



Università degli Studi della Tuscia di Viterbo

**Dipartimento per la Innovazione nei sistemi Biologici, Agroalimentari e Forestali
(DIBAF)**

**Corso di Dottorato di Ricerca in
Scienze, Biotecnologie e Tecnologie per la Sostenibilità**

XXXVII ciclo

**From Loss to Value: Socio-Technical Innovations Driving Sustainability in the
Fruit and Vegetable Value Chain**

Settore scientifico-disciplinare

AGRI-01/A

Tesi di dottorato di:

Dott. Marco Nasso

Firma

Coordinatore del corso

Prof. Andrea Vannini

Firma

Tutore

Prof. /Dott. Emanuele Blasi

Firma

Co-tutore

Prof./Dott. Clara Cicatiello

Firma

A.A. 2023/24 (A.Y. 2023/24)

Audentes fortuna iuvat

Table of Contents

1. Introduction	2
1.1 Socio-technical innovations driving sustainable agri-food systems.....	3
1.2 State of art of waste prevention and surplus management in the European F&V sector	7
1.3 The “Sustainable Food Management Innovation Hierarchy” framework	11
1.4 Research questions	15
2. Research Design and Methodology	18
2.1 Conceptual Framework.....	19
2.2 Methodological Approach	22
2.3 Contribution of each chapter to the thesis framework.....	24
3. Investigating Co-Innovation Strategies to Prevent Food Loss in the Fruits and Vegetables Sector.....	27
3.1 Introduction	28
3.2 Methodology.....	30
3.3 Results and Discussion	43
3.4 Conclusions	48
4. Adoption dynamics of food redistribution technology to enhance policy measures in the agri-food sector	52
4.1 Introduction	53
4.2 Methodology.....	57
4.3 Results	65
4.4 Discussion.....	68
4.5 Conclusion.....	69
5. Socio-Technical Innovations for Food Surplus Redistribution: Assessing the social benefit generation of the EU CMO policy.....	72
5.1 Introduction	73
5.2 Data and Methods.....	77
5.3 Results and Discussion	85
5.4 Conclusions	94
6. Discussion and Conclusion.....	96
6.1 Summary of results	97
6.2 Theoretical Contribution.....	100
6.3 Policy recommendations	103
6.4 Limitations and further research.....	107
Summary.....	108
References	111

1.

Introduction

1.1 Socio-technical innovations driving sustainable agri-food systems

During the last decade, the transition towards sustainable food systems has become an urgent priority in response to the growing environmental, economic, and social challenges (FAO, 2021). In this context, food waste management has become an increasingly critical topic towards sustainable systems, posing significant environmental, economic, and social challenges at global, European, and local scales (Papargyropoulou et al., 2014).

The agri-food sector lies at the heart of this evolving scenario, as it contributes significantly to the environmental degradation while being central to food security and economic stability (European Commission, 2022). The sector must address interconnected issues such as resource inefficiency, climate change, and social inequalities, which require innovative, systemic, and interdisciplinary solutions (Tort et al., 2021; Aramyan et al., 2020). Indeed, inefficiencies leading to food losses and waste, particularly in the fruit and vegetable (F&V) value chain, have been consistently identified as critical barriers to improve sustainable improvement across the supply chain (Caldeira et al., 2019; Notarnicola et al., 2017).

Providing advancements towards solutions capable of enhancing the agri-food sector's ability to tackle the interconnected issues described above represents a complex challenge (Springmann et al., 2018). From an academic perspective, the mitigation food losses and waste at its source, defined as prevention, has been consistently identified as a strategical approach (Thyberg & Tonjes, 2016; Caldeira et al., 2019). This perspective is shared also by policymakers since preventing food losses and implementing waste management strategies aligns with circular economy principles, that are central objectives in global and particularly European agri-food policies (Ghisellini et al., 2016; Esposito et al., 2020). These strategies prioritize prevention and redistribution approaches, aiming to ensure that edible products do not become waste. Subsequently, the fraction of food that cannot be prevented or redistributed due to various constraints should be systematically collected and recycled through ad-hoc waste management options that allows for reintroducing these valuable resources into the agri-food production system. This comprehensive approach is at the core of the sustainable transitions of the agri-food sector as it effectively combines traditional agricultural practices familiar to farmers with modern socio-technical innovations driven by novel technologies.

The sustainable shift asked by both policymakers and academical researchers refers to a transformative process through which socio-economic systems, such as the agri-food

sector, evolve toward more equitable, resilient, and efficient models. It integrates technological, organizational, and policy innovations to balance environmental, economic, and social dimensions, ensuring long-term sustainability (Tort et al, 2021). In this regard, the fruit and vegetable (F&V) value chain is considered strategic and prioritize intervention is crucial considering the persistent inefficiencies and crises, including high levels of food loss and waste compared with other agri-food value chains (Perez-Mesa et al., 2021). This vulnerability mainly arises during production phases, because of inefficiencies during products management, the high perishability of fresh products and uneven access to technological solutions of operators (Ishangulyyev et al., 2019). These challenges compromise resource optimization, intensify environmental impacts, and amplify economic disparities across the value chain, posing significant obstacles to achieving fair access to sustainable practices and investments for all operators (Knickel et al., 2021; FAO, 2021).

To address these challenges and enhance the sector's resilience, European policy initiatives have increasingly prioritized the management of food losses and waste. In recent decades, institutional solutions and dedicated funds, such as those provided under the Common Agricultural Policy (CAP) and the Common Market Organization (CMO), have been introduced explicitly to support food waste prevention and management efforts among farmers and other stakeholders within the value chain (European Commission, 2023; Garcia Azcarate, 2021).

In this context, the diffusion of innovative solutions has emerged as a crucial enabler for the transition towards sustainable F&V value chains (Krishnan et al., 2021). Indeed, the adoption of innovations at various value chain levels can provide benefits to the entire system, acting as a driver for sustainability and efficiency (Zhao et al., 2023). Nevertheless, the widespread diffusion of such innovations is limited by economic constraints, resistance to change, and fragmented institutional support, highlighting the need for systemic and collaborative approaches (Midgley, 2014).

In this regard, stakeholder engagement is critical to raising awareness of food loss and waste levels while ensuring that the adoption of innovative systems is impactful and effective in achieving food waste reduction (Gupta et al., 2019). Actors within the supply chain operate under diverse priorities and values, significantly influencing their decision-making processes (Brown, 1993). Effectively aligning these differing perspectives through collaborative strategies is essential for overcoming systemic barriers and achieving equitable outcomes in waste management and surplus redistribution

(Papargyropoulou et al., 2022; Aramyan et al., 2020). Research consistently demonstrates that stakeholder involvement in co-designing and implementing solutions leads to strategies better aligned with real needs and greater potential for long-term success (Cuppen, 2012). An important outcome of stakeholder collaboration is the development of socio-technical innovations, defined as integrated solutions co-created by diverse stakeholder groups working towards shared objectives (Geels, 2019). Socio-technical innovations leverage integrated approaches that combine new technologies, organizational structures, and governance mechanisms to tackle specific challenges, resulting as a novel approach that has proven particularly effective within the agri-food system (Vermunt et al., 2020). The potential of socio-technical innovations to enhance sustainability transitions in the agri-food sector has been extensively analysed in the literature, reporting positive results by addressing food loss and waste challenges through the diffusion of scalable, innovative and effective solutions (Menard and Valceschini, 2017; Canali et al., 2017). Indeed, the development of socio-technical systems was demonstrated effective when addressing complex challenges at multiple levels, by leveraging technological advancements, building on organizational strengths, and aligning with policy objectives (Canali et al., 2017). At the same time, the successful implementation of socio-technical systems relies also on strong institutional support, robust and trustworthy stakeholder collaboration, and the ability to navigate contextual challenges, such as regulatory complexity and geopolitical crises (Dumont et al., 2020). Moreover, effective governance mechanisms are crucial for creating a positive environment to innovation diffusion, incentivizing sustainable practices while ensuring that benefits provided by the adoption and diffusion of socio-technical innovations are distributed equitably across the supply chain (Tort et al., 2021). Policy frameworks must bridge the gap between institutional objectives and practical need, enabling stakeholders to adopt innovations that address systemic inefficiencies while fostering long-term resilience (Georghiou et al., 2014).

This thesis explores three interconnected themes through dedicated research papers to provide insight into the potential impacts of socio-technical innovations on the transition towards sustainable systems in the agri-food sector, with a focus on the European context.

Chapter 3 investigates stakeholder motivations and perceptions, analysing their role in shaping opportunities for co-innovation. Chapter 4 examines the dynamics of adopting innovations, identifying institutional drivers and barriers over time. Finally, Chapter 5 assesses the impact of a socio-technical innovation operating within the fruit and

vegetable value chain, emphasizing the economic value created by enhancing public policies with digital technologies to improve surplus management and social outcomes.

The remainder of this chapter introduces the relevant literature, starting with an analysis of the state of art by reporting advancement and gaps in the scientific literature (Section 1.2). The next section (Section 1.3) provides the discussion about the theoretical framework developed in this research, defined as “Sustainable Food Management Innovation Hierarchy” framework, that will be used across the thesis to connect the research chapters and to discuss the result. Section 1.4 presents the research questions addressed in the thesis. Following sections present the research design and methodology of the thesis (Section 2), discussing the conceptual framework (Section 2.1), the methodological approach (Section 2.2) and the contribution of each research chapter to the thesis (Section 2.3). The thesis concludes with a collection of practical and policy recommendations in Chapter 6, contextualizing the findings within the “Sustainable Food Management Innovation Hierarchy” framework as a basis for future advancement in the field.

1.2 State of art of waste prevention and surplus management in the European F&V sector

The F&V sector has been consistently identified as critical for addressing inefficiencies related to food waste and surplus management (Smith, 2008). The life cycle of fruit and vegetable products typically develops along five stages of a typical value chain, including: production, post-harvesting, manufacturing and distribution, retailing, and consumption. According to the European Commission, the definition of food loss refers to edible foods that fail to reach the retail stage, whereas food waste includes discarded products during later stages, including final consumption (European Commission, 2008). Food loss and waste are primarily driven by inefficiencies during the inventory management phase of fresh products, including challenges related to fast perishability, quality preservation, cold-chain logistics, and demand volatility, which is closely linked to price volatility (Notarnicola et al., 2017).

At the global level, the Sustainable Development Goals (SDGs) provide a comprehensive framework established by the United Nations in 2012 to promote economic growth, social inclusion, and environmental sustainability by 2030 (UN, 2015). The SDGs consist of 17 interconnected goals addressing areas such as poverty alleviation, quality education, clean energy, climate action, and gender equality. Food waste prevention aligns with multiple SDGs, promoting efficient resource use, reducing environmental impact, and enhancing global food security. The *SDGs 1 – No Poverty* aim to promote initiatives to reduce food waste while increasing food access for disadvantaged populations, alleviating poverty and hunger. Additionally, the *SDGs 2 – Zero Hunger* focuses on ensuring food security and sustainable nutrition, thereby improving global food distribution. In the same way, the *SDGs 12 - Responsible Consumption and Production*, specifically the target 12.3, aim to halve per capita food waste at the retail and consumer levels and reducing food losses throughout production and supply chains, encouraging sustainable consumption and production pattern. In addition, cross-cutting targets embedded across the SDGs further support food waste reduction efforts, reinforcing alignment with global objectives for economic growth, environmental protection, and social well-being (Trotter et al, 2023).

Within the European Union, the legislative framework addressing food waste prevention and reduction has evolved significantly, reflecting a progressive alignment with the SDGs and a commitment to sustainability and circularity in key sectors (Ghisellini et al., 2016). Starting with the 2015 Circular Economy Action Plan, the EU established the foundational principles to transform production and consumption patterns, focusing on

closing the loop in product lifecycles and setting actionable food waste reduction targets (Esposito et al., 2020). This effort was reinforced by the 2018 revision of the Waste Framework Directive (WFD), which emphasized the waste hierarchy as the main framework for prioritizing waste management interventions providing a clear definition for: Food waste, prevention, redistribution, reuse, recycling and recovery operations. In addition, the revised WFD mandated Member States to implement comprehensive waste prevention programs and improve food waste monitoring systems (Lombardi et al., 2021). In the 2020, the issue of the European Green Deal represented a pivotal action plan for Europe, introducing an ambitious growth strategy to achieve climate neutrality by 2050 (COM (2020) 381 final). Part of this strategical regulatory framework, the Farm to Fork Strategy specifically addressed the sustainability of food systems, setting a clear target to halve per capita food waste at retail and consumer levels by 2030, also promoting sustainable agricultural practices and fostering fair and environmentally friendly consumption (COM (2019) 640 finale).

Starting from the European legislative framework, the agri-food sector, especially the F&V sector, faced a profound transition toward the inclusion of sustainable practices as required by targeted policy initiatives (Garcia et al, 2021). The Common Agricultural Policy (CAP) represents the EU's primary regulatory that establish rules and strategies for the development of subsidies and programs aimed at supporting farmers, ensuring food security, fostering sustainable rural development, and addressing environmental challenges (Reg. EU 2021/2115). The CAP is a cornerstone of the EU policy, adapting over time to incorporate sustainability goals and align with global trends such as the SDGs, representing now one of the largest components of the EU budget, reflecting the societal importance of the strategy for the agri-food sector. Established in 1962, the CAP has continually evolved to integrate sustainability goals, aligning also with broader EU initiatives like the European Green Deal and the Farm to Fork Strategy (COM (2019) 640 final; COM (2020) 381 final).

For the actual 2021-2027 programming period, the CAP accounts for approximately €387 billion, representing one-third of the total EU budget, emphasizing its role in financing sustainable practices and rural development. Notably, a significant proportion of this budget supports measures to reduce food waste, optimize surplus management, and foster innovation in agricultural practices ((Reg. EU 2021/2115). The previous programming periods (2014-2020) also allocated substantial resources, with approximately €408 billion

designated for modernizing agriculture, addressing climate change, and improving market efficiency (European Commission, 2021).

Within the CAP framework, the Common Market Organization (CMO) provides a regulatory structure governing agricultural markets in the EU. The CMO regulation plays a pivotal role in structuring the European Union's agri-food system regulating seven different key value chain. The CMO aims to stabilize markets, ensure fair prices for producers and consumers, and promote the efficient functioning of the agricultural sector. Producers' Organizations (POs), recognized under the CMO framework, are key actors in the F&V sector, coordinating activities, managing logistics, and ensuring that farmers' production reaches the market. POs are intended to consolidate the fragmented agricultural supply, to strengthen farmers' bargaining power, and to drive innovation through targeted programs and funding mechanisms. The CMO role in strengthening the F&V supply chain focuses on empowering POs to enhance competitiveness, mitigate crisis, and market alignment. Funding under the CMO is primarily channelled through operational programs developed by POs and their associations, defined as Associations of Producers' Organizations (AOPs), as mandated by Regulation (EU) No. 1308/2013. The operational programs, with durations ranging from three to five years, address strategic objectives for farmers, including market access improvement, competitiveness enhancement, and sustainability promotion through environmentally friendly practices and climate change mitigation. The programs provide also the possibility to finance market mechanisms for managing supply and demand, crisis prevention, and market stabilization. At the same time, for the F&V sector, the CMO specifically provide to farmers and POs funding to invest in environmental measures aiming at reducing food waste and promote sustainability.

At the European level, approximately 1,719 POs have been officially recognized for the F&V sector, accounting for 46% of the total production marketed through organized structures (European Commission, 2023). The value of production marketed by these POs is estimated at €17.7 billion on 2023, representing about 33.2% of the total value of F&V production in the EU. These figures highlight the significance of POs in consolidating fragmented production systems and improving producers' bargaining power across the value chain, enabling more efficient market access and fostering innovation (European Commission, 2024). Thanks to the CMO, the annual expenditure for operational programs implemented by recognized POs in the fruit and vegetable sector is estimated at approximately €1 billion for all Member States (European Commission, 2024). This

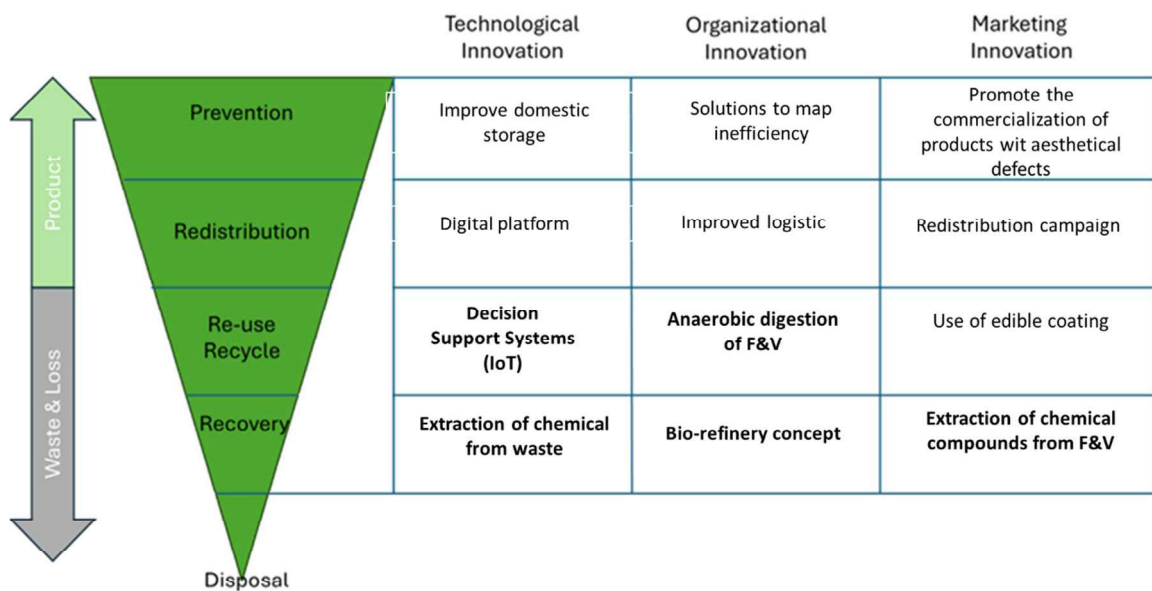
funding represents a significant proportion of the CMO budget dedicated for improving the efficiency and sustainability of the F&V supply chain. In Italy, the sector accounts for a considerable share of the operational program expenditure within the CAP framework. In 2020, Italy allocated €256.3 million to operational programs for the F&V sector, representing 23% of the total EU expenditure. This reflects Italy's strategic reliance on POs to consolidate jeopardized production by implementing targeted investments that address environmental challenges, product quality improvement, and market stabilization.

Despite the efforts, current strategies and frameworks have proven insufficient to fully address the scale and complexity of these challenges. These issues not only undermine environmental and economic sustainability but also extend social inequities, making food waste and surplus management a key priority for policy intervention and academic research (Aramyan et al., 2020; Tort et al., 2021).

1.3 The “Sustainable Food Management Innovation Hierarchy” framework

The revised WFD provides a framework to prioritize interventions for food waste management and prevention, known as the Food Waste Hierarchy. This conceptual framework is widely recognized for ranking actions to manage food waste in an environmentally sustainable manner (Papargyropoulou et al., 2014). Developed in the context of the WRAP project (www.wrapproject.org) and further discussed by the scientific literature, it is typically represented as an inverted pyramid with different waste management option on each of the steps (Caldeira et al, 2019). The most preferred option is positioned at the top, while less desirable strategies appear at the bottom, as shown on the left side of Figure 1. The hierarchy ranks strategies for the management of food waste, emphasizing actions with the highest environmental, social, and economic benefits at the top, considering disposal as the last option as it is the least preferred option for food waste. The Food Waste Hierarchy is used not only to guide policies and practitioners, but it also provides a conceptual basis for policy developments and academic research on sustainable food systems and circular economy models (Papargyropoulou et al., 2014). As highlighted by FAO (2019), it is also a useful tool to assess the effectiveness of different approaches to food waste prevention.

Figure 1 – “Food Waste Prevention and Management Innovation Hierarchy” framework



Source: Own elaboration based on Papargyropoulou et al., 2014

Building upon this established hierarchy (Papargyropoulou et al., 2014) and the OECD framework on innovation, productivity, and sustainability in food and agriculture (OECD, 2018; OECD, 2019), this thesis proposes a novel and integrated framework defined as the “Sustainable Food Management and Innovation Hierarchy”, as shown in Figure 1. This

original approach combines waste management priorities with innovation strategies to effectively address sustainability challenges specifically within the fruit and vegetable sector. The "Food Waste Prevention and Management Innovation Hierarchy" framework has been developed in the context of this thesis to represent a structured approach to prioritizing strategies and innovative advancement for reducing food waste and managing surplus within the agri-food system. The proposed framework distinguishes itself by explicitly integrating the traditional Food Waste Hierarchy with categories of innovation defined by the OECD.

