost optimization*	Including the purchasing, holding and transportation cost optimization, it contributes to improve significantly the service level to customers (Farahani and Elahipanah, 2008).
(C11) *Contingency planning*	Involving a sequential and pre-planned process designed for precautionary purposes against disruptions (Svensson, 2004), it helps to reduce vulnerabilities and to mitigate the risk of economic losses.

Source: own elaboration based on Das et al. (2022)

From the perspective of strategies for dealing with disruptions and uncertainties, in Table 2, the different types of resilience approaches, based on López-Castro et al. (2021), are indicated, which represent the alternatives in our model.

Table 2. Resilience approach alternatives

Alternatives / Type of resilience approach	Descriptions
(A1) *Robustness*	Ability of a supply chain to resist or avoid change (Durach et al., 2015)

(A2) *Agility*	Strategic capability to respond to unpredictable changes (Fayezi et al., 2017)
(A3) *Flexibility*	Operational ability at the tactical level to perform a predetermined action in a manner that adapts to predictable changes (Edwin Cheng et al., 2022)
(A4) *Risk assessment*	Ability to determine the mitigation strategies to be implemented when a disruption occurs (Tran et al., 2018)

Source: own elaboration based on López-Castro et al. (2021)

Through ANP analysis, the inner and outer dependencies between the critical factors evaluated by the panel of experts are considered. In order to carry out the ANP, the software SuperDecision was used, allowing for the definition of the structure model.

ANP results place at the first position in the ranking of critical factors, the outsourcing of business operations (C3). With agrifood companies focusing more on their core businesses, the outsourcing of business operations, especially transport services, gives logistics service providers (LSPs) exactly the capacity they need and provides flexibility in the supply chain (Wilson, 2020). Since agrifood supply chains can be considered as networks of agents mutually and co-operatively working to manage the flows from suppliers to end users, it should be stressed that they rely on logistics, mainly transport and warehouse services. In the last decades LSPs became crucial, due to the increasing outsourcing of transport and warehousing functions by the companies (Agnusdei et al., 2022b; Gkanatsas and Krikke, 2020; Liu and Lee, 2018). In fact, by limiting or even eliminating risks that may occur due to volatile demand, supply or during shocks (König and Spinler, 2016), LPSs are key agents for achieving supply chain resilience. The second and third positions, instead, are held by C8 and C4, referring respectively to human resource management and the geographical integration of supply chain agents.

In order to reveal the best alternative, i.e., the best type of approach to be implemented in order to achieve the resilience of agrifood supply chains, based on the above identified critical factors, the ADAM method was applied. The volume of complex polyhedra defined by the reference and weighted reference points were obtained using the ADAM software package developed by Krstić and Kovač (n.d.).

The alternatives are assigned a final ranking by arranging them in descending order based on the values of the corresponding polyhedron volumes. The results highlight that the first position in the ranking was assigned to A2 – Agility, i.e., the strategic capability to rapidly sense and respond to internal and external uncertainties via effective integration of supply chain relationships.

In this perspective, there is the need to simultaneously activate several capabilities that require support and commitment from managers to develop resilient agrifood supply chains. They are called to build agility and encourage knowledge sharing and improve visibility across the supply chain (Mishra et al., 2022). In fact, the readiness to identify and respond to changes in market fluctuations is the cornerstone of supply chain agility (Baležentis et al., 2023). In the era of shocks, under rapidly developing situations, agrifood supply chains witnessed major changes in the stakeholders' behaviors, the agile approach appears the best solution allowing for timely analysis and decisions, resilience and continuity.

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