According to the OECD framework, innovations in the F&V sector can be categorized into three types: technological, organizational, and marketing innovations (OECD, 2018; OECD, 2019). Technological innovations are advancements that focus on the development and implementation of tools, devices, and processes to improve the efficiency of the supply chain. Organizational innovations are changes in management practices, processes, and governance structures designed to improve coordination and collaboration across the supply chain. Marketing innovations are strategies that focus on reshaping consumer perceptions and behaviours to reduce waste and promote sustainability. Despite the potential of each category of innovations, the scientific literature highlights that integrating these advancements to provide cross-cutting solutions remains a significant challenge in the transition towards sustainable systems since each category of innovation tends to address specific issues in isolation, making it crucial to develop frameworks that bridge these gaps (Krishnan et al., 2021).

Food waste prevention is at the top of the "Food Waste Prevention and Management Innovation Hierarchy". This is considered the most impactful and cost-efficient approach, focusing on eliminating food waste at its source through innovative technologies, improved planning, and organizational practices. Key strategies include optimizing production processes, advanced inventory management, demand forecasting, and implementing technological innovations like real-time monitoring and smart packaging systems. Prevention minimizes economic losses and environmental impact in line with sustainability principles tackling products by eliminating waste before it is generated, though products meet human nutritional needs and are still safe for consumption (Garrone et al., 2016).

Redistribution targets surplus edible food, ensuring it is reallocated to individuals or charitable organizations. This level of intervention addresses both food waste reduction and social inequality by facilitating food surplus donations to food banks, charities, and

redistribution networks (Teigiserova et al., 2020). Food surplus refers to raw, semi-finished, or finished products that, for various reasons, are not sold or consumed (Albizzati et al., 2019; Garrone et al., 2014). In this case, innovations such as digital platforms for food sharing and Information & Communication Technologies have emerged as critical tools in enhancing the efficiency of redistribution systems.

In the case that the F&V products are unsuitable for human consumption, or when surplus food cannot be prevented or redistributed, re-use and recycling strategies become the next priority. These measures focus on repurposing food loss for secondary uses, such as animal feed production, composting, or bioenergy generation. While recovery reduces the environmental burden of food waste disposal, it offers the lowest return in terms of resource efficiency, as the food's nutritional and economic value is largely lost (Eriksson et al., 2016). Finally, the least favourable option is disposal, such as landfilling or incineration without energy recovery. This approach has significant environmental downsides, including greenhouse gas emissions and resource depletion, and is considered a last resort. Innovations at this level includes the development of modern approach to waste recovery and zero-emission facilities. In conclusion, Prevention and Redistribution are the most impactful solutions within the food waste hierarchy (Casson et al., 2024). These approaches not only minimize the generation of waste upstream but also maximize the social and nutritional value of food, aligning with both sustainability and equity objectives (Vittuari et al., 2017).

One of the key areas of improvement for the European F&V sector, highly sensitive to market crisis and to high production volumes, is represented by the strengthening of the redistribution system of fresh F&V (Perez-Mesa et al., 2021). Surplus management, although presenting opportunities to mitigate losses, is constrained by inefficiencies in redistribution mechanisms, logistical challenges, and fragmented institutional support (Tort et al., 2021). These inefficiencies, often exacerbated by systemic barriers and crises such as market volatility and logistical constraints, require targeted solutions that bridge theoretical and practical considerations (Galli et al., 2019; Canali et al., 2017). Another challenge lies in the scalability of technological solutions, their adoption remains uneven due to infrastructural disparities, stakeholder resistance, and insufficient technical knowledge among key actors. Addressing these barriers requires a deeper understanding of the conditions that enable the integration of technological innovations into existing systems (Vermunt et al., 2020). For these reasons, traditional innovations are insufficient, and socio-technical innovations provide a novel and holistic approach to these challenges

(Menard et al., 2019). Stakeholders such as producers, wholesalers, retailers and policymakers operate within separate context, often prioritizing conflicting goals. In practice, while producers may focus on minimizing operational costs (Ghisellini & Ulgiati, 2020), policymakers prioritize regulatory compliance (Surucu-Balci & Tuna, 2022), resulting in misaligned objectives (Avolio et al., 2014). This lack of coordination restricts the adoption of innovative solutions and limits the effectiveness of food waste prevention strategies. These issues highlight the complexity of the transition from traditional practices to more holistic approaches that prioritize resource optimization and equitable redistribution indeed the development of socio-technical innovations provide a novel approach to the problem. (Bolwig et al., 2021; Avolio et al., 2014).

By developing socio-technical innovations, the potential of each level in the hierarchy is amplified, achieving greater environmental, economic, and social impacts (Vermunt et al., 2020). This synthesis of frameworks, supported by collaborative governance and innovative solutions, represents a critical step in bridging the gap between theory and practice in food waste prevention and surplus management, which will be discussed further in the thesis. The following chapters empirically validate and further discuss this novel hierarchy, highlighting specific socio-technical innovations and their practical implications within the agri-food system. Also, the discussion and the results of this thesis will be presented considering this framework and practical implications derived from the results of each research chapter.

1.4 Research questions

The aim of this thesis is to contribute to the existing literature on food loss prevention and surplus management by focusing specifically on strategies and innovations within the fruit and vegetable sector. This research is focused on the critical role of socio-technical innovations, institutional frameworks, and collaborative strategies in addressing inefficiencies across the supply chain, with a particular emphasis on redistribution mechanisms as a key intervention within the “Sustainable Food Management Innovation Hierarchy” framework. By integrating these dimensions, the expected outcome is a cohesive framework for evaluating sustainable and collaborative methodologies that align economic, environmental, and social objectives across the agri-food sector, with a particular focus on the European fruit and vegetable supply chain.

This topic is addressed following three research questions (R.Q.) from an empirical perspective:

R.Q. - 1. How do stakeholders’ subjective point of view on strategies to reduce food losses shape co-innovation opportunities in the agri-food sector?

R.Q. - 2. What contextual factors and institutional dynamics influence the adoption of food redistribution technologies in the agri-food sector?

R.Q. - 3. How can socio-technical innovations enhance the economic, environmental, and social impacts of food surplus redistribution systems?

To provide a cohesive analytical structure, these research questions are designed to reflect a logical and thematic progression. R.Q.1 focuses on the cognitive and motivational dimensions that shape the decision-making environment for innovation adoption in food loss prevention area. R.Q.2 builds upon this concept by analysing how these internal dynamics interact with external institutional and contextual factors that facilitate or hinder the actual adoption of redistributive innovations. Finally, R.Q.3 evaluates the real-world implications of socio-technical innovations, quantifying their effectiveness in addressing economic, social, and environmental goals. Taken together, the questions outline a three-tiered perspective (individual/motivational, institutional/adoption-related and systemic/impact-oriented) that reflects the structure of the “Sustainable Food Management and Innovation Hierarchy” framework and supports an integrated understanding of transition dynamics. Each R.Q. is placed within the context of the food innovation hierarchy, showing how the thesis progresses from preventive strategies shaped by stakeholder perspectives to the redistribution mechanisms shaped by adoption

dynamics, to the system-level assessment of redistribution impacts. This structure enhances the research design and provides a comprehensive picture of how socio-technical innovations can drive sustainable food management linking the research questions to their respective conceptual levels and methodological approaches.

Table 1 provides an overview of the research questions, summarizing each key concept and the contribution to the research topic.

Table 1 - Research questions of the thesis

Research Question	Chapter, Type and Title	Key concept	Contribution to the research topic
R.Q. – 1 How do stakeholders' subjective perspectives on strategies to reduce food losses shape co-innovation opportunities in the agri-food sector?	Chapter 3 Empirical / Discussion “Investigating Co-Innovation Strategies to Prevent Food Loss in the Fruits and Vegetables Sector” <i>Article published</i>	Stakeholder perspectives as drivers of collaborative innovation strategies.	Identifies critical areas of stakeholder alignment and divergence, offering a foundation for collaborative innovation across the value chain operators.
R.Q. – 2 What contextual factors and institutional dynamics influence the adoption of food redistribution technologies in the agri-food sector?	Chapter 4 Empirical / Theoretical “Adoption dynamics of food redistribution technology to enhance policy measures in the agri-food sector” <i>Article under review</i>	The interplay between institutional logics and contextual barriers.	Explore driver and barriers to innovation adoption, providing practical insights for enhancing the effectiveness of redistribution technologies.
R.Q. – 3 How can socio-technical innovations enhance the economic, environmental, and social impacts of food surplus redistribution mechanisms?	Chapter 5 Empirical / Case Study “Socio-Technical Innovations for Food Surplus Redistribution: Assessing the social benefit generation of the EU CMO policy” <i>Article submitted</i>	Evaluating socio-technical innovations within surplus redistribution systems.	Demonstrates the socio-economic benefits of surplus management policies and provides recommendations for improving scalability and equity.

Firstly, the analysis in Chapter 3 explores stakeholder perceptions regarding strategies to reduce food loss, focusing on how subjective viewpoints shape opportunities for co-innovation. The chapter examines the diversity of perspectives among stakeholders operating in various entry points along the upstream phase of the Italian F&V value chain (Nasso et al., 2024). This approach identifies key stakeholder categories, highlights areas of consensus and conflict, and offers insights for fostering collaborative strategies in the agri-food sector.

Secondly, Chapter 4 investigates the contextual factors and institutional dynamics influencing the adoption of food redistribution technologies. This chapter identifies critical barriers and drivers to technology adoption, such as economic constraints, policy support, and market crises, like the COVID-19 pandemic and the Russian import ban (Scalvedi et al., 2019; Porter et al., 2018). The findings aim to inform institutional

interventions reporting the factors that can accelerate technology adoption and improve operational efficiency.

Thirdly, Chapter 5 assesses the role of a socio-technical innovations to enhance the economic, environmental, and social impacts of the CMO food surplus redistribution mechanisms. The analysis focuses on the implementation of a digital platform to facilitate and streamline the market withdrawal of fresh F&V products for the free redistribution to charities. The results of the chapter provide an estimation of the value generated by redistribution systems, revealing significant economic savings and reduced environmental costs.

In summary, the three research chapters explore different aspects related to approaches used by operators towards sustainable value chain. Firstly, providing insights on the stakeholders' decision-making processes regarding strategies to reduce food losses and the contextual factors influencing their roles within the co-creation of shared strategies among the supply chain (Chapter 3). Secondly, after the investigation and the analysis of the perspective emerged, the research keeps assessing the adoption dynamics of a socio – technical innovation in Italy during a 10-years period (Chapter 4). Here, we assess the factors that facilitate or hinder the integration of redistribution technologies, particularly during market crises. Finally, we evaluate the role of socio-technical innovations as a governance mechanism to enhance the efficiency, equity, and scalability of surplus redistribution efforts, providing a quantification of the impact related to the measure (Chapter 5). The integration of these chapters supports a comprehensive, multi-scalar understanding of how innovation emerges, diffuses, and generates impact within the fruit and vegetable supply chain. The cohesion between the research questions and methodological approaches creates an analytical discussion from stakeholder-driven strategy design to empirical adoption modelling and finally to outcome-oriented policy evaluation, reinforcing the theoretical and practical coherence of the overall research design.

2.

Research Design and Methodology

2.1 Conceptual Framework

The conceptual framework of this thesis is based on the theories of the transition towards sustainable fruit and vegetables systems, emphasizing the contribution of collaborative strategies, institutional dynamics and socio-technical innovations to reducing food loss and optimizing surplus redistribution systems in the agri-food sector (Aramyan et al., 2021). This research addresses critical gaps through a multi-layered approach. The aim is to investigate the different dimensions that interact to foster or hinder sustainability transitions using a common conceptual framework, while providing both theoretical and practical insights (Table 2).

Table 2 - Conceptual framework of each chapter

Chapter	Conceptual framework	Conceptual contribution to the topic of the thesis	Novelty
3	Stakeholder-centred framework	Analysis of the cognitive and motivational processes shaping stakeholder decision-making in the adoption of food loss prevention strategies.	Development of a novel approach to analyse the driver of adoption of sustainable co-innovations.
4	Adoption dynamics in redistribution systems	Insights into the systemic barriers and opportunities influencing the adoption and scaling of food redistribution technologies.	The framework reveals that innovations increase when diverse interests are harmonized, offering novel insights into food redistribution technology adoption.
5	Governance mechanisms in surplus management	Quantitative evaluation of the impacts and effectiveness of socio-technical innovations, focusing on surplus management mechanisms.	Novel study on the effectiveness of the CMO policy implemented through socio-technical innovations. The analysis focuses on quantifying the leveraging effects of digital tools and governance mechanisms to optimize surplus management.

Central to this study is the examination of the stakeholder interactions influenced by the institutional frameworks shaping the adoption and scaling of innovative practices aimed at addressing inefficiencies in the F&V value chain. The thesis builds on the evidence reported by different authors that the transition towards sustainable food systems requires aligning cognitive, organizational, and policy-level dimensions to overcome existing barriers and promote effective innovation diffusion (Matzembacher et al., 2021). In particular, a shared orientation fosters the development of more collaborative and scalable

solutions to tackle food loss and surplus management challenges through a holistic approach (Canali et al., 2017).

In Chapter 3, the thesis investigates the cognitive and motivational factors that influence stakeholders' decision-making processes regarding food loss prevention strategies. The research employs a quali-quantitative methodology, defined Q-methodology, to investigate and classify the mixture of a sample of stakeholders' point of view about a range of innovations and strategies to prevent food losses in the F&V sector (Brown, 1993). This methodological approach offers a novel lens to identify economic, social, and environmental priorities that shape decisional process moving different stakeholders to adopt (Hassink et al., 2018). In particular, the study highlights the importance of subjective perceptions in fostering or hindering co-innovation opportunities. The novelty lies in applying an empirical methodology to an uneven sample of agri-food stakeholders, offering actionable insights for aligning their interests and driving systemic change.

Chapter 4 shifts the focus to the adoption dynamics of food redistribution technologies, exploring systemic barriers and facilitators that influence their scaling. Based on the concept that time-sensitive events and external pressures significantly impact organizational decision-making, the chapter examines how policy frameworks, economic constraints, and crises shape the behaviour of producer organizations (D'Emden et al., 2006). This chapter proposes a time-series analysis methodology, namely Duration Analysis, to evaluate the internal and external factors to an organization affecting the adoption processes of a digital platform over a ten-year period (D'Emden et al., 2016). The analysis demonstrates how endogenous factors, such as organizational capacity and policy structures, interact with exogenous shocks (e.g., economic crises and regulatory changes) to accelerate adoption. The findings contribute to the broader discourse on sustainability transitions by identifying drivers and constraints for innovation diffusion (Vermunt et al., 2020). The novelty of this chapter lies in its empirical analysis of adoption timelines, offering a unique perspective on the role of shocks as accelerators in technology adoption (Kalbfleisch and Prentice, 2002).

Chapter 5 focuses on a case study in Italy, analysing a socio-technical innovation implemented within the CMO framework to enhance surplus management operations. The research employs a quantitative methodology to measure the economic, environmental, and social impacts of redistribution processes facilitated by a digital platform. This chapter investigates how digital tools developed to optimize redistribution processes can improve operational efficiency, equity, and scalability. A scenario-based

analysis is utilized to compare multiple redistribution strategies, evaluating the gains associated with different policy and operational configurations. This approach allows the research to explore how variations in the legislative framework may influence resource optimization, waste reduction, and societal benefits, providing a comprehensive assessment of potential improvements (Canali et al., 2017). The novelty of this chapter lies in its comprehensive empirical assessment of digital tools as governance innovations, showcasing their potential to improve the efficiency and impact of surplus management policies.

The theoretical approach adopted in this thesis provides a cohesive framework for understanding the interplay of cognitive, institutional, and socio-technical dimensions in fostering transitions toward sustainable food systems. The empirical findings presented within this framework align with broader literature on sustainability transitions, including studies emphasizing collaborative innovation and systemic change as key drivers (see Vermunt et al., 2020; Canali et al., 2017). By bridging micro-level cognitive processes, meso-level institutional practices, and macro-level policy interventions, the thesis offers a multi-dimensional perspective that enriches theoretical discourse and contributes practical insights for designing effective strategies for food loss prevention and surplus redistribution.

2.2 Methodological Approach

The methodological approach adopted in this thesis can be considered a mixed-methods strategy, combining both qualitative and quantitative methodologies, with the use of primary and secondary data. This approach was chosen to address the diverse research questions posed in the study, each of which required tailored methodological tools to capture the complexity of food loss prevention and surplus redistribution within the agri-food system. By integrating these methods, the thesis ensures a robust analysis that addresses cognitive, institutional, and governance-related dimensions of sustainability transitions. Each chapter applies a distinct methodological framework tailored to specific research questions, collectively contributing to the overarching goal of understanding and facilitating the transition toward sustainable food systems (Table 3).

Table 3 - Methodological approach for each study

Chapter	Methodology	Approach	Sample of the analysis	Type of data
3	Q – methodology	Quali-quantitative analysis of the one-to-one interviews of a sample of stakeholders in Italy	16 stakeholders of the Italian FV value chain	Interviews
4	Duration Analysis	Adoption analysis of a food redistribution technology during the period 2012 – 2022	135 Producer Organization in Italy	Panel data analysis
5	Comparison between scenarios	Quantitative analysis and comparative scenario assessment during the period 2012 – 2022	SIR platform POs / 46 fresh fruit and vegetables products	Interviews + Panel data analysis

Chapter 3 employs a qualitative-quantitative approach using Q-methodology to explore stakeholder perspectives on strategies to reduce food loss. This method involves conducting one-to-one interviews with key stakeholders, including producers, policymakers, and supply chain actors, to gather subjective data on their priorities and motivations. During the interview phase the participant were asked to rank a series of statements accurately developed after a critical review of waste management option and innovation in the F&V sector, accurately selected to reflect the range of opinion varying in the sample considered. The investigation allows for the identification of shared viewpoints and divergences, providing insights into the cognitive and motivational drivers of each group of stakeholders about their decision-making process during the adoption of innovations. These approach offers an empirical understanding of how different perspectives foster or hinder co-innovation opportunities within the agri-food system.

Chapter 4 adopts a quantitative approach through duration analysis to investigate the dynamics of adopting food redistribution technologies. This method analyses the factors influencing the adoption process over a 10-years period (2012–2022) of a socio-technical innovation in a form of a digital platform, namely the Sistema Informativo Ritiri (SIR) platform, in Italy. Using panel data from 135 Italian Pos operating in the F&V sector, the study evaluates the impact of contextual factors such as economic conditions, policy incentives, and external shocks on the innovation adoption process. A statistical model is provided at the end of the study to report the critical barriers and facilitators to the diffusion of food redistribution technologies resulting from the duration analysis, contributing to the broader discourse on innovation diffusion within institutional settings. The relevance of duration analysis in this context lies in its possibility to capture the time-dependent nature of innovation uptake. Understanding not only whether but when a PO decides to adopt a technology is critical in designing effective interventions, especially in complex sectors. The methodology allows modelling how adoption evolves over time in response to internal characteristics and external events, offering dynamic insights by incorporating time as a dimension of analysis it is highlighted the importance of policy timing and adaptive strategies that align with real-world innovation cycles.

Chapter 5 employs a scenario-based quantitative analysis to assess the economic, environmental, and social impacts of surplus management innovations, starting specifically on the performance obtained by the SIR platform. By conceptualizing and analysing multiple scenarios representing different market conditions, this research provides an economic quantification of the value generated by the surplus redistribution systems. This approach integrates secondary data on redistribution volumes and economic index with primary data on stakeholder practices, providing actionable policy recommendations for improving surplus management mechanisms within the CMO framework.

The methodological diversity adopted in this thesis not only aligns each chapter's research tools with its specific questions but also provides a holistic perspective on sustainability transitions in the agri-food system. The integration of qualitative and quantitative methods in each chapter strengthens the validity and reliability of the findings, highlighting the interconnected roles of stakeholder behaviour, institutional frameworks, and socio-technical innovations in addressing systemic inefficiencies.

2.3 Contribution of each chapter to the thesis framework

The thesis is organized around a coherent framework that integrates three core research questions, each addressed in a dedicated chapter, and collectively contributes to the understanding of socio-technical systems for food loss prevention and surplus management within the fruit and vegetable supply chain. This section outlines the distinct contributions of each chapter to the overarching framework, emphasizing their theoretical, methodological, and practical relevance, as summarized in Table 4. Each chapter addresses critical gaps in knowledge and offers insights that align with broader sustainability objectives. Moreover, these contributions are strategically positioned within the “Sustainable Food Management and Innovation Hierarchy” framework developed in Chapter 1.3, which serves as a unifying lens to connect the research questions, empirical findings, and proposed policy recommendations.

Table 4 – Contribution of each chapter to the framework of the thesis

Chapter	Research Question	Conceptual framework	Methodology	Results
3	R.Q. - 1	Explore how stakeholder perceptions influence the adoption of technological and organizational innovations aimed at minimizing food loss	Quali-quantitative analysis of the one-to-one interviews of a sample of stakeholders in Italy	Identification of stakeholder categories and insights into areas of consensus and conflict to inform co-innovation strategies
4	R.Q. - 2	Identify the barriers and facilitators that affect adoption rates and the timing of engagement	Adoption analysis of a food redistribution technology during the period 2012 – 2022	Understanding how contextual variables can be tailored to accelerate the adoption process of a socio-technical innovation
5	R.Q. - 3	Explore the role of socio-technical innovations in enhancing redistribution mechanisms under the OCM framework	Quantitative analysis and comparative scenario assessment	Quantitative estimates of the Net Social Value (NSV) and policy recommendations for improving OCM surplus management mechanism

Chapter 3 provides a theoretical and practical understanding of stakeholder engagement as a driver for collaborative innovation strategies. By analysing how stakeholders' subjective perspectives shape co-innovation opportunities, this chapter enhances the knowledge for aligning diverse priorities to foster collective action. It provides insights into the social dynamics and cognitive drivers that influence the adoption of sustainable practices, laying a foundation for designing participatory strategies in the fruit and

vegetable supply chain. This approach is critical for designing effective and inclusive approaches that address food loss reduction through shared goals and collective action.

Chapter 4 expands the discourse on institutional dynamics by analysing the factors that affect the adoption and scaling of redistribution technologies within the agri-food sector in Italy. This chapter identifies systemic enablers and barriers to the integration of innovative solutions. The findings provide valuable insights into designing policies and institutional interventions that promote the diffusion of socio-technical innovations, addressing systemic inefficiencies and enhancing the resilience of agri-food systems. These results are situated in the middle tier of the “Sustainable Food Management and Innovation Hierarchy” framework, focusing on redistributive solutions. The chapter offers a critical understanding of the adoption process, showing how the success of redistribution technologies hinges on institutional support, financial stability, and region-specific governance.

Chapter 5 evaluates the socio-economic impacts of the CMO surplus management mechanisms enhanced by the SIR digital platform. By quantifying the value generated by the redistribution mechanisms, the chapter highlights the potential of socio-technical innovations to align environmental, social, and economic objectives. It also provides actionable recommendations for improving the scalability of surplus redistribution systems, optimizing governance mechanisms, and aligning policies with practical sustainability goals. This chapter provides an impact-level analysis of redistribution and valorization mechanisms. It strengthens the empirical foundation for designing policy tools that maximize returns on public spending and redistribute societal value, confirming the role of socio-technical systems in enabling circular and equitable agri-food governance.

The three chapters constitute a methodologically integrated and conceptually layered exploration of sustainability transitions. Chapter 3 addresses upstream behavioural and social dynamics (prevention), Chapter 4 evaluates the operational adoption of redistributive tools (redistribution), and Chapter 5 quantifies the systemic benefits of surplus management innovations. This progression not only reflects the structure of the “Sustainable Food Management and Innovation Hierarchy” but also demonstrates that integrated socio-technical innovations can serve as cohesive solutions across the hierarchical levels of the framework. The contributions of each chapter address critical dimensions of sustainability transitions, bridging distinct but interconnected aspects. This structured approach provides a comprehensive framework for addressing sustainability

challenges in the fruit and vegetable supply chain, contributing to the development of targeted, evidence-based strategies for reducing food loss and optimizing surplus redistribution, advancing both theoretical and practical approaches to sustainable agri-food systems. The coherence between the empirical chapters and the conceptual framework facilitates an interdisciplinary understanding of the drivers, mechanisms, and impacts of innovation in the F&V sector, reinforcing the outcome and the discussion of results presented in the thesis.

This thesis now turns to the research output, specifically three research papers that address the three research questions, present research findings and discuss their theoretical and practical implications for sustainable food systems.

3.

Investigating Co-Innovation Strategies to Prevent Food Loss in the Fruits and Vegetables Sector

Published as: Nasso, M., Blasi, E., Pezzoli, F., & Cicatiello, C. (2024). Investigating Co-Innovation strategies to prevent food loss in the fruits and vegetables sector. *Journal of Cleaner Production*, 467. <https://doi.org/10.1016/j.jclepro.2024.142984>

3.1 Introduction

The production of fresh fruit and vegetables (FFV) is a key activity in the European agri-food sector. In 2022, the value of fruit and vegetables produced in Europe was estimated at €73,4 billion, being more than 14% of all agricultural production (European Commission, 2022). At the same time, almost half of the total FFV produced and/or distributed for human consumption is lost or wasted due to value chain inefficiencies and the scarce collaboration of value chain actors, causing environmental, social, and economic issues (Caldeira et al., 2019). Moving towards sustainable and effective value chain management systems has been reported to produce a wide positive impact to improve food safety, reduce waste, and enhance the collaboration of different value chain members (Smith, 2008; Aramyan et al., 2021). Nonetheless, addressing the various challenges towards the transition to sustainable agri-food systems is a complex topic that requires shared approaches, economically viable innovations, and a supportive policy framework (Krishnan et al., 2021). The life cycle of FFV products typically develops along five stages of an organized value chain, including: production, post-harvesting, manufacturing and distribution, retailing, and consumption. Post-harvest losses and waste happens during all these phases and are related mainly to inefficiencies during the inventory management of fresh products, like fast perishability, quality preservation, cold-chain management, and demand volatility that is closely linked to price volatility (Notarnicola et al., 2017). A relevant fraction of waste has also been reported during the intermediate phases, like packaging, storage, and transportation, due to a lack of investment to improve the efficiency of operations (FAO, 2019; Tort et al., 2021). The challenges during the production and commercialization of FFV products, combined with contextual differences among operators, enveloped a lack of common goals and shared approaches, making FFV products a particular challenge for the transition towards sustainable value chains, especially when operators have to deal with the prevention of food losses and waste (Bossle et al., 2016). The terms food losses refer to edible foods that do not reach the retailer phase, while the definition of food waste can be applied in the case of discarded products during the remaining downstream stages, including the final consumption (European Commission, 2008). Contrarily, food surpluses are raw, semi-finished, or finished items produced throughout the agri-food chain that, for a variety of reasons, are not being sold or consumed (Garrone et al., 2014; Teigiserova et al., 2020). Food surplus can be collected and redistributed for human consumption purposes (Garrone et al., 2016) but it is important to highlight that to be recoverable and meant for human consumption, surplus products must meet all hygienic and sanitary

regulations (Pietrangeli et al., 2023b). The present research paper aims to explore the subjective perspectives of upstream stakeholders (considering after the harvesting stage and up to, but excluding, retailers) in the Italian FFV value chain about the adoption of sustainable innovations to prevent food waste and reduce the volume of food losses. Examining the relationships between the diverse viewpoints of upstream stakeholders about the efficacy of strategies and policies put in place could provide additional information for the political implications of waste and surplus management and the development of co-innovation approach based on shared solutions (Doukidis et al., 2007).

3.1.1 Literature Review

The collaboration of different value chain members, especially during the upstream phases, can improve the performance of the whole value chain as a driving force for the adoption of sustainable innovations and shared practices, defined also as “co-innovation” (Benyam et al., 2021). The concept of "co-innovation" refers to collaborative approaches to innovation that involve multiple stakeholders working together to create novel solutions or improve existing practices (Krishnan et al., 2021). This topic has been reported by different authors as effective in the prevention and reduction of food loss and waste (FLW), but since this topic has only gained interest in recent years, only a few relevant studies exist that address this topic (Magalhães et al., 2022; Krishnan et al., 2021). Surucu-Balci & Tuna (2022) evaluated different collaboration measures across near-stakeholder groups in the Türkiye FV value chain. The authors reported not only specific problems to tackle in each phase of the supply chain but also differences in the perspectives of the stakeholders about the best approach to adopt to tackle FLW generation. In the same way, Matzembacher et al. (2021) pinpointed that tackling the complex causes of loss and waste need collaboration and coordination efforts from different stakeholders, considering crucial to clarify which entry level of the value chain plays a key role in FLW prevention activities. Ishangulyyev et al. (2019) reported that for the adoption of effective solutions to reduce FLW the identification of opportunity through linkages among the distinct stages of a food value chain is one of the key elements. At the same time, the institutional and research sector should facilitate and improve the knowledge and tools available to operators. In this regard, Mourad (2016) described different approaches to implementing sustainable innovations in food value chains by assessing two distinct national policy contexts, concluding that prevention measures are not effectively implemented if they are not shared by the stakeholders in charge of the implantation. Therefore, to effectively adopt practices and innovations to reduce FLW, it

is essential to target stakeholders who can have a considerable influence on reduction activities and discuss collaboration-related mitigation strategies also according with their closer stakeholders on the chain (Avolio et al., 2014; Schanes et al., 2018). The topic of collaborative approaches from the viewpoint of relevant players in the FFV value chain could be explored directly with the involvement of the operators and an assessment of their subjective point of view (Vellema & van Wijk, 2015). The aim of this study is to report and discuss the point of view of upstream operators towards sustainable innovations to prevent and reduce the generation of FLW using an empirical approach that can be replicated in other contexts. Indeed, investing in co-innovation and a circular business model may increase knowledge on the topic of FLW prevention and facilitate the transition towards sustainable value chains (Ciccullo et al., 2021). At the same time, a general exploration of the drivers and challenges for innovation adoption needed to better design future policy development to reduce food losses and waste can be a future reference for tailoring future policies and strategies in the field (Magalhães et al., 2022).

3.2 Methodology

The investigation of subjective viewpoints towards co-innovation approaches to prevent and reduce food losses is performed by establishing a Q-methodology study (Webler & Danielson, 2009; Mandolesi et al., 2015).

3.2.1 Q-methodology

The Q-methodology was developed in the 1930s by W. Stephenson, adapting his master Spearman's approach to factor analysis (Brown et al., 1980), shifting from variable factor analysis, R-methodology, to person factor analysis, Q-methodology. Stephenson's approach considers participants as variables providing a by-person rather than by-item factor analysis (Webler & Danielson, 2009). It offers a useful tool for the methodical investigation of subjectivity through the examination of intercorrelations and patterns across individuals (Brown, 1993, 1996). Q-methodology has extensively been used in a variety of fields, including educational, behavioural, and health sciences (Webler & Danielson, 2009), and its popularity has recently grown in environmental and agricultural sciences (Dieteren et al., 2023; Mandolesi et al., 2015). The Q-methodology combines qualitative and quantitative methods for data collection and analysis, so it can be viewed as a "discourse analysis technique" based on a mixed method (Brown, 1996). The theme or topic under investigation is defined as *concourse* (Brown et al., 1980; Watts & Stenner, 2012). The development of the concourse, which Brown (1993) defines as "*the flow of*

communicability surrounding any topic", is a collection of all the statements relevant to the topic of the study, organized to form the Q-sample. A Q-study involves the sorting of written and/or graphical Q-statements, defined as individual units of measure that shall cover the full range of opinions or feelings about the subject. During the data collection process, each participant is invited to order the statements, according to his personal agreement with the stimulus provided, and describe their personal preferences, enabling the identification of common patterns inspired by their own words (Watts & Stenner, 2012). The participants in a Q-study are part of the P-sample (participant sample), which is typically made up of a specific segment of society. The selection of participants is not random but strategic, targeting individuals who can provide insight into the specific attitudes, beliefs, or opinions being investigated (Mandolesi et al., 2015). As suggested by Webler & Danielson (2009), subjects with knowledge and/or roles coherent with the topic should be included in the analysis. Indeed, Q-participants are selected to reflect the range of opinions within a target sample rather than the distribution of beliefs within a community (Watts & Stenner, 2012). Q-participants are also selected to reflect the varied and well-developed social viewpoints within a given population. So, individuals who have well-formed beliefs will find it easier to perform the Q-sort and are likely to produce a more robust sort (Dieteren et al., 2023). Factor analysis techniques, like principal component analysis (PCA) or Centroid, are used to analyse collected data. The Q-researcher's objective is to identify patterns in the Q-sorts of the participants, indicating that there may be common intersubjective orderings of beliefs among individuals. This leads to the notion proposed by Brown (1993) of "social perspectives", since many people's subjective expressions are covered (Brown, 1993; Webler & Danielson, 2009). The aim of the Q-researchers is to develop a narrative that describes each social perspective revealed, thus discussing social viewpoints. The goal is to uncover an explanation that describes a narrative related to the research topic (Dieteren et al., 2023). This is particularly relevant in the case of sustainable innovations considering the complexity of different viewpoints that hamper the possibility of cooperative agreements (Iñigo and Albareda, 2016). The Q-methodology has proven useful in connecting the effects of individual preferences and knowledge with the variables influencing the process of innovation adoption and the drivers of FLW reduction through environmental sciences innovations (Webler & Danielson, 2009; Sneegas et al., 2021; Dieteren et al., 2023). Other authors adopted this methodology to interpret insights into the factors that influence upstream stakeholders' decision-making, and the complexities involved in a topic (Dieteren et al., 2023). Moreover, the Q-methodology has proven to be a reliable tool to

understand complex topic and explore stakeholder perspectives in the European agri-food sector. D'amato (2019) employed the Q methodology employing Q methodology to distinguish between circular, green, and bio-economies within growth models. Their findings indicated a general mistrust of the growth-oriented bioeconomy suggesting a policy shift towards synergistic, non-growth-focused approaches. In Italy, Mandolesi adopted the Q-methodology to examine farmers' attitudes towards sustainable innovations, revealing varied viewpoints and informing potential strategies to integrate sustainable food practices (Mandolesi, 2015). Other research in Italy focused on the adoption of precision agriculture, emphasizing farmers' preferences and the influencing factors in technology adoption for advancing agricultural productivity and sustainability (Iofrida et al., 2018). Relevant literature reviews are also available in scientific literature to assess the strong and weak points of setting a Q-methodological study to uncover complex topics (Sneegas et al., 2021; Dieteren et al., 2023).

3.2.2 Study design and development

The five steps involved in the implementation of Q-methodology include: concourse development, Q-sample creation, P-sample selection, Q-sorting, and Q-factor analysis. The focus of this study is on the Italian stakeholders' viewpoints about the concourse: sustainability innovations and best practices to enhance the management of surplus and prevent food losses during the upstream phases of the Italian FFV value chain (following the harvesting stage and up to, but excluding, retailers). Pertinent sources such as scientific research, grey literature, and transcripts of public talk, together with one-on-one interviews with consultants and experts, were evaluated to develop the narrative around this topic (Webler & Danielson, 2009). After the inspection of the research materials, over three hundred written statements were collected, sorted, investigated, and eventually included in the Q-sample. A factorial design was used to be sure that the Q-sample fully represents the concourse and to include all the relevant statements (Watts & Stenner, 2012). A deductive approach was adopted for developing a 9-cell sampling matrix composed by theoretical categories derived from patterns observed during the collection phase (Dieteren et al., 2023). Inspired by the waste hierarchy concept, three categories of measures – representing food surplus prevention, food surplus optimization, and food loss recycling and recovery – were defined to categorize the statements (Papargyropoulou et al., 2020). Then, to include all the relevant aspects related to the concept of innovations' adoption three classes of innovation were used to finalizing the grouping of all the relevant statements. Considering the traditional concept of

innovations, technology and product innovations is related with development of new products or services generally related to technological advancements; organizational innovation refers to the implementation or the development of new organizational methods and the enhancement of new ideas or behaviours internally or externally to the firm; marketing innovations represent different approaches developed to marketing products to potential or existing customers (OECD, 2018; Lam et al., 2006; Salunkhe, 1974). The final Q-sample is composed of thirty-four written statements selected to represent the entire concourse. Table 5 shows the sampling matrix developed for this study reporting the number of statements for each category. The number of statements is not equally distributed between the theoretical categories developed, but the authors observed that additional statements would not improve the accuracy of the Q-sample (Watts & Stenner, 2012).

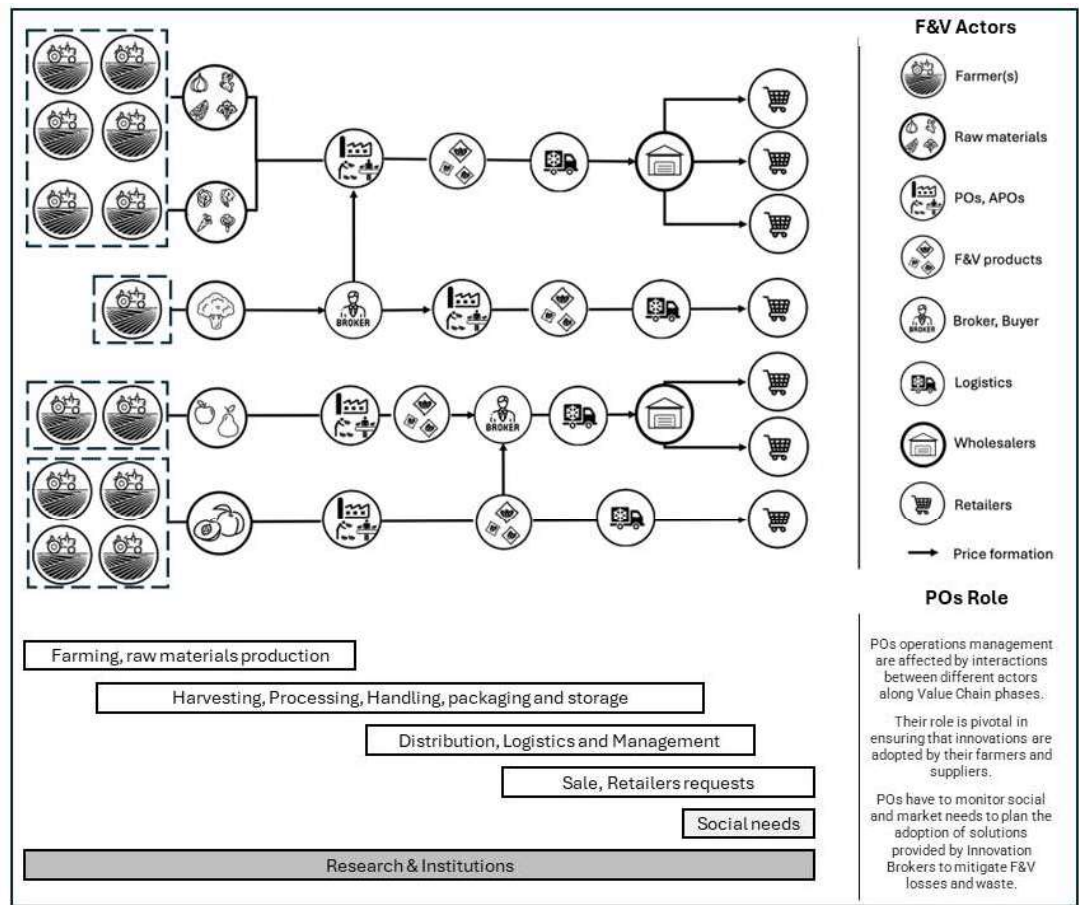
Table 5 - Sampling Matrix

Class of innovation	Technology & Product Innovation	Organizational Innovation	Marketing Innovation
Measure			
Food surplus prevention	4	4	4
Food surplus optimisation	4	4	4
Food losses recycling and recovery	3	4	3

The Q-sample was developed and administered in Italian. For the sake of the study, the statements reported are translated in English. A pilot test was conducted in December 2022: the list of statements was refined, reworded, and reorganized to include all feedback. Figure 2 illustrates the complex interactions between the several actors of a classical supply chain models in the fruit and vegetable sector. The diagram is segmented into layers that represent different stages of the value chain: at the core of the supply chain are placed POs & APOs, which are pivotal in aggregating efforts and resources of producers, supported by public funding and the collaboration with research and public institutions (Diaz-Ruiz et al., 2019; Gutiérrez & Macken-Walsh, 2022). They are linked to other key actors, such as farmers, brokers, buyers, wholesalers, and retailers through a network of interactions representing the flow of goods and information, denoting the activities involved during the price formation process, indicated by arrows. Each activity is represented by specific icons characterizing raw materials, F&V products, and logistics.

By focusing on the upstream stages, the study intentionally excludes retailer interactions, directing instead on addressing inefficiencies and reducing food loss among the primary producers and intermediaries. This approach supports the research objectives, aiming to enhance food waste and losses prevention activities through improved coordination among producers, experts, and institutions.

Figure 2 - Supply Chain features and dynamics in the Fruit and Vegetable Sector



As reported in Table 6, the P-sample consists of eighteen participants, among which 40% are women, equally composed by representatives of POs and their closest stakeholders. The age range and experience in the sector is wide, with most participants having over 10 years of experience in the sector and distinct roles in the innovations' adoption process (Table 2). Those directly involved in the final decision about the adoption of an innovation are considered adopters (Knickel et al., 2021). They can be seen as the link between the strategic vision of the planners and the practical adoption of innovations (Al Zaabi et al., 2013). Their role is critical in ensuring that innovative ideas are not only adopted but also effectively integrated into existing systems and practices (Gutiérrez & Macken-Walsh, 2022). Adopters in the agri-food sector need to navigate the trade-offs between different values and perspectives (e.g., economic viability vs. environmental sustainability) (Tort

et al., 2021; Batterink et al., 2010). Planners participate in the higher-level decision-making processes and are responsible for setting the course for how innovation is approached and implemented within the organization (Batterink et al., 2010). They bring a top-down perspective to innovation, focusing on aligning innovative practices with broader organizational goals and strategies (Knickel et al., 2021). Innovation brokers play a pivotal role in the innovation ecosystem (Boons et al., 2013). They function as intermediaries who facilitate the transfer and sharing of knowledge, resources, and technologies between different entities (Howells, 2006) (Figure 2). The diversity of roles within the P-sample is considered significant for a comprehensive understanding of the theme underneath the analysis (Brown, 1996). Each participant adds a subjective perspective, shaped by their experiences and position within the value chain, as well as the P-sample involved professional with expertise in various upstream stages and aspects of the value chain (Dieteren et al., 2023). Since the characteristics of the membership organizations might influence the interviewees' subjective perspectives, it was decided to include in the P-sample a diverse range of organizations that operate at local, national, and international levels, market fresh fruit and/or vegetable products, and have previously engaged in research projects or implemented innovations in collaboration with research bodies or institutions. Annex 1 provides additional details on the participants included in the study and information about their respective membership organizations.

Table 6 - P-sample

Role in the adoption process	ID	Membership organization	Role in the organization	Gender of the Q-sorter	Age	Experience in the sector
Adopter	APO2	APO	Operative Programs Manager	M	50-55	> 10 years
Adopter	PO2	PO	Organization Manager	F	40-45	>10 years
Adopter	PO3	PO	CMO Manager	F	40-45	>10 years
Adopter	PO4	PO	Market Withdrawals Manager	F	35-40	> 5 years
Adopter	PO5	PO	President	M	60-65	> 20 years
Adopter	EXP4	Institutional	Expert	F	40-45	> 15 years
Adopter	EXP5	Institutional	Agronomist	M	40-45	> 15 years
Innovation broker	PO7	PO	Commercial and Controlling Manager	M	40-45	> 10 years

Innovation broker	PO8	PO	Operative Programs Manager	F	45-50	>10 years
Innovation broker	PO9	PO	Agronomist	M	45-50	> 15 years
Innovation broker	EXP2	Research	Expert	M	30-35	> 5 years
Innovation broker	EXP3	Research	Agronomist	F	30-35	> 5 years
Planner	APO1	APO	Organization Manager	F	40-45	> 15 years
Planner	PO1	PO	Operative Programs Manager	M	60-65	> 20 years
Planner	PO6	PO	Commercial and Controlling Manager	M	35-40	>10 years
Planner	EXP1	Commercial	Buyer	M	45-50	> 15 years
Planner	EXP6	Commercial	Expert	M	35-40	> 5 years
Planner	EXP7	Research	Buyer	M	40-45	>15 years

3.2.3 Data collection

The Q-sorting process involved the data collection organized by one-to-one remote interviews. The online tool Miro® (<https://miro.com/it/>) was used to present the statements included in Q-sample in the form of digital cards and to perform the sorting of each one on the Q sorting grid (Table 7). Two rounds of interviews were held during March–May 2023 and October–December 2023. The first part of the interview was focused on a general description of the participant and their membership organization (See Annex 2 for a list of descriptive questions asked in the interview). Before beginning the Q-sorting process, the interviewees were asked to read each statement and starting the discussion about the topic. The cards were divided into three groups: the statements with which they mostly agree, the statements with which they mostly disagree, and the statements with which they feel neutral. Then participants were asked to sort the 34 cards (e.g., statements), following the sorting condition: *"For each statement, indicate, based on your preferences, if you agree, disagree, or are neutral to the effectiveness of the practice or innovation for the management of production surpluses and preventing food losses,"* from the "mostly agree" (+9) to the "mostly disagree" (+1), starting from the extremes. The employment of a solely positive scale in the Q-sorting grid, ranging from +1 to +9 as delineated in Table 7, was decided after the feedback obtained through the pilot test. The positive concourse under examination suggests that evaluating such

progressive elements should naturally involve positive ratings (Mandolesi, 2015). The researchers noted that participants perceived the Q-sorting task as more straightforward when utilizing a scale with exclusively positive values, rather than a scale ranging from negative to positive. Therefore, the use of a positive scale not only makes the sorting process easier but also more accurate when the positive impact of the innovations to tackle food losses being studied (Diaz-Ruiz et al., 2019). Using this approach, a neutral feeling about what communicated by a statement is represented by placing the card in a cell of value (+4, +5, +6). Negative values correspond to (+1, +2, +3) and positive value correspond to (+7, +8, +9). Finally, during and after the Q-sorting process, the participants were invited to describe their personal point of view. As clearly stated to the participant, the goal of the Q- sorting is to rank the statements according to which solution they believe is more effective to prevent and optimize FFV products. The shape of the grid in Table 3 is also relevant since respondents are "forced" to classify the statements of the concourse in a normal distribution to set up the data analysis (Mandolesi et al., 2015).

Table 7 - Q-sorting grid

Mostly Disagree			Neutral			Mostly Agree		
+1	+2	+3	+4	+5	+6	+7	+8	+9
+1	+2	+3	+4	+5	+6	+7	+8	+9
	+2	+3	+4	+5	+6	+7	+8	
		+3	+4	+5	+6	+7		
			+4	+5	+6			
				+5				

The study assumed a basic understanding of the concourse, along a broader comprehension of the participants' operational context (Addams & Proops, 2000). For this reason, the distribution of the Q-grid is steep, leaving more free space for ambiguity and uncertainty. After the Q-sorting process is completed, all participants are asked to review the Q-sorting grid and discuss with the researchers the statements placed on the extremes of the distribution. Questions about the topic raised during the Q-sorting and other broad questions were discussed at the end of the Q-sorting to improve the availability of information and improve the overall quality of the outcomes (Brown, 1993; Webler & Danielson, 2009).

3.2.4 Data Analysis

The analysis of the Q-sorts was conducted using the KadeQ® software (v. 1.2.1). The Q-sorts were subjected to factor analysis using principal component analysis (PCA) to

identify the number of significant Q-statement combinations, or factors, to be extracted from the distribution (Watts & Stenner, 2012). Each factor can be referred to as “idealized sorts” because they are generated by the analysis rather than the participant (Brown, 1993). The decision about the number of significant factors to be extracted was made according to the relevant suggestions available in the scientific literature (D’Amato et al., 2019; Dieteren et al., 2023). A first decision can be made considering those factors that present an eigenvalue > 1 (Watts & Stenner, 2012). After the PCA, more than seven factors satisfy this condition, but the authors observed low variation in the explained variance by adding supplementary factors after the fourth. Therefore, the scree plot test facilitated the final decision: this analysis is based on the observation of a typical “elbow” when plotting the eigenvalues of each factor (Watts & Stenner, 2012). This analysis confirmed the choice of four factors to be extracted and examined, representing 60% of the explained variance (Table 4).

Table 8 - Eigenvalues and variance explained.

	Factor 1	Factor 2	Factor 3	Factor 4
No. of defining variables	6	4	4	4
Eigenvalues	4.5489	2.7933	2.0579	1.4980
% Explained variance	25	16	11	8

Table 4 reports the number of defining variables, e.g., participant (or Q-sort), for each factor and their relative eigenvalues. A percentage of the overall study variance is explained by the statistical relationships between each factor and Q-sorts (Watts & Stenner, 2012). As recommended by other researchers and for data analysis purposes, the scale used for data collection were converted into a negative-to-positive scale ranging from (-4) to (+4) (Mandolesi et al., 2015). On this scale, Q-sort values in the middle of the distribution, such as (-1), 0, and (+1), indicate neutrality. The statements that are particularly relevant for the discussion are those ranked at the extremes of the scale, indicating disagreement (-4, -3, -2) and agreement (+2, +3, +4) with the topic under investigation (Table 5). These statements highlight distinct viewpoints and will be further analysed to explore the stakeholder perspectives represented by each factor (Barry & Proops, 1999).

Table 9 - Factor Arrays

Measure	Statement	Factor 1	Factor 2	Factor 3	Factor 4
Pr	1. Investments to reduce the risk of contamination between products during conservation in fridges	-1	-3	0	4
Pr	4. Innovations to monitor the quality of products during sorting phases	2	1	-1	-1
Pr	8. Investments to improve efficiency during transport phases	1	0	0	-3
Pr	12. Investments to maintain the cold chain from harvesting to retailers	4	2	-2	-3
Pr	13. Diversify the portfolio of customers to optimize the logistical efficiency of the volumes delivered	-1	-2	-2	2
Pr	20. Innovations for monitoring commercialization phases and warehouse flows	1	-1	0	1
Pr	23. Facilitate access to European and national funds	3	0	1	3
Pr	25. Improve the cooperation with institutions through projects and initiatives	0	-2	2	-2
Pr	26. Implement long-term action plans to address the climate crisis	0	2	0	1
Pr	28. Use of innovative packaging during the storage and transport phases	-2	-4	-2	-3
Pr	29. Improve contracts with large-scale retail by providing incentive in the case of activation of practices that prevent FLW	-1	-4	4	0
Pr	32. Promote commercial campaigns for the sale of products with aesthetic defects	2	-1	4	3
Op	2. Develop "short supply" chain business models	-3	3	-4	-2
Op	3. Innovations in automation and robotics for the sorting of products	0	0	0	-1
Op	6. Use of innovative packaging for freshly harvested products	-3	-2	1	-1
Op	9. Software to optimize sales forecasting	-2	-3	-3	3
Op	10. Preservation of products with innovative chemical compounds	-2	-3	-1	1
Op	14. Allocate the surplus to charitable activities at a production cost	4	1	1	2
Op	16. Promote personal initiatives over collaborative actions	-4	1	-4	-2
Op	17. Participation in digital platforms to improve surplus' allocation	3	0	1	-1
Op	18. Improvement of agricultural production Decision Supporting Systems	3	3	-2	1
Op	21. Sale of fresh fruit and vegetables by digital platforms	-3	-2	-3	-1

Op	22. Setting up physical or digital spaces for training activities and exchange of good practices	0	1	-1	2
Op	27. Increase the portfolio of product with sustainability and/or quality labels	2	-1	2	2
Re	5. Organization of farms for investments in a common biodigester*	-4	0	3	-4
Re	7. Develop business models considering a “biorefinery” perspective	-2	-1	-3	-4
Re	11. Training of experts for the management of food surplus and waste	0	2	-1	0
Re	15. Transformation of fresh surpluses close to deterioration into long-life finished products*	2	0	0	4
Re	19. Use of discards and waste to produce energy and animal feed	1	4	2	1
Re	24. Development of collective composting facilities at distribution centres level	1	1	2	0
Re	30. Investments to optimize the management of FV product at distribution centres level	1	-1	-1	-2
Re	31. Increase knowledge and communication on tools to manage and reduce food surpluses	0	3	1	0
Re	33. Development of a shared protocol and guidelines to valorise FV surpluses management	-1	4	3	0
Re	34. Investments for the measurement of the volume of FV surplus and waste generated	-1	2	3	0

Please note that the letter in Column 1 “Measure” in Table 5 are referring to: **Pr**: Food surplus prevention; **Op**: Food surplus optimization; **Re**: Food losses recycling and recovery

Varimax is an algorithm designed to maximize the amount of variance explained by each factor without compromising the accuracy of the data (Webler & Danielson, 2009; Watts & Stenner, 2012). This analysis is performed by analysing the factor loading values (which represent the correlation between Q-sorts in Table 6) and deciding which solution maximizes the variance explained by the extracted factors (Naspetti et al. 2011). Selecting statistically significant factor loading is done by applying the Brown rule (Brown et al., 1980). Each Q-sort is related to each factor, and the decision on the number of Q-sorts to be rotated is based on the value of the factor loading that was statistically significant at the 0.05 level ($\pm 1.96 \times 1/\sqrt{n}$. of statements, e.g., ± 0.34). In cases of significant loadings on more than one factor, the authors decided to flag the factor with the highest loadings (Loučanová et al., 2017). For each factor, rotated Q-sorts and their relative factor loadings are reported in Table 6. Assessing which Q-sort is related to each factor is also crucial for detecting patterns between the participants (Cuppen, 2012).

Table 10 – Rotated factor loadings

ID	Factor 1	Factor 2	Factor 3	Factor 4
APO1	0.8689*	0.1967	0.1107	0.2209
APO2	0.5530*	-0.0103	-0.0316	0.2509
PO1	0.3963	0.2687	-0.0285	0.4097*
PO2	0.8547*	0.2034	0.1020	0.1521
PO3	-0.0158	0.6365*	0.3233	0.1230
PO4	0.1135	0.0309	0.2419	0.5879*
PO5	0.5646*	0.0835	0.0788	-0.4408
PO6	0.4498*	0.0525	0.4317	0.1632
PO7	0.5594*	-0.0126	0.3901	-0.2851
PO8	0.2237	-0.1184	0.1021	0.7848*
PO9	0.0094	0.2750	0.2159	-0.4802*
EXP1	0.1630	0.8681*	-0.1031	-0.1348
EXP2	0.4363	-0.1699	0.7128*	-0.0082
EXP3	0.0846	0.2461	0.7723*	0.0503
EXP4	0.0763	-0.1175	0.8609*	0.1053
EXP5	-0.1271	0.3928	0.6003*	-0.0773
EXP6	0.1937	0.8047*	-0.0476	0.0267
EXP7	0.0866	0.8441*	0.1120	-0.2464

The discussion concerning the social perspective contained in the four factors can be expanded by examining the Z-scores. The Z-score is a value calculated during the analysis that indicates where, on average among the participants of each factor, the statement was placed on the scale from -4 to +4 (Watts & Stenner, 2012). One of the possible approaches is to assess the value of Z-scores for each statement, taking into consideration the category assigned during the construction of the Q-sample (Table 5 – See also Annex 3). It is possible to sum Z-scores by category and standardize the aggregate to the number of Q-statements in that category to compare salience across categories (Webler & Danielson, 2009; D’Amato et al., 2019). Table 7 shows the normalized mean Z-scores calculated for each factor in relation to the given type of measure, as:

$$Z - score_m: \sum \frac{Z - score_i}{M}$$

m : category of measure

i : i^{th} statement

M : number of statements in the category of the measure

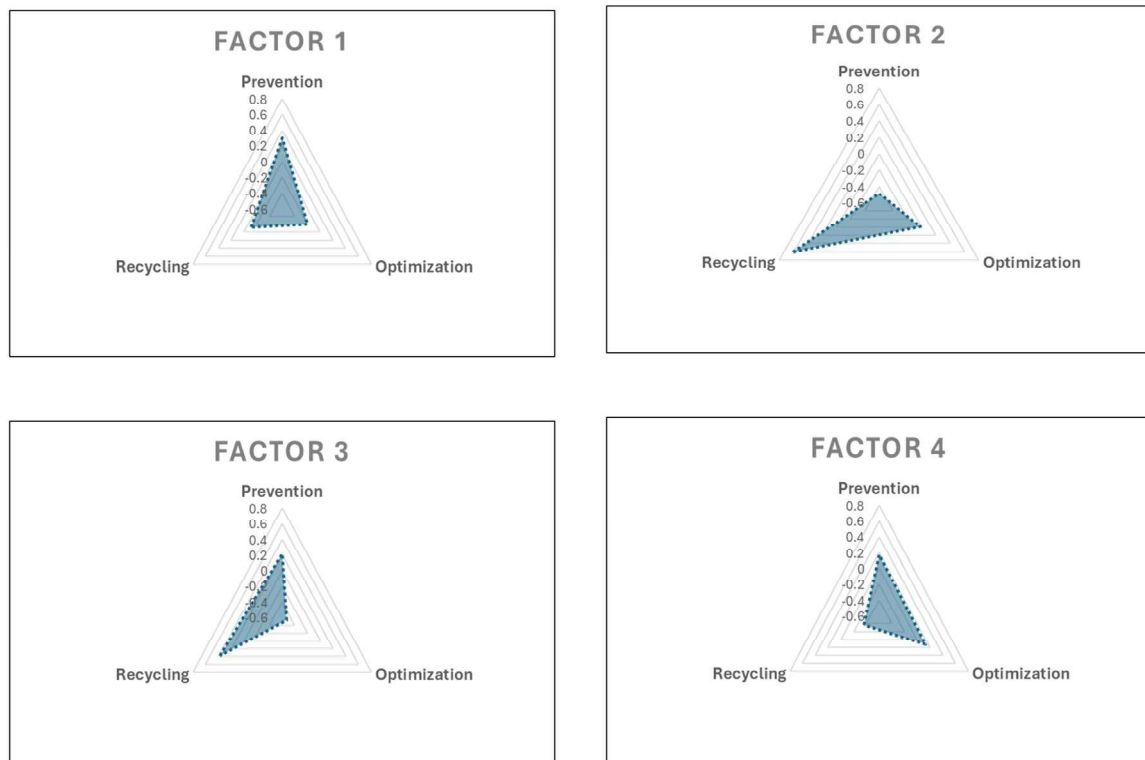
Table 11 – Normalized Z score

Type of measure	Factor 1	Factor 2	Factor 3	Factor 4	Mean
Food surplus prevention	0.2967	-0.4892	0.21167	0.1733	0.04812
Food surplus optimisation	-0.1983	-0.01833	-0.5292	0.1283	-0.1543
Food losses recycling and recovery	-0.1180	0.6070	0.3810	-0.3610	0.1272

The four factors resulting from the PCA represent the individualized opinions that emerged after the analysis of the Q-sorting (Mandolesi et al., 2015). Each factor represents a subjective point of view shared by the participants with a similar Q-sorting (Zabala et al., 2017). A graphical representation of the mean normalized Z-score for each factor in relation to their relative category of statement is provided in Figure 1. The graphs in Figure 1 illustrate the mean Z-scores for Factor 1 to Factor 4. Each of the spikes in the

triangles represents the measure described by the statement according to categories defined during the design of the analysis (see Par. 2.1).

Figure 3 - Normalized Z-score for each factor



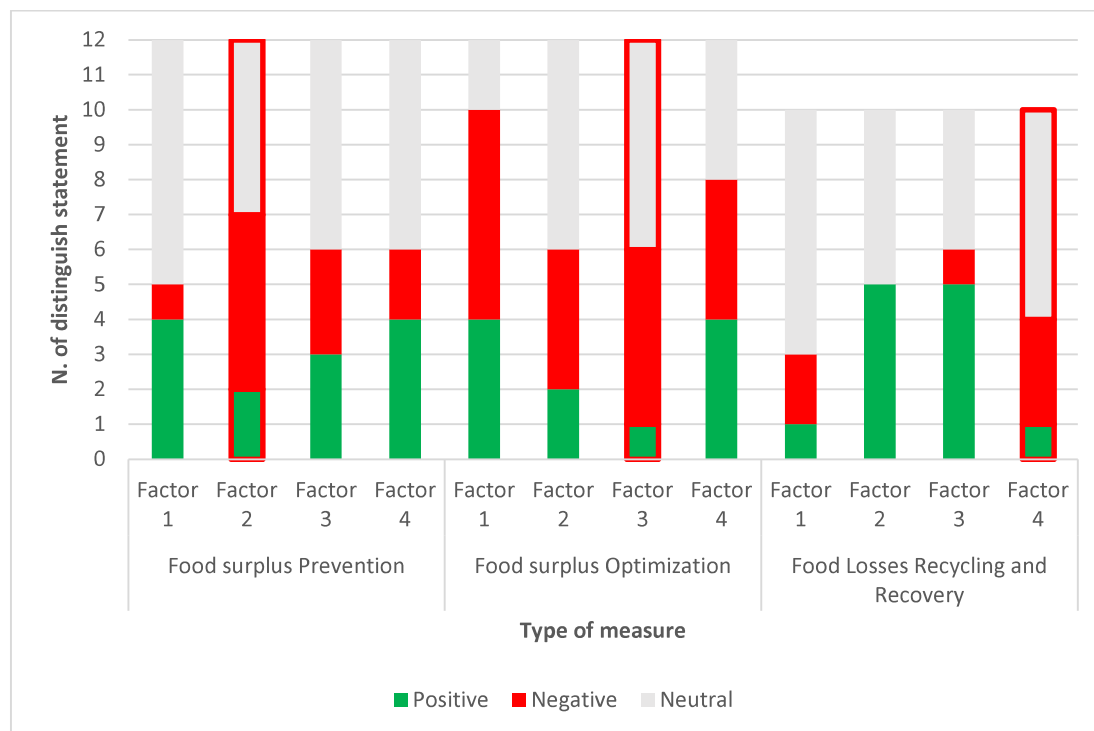
The graphical representation of the results facilitates the interpretation of the revealed stakeholders' perspectives after the analysis. These reflect the subjective point of view shared by the participants in the same factor about the best approach to reduce food loss in the FV value chain (Jaitiang et al., 2022). Defining the social point of view described by each factor is made taking into consideration the sorting of the statements for each factor (Table 5) and reporting relevant comments from the participant (Annex 4).

3.3 Results and Discussion

The findings of this study provide four stakeholders' social points of view on reducing food losses in the FFV sector, adding significant implications in light of sustainable transition and the sector's structural and commercial vulnerabilities (Thyberg and Tonjes, 2016). The viewpoints' convergence and divergence provide insightful information to optimizing tactics to match stakeholder priorities and for future policy formulation (Surucu-Balci & Tuna, 2022). Firstly, emerges a clearly claim about future policies that should be tailored to support the sector's sustainability and resilience, driven by the requests of operators, stakeholders, and researchers (Al-Obadi et al., 2022). The analysis

of statements and the resulting Z-score analysis provide a clear view of where stakeholder opinions converge and diverge (Figure 2). In Table 8, it is highlighted the distribution of distinguish statements across the four factors relating to the three categories of measure aimed at preventing food loss within the fruit and vegetable sector. Following the framework of the study, the measures are categorized into three distinct types: Food Surplus Prevention, Food Surplus Optimization, and Food Losses Recycling and Recovery, and are analysed across the factors. This is crucial for identifying the topic of the measures stressed by each factor and the importance of developing policies that are well-suited to the different and sometimes opposing priorities of stakeholders (Pancino et al., 2019). Inside the Food Surplus Prevention category, Factor 2 is predominantly associated with negative viewpoints. Conversely, the other factors present a balanced range of opinions regarding the adoption of innovations or investments proposed in the statements. For the Food Surplus Optimization category, Factor 3 exhibits the greatest disagreement, with a general inclination towards agreement in the opinions of Factor 1 and Factor 4. In the category of Food Losses Recycling and Recovery, Factors 2 and 3 display the strongest preferences towards this type of measure. However, Factor 4 contrasts with substantial disagreement, suggesting that there are divergent points of view in this category that require further considerations.

Table 12 - N. of distinguish statement for each factor grouped by type of measure



3.3.1 Factor 1 – Innovation and Digitalization

Factor 1 underscores the importance of using technology and digitalization to enhance efficiency, reduce waste, and contribute to social causes. This viewpoint represents a perspective that prioritizes the use of innovative strategies to manage surpluses and optimize supply chain operations (14, +4) supported by digital tools to improve operations (17, +3). Indeed, the Q-sorts in this factor highlight the need for technological advancements and digital platforms to manage surpluses and improve supply chain efficiency. This stresses the importance placed on infrastructure to keep produce fresh from producer to consumer, emphasizing quality maintenance (12, +4). On the opposite, there is an apparent reservation about the effectiveness of utilizing digital platforms for the sale of fresh fruits and vegetables (21, -3), pointed out by a *“preference for traditional marketing channels and a lack of readiness for digital marketplaces among the target customers”* [APO1]. The negative values associated with the organization of farms for common biodigester investments (5, -4) and the promotion of individual-level actions (16, -4) suggest a critique of these approaches.

3.3.2 Factor 2 – Sustainable Resource Valorisation

Factor 2 emphasizes sustainable practices and the importance of effective communication and education regarding waste management. This perspective is characterized by a claim for enhancing knowledge and establishing protocols to manage and valorise food surpluses (33, +4), underscoring the importance of structured approaches and education in achieving sustainability goals. Despite this, there's a clear endorsement of the “short supply chain” concept (2, +3) and the utilization of surpluses for energy (19, +4), reflecting a commitment to local economies and already consolidated circular economy practices. This factor also indicates a resistance to incentivized contracts for reducing waste in retail (29, -4), due to “doubts about their practical implementation due to the strong market power of retailers” [PO3]. In general, Factor 2 disagrees with the use of novel packaging and chemical preservation (28, -4); in the opinion of the participant, “these approaches are viewed as non-essential and less effective compared to other actions.” [EXP6].

3.3.3 Factor 3 - Market-Oriented Prevention Strategies

Factor 3 reflects a viewpoint that emphasizes the need for campaigns to market surplus products and the importance of discussing novel contracts with retailers to incentivize economically the adoption of sustainable surplus management practices (32, +4; 29, +4). This perspective is supported by the high ranking of the statements related to the

development of protocols to valorise surplus and waste (33, +3), indicating a strategic approach towards secondary raw materials and resource recovery. The negative perception of the “short supply chain principle” (2, -4) reflects “concerns about the scalability and inclusivity of such models and a belief that broader systemic changes are necessary for meaningful impact” [EXP5]. Factor 3 portrays a social-oriented perspective that emphasizes collective action and systemic change over individual initiatives (16, -4), suggesting that social and environmental responsibility are seen as inseparable.

3.3.4 Factor 4 - Investment in Value Adding and Supply Chain Optimization

Factor 4 is centred on the importance of investments in risk management and the optimization of value chain operations. The agreement towards statements related to the transformation of perishable surpluses into long-life products (15, +4) and for mitigating contamination risks (1, +4) reflects a strong emphasis on extending the lifecycle of FV products and safeguarding quality. Also, the promotion of commercial campaigns for products with aesthetic defects (32, +3) further represents a progressive attitude towards reducing food waste and enhancing market opportunities for all producers, while also taking into consideration the damages to crops related to climate change. Conversely, Factor 4 shows a pronounced disagreement towards investments solely focused on the cold chain and transport efficiency (8, -3), suggesting a critical view of these areas as either “sufficiently addressed within current practices” [PO8] or “less impactful compared to other interventions” [PO1]. The negative values assigned to the organization of farms for common biodigester investments (5, -4) and the development of biorefinery business models (7, -4) imply reservations about these specific approaches towards novel circular economy systems.

3.3.5 Discussion on shared insights

Factor 1 and Factor 4 are those factors representing mainly the point of view of POs and APOs, suggesting agreement in those innovations converging in the prevention area, by using different approaches. In general, these factors disagree on the development of biodigesters at the farm level (5; F1: -4; F4: -4) and the promotion of personal initiative over collaboration approaches (16; F1: -4; F4: -2). The focus on innovation and digitalization highlighted in Factor 1 aligns with the need for technological advancements in the sector and all the factors tend to agree on the allocation of surplus product to charitable organizations using digital platforms (Tort et al., 2021). Innovations like novel packaging products and optimized logistics are seen as relevant to reduce waste and

enhance competitiveness (Mylona et al., 2018; Aramyan et al., 2020). However, the investment costs and risks associated with innovations are reported as barriers to their adoption, as also discussed by other authors (Ghisellini & Ulgiati, 2020). The strong emphasis of Factor 2 and Factor 3 is towards innovations focused on the recycling of FLW and this could stand for a clear economic opportunity to valorise surplus and discards (Klewitz & Hansen, 2014). Comparing the four perspectives that emerged from the analysis is indeed relevant when discussing the four social perspectives emerged from this study (Reina-Usuga et al., 2020). To this aim, it is possible to consider the mean Z-score obtained from the individual statements within the factors to identify the so-called “consensus statements”. Consensus statements point to areas where all participants can agree on a way forward through conflict. (Webler & Danielson, 2009). Indeed, the exploration of statements with a high Z-score for each category shall suggest additional shared insights on particular topics during the adoption of sustainable practices, useful for producing advancement in the sustainable transition (Bryngelsson et al., 2016). In the Food Surplus Prevention Category, the use of innovative packaging during storage and transport (28, Z-score: -1.06) did not receive a strong endorsement due to “the perceived cost required that is often related to commercial choices imposed by the retailers” [EXP1]. On the other hand, promoting commercial campaigns for the sale of aesthetically flawed products (32, Z-score: 0.94) has been sorted on top, highlighting that imperfection and defect do not compromise the quality of the product (Pietrangeli et al., 2023a). Current regulatory frameworks about the use of novel packaging materials to preserve food products emphasize sustainability and reduction of environmental impact. European regulations, for instance, encourage the adoption of recyclable and reusable packaging materials to minimize waste (European Commission, 2021). These legislative measures not only aim to address environmental concerns but also align with consumer expectations for sustainable practices. Nonetheless, the high costs associated with implementing these environmentally friendly packaging solutions can be a significant barrier, especially for smaller producers who are often bound by the commercial demands of larger retailers (Afif et al., 2021). For the food optimization category, the idea of promoting actions or innovations at the individual actor level rather than at the supply chain level (16, Z-score: -1.11) was not favoured. This also reflects a homogenous preference of the sample for systemic advancement over individual solutions. In contrast, the disposition of unsold goods for charitable activities at production cost (14, Z-score: 0.925) was more welcomed, highlighting a societal inclination where businesses engage in social welfare and the agreement with institutional measure in case of crisis (Sundin et

al., 2023). This confirms the agreement towards the European regulatory framework during crises event in the agricultural sector, highlighting the potential for enhancing regulatory reforms to encourage redistributions by facilitating the bureaucracy which is often mentioned as a barrier. Finally, the distinguish statements that fell under the Food losses recycling and recovery domain offers insight into the community's valuation of circular economy principles. The development of business models with a "bio-refinery" approach (7, Z-score: -1.1575) received a less favourable score, potentially indicating a societal disagreement or perceived impracticality of implementing such business models at the present time (Bauer et al., 2018). Conversely, the utilization of losses and waste for energy and feed production (19, Z-score: 1.03) was viewed more favourably, suggesting a general endorsement of consolidated recycling strategies that directly convert waste into useful resources in line with circular economy principles (Klewitz & Hansen, 2014). Therefore, the preference for more immediately implementable solutions reflects a pragmatic approach to sustainability in the agricultural sector, prioritizing initiatives with quicker returns on investment and simpler integration into existing practices (Smith, 2008).

3.4 Conclusions

The application of the Q-methodology has revealed different stakeholder perspectives on strategies to mitigate FLW in the Italian fruit and vegetable sector. After analysing the responses from a sample of eighteen operators from the upstream phases of the FFV value chain, four distinct viewpoints were identified, emphasizing varied approaches to adopting innovations that prevent and optimize the management of fresh fruits and vegetables loss. A key theme is the preference for collaborative efforts over individual advancement, indicating readiness among stakeholders to participate in a structured and sustainable food system. The outcome from the operators outlines the need to tackle organizational challenges to promote digitalization, enhance the value of domestic products, and foster sustainable practices. However, the adoption of novel technologies is often hindered by high investment costs and perceived risks, highlighting the need for supportive policies to facilitate the access to public funds. This is also crucial for fostering dialogue and partnerships to develop solutions aligned with environmental, economic, and social goals. The need for developing co-innovation approaches based on shared objectives and dialogue among parties emerged also as a crucial theme. It was reported that the influence of commercial choices by retailers on the adoption of sustainable innovations by upstream actors is significant, directing investments that may not always

meet producers' needs, reflecting trends highlighted in recent literature. This is particularly evident in the discussion concerning the adoption of novel packaging materials. Scientific research strongly supports the introduction of sustainable packaging, yet several significant challenges persist, as both Producer Organizations and experts have identified, even if from different perspectives. A primary concern is the question of who will bear the allocation of additional costs associated with packaging changes and their management. In a market dynamic where POs face difficulties negotiating on equal terms, these costs are predominantly borne by them. This financial burden represents a critical element within the supply chain, as underscored also by experts. Moreover, POs often raise a concern that can be encapsulated by the phrase "it's not worth it.", since they do not receive a direct economic benefit from this choice. This perspective fundamentally relates to their responsibility for organizing and managing new packaging solutions in a global context that is increasingly moving towards de-packaging initiatives. The study highlighted that differing stakeholder perspectives on innovative packaging are a significant area of discussion. The core of collaborative decision-making relies on the stakeholders' ability to establish an integrated framework for actions that addresses broader needs beyond their immediate concerns. Engaging in dialogue among stakeholders can prompt a revaluation of existing practices, such as the introduction of shared strategies on packaging, which can serve as a focal point for future discussions. These interactions offer a compelling opportunity to redefine the dynamics of industrial decision-making power, particularly among those stakeholders with substantial contractual influence. Our final suggestion is that future Q-methodology studies could further explore these emergent topics, deepening insights into the sector's complexities and guiding more effective interventions.

3.4.1 Recommendations to foster Co-Innovation Actions

The insights from the Q-methodology study clearly point towards co-innovation strategies as pivotal for tackling the challenges in the Italian fruit and vegetable sector. Co-innovation, involving collaborative efforts that integrate diverse stakeholder contributions, emerges across all identified factors, emphasizing the necessity of joint actions to enhance sustainability and efficiency. The convergence and divergence of viewpoints provide valuable insights to encourage co-innovation as subsequent to informed policy development, particularly in refining strategies to align with stakeholder priorities to foster co-innovation, it is essential to facilitate cross-sector collaboration, ensuring that technology developers, agricultural producers, educational institutions, and

policymakers are not only aligned but also actively engaged in creating solutions. Participants agreed with solutions that merge technological advancements with traditional practices, suggesting a strong inclination towards collaborative systems that enhance supply chain sustainability. To promote sustainable food business models where technology, policy support, and stakeholder engagement converge it is crucial to enhance co-innovation approaches and efficiency. Strengthening public-private partnerships can facilitate the effective implementation of sustainable value chains. Moreover, educational campaign aimed at aligning all parties toward common goals are central, ensuring that each stakeholder not only contributes to, but also benefits, from the collective efforts is needed. Our results support that adopters are ready to include prevention and optimization innovations in their businesses but despite the recognition of the potential benefits from innovations, such as novel packaging and optimized logistics, the high costs and perceived risks remain significant barriers. Areas for improvement and discussion are still related to the scalability of innovative practices, the economic viability of modern technologies, and the need for comprehensive policy support. Stakeholders also highlighted concerns about the actual implementation of collaborative strategies across different levels of the supply chain, which can be hindered by varied interests and the power dynamics among large and small players. Finally, there is an ongoing need to address the educational gaps that exist regarding the benefits and practical applications of sustainable innovations to develop a framework that ensure a fair widespread of sustainable innovations.

3.4.2 Limitations

A benefit of a Q-methodology study is that it clarifies the positions held by stakeholders and allows them to use this knowledge constructively. It gives insight into the ways stakeholders see the issue, revealing the logic behind their position and putting the most critical issues in context, and provides a valid representation of the potential range of the main relevant perspectives in the general population. However, the findings cannot be generalized to the population because they are only specific to the participants. The P-sample is composed primarily of representatives of POs and APOs since the authors' interest was in exploring upstream stakeholders' points of view about innovations and policies. Also, during the Q-sorting process, the operator was the one in charge of moving the statement on the grid shown on the software. This may have somehow influenced the decision of the interviewee. Future studies should also consider the point of view of other stakeholders in the FV value chain, including the point of view of retailers. A future Q-

methodology study on this topic should involve a sample including the downstream phases of the chain, with a specific suggestion for the retailer phase and representative of wholesale markets, in addition to consumers. Finally, it is relevant to claim the inclusion of a statement in each specific category has been conducted on the experience and knowledge of the authors and is considered only for the purposes of this study. The categories were created to qualitatively represent the results.

4.

Adoption dynamics of food redistribution technology to enhance policy measures in the agri-food sector

Under Revision as:

Nasso, M., Alcon, F., Blasi, E. (2024) Adoption dynamics of food redistribution technology to enhance policy measures in the agri-food sector. In Food Policy

4.1 Introduction

Over the past few decades, there has been a significant emphasis on the transition towards sustainable business models in the fruit and vegetables (FV) sector to address challenges such as food security, resource scarcity, and food waste prevention (Tort et al., 2022). This is particularly relevant in regions like Europe, where FV production supplies global markets resulting as one of the key sectors (Knickel et al., 2021). Institutions play a central role in the sustainable transition as they are responsible for providing crisis management services, ensuring quality food availability, and limiting price volatility. Collaboration between the public and private sectors has been instrumental in facilitating access to resources, sharing information, and developing supportive networks (Menard, 2014). This synergy is often enhanced by emerging technologies, such as digital twin models, which are crucial for coordinating efforts and developing innovative business models to promote sustainable production and consumption (Aparicio et al., 2016). Policy development serves as a driver for collaborative environments, promoting the diffusion of innovative approaches to design sustainable business models, and products, processes, or strategies, that foster collaboration among major groups (including institutions, private sector entities, non-governmental organizations), and communities, promoting collective approaches to drive the diffusion of innovations (Zhao et al., 2023). Within the European Union, the Common Market Organization (CMO) regulation for the FV sector provides a market stabilization mechanism that allows for the withdrawal of surplus fresh FV from market for free distribution to charities or defined valorisation actions for the remaining fractions (Regulation (EU) No. 1308/2013). According to the European Commission, surplus food is a product that has not been sold or is not marketable but is still suitable for human consumption. This can be redistributed to charity organizations, recycled, or recovered (Albizzati et al., 2019). The main causes of surplus production are overproduction, geo-political crises, and market failure. The entities responsible for withdrawing FV products from the market are producers' organizations (POs) of farmers. These actors have to interact with several stakeholders to accomplish all the operations and bureaucratic requirements requested by the directive (Perez-Mesa et al., 2021). The price of the products withdrawn is updated periodically and regulated by directives from the European Commission. The costs incurred by the POs, associated with product withdrawal, packaging, and transportation, are established by law and covered by CMO funds through national or regional payment bodies (European Commission, 2014). The economic value of the market withdrawal measure in Europe was about € 65 million in 2022, corresponding to the 3.2% of total funds dedicated to investment within the POs in

the FV sector (European Commission, 2023). The budget for crisis prevention and management measures in Europe has been rising in recent years, representing half of the total fund provided by the CMO to the POs in 2022. This trend highlights the increasing use of CMO funds due to the mutual benefits for farmers, producers, and social welfare, particularly through waste prevention and improved access to fresh products for people in need (Solano et al., 2023). The main barriers to the application of the measure are reported to be logistical limitations and difficulties in organizing a network of actors (Midgley, 2014).

In this context, Food Redistribution Technology (FRT) is defined as an organizational innovation capable of connecting stakeholders through information and communication technologies (ICT) to develop business models based on redistribution activities (Vittuari et al., 2017). FRT is crucial in managing the redistribution of high-perishability products, providing logistical support, digitalizing documents, and creating a network among the actors involved in redistribution activities (Pérez-Mesa et al., 2021; Vittuari et al., 2017). FRT can be designed to enhance the effectiveness of the withdrawal activities in synergy with policies aimed at boosting the sustainability of the agri-food sector (Aramyan et al., 2021). Despite the growing attention on food redistribution activities in the scientific and policy arena, little is known about the factors influencing the adoption of FRT. Understanding these factors is essential for promoting the adoption of FRT as innovations that mitigate the impact of crisis and secure food access for vulnerable populations (Falkowski and Chlebicka, 2021). This study aims to model the adoption process of a FRT platform in Italy using Duration Analysis (DA). This methodology allows for an assessment of complex contexts by developing statistical models that includes both endogenous and exogenous factors that influence the adoption process of POs (Kauffman et al., 2012). For this reason, it is considered suitable for analysing the adoption of FRT, which is influenced by a variety of factors that are generally beyond the control of the POs and their members (Papargyropoulou et al., 2014). Italy is one of the leading users of funds for redistribution activities in Europe (European Commission, 2023), making the Italian case study a reference point in Europe given its context, where an operational FRT developed by an institutional body facilitates redistribution activities between Institutions, POs, and NGOs within the FV value chain. This research presents a novel approach by providing a comprehensive framework to analyse the adoption dynamics of FRT, offering valuable insights into the conditions and factors that encourage or hinder

the diffusion of FRT into existing systems, and providing valuable insights for the diffusion of FRT in other Member States.

4.1.1 Adoption process of Food Redistribution Technology

The study of the adoption and diffusion of innovations is crucial for understanding how technological advancements are integrated into the operations of stakeholders in the agri-food sector. POs play a pivotal role in the European FV sector by strengthening cooperation among farmers and other value chain operators, aiming to concentrate supply, enhance the marketing power of their members, and providing technical and logistical support (Batterinik, 2010). The collective principles of POs enable them to provide formal and informal social benefits to their members, their stakeholders, and society as a whole (Tirivayi et al., 2018). Investment in innovation within POs is designed to achieve environmental objectives while safeguarding potential gains for the network of farmers and producers (Coppola and Ianuario, 2017). The innovation selection and implementation process in POs is the result of negotiation among a range of stakeholders connected by supply chain relationships. The collaborative environment shifts the focus from individual firms to their entire supply chain networks, jointly defining needs and objectives. This perspective introduces the concept of supply chain innovation, where collective efforts and interactions within the supply chain drive innovative outcomes (Krishnan et al., 2021). In scientific literature, several factors have been identified to explain the rate of adoption of organizational innovations in collaborative value chains (Menard, 2014). Georgihiou et al. (2014) demonstrate that the development of a proper policy framework, where institutions promote actions aimed at strengthening the collaboration between stakeholder and encouraging policy instruments, is key to the diffusion of organizational and social innovation. Avelino et al. (2019) report that collaboration between public and private institution promotes the development of innovation that increase the social impact consequent to the adoption. In this case, public institutions are the main actors responsible for promoting stakeholder dialogue, revealing that the social benefit associated with the innovation can also increase the economic gains of the organizations involved. In their study, Manda et al. (2020) highlight that cooperative membership increases the likelihood of adopting technological and organizational innovations. Their findings suggest that policies should support the formation and strengthening of cooperatives to accelerate the adoption process of modern technologies. Regarding the case of FRT adoption, Midgley (2013) emphasizes the complexity of surplus food redistribution, highlighting the interplay between market

mechanisms, social values, and environmental considerations. The author claims that more structured approaches and policies enhance the effectiveness and reach of innovations, yet the FRT prototyping process creates networking and cooperation among external agents like charities, communities, and NGOs. In Italy, Vittuari et al. (2017) assess the social impact of food redistribution activities. The authors identify social, economic, and psychological benefits for people with limited access to FV products and for charities organization volunteers though highlight limitations in addressing the structural causes of food poverty. Their results identify public support policies as the key factor for the development and diffusion of co-innovative approaches in food redistribution, even when supported by advanced technology, as in the case of FRT adoption. A positive externality of these policy approaches results in a positive impact on public image and staff cohesion in public entity that promote policy tools, entrepreneurs and people involved in the activities. Indeed, economic benefits are more related to cost savings for farmers and improvements in the value of their production due to avoiding waste. As confirmed by the study of Casson et al. (2024), the environmental importance of food redistribution activities, particularly in the upstream phases of the FV value chain, suggests that such initiatives can contribute significantly to sustainability efforts by reducing food waste and its associated environmental impacts, while also providing a positive social impact due to the collaboration among organization and charities. As a result, among the main factors that affect the adoption of FRT there are proximity to cooperative bureaus, socio-economics features of organizations, structured relationships with extension services agencies, the type of sectorial organizations, and market dynamics.

A review of recent literature on food redistribution activities and the adoption of digital innovation was essential in developing a case study aimed at understanding the main factors influencing the decision to adopt a co-innovative approach, particularly in the collaborative development and implementation of FRT. The classic economic literature on innovation adoption has developed along two primary lines to explain why some organizations decide to adopt while others do not. One approach utilizes individual-level discrete choice models, which focus on the decision-making processes of individual adopters (Feder et al., 1985; Rogers, 2003). These models consider several factors such as perceived utility, cost-benefit analysis, and personal characteristics. On the other hand, aggregate models describe the diffusion process of technology across a population over time. These models, as proposed by Burton et al. (2003), aggregate individual adoption

decisions to understand broader diffusion patterns associated with the business environment characteristics. This approach emphasizes the importance of viewing technology adoption as a dynamic process, considering the timing of adoption and the effect of changing conditions by observing key variables that change over time (D'Emden et al., 2006; Souza Filho et al., 1999). The assessment reported in the study merges these two approaches, using variables suitable for assessing firms' characteristics over time and considering dynamics related to other factors stemming from institutional and market change. To pursue this goal, the DA methodology, which allows for the analysis of the adoption and diffusion of innovations over time, is considered appropriate for capturing the temporal dynamics of technology adoption, assessing how various factors influence the timing and rate of adoption among different potential users.

4.2 Methodology

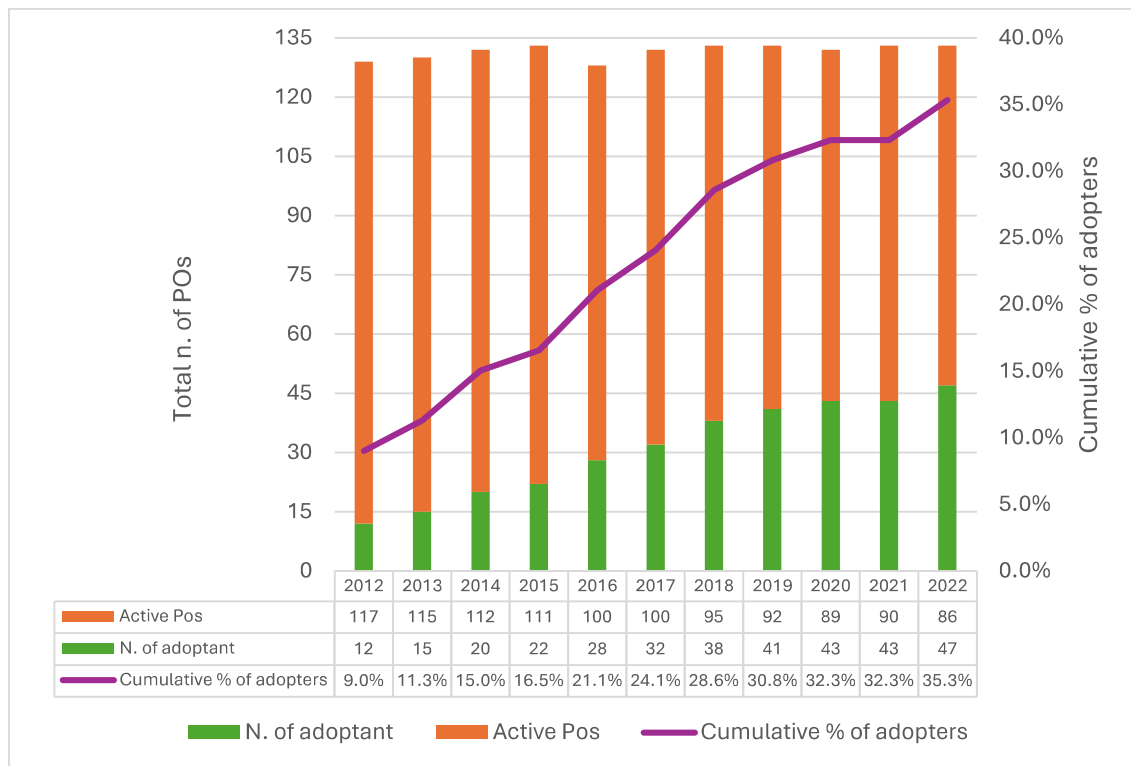
4.2.1 Context of the study

The case study examines the adoption of a FRT, namely the *S.I.R.* platform, by POs active on the FV sector in Italy. This country has one of the highest rates of farmers organized in POs in Europe, with over 300 POs active in the FV sector, aggregating over 65% of the total farmers (CREA, 2020). The FRT is a digital platform operational in Italy since January 2012. The *S.I.R.* platform was developed by the OCM payment authority of the Emilia – Romagna Region to facilitate the management of surplus fresh FV products withdrawn from the market by the PO under the CMO directive. Its introduction has facilitated the redistribution of fresh FV to charitable organizations previously registered by the authority in a list of beneficiary bodies. Since its development, more than 148,000 tons of fresh FV surplus products have been withdrawn and redistributed (Emilia – Romagna Region, 2022). More than 75% of the products withdrawn by the platform have been redistributed for free to charitable organizations, with the remaining fraction delivered to processing industry and other valorisation actions according to the CMO regulation. Approximately 60 kg of fresh FV products per year have been delivered to people in need through charity programs. Data provided by the *S.I.R.* platform indicate that the entire quantity of product managed by the platform is either redistributed or valorised, effectively overcoming logistical issues related to the high perishability of FV product and the lack of networking among operators. The total economic value generated by the POs using the platform exceeds €10 million per year, which otherwise would be lost due to the possible destruction of surplus products. Despite the successful results

achieved by the platform within the Emilia – Romagna region, the diffusion process of the S.I.R. platform is not uniform across other Italian regions and affects only a small fraction of the total population of POs in Italy (CREA, 2020). To explore the causes affecting the uneven adoption of the platform, an assessment of the factors influencing the decision, and the timing of adoption is conducted using panel data for a sample of POs in the FV value chain in Italy over the period 2012 - 2022. During the 10-year analysis, the platform attracted a total of 49 POs, of which 20 are based in 9 different regions across Italy and 29 POs are from the Emilia-Romagna region.

The sample under analysis is designed to be statistically representative of the POs operating exclusively in the fresh FV market. Organizations that commercialize products outside the scope of the market withdrawal regulation or work exclusively in processing were excluded from the analysis. The geographical distribution of the POs in the sample includes each Italian region with at least one PO participating in the platform. The sampled POs are from 9 different Italian regions: Veneto, Emilia-Romagna, Lombardia (North Italy), Lazio, Marche (Central Italy), Campania, Basilicata, Puglia, Sicilia (South Italy). The decision to include each PO in the sample followed a randomized approach. A sample size of 135 POs was selected from the population of 300 POs active in the sector as of January 2023, providing a sample error below 5% for adoption proportions, given that that 35.3% of POs adopted the platform by the end of the analysis. The trend in the adoption among the sample is reported in Figure 1. During the period under assessment, some POs entered the analysis after the starting year (2012) or exited before the ending period without adopting, reflecting the dynamic context observed (Van Den Berg, 2001).

Figure 4 - Timeframe and adoption trend of the sample



The application of the DA methodology aims to statistically identify the factors influencing the length of the adoption period. During the period under assessment, the agricultural sector in Italy faced multiple crises that impacted farmers' production and income. In particular, the Russian ban on importing FV products from Europe during the period 2015 - 2018 led to significant market disruptions, forcing POs to find alternative solutions to commercialize their surplus products and innovate their market strategies to mitigate the economic damages. More recently, the COVID-19 pandemic caused severe logistical challenges and market instability in the sector, resulting in high price volatility (ISMEA, 2021).

4.2.2 Data Analysis

Panel data from December 2011 to December 2021 were gathered from the AIDA database developed by Moody's (accessible at <https://aida-r1.bvdinfo.com/>). This comprehensive financial database contains detailed information on Italian companies, including company profiles, financial statements, and ownership structures, in collaboration with the Italian Chamber of Commerce institutional network. Additionally, data from the S.I.R. platform and official statistics released by the European Commission and the Italian Ministry for Agriculture were used to supplement the availability of information. The dataset covered a 10-year period and included a set of variables

explaining the adoption process for each PO in the sample. This dataset included a range of factors related to economics performances, financial and equity features, market trends, and the volume of FV products managed by S.I.R platform. The Variance inflation factor test was used preliminarily to exclude variables with a collinearity above 10 to establish a manageable list of variables explaining the interactions and relationships between the adoption choice and other endogenous and exogenous factors.

Three types of variables were distinguished:

Cross – sectional (CS): Cross-sectional variables are collected by observing many subjects at a single point in time without regard to differences over time. CS data provide a snapshot of the population or phenomenon at a specific point in time (Wooldrige, 2012).

Time dependant – Internal (TDI): these refer to variables whose values change over time and are influenced by the event of interest or are intrinsic to the individual subject. TDI variables are typically measured repeatedly over time for each subject and reflect changes that occur within the subjects' lifetimes (Kalbfleisch and Prentice, 2002).

Time dependant – External (TDE): these are variables that change over time but are not influenced by the event of interest. TDE variables are external to the individual subjects and are typically associated with environmental or contextual factors that affect all subjects in the study uniformly (Hosmer et al., 2008).

Including time-dependent variables in DA model, both internal and external to the organizations or phenomena under analysis, allows researchers to observe the dynamics of adoption. This approach has proven effective in many studies employing DA, offering a clear understanding of how variables evolve over time and impact the adoption process (D'Emden et al., 2006). The adoption of the FRT is influenced by a complex interplay of managerial and entrepreneurial characteristics, PO's economic performance and production features, as well as institutional and social factors. According to the literature on the diffusion of innovation, the probability of adoption is considered a function of a vector of dimensions (Alcon et al., 2011). Table 1 reports the list of the independent variables used to develop the DA model, grouped by dimension. For any given PO, the probability of adopting the platform over time is a function of vectors for each dimension affecting the adoption process (1):

$$P_a = f(M, E, P, I)$$

where:

- P_a Probability of adopting the platform.
- M Vector of variables describing managerial and entrepreneurial characteristics.
- E Vector of variables describing economic performances.
- P Vector of variables describing production features.
- I Vector of variables describing institutional factors and market crisis.

Table 13 - Descriptive characteristics of independent variables affecting the adoption process

Dimension	Variable	Obs.	Unit of measure	Mean	Min	Max	Type of variable
M	Age _t	1458	Years (n.)	20.17	1	62	TDI
M	Inv_Return _t	1458	Index (%)	3.17	-26.75	29.91	TDI
M	DebtRatio _t	1458	Index (%)	17.84	-193.7	982.46	TDI
E	Profit_Losses _t	1458	M€	0.17	-3.97	20.44	TDI
E	Prod_Value _t	1458	M€	16.18	0	387.02	TDI
E	Asset_Return _t	1458	Index (%)	0.89	-53.73	30.72	TDI
P	Infrastructure _t	1458	M€	1.23	0	51.30	TDI
P	Inventory _t	1458	M€	0.94	0	62.29	TDI
P	Fruit	1458	Dummy	0.15	0	1	CS
I	Fruit_Price	1458	Index (2010=100)	107.95	105.45	113.24	TDE
I	Reg_Crisis_Russia	1458	Dummy	0.46	0	1	TDE
I	Reg_Crisis_Covid	1458	Dummy	0.18	0	1	TDE
I	Regional Dummy*	1458	Dummy	-	0	1	CS

The managerial and entrepreneurial characteristics dimension refers to the attributes and capabilities of leadership within PO that influence decision-making processes, including innovation adoption (Caswell et al., 1990). Typically, the age of the organization

represents its maturity and greater propensity to assume the risk for the investment costs and develop an organized network of stakeholders. These factors have been measured by *proxy* variables reflecting the measure of profit earned by investments (Green and Sunding, 1997). Well-developed organizations are also more structured to make profitable investments using their own capital without third parties' debts. Similarly, assessing the value of debt in relation to the value of production provides insight into the company's leverage and financial stability (Jaitiang et al., 2022). The economic performance dimension reveals the financial health and capacity to invest in modern technologies and physical assets of each PO (Green and Sunding, 1997). The variables related to economic performance and the value of production are useful to assess the economic performance directly influencing the capacity to adopt modern technologies. The index for the profitability of the assets indicates how efficiently a company uses its resources and is included to observe the organization's propensity to manage its physical and economical assets profitably (Doss, 2006). Production features also play a significant role in the adoption process, explaining the trade-offs during the decision to innovate (Pietrangeli, 2023). The value of infrastructure owned by the PO can determine the size, supplying a proxy for the scale of innovative technologies that can be implemented and become operational (Feder et al., 1993). Within the FV sector, the type of crops cultivated and commercialized affects the adoption of specific technologies, with high-value crops requiring more advanced solutions to manage the fast perishability of products to preserve their value (Caswell et al., 1990). The value of inventory products provides information about the correlation between the capacity of PO to manage surplus production, capitalize on market opportunities, and assess the decision to adopt innovative methods to transform potential losses into value. Institutional factors are beyond PO control and are related to the operative context in which FRT adoption occurs. In the case of surplus production, changes in the fresh FV prices impact the opportunity to commercialize FV products, so a proxy value is included in the model to assess market volatility. This index is derived from the price control authority in Italy, considering the evolution of the fruit prices from 2010 as a baseline year. Additionally, regional factors, including socio-economics and market conditions, vary across different regional areas, affecting the adoption rate, especially in collaborative innovations. Regions with supportive systems and robust policy networks, such as Emilia-Romagna, are expected to exhibit higher adoption rates over time (Alcon et al., 2011). To test the regional impact on the adoption process, a dummy variable for each of the 9 regions included in the study was included in the final model. The issue of a crisis regulation is described by dummy variables related to the

Russia ban period (2014 – 2017) and the COVID-19 crisis (2019 – 2021) to assess the effect on the probability of adoption.

4.2.3 Duration Analysis Model

Duration analysis, also known as survival analysis or event history analysis, is a statistical methodology used to explore the time until the occurrence of an event of interest (D’Emden, 2012). DA investigates a complex context through a dynamic assessment over time to identify the variables influencing the transition to another state of an event of interest (Van De Berg, 2001). Originally used in medical and clinical science, DA has subsequently found applications in economics and social sciences (Alcon et al., 2011). In recent scientific literature, DA is employed to explain dynamic environments to investigate people’s status and health shocks on the length of life using panel data (Frijters, 2011), factors affecting unemployment rates in adults (Stewart, 2001) and risk factors for mortality related to the COVID-19 crisis (Gupta et al., 2021). The methodology is also applied in the agri-food sector to assess drivers affecting the comparative advantage of agri-food firms in Europe (Bojnec and Ferto, 2008), the adoption of drip irrigation technology by farmers in Spain (Alcon et al., 2011), and the adoption of product innovation in the food supply chain (Shipmann and Qaim, 2010). In the area of social innovation, Kim and Park (2011) studied the effect of voluntary adoption of innovations proposed by third parties.

DA examines the factors (variables) that statistically influence the duration time T needed before a specific event occurs (Burton, 2003). In the case that the event does not occur by the end of the time T , the subject is defined as *right – censored*. This means that the state of the subject did not change during time T and the eventual future transition is unknown. Conversely, a subject can enter in the study in a period t after T and the observation is defined as *left – censored*. The importance of time-dependent covariates and censoring in the data makes duration models especially useful and flexible for replicating real contexts (van Oorschot et al., 2018). According to the study framework, the observation period for each PO starts in the year 2012, when the S.I.R. platform was launched, or the year in which the organization began operating, whichever is the latter. The observation period ends when the PO starts to participate in the platform (move to another state) or the final year of the analysis (2022). The objective is to determine the effect of the variables that influenced the choice to adopt over the period and interpret the sign of each coefficient affecting the random variable T in the final model. The dependent variable of the study is the duration time between the year of the platform’s availability for adoption (2012) and

the year when a PO decides to participate in the platform, or the last year of analysis in case of non-adoption (2022). The length of the period T for any subject is described by a continuous random variable T with a cumulative distribution function $F(t)$, also known as failure function, and a probability density function $f(t)$. $F(t)$ is the cumulative probability of adopting the platform defined as the probability of adoption on or before t (1):

$$F(t) = \int_0^t f(t)dt = P(T \leq t) \quad (1)$$

From (1), it is possible to derive the survivor function $S(t)$, representing the probability that the adoption has not occurred prior to time t (2):

$$S(t) = \exp \left\{ - \int_0^t H(s)ds \right\} = 1 - F(t) = Pr(T \geq t) \quad (2)$$

The failure function $F(t)$ and the survivor function $S(t)$ are both probabilities. For all the points that $F(t)$ is differentiable, the probability density function $f(t)$ is defined as (3):

$$f(t) = \lim_{\Delta t \rightarrow 0} \frac{Pr(t \leq T \leq t + \Delta t)}{\Delta t} = \frac{\partial F(t)}{\partial t} = - \frac{\partial S(t)}{\partial t} \quad (3)$$

The transition probability to enter a new state is defined as the Hazard function $H(t)$, representing the relationship between the probability density function $f(t)$ and the survival function $S(t)$. $H(t)$ is the conditional probability that an organization that has not yet adopted the platform will adopt in the short period of time dt after t (4):

$$H(t) = \lim_{dt \rightarrow 0} \frac{Pr(t \leq T < t + dt | T \geq t)}{dt} = \lim_{dt \rightarrow 0} \frac{F(t+dt) - F(t)}{dt(1 - F(t))} = \frac{f(t)}{S(t)} \quad (4)$$

$H(t)$ provides information about the rate of failure per time unit in the interval $t + dt$ conditional on survival at or beyond time t . It reports the rate of adoption conditional on survival. The hazard function is at the heart of survival analysis study. Over time, the hazard rate can increase, decrease, remain constant, or even take irregular shapes. There is a one-to-one relationship between the probability of survival past a certain time and the amount of risk accumulated up to that time, with the hazard rate measuring the rate of risk accumulation.

The hazard function can be specified using a proportional hazard specification by decomposing the hazard into a baseline component and a component dependant on the individual covariates. In this case, the hazard function reflects the effects of the explanatory variables (X) and the baseline hazard function (5):

$$h(t, X, \theta, \beta) = h_0(t, \theta) \exp(X, \beta) \quad (5)$$

X is the vector of covariates, β is the associated unknown parameter vector, and h_0 the baseline hazard function, independent of the covariates, including a generalized gamma factor θ . The baseline function can be unspecified or parametrized using different functional forms. In the latter case, the hazard can be parametrized in a general form (6):

$$h_i(t) = h_0(t, \theta) \exp(X, \beta) \quad (6)$$

In this case, θ is a random variable that is assumed to be independent from X (Meyer, 1990). This factor represents the unobserved heterogeneity present in the model when assuming a specific parametric form for the baseline hazard (Prentice and Glocker, 1978). Following the approach proposed by Meyer (1990), the D model for this study is developed considering a gamma mixture distribution to summarize unobserved individual heterogeneity. This approach allows for the use of a log-likelihood function to estimate the survivor function without making any assumptions about the parametric form of the baseline hazard function (Meyer, 1990) and is useful when inconsistent estimation of β is caused by incorrect assumption about the baseline hazard (Jenkins, 1995).

The vector of variables is included to provide underlying information on the adoption process and to specify duration dependency (Burton, 2003). The general model applied in this case is written as:

$$h_i(t|x_i, \beta_i) = h_0(t, \theta) \exp(x_i \beta) \quad (7)$$

Where β is a vector of unknown parameters and $x_i \beta$ is the value of the covariates for each dimension of vectors. Positive coefficients of a covariate imply that the variable increases the hazard and thus reduces the time to adoption. The proportional hazard model is estimated for discrete period t of one year.

4.3 Results

The model reported in Table 2 is a generalized linear model, as described by Prentice and Glocker (1978), incorporating a gamma mixture distribution to summarize unobserved individual heterogeneity, as in Jenkins (1995). The table presents the results of the two duration models estimated. Model 1 is a general model that includes all the variables affecting the adoption process assessed in the study. From the pool of 22 variables studied, 16 were significant at the 5% level against the null hypothesis of no impact on the hazard ratio. Model 2 excludes non-significant variables at a confidence level of 95% from Model 1. The log-likelihood test (LLT) was used to compare the goodness-of-fit between the two nested models (Kleinbaum and Klein, 2012). Model 2 is preferred because the

LLT statistically failed to reject Model 1 in favour of Model 2 ($LLT=17.62 \chi^2_{0.05,6}=12.59$). According to the hazard function, variables characterized by positive coefficients denote an increase in the probability of adoption. The exponential of the coefficients indicates the effect on the probability of adoption for a unit change in each variable. For example, the hazard ratio for the variable indicating the economic performance of investment (Inv_Return_t) is $e^{0.06} = 1.06$. This indicates that a PO with a tendency to make profitable investments has a 6% higher probability of adopting the platform than those with an index value one unit lower.

Table 14 - Duration models for the S.I.R. platform adoption

Model 1				Model 2			
Variable	Coef.	Std. Err.	P> z	Variable	Coef.	Std. Err.	P> z
Age _t	0.02	0.02	0.33				
Inv_Return _t	0.07	0.03	0.01*	Inv_Return _t	0.06	0.03	0.03*
DebtRatio _t	0.00	0.00	0.11				
Profit_Losses _t	0.81	0.36	0.03*	Profit_Losses _t	0.83	0.31	0.01*
Prod_Value _t	0.07	0.03	0.01*	Prod_Value _t	0.06	0.02	0.01*
Asset_Return _t	-0.09	0.05	0.06*	Asset_Return _t	- 0.09	0.04	0.03*
Infrastructure _t	-0.45	0.18	0.01*	Infrastructure _t	- 0.45	0.16	0.01*
Inventory _t	-0.26	0.10	0.01*	Inventory _t	- 0.22	0.09	0.02*
Fruit	-1.02	0.68	0.14				
Fruit_price	-0.02	0.01	0.02*	Fruit_price	- 0.02	0.01	0.01*
Reg_Crisis_Russia	0.62	0.45	0.17				
Reg_Crisis_Covid	-0.11	0.66	0.87				
BASILICATA	-2.02	0.97	0.04*	BASILICATA	- 2.05	0.90	0.02*
CAMPANIA	-5.30	1.30	0.00*	CAMPANIA	- 4.79	1.21	0.00*
LAZIO	-5.02	1.12	0.00*	LAZIO	- 4.06	0.90	0.00*
LOMBARDIA	-2.33	0.74	0.00*	LOMBARDIA	- 1.98	0.67	0.00*
MARCHE	-1.09	1.54	0.48				
PUGLIA	-3.23	0.76	0.00*	PUGLIA	-2.91	0.70	0.00*
SICILIA	-4.59	0.95	0.00*	SICILIA	-4.30	0.92	0.00*
VENETO	-4.33	1.24	0.00*	VENETO	-3.91	1.17	0.00*
log_t	1.11	0.55	0.05	log_t	0.86	0.43	0.04
_cons	-0.69	0.47	0.15	_cons	-0.69	0.38	0.07
Log likelihood	-140.94			Log likelihood	-149.75		
N. of obs.	1167			N. of obs.	1167		
Prob.>=chibar2	0.02			Prob.>=chibar2	0.05		
LR test of Gamma var.	4.23			LR test of Gamma var.	2.57		

The analysis of managerial and entrepreneurial characteristics revealed that most variables used to study this dimension positively affect the adoption of the FRT platform. Specifically, the results indicate that a PO with higher returns on their investments are more likely to adopt the platform, suggesting that these organizations have the necessary resources and incentives to integrate the FRT into their operations. Other variables in this dimension were found to be non-significant when assessing the rate of adoption. Regarding the economic dimension, the DA model reveals that the value of production plays a significant role in increasing the rate of adoption. An increase in the income of a PO increases the likelihood of adopting the platform and the propensity to invest in FRT. The negative coefficient of the *Asset_Return_{it}* variable indicates that a focus on improving organizations' financial and physical assets minimizes the effect of the high perishability of FV products, thereby improving the capacity to find alternative market channels to preserve the added value of the products being commercialized. This is also confirmed by the analysis of the production features dimension. The negative coefficient for the *Infrastructure_{it}* variable indicates that investment in facilities to storage FV products decreases the probability of adoption due to the improved capacity to manage surplus products. Indeed, a PO with extensive infrastructure, such as advanced storage and distribution facilities, are better equipped to manage the logistics of perishable products. Conversely, the negative coefficient related to the *Inventory_{it}* variable suggests that a higher stock of finished FV goods in storage is not related to an increase in the likelihood of adoption. The evaluation of institutional factors highlighted the critical role of supportive regulatory frameworks in the adoption process. The 9 regional dummies analysed revealed notable regional disparities, as the negative coefficient of all the variables indicates a slower rate of adoption for the POs based in these regions compared with the POs based in the Emilia – Romagna region. However, regions in a favourable geographical position relative to the Emilia – Romagna region (e.g. *Lombardia*), exhibit a negative coefficient but a higher probability of adoption compared to the other regions in a less favourable geographical location. Additionally, the effect of crisis events, measured by the coefficients related to crisis regulation variables (e.g., the case of the Russian ban on importing products) was not statistically significant but appeared to accelerate the adoption of FRT, as these events increased the urgency for efficient surplus management measures. Finally, the inclusion in the model of a variable related to the logarithm of time (*log_t*) and the statistical significance of this variable confirmed that the adoption of the FRT is not linearly related to time but is influenced by external factors.

4.4 Discussion

The DA model developed identifies the factors influencing the length of time for adopting FRT in the Italian agri-food sector, examining the interaction between economic, organizational, and institutional factors. The propensity towards investment and higher income levels emerged as significant enablers of technology adoption. However, investment already made by a PO in both digital and physical infrastructure and assets can either facilitate or hinder the adoption of FRT. While advanced logistical capabilities are necessary, a PO with substantial existing infrastructure might be less motivated to adopt FRT, as they may already have sufficient systems in place for surplus management. Financial stability emerged as the main driver of FRT adoption, indicating that well-resourced POs are better positioned to implement innovative solutions. This observation aligns with the existing literature, where investment capacity is often linked to a higher likelihood of adopting modern technologies (Coppola and Ianuario, 2017). Although ICT-based technologies are frequently recognized as a driver for networking and data management, the study reveals that physical infrastructure, such as storage and transportation facilities, also plays a critical role in the effective adoption of FRT. In this context, infrastructure development should be viewed as a factor associated with risk management for the perishability of products in case of surplus; consequently, the adoption of both ICT systems and logistical improvements are strategic investment for a PO to avoid wastage of products (Krishnan et al., 2021). Indeed, the role of infrastructure is particularly relevant, as a PO with advanced storage capabilities were less likely to adopt FRT, emphasizing their investment in physical and digital infrastructures to create value from the surplus management. The model developed indicates that the adoption of FRT is not merely a matter of organizational choice but is heavily influenced by external and contextual factors, such as sectorial crises. Exogenous shocks influence the adoption probability, suggesting that periods of crisis can accelerate or decelerate technological uptake depending on their nature and impact, a phenomenon also confirmed in other studies examining market disruptions and technology adoption (Manda et al., 2020). Furthermore, the findings revealed the importance of institutional support in fostering collaboration among POs, charities, and institutions (Midgley, 2013), particularly in the development of a strong policy framework for the diffusion of innovations. The variation in adoption rates across regions, with Emilia-Romagna displaying higher engagement levels, points to the importance of local support systems and infrastructure development, which also result from the social impact related to the diffusion of ICT-based technologies and the collaboration of different categories of stakeholders. This finding supports the

concept of sustainable supply chain innovation, where collective efforts across the supply chain drive the adoption (Krishnan et al., 2021). Addressing regional disparity should be a priority for tailored policy interventions that consider local conditions and provide necessary support to lagging regions. Institutional factors, including price volatility and the access to CMO funds, are significant determinants of FRT adoption, aligning with the findings of Avelino et al. (2019). The availability of funds for market withdrawal measures provides financial support for POs, making the adoption of FRT a more attractive option. The results support the conclusions from similar works in the field, confirming that regions with limited institutional support and less favourable policy environments tend to have lower adoption rates and are more exposed to wastage during period of crisis (Samoggia et al., 2022). Finally, the nature of the production output influences the decision to integrate FRT, as these emerging technologies can help manage the challenges associated with highly perishable products and surplus management. The observation in the model proposed that time it is not linearly related to the adoption of FRT, unlike classical innovations' theory reports, showing that a PO experience does not affect the adoption time. A PO that has to manage surplus products without structured storage capacity are quicker to choose tools that can support their income in case of crisis, regardless of their age or geographical position. This observation should be carefully considered for future policy development in technological adoption within the food value chain, considering that the length of time to adopt is mainly driven by a combination of financial health, external pressures, and regional characteristics.

4.5 Conclusion

The analysis of the factors affecting the adoption of the S.I.R. platform by a sample of POs in the Italian fruit and vegetable sector using duration analysis provides valuable insights into the dynamics of innovation diffusion within the broader agri-food sector. This study highlights the factors affecting the adoption process of FRT for improving the management of the market withdrawal policy to manage surplus food, supporting the crucial role of innovations to reduce food waste and support local communities. The uneven adoption of the S.I.R. digital platform across Italian regions stresses the importance of understanding the factors that influence technology diffusion. The DA model developed in the analysis identifies key determinants for the adoption of the platform, including organizational and managerial characteristics, economic performance, production features, and institutional factors, that significantly impact the decision-making process of POs regarding the adoption of the FRT technology. Assessing

the impact of key variables on the adoption process of FRT, this study provides insights useful for developing a framework to investigate the role of the complex interplay between cooperative membership, policy support, and multi-stakeholder collaborative efforts in driving innovation diffusion. This approach facilitates the identification of factors behind the FRT adoption and offers insights into the long-term impacts of redistribution innovations on economic outcomes and social welfare. The DA model reveals that regions with structured CMO support systems and proactive policy environments, where stakeholders are actively engaged in FRT prototyping, exhibit higher adoption rates. This highlights the need for targeted policies that address regional disparities and offer tailored support to enhance the diffusion of innovations. Institutional support is crucial for facilitating the adoption of FRT by providing tools designed to improve the efficacy of consolidated policies and broadening the diffusion of innovation, facilitating the bureaucracy and providing a structured network of stakeholder operating in different contexts, demonstrating that regions with strong institutional support tend to have higher adoption rates due to the trustworthiness given by the organizations. Nonetheless, the study highlights the mutual benefits of FRT, not only in preventing food surplus from becoming waste but also in promoting social benefits for vulnerable populations and supporting farmers' income stability. However, external shocks, such as market crisis and failures, can have a dual impact, either accelerating or hindering adoption, depending on their nature and the resilience of the local systems. Access to CMO and CAP funds is often hindered by bureaucratic processes and the lack of logistical structures; the use of FRT can enhance and facilitate the availability of public funds, strengthening at the same time the social impact delivered by the market withdrawal mechanism. The involvement of public and non-governmental institutions in crisis management and innovation development is crucial for a well-structured collaborative network across the entire value chain. Indeed, collective approaches, involving diverse stakeholders, strengthen the effectiveness of public funds while simultaneously increasing the participation of different categories of organizations in novel sustainable business models. As highlighted, such collaborative arrangements are vital for driving innovation and ensuring that the public sector's efforts are complemented by private and non-profit sectors. Only through cooperation between all the actors involved in the development of FRT the full potential of the policies can be exploited and replicated. In conclusion, promoting the adoption of innovations that improve policy development can significantly contribute to a more sustainable and resilient agrifood sector, especially in sectors where the perishability of products is one of the main causes of wastage. Future policy development should focus

on removing barriers to adoption, providing tools to improve POs' access to financial incentives made available by CMO, and enhancing institutional support to ensure widespread implementation. Similarly, future research should explore the long-term impacts of FRT adoption on food waste reduction and social welfare, as well as identifying strategies to overcome barriers in less supportive regions.

5.

Socio-Technical Innovations for Food Surplus Redistribution: Assessing the social benefit generation of the EU CMO policy

Submitted as: Nasso, M., De Martino, G., Zappi, L., Cicatiello, C., Blasi, E. (2024) Socio-Technical Innovations for Food Surplus Redistribution: Assessing the social benefit generation of the EU CMO policy. In Sustainable Futures

5.1 Introduction

The fruit and vegetables (F&V) sectors are fundamental pillars of the European agriculture, supporting regional economies and contributing to public health by providing healthy and high-quality food. However, this sector is exposed to crisis events that cause unpredictable volatility in supply and demand, resulting in market imbalances and food surplus (Bellemare, 2015). The perishability of fresh F&V products intensifies the problem, as inefficiencies in distribution or sale frequently leading to spoilage (Raak et al., 2017). Food surplus, as defined by the European Commission, refers to the quantity of food produced that exceeds market demand, remaining unsold or unused across various stages of the supply chain, particularly in upstream supply chain phases (Galli et al., 2019). The surplus can arise from various factors, including market crisis (Porter et al., 2018), stringent quality standards (Pietrangeli et al., 2024), shifts in consumer preferences (Taylor, 2009), and logistical constraints (Alexander & Smaje, 2008). The mismanagement of surplus products causes adverse impacts to the various stakeholders in the sector, economic losses for farmers, who are unable to sell their products at profitable prices, as well as imposing environmental costs associated with the loss of agricultural inputs, such as water, land, and labour (Eriksson et al., 2016).

In Europe, The Common Market Organization (CMO) regulation allows for the market withdrawal (MW) of surplus fresh F&V from the market in case of market crisis that causes surplus production (Porter et al., 2018), providing financial support for the process of withdrawal of fresh F&V (EU Regulation 1308/2013). This mechanism is managed at NUTS1 and NUTS2 level, it aims to moderate economic losses and minimize food waste in the context of the crisis mitigation and prevention measures of the regulation. On the other hand, the effectiveness of the measure is still limited, due to administrative complexities and procedural burdens that hinder its application (García Azcárate, 2021). To improve the efficacy of CMO policy efficacy, socio-technical innovations are increasingly developed to facilitate surplus management operations under the CMO framework (Tort et al., 2022; Aramyan et al., 2021). This approach merges the importance of social relations with technological advancement within a society (Lowe et al., 2008). By linking diverse stakeholders, socio-technical innovations foster a collaborative environment for the redistribution of surplus products by providing a centralized and digital infrastructure (Midgley, 2014). This cooperative approach allows stakeholders to contribute with their expertise and resources, resulting in a service that is both innovative and responsive to the complexities of food redistribution (de Souza et al., 2021; Canali et

al., 2017). These systems are in general developed and supported by institutional bodies, and function as a critical tool for enhancing public policies aimed at reducing food waste and improving food security (Vittuari et al., 2017). While the CMO's mechanism provides a policy tool for addressing these challenges, its impact is often constrained by implementation barriers, requiring further analysis to quantify the impact of innovations on policy enhancement aiming at achieving the desired level of diffusion expected by the policy maker (Bolwig et al, 2021). The complexity of coordinating withdrawal operations involves organizing the logistics of multiple stakeholders, including regional authorities, financial institutions, and beneficiaries, resulting as the main operational challenges to be tackled (Menard and Valceschini, 2017). This study aims to evaluate how socio-technical innovation has enhanced the CMO policy in managing surplus redistribution from 2012 to 2023 in the fresh F&V sector in Italy. The objective is to quantify the economic, environmental, and social impacts of the CMO policy, focusing on its implementation. While existing literature reports the impact of traditional surplus management practices along the agri-food value chain, there is a need to assess novel systems that improve policy effectiveness using socio-technical innovations (Principato et al., 2023). Furthermore, research on food redistribution frequently lacks detailed quantitative assessments of the socio-economic and environmental benefits offered by digital solutions in this sector (Porter et al., 2018). This study aims to fill these gaps focusing on the following research questions:

- 1) What are the economic, environmental, and social impacts related to CMO expenditure for market withdrawal in the fresh F&V sector, specifically when supported by socio-technical innovations?
- 2) Does the market withdrawal measure provide measurable economic benefit to farmers while generating positive externalities for other stakeholders?
- 3) How does the integration of socio-technical innovations, such as the SIR platform, leverage CMO funds to enhance the efficiency and outcomes of surplus redistribution?

5.1.1 Literature review and Policy context

The CMO framework of the European Union, part of the Common Agricultural Policy (CAP), is a fundamental component in stabilizing the agricultural markets, ensuring fair incomes for farmers, and safeguarding food security across Member States (Velázquez & Buffaria, 2017). The regulation aims are to support and manage production, trade, and

crisis response in several agricultural sectors (Camanzi, 2011). In the agri-food sector, a market crisis is a sudden imbalance between supply and demand, causing economic instability for producers and distributors, leading to surplus and price volatility (Bilska, 2016). The CMO addresses these crises through direct interventions, such as crisis prevention and mitigation measures that stabilize prices, reduce waste, and promote sustainability (García Azcárate, 2018). Among its mechanisms, MW of fresh surplus F&V is designed to absorb market shocks caused by volatility, protecting both producers and consumers (Rezitis and Pachis, 2020). The CAP and the CMO established the legislative structure of MW, defining the rules governing direct interventions to avoid market distortions. Products withdrawn from the market are primarily redistributed to charitable organizations, with remaining fractions used for valorisation. This ensures that surplus food is delivered to vulnerable populations rather than non-human consumption (Papargyropoulou et al., 2022). The MW process is managed and controlled by institutional bodies through recognized PO, which act as intermediaries between individual farmers and the other stakeholders involved. PO are responsible for coordination activities, managing logistics, and ensuring that the surplus is redistributed in compliance with both European and national law. Financial support is provided through funding available under the CMO regulation in the form of financial aid within their operational plans. These are multiannual strategic programs to plan investments for enhance PO production, quality-management, and marketing of agricultural products. The operational plans are co-funded by the European Union, covering a period of 3 to 5 years. Allocating part of the fund to finance MW allows for 100% financing of the operational programs compared to the usual fixed limit of 50% in other cases (Camanzi et al, 2011). The MW scheme is restricted by quantitative limits designed to prevent market distortions, although these limits can be adjusted in case of necessity. Under normal conditions, the cap for the quantity of F&V products that can be withdrawn is set at 5% of each PO's total marketed volume. PO receive compensation based on fixed prices for each product category, which are updated periodically to reflect current conditions (EU Reg. 1308/2018).

According to several authors, the redistribution of food surplus is a viable strategy to mitigate these effects and align sustainability goals outlined in the European legislative framework (De Jong et al., 2023; Wesseler, 2022). Some researchers indicate that surplus redistribution can address food insecurity by providing healthy food to vulnerable populations while reducing food waste (Canali et al., 2017). Additionally, it offers

economic benefits to producers by creating partial revenue streams and reducing disposal costs, resulting as a driver for the adoption of redistribution systems (Franco and Cicatiello, 2021). Damiani et al. (2021) highlight the environmental benefits of surplus food redistribution when properly handled, showing that it significantly reduces greenhouse gas emissions when compared to alternatives like composting or landfilling. However, obstacles like infrastructural requirements and logistical complexity call for organizational and policy support. On the other hand, Porter et al. (2018) highlights the misalignment of the EU's Common Agricultural Policy (CAP) with sustainability goals, showing that withdrawal and destruction of surplus products lead to wasted greenhouse gas emissions embedded in the production phase. The dominant "win-win" narrative is also criticized by Papargyropoulou et al. (2022), who argue that redistribution just treats the symptoms of waste and inequality rather than their underlying causes. Indeed, they call for a paradigm shift toward upstream prevention and sustainable food systems.

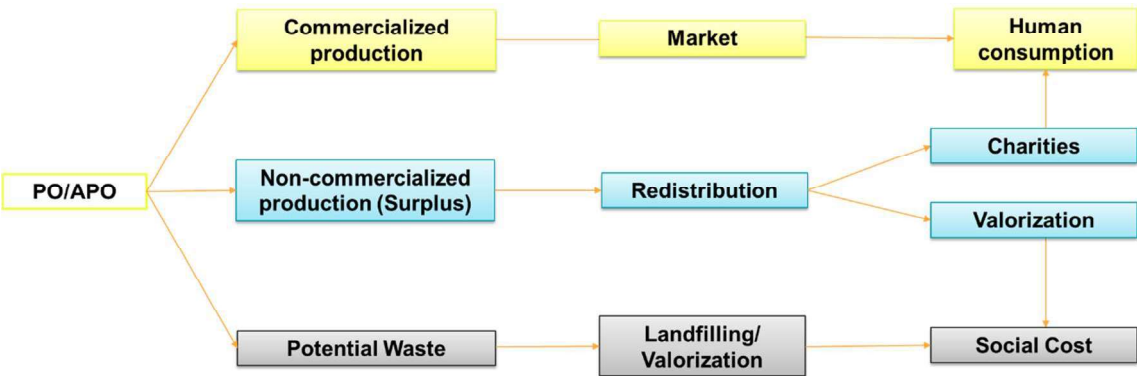
At the same time, while MW has stabilized markets and supported sustainability, its effectiveness varies across Member States (Porter and Reay, 2016). Countries like Poland and Romania report positive outcomes, while others, like Germany, have expressed concerns about potential long-term market distortions (European Commission, 2018). Additionally, administrative and logistical complexities often deter PO from using this measure (Porter et al., 2018). From 2013 to 2018, MW represented up to 40% of total crisis management expenditure in certain countries, benefiting sectors like tomatoes, apples, and cauliflower (European Commission, 2022). Historically, Spain and Italy have been primary users of the withdrawal measure. However, other Member States are increasingly allocating more funds to it within their operational programs. As a result, in 2022, MW and redistribution accounted for half of the total crisis prevention and mitigation budget under the CMO framework (European Commission, 2022). In Italy, MW are mainly directed toward charitable redistribution, with about 82% of withdrawn produce allocated for human consumption via charities and food banks (Scaveldi et al., 2019). This result aligns with CMO policy incentives, reinforcing the social impact of withdrawals while reducing food waste and supporting vulnerable populations (Kenny, 2021). Despite this, participation in market withdrawals remains limited. In 2018, Italian PO collected approximately 32,237 tons of fresh F&V surplus, primarily fruits (84%), with vegetables comprising the residual fraction (16%). This volume represents only 0.3% of the total output managed by organized PO, far below the EU's regulatory cap of 5%. Nonetheless, F&V losses along the supply chain still occur due to the

mismanagement of surplus product (Scalvedi et al., 2019). Only about 27% of PO in Italy actively include market withdrawals in their operational plans. Low engagement is attributed to the administrative burden, logistical challenges, and lack of awareness among smaller PO about the measure’s benefits (Nasso et al., 2024). However, PO activating MW tends to represent higher production values and exhibit better infrastructure, enabling efficient operations and product management. This trend is observed across many Member States, suggesting a need for structural support or additional policy incentives to enhance participation and improve the mechanism’s efficacy (Scalvedi et al., 2019).

5.2 Data and Methods

The main objective of this study is to quantify the economic, environmental, and social value generated by the redistribution of fresh F&V products under the CMO regulation supported by socio-technical innovation. To achieve this result, a comparative scenario-based approach is employed to analyze the impacts of market conditions on surplus management. This research design is based on the development of three distinct scenarios, each representing a specific set of market conditions that influence the effectiveness of surplus management and redistribution processes under the CMO framework. This methodology, as applied in studies such as De Laurentis et al. (2020), allows for a comprehensive assessment of how policy interventions, particularly by the implementation of digital platforms such as the SIR platform, affect outcomes under varying levels of market stability. The use of the scenario-based approach primarily serves to quantify the value generated under different conditions and compare it to the observed outcomes in the current real-world scenario, thereby enabling an evaluation of the platform's performance.

Figure 5 - Framework of the study.



- (i) The HBS Scenario assumes optimal market conditions where no market crises exist, making CMO regulatory interventions unnecessary. F&V products are commercialized through standard market channels, ensuring that the full volume reaches the consumers without interruptions. Consequently, there is no surplus that requires MW, and no associated social or environmental costs from waste management. This hypothetical scenario reflects market conditions where all actors maximize their expected value and the food surplus is absent, eliminating any cost related to CMO interventions or waste management. The economic value provided to the consumer (V_{HM}) is calculated as the total quantity of fresh F&V products (Q_{SMi}) multiplied by the monthly market prices at the consumer level (P_{Mi}) for each product I (1):

$$V_{HM} = \sum_{i=1}^n Q_{SMi} * P_{Mi} \quad (1)$$

Where:

Q_{SMi} is the total quantity of the products purchased by consumers (1,000 kg).

P_{Mi} are the market prices at consumer level for each product (€/Kg).

- (ii) The HWS Scenario assumes the presence of market crises in the F&V sector without support from the CMO. The entire quantity of surplus is not delivered to consumers due to market failures, leading to significant wastage. In addition, surplus products in this scenario incur disposal, resulting in economic losses from waste management expenses, environmental costs from waste processing, and social costs from product wastage. The lack of crisis mitigation tools intensifies the negative economic impact. This scenario highlights the economic loss from unsold products and the environmental and social costs of waste disposal, with no offsetting benefits from policy intervention. In the HWS scenario, the value of food reaching consumers and the revenue for farmers are both zero. The economic cost for the environmental impact of disposal (V_{TA}) is calculated based on the Emissions (tCO₂eq) generated by the disposal of the full surplus quantity, estimated using the Food Waste Prevention Calculator developed by the European Commission (DG SANTE European Commission), and quantified using the Carbon Credit Price per tCO₂eq of emission (De Laurentis et al.,2020) (2):

$$V_{TA} = E_{QS} * P_{CC} \quad (2)$$

Where:

V_{TA} is the environmental cost for disposal (M€).

E_{QS} is the quantity of emissions from the disposal process (tCO₂eq).

P_{CC} is the Carbon Credit Price (€ 30 / tCO₂eq).

- (iii) The AOS Scenario reflects current conditions, where market crises are mitigated by the CMO's support mechanisms, with the SIR platform facilitating MW and redistribution. In this scenario, from the total surplus quantity (Q_S), a portion is withdrawn from the market and redistributed to charities under the CMO regulation (Q_{SC}). The remaining fraction is redirected for valorization purposes (Q_{SV}) through destinations such as: animal feeding, distillation, biodigestion. Real data from the SIR platform is used to calculate the different indicators used in this scenario. The economic value of redistribution for charitable use (V_{HC}) is calculated as the quantity of surplus redistributed to charities (Q_{SC}) multiplied by the market price at the consumer level for each F&V product (P_{Mi}). The environmental costs for the fraction directed at valorization (Q_{SV}) are calculated similarly to the HWS, adjusted for different waste management conditions (3), (4), (5):

$$Q_S = Q_{SC} + Q_{SV} \quad (3)$$

$$V_{HC} = \sum_{i=1}^n Q_{SCi} * P_{Mi} \quad (4)$$

$$V_{TV} = E_{QSV} * P_{CC} \quad (5)$$

Where:

Q_S is the total surplus quantity (x 1,000 Kg).

Q_{SC} and Q_{SV} are the quantities of F&V surplus redistributed and valorized (x 1,000 Kg).

V_{HC} represents the economic value of human consumption provided to charities (M€).

P_M is the market price at the consumer level (€/Kg).

V_{TV} is the total environmental cost for the valorization process (M€).

E_{QSV} represents emissions from surplus allocated for valorization (tCO₂eq).

P_{CC} is the Carbon Credit Price (€ 30 / tCO₂eq).

The scenario-based approach described enables a detailed assessment of the value generated by the SIR platform in enhancing surplus management through CMO support. To provide a comprehensive foundation for the economic assessment and analysis of surplus redistribution, the following sections outline the regulatory pricing structures, market price benchmarks, and key data used for this study.

Crisis regulation price

The European Union's crisis regulation framework, established through the CMO regulation and specific crisis regulations, provides structured guidelines for setting maximum support prices and allowable quantities during MW of fresh F&V products (Deloitte, 2014). There are distinct support prices for each redistribution channel, in case of valorization these typically lower, often set at 30% less than the rates for charitable distribution. Additionally, to support PO in managing these withdrawals, funding for packaging and transportation costs is available under the CMO regulation; however, this compensation is exclusively applicable to products withdrawn for free distribution to charities and is not included in this study's calculations. The prices established by the EU apply uniformly across all Member States, providing a standardized framework for MW. However, for products not listed within the CMO crisis regulations, individual Member States are responsible for setting withdrawal prices based on current market data. These prices are generally calculated using a five-year average of market prices at the producer level, ensuring that support levels align with local economic conditions and market dynamics. A detailed list of crisis regulation prices at European, Italian and regional level for each of the 46 products is provided in the Research Data.

Market price at producer level

Market prices at producer level for F&V products represent the prices paid to producers at wholesale and retail distribution phase. These serve as a benchmark for assessing the economic conditions affecting primary producers and play a pivotal role in agricultural economics, guiding decisions on production planning, policy formulation, and market analysis. In Italy, market prices at the producer level are systematically collected and analyzed by the Italian Institute for Studies on the Agricultural and Food Market (ISMEA). These prices are essential for various stakeholders: for producers, they serve as an indicator of price expectations under different market conditions, while for policymakers, they are vital for designing support measures, especially during periods of market instability or crisis (Finizi e Manfredi, 2024). Furthermore, the average value of

the market prices at producer level is used as a benchmark for the quantification of the crisis regulation prices in CMO regulations. A list of the market prices at producers' level in Italy during the period 2012 – 2023 is reported in the Research Data.

Market price at consumer level

Market prices at the consumer level represent the prices paid by consumers at retail, reflecting a combination of production costs, supply chain dynamics, and market demand. These prices are determined by several factors throughout the supply chain, including production and harvest costs, transportation, processing, and transaction costs, each contributing to the final price. The volatility in consumer prices shapes consumer access to fresh F&V products and is often caused by fluctuating production yields, seasonal availability, and regional supply chain challenges (Taylor and Fearn, 2009). In this study, consumer-level market prices are used to calculate the economic value of food allocated for human consumption, serving as a proxy for the total value created across the supply chain. The database on consumer prices was compiled using data from ISMEA and Nielsen, covering the period from 2012 to 2023. Monthly data were collected for a range of 45 products identified as surplus during the study period, offering a detailed and dynamic understanding of price trends over time. A comprehensive list of market prices in Italy from 2012 to 2023 is provided in the Research Data.

5.2.1 Net Social Value assessment

The Net Social Value (NSV) index is developed within this study to quantify the benefit arising from the redistribution of surplus fresh F&V products in the case study. The index consists of three primary components: the economic value of food redistributed for human consumption using the SIR platform, the total expenditure from the CMO (incorporating a partial loss of value from producers), and the cost savings achieved by avoiding waste disposal.

To accurately define the NSV index, further consideration is given for the calculation of the CMO expenditures and the expected value for farmers from their production. The total CMO expenditure (CMO_T) is determined by aggregating the spending associated with withdrawing surplus products from the market as determined by crisis regulation market prices. These costs vary depending on the destination of the withdrawn products, which include free distribution to charitable organizations (CMO_C) and valorization (CMO_V). The total expenditure for the CMO regulation is calculated as follows (6):

$$CMO_T = CMO_C + CMO_V = \sum_{i=1}^n Q_{SC} * P_{RC} + \sum_{i=1}^n Q_{SV} * P_{RV} \quad (6)$$

Where:

CMO_T is the total expenditure for MW under CMO regulations (€).

CMO_C and CMO_V quantities of expenditure for the MW for the redistribution to charities and for other valorization management (€).

Q_{SC} and Q_{SV} quantities of F&V surplus products redistributed to charities and for other valorization management (Kg);

P_{RC} and P_{RV} price fixed by the CMO regulations for each product for the redistribution to charities and for other valorization management (€/100 Kg).

The maximum support prices (P_{RC} and P_{RV}) are established for each product through European, national, and regional regulations and are applied per unit quantity based. This calculation assesses the fiscal load that the CMO budget assumes in financing the redistribution and valorization of surplus, offering financial incentives to producers under crisis conditions, though these resources could otherwise support direct interventions rather than crisis mitigation, representing a social opportunity cost.

The expected producer value (V_{PO}) estimates the projected revenue that PO would generate if the full quantity of surplus (Q_{SM}) were commercialized under optimal market conditions, calculated using market price at the producer level (P_{Oi}), it is calculated as (7):

$$V_{PO} = \sum_{i=1}^n Q_{SM} * P_{Oi} \quad (7)$$

Where:

Q_{SM} represents the total surplus volume that would have been sold under ideal market conditions (x 1,000 Kg).

P_{Oi} is the market price for fresh produce at the producer level for each product (€/Kg).

The loss of value suffered by the farmers (Δ_{PO}) is the difference between the expected value of their production V_{PO} and the partial fund gained by the application of the MW measure under the CMO regulation (CMO_T), this difference is calculated as (8):

$$\Delta_{PO} = V_{PO} - CMO_T \quad (8)$$

This indicator offers a baseline to measure the private opportunity cost associated with surplus production, reflecting the potential loss if products are not sold at market price, and the decision to use the redistribution mechanism over other interventions.

Finally, the NSV index captures the net benefit of the redistribution process by accounting for both costs and savings, providing a quantifiable measure of the social and environmental contributions of CMO interventions and the SIR platform support. The NSV index is calculated as follows (9):

$$NSC = V_{HC} - \Delta_{PO} + (V_{TA} - V_{TV}) \quad (9)$$

Where:

V_{HC} represents the value of surplus F&V redistributed to charities for human consumption.

Δ_{PO} measure the opportunity cost suffered by the PO.

V_{TA} and V_{TV} represent, respectively, the waste disposal cost without redistribution and the reduced disposal cost due to valorization. The difference $(V_{TA} - V_{TV})$ indicates the savings in waste disposal costs achieved by redistributing surplus rather than disposing of it, providing both an environmental and economic benefit.

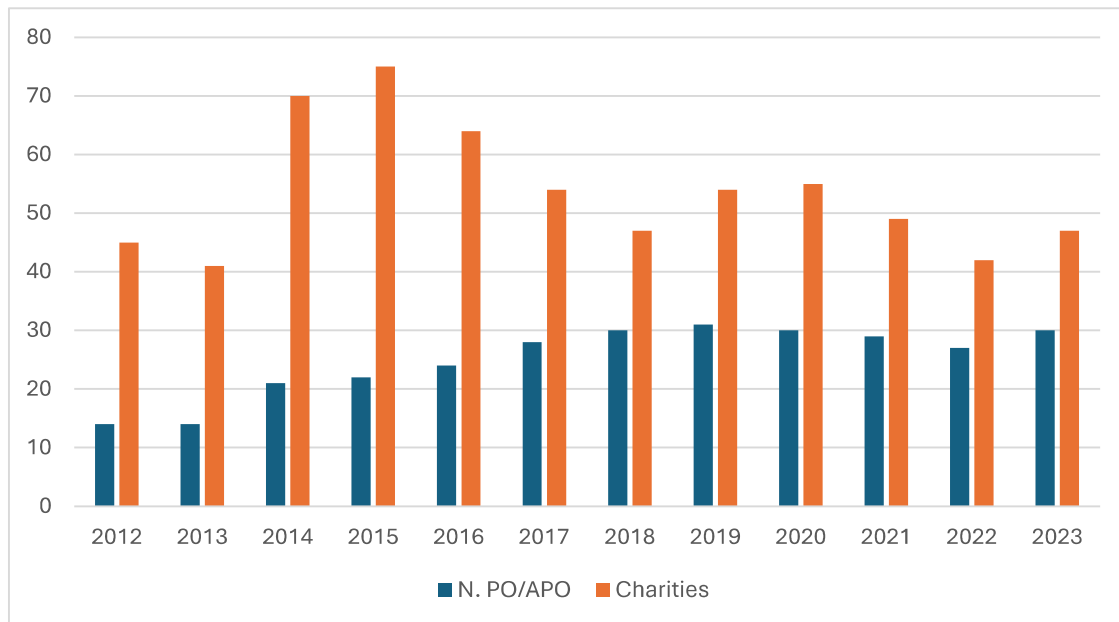
5.2.2 Case study

The Sistema Informativo Ritiri (SIR) platform, developed in 2012 by the Emilia-Romagna region in Italy, represents a socio-technical innovation designed to streamline surplus management of fresh F&V under the CMO framework. This digital tool facilitates the MW procedures for PO, reducing administrative burdens while enhancing operational efficiency. Developed through the collaboration of regional and national authorities, it provides a user-friendly digital interface for PO to manage the planning, execution, and reporting of MW activities. It automates processes such as submitting withdrawal plans, coordinating logistics with collection centers, and updating distribution records in real time. This functionality fosters collaboration among stakeholders, including PO, charitable organizations, regulatory authorities, and payment agencies.

The platform integrates surplus tracking and redistribution, ensuring compliance with EU regulations while optimizing logistics (García Azcárate, 2018). Data collected includes the quantities and types of withdrawn products, distribution channels, and end-use destinations. During the development phase of the case study, multiple interviews and

meetings were conducted with representatives from the Emilia-Romagna regional government, providing valuable insights into the platform's operational mechanisms and evolution. Figure 2 illustrates the platform's users' growth over the past decade (Figure 2).

Figure 6 - Trend of the number of users in the SIR platform (2012 – 2023)



The number of PO actively using the SIR platform has grown steadily since its inception. Also, the number of beneficiary organizations has expanded significantly, reflecting the increasing demand for surplus redistribution to support social welfare. The PO participating in the platform are based in nine different Italian regions with a strong concentration in Northern and Central Italy. These PO are associated with Association of Producers Organization (APO), which serves as a key driver or enabling the platform's use for MW across multiple regions in Italy. Over the past 10 years, the platform has reached charitable institutions redistributing food to a total of over 2 million individuals, emphasizing SIR's impact on food security and social support. These results have been achieved thanks to institutional support of the Emilia Romagna region and the collaboration of experts and volunteers from the PO and from the charities. At the same time, the efficient logistic supporting redistribution activities have been developed over the years through close collaboration between the PO and APO. Member States in Europe have introduced digital tools to streamline the CMO withdrawal process, often promoted by institutional bodies to improve efficiency (Casson et al,2024; Ayala et al., 2022). Countries like France and Spain developed digital systems for managing agricultural crises, focusing on specific functions, such as real-time price monitoring or coordination

with beneficiary organizations. However, these systems tend to operate in isolated capacities, addressing only specific aspects of the withdrawal and redistribution process (Sundin et al., 2022). The SIR platform distinguishes itself within the EU context by integrating the entire withdrawal process, from planning and execution by PO, to the development of a coordinated network with charitable organizations, oversight by regulatory authorities. This comprehensive approach has positioned SIR as the best practice model within the EU, illustrating how regional innovation can enhance the broader application and efficacy of market stabilization policies (Spring and Biddulph, 2020).

5.3 Results and Discussion

From 2012 to 2023, the total quantity of surplus fresh F&V redistributed through the SIR platform amounted to 224,090 tons, across 46 different categories of products (Table 15).

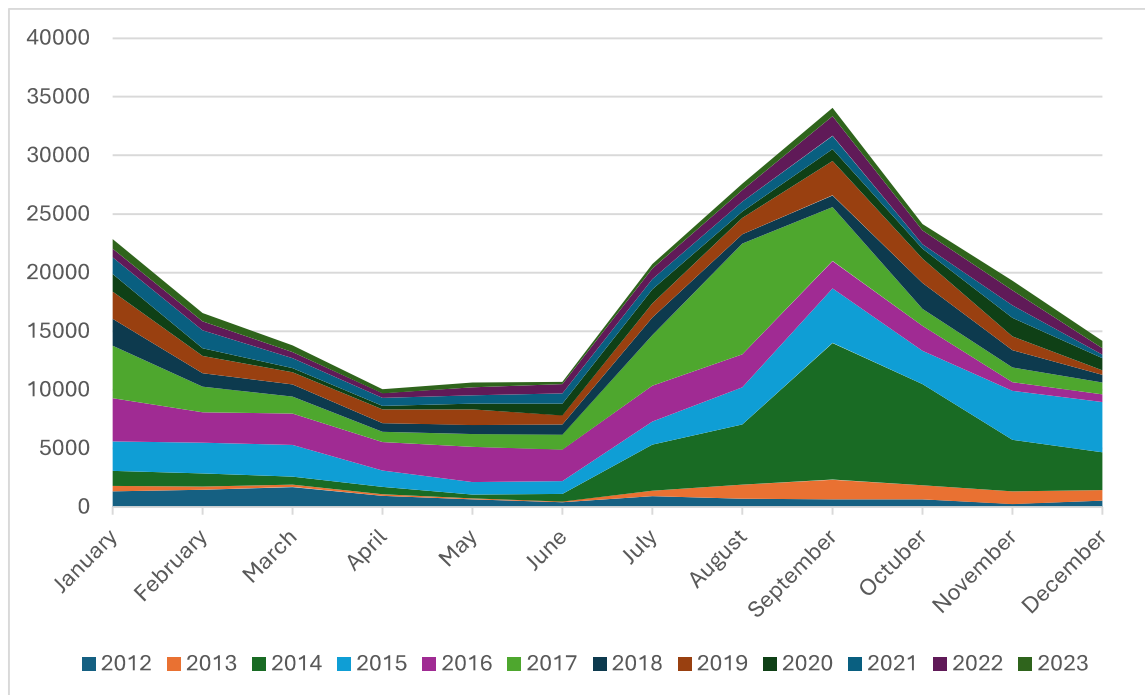
Table 15 - Fresh F&V categorization and quantification

Category (Fruits)	Surplus 2012 - 2023 (x 1,000 Kg)		Category (Vegetables)	Surplus 2012 - 2023 (x 1,000 Kg)	
Apples	37,156.5	18.37%	Artichokes	414.7	1.90%
Apricots	1,240.8	0.61%	Broad beans	4.6	0.02%
Cherries	103.7	0.05%	Broccoli	33.3	0.15%
Clementines	5,936.7	2.93%	Carrots	1,306.7	6.00%
Grapes	2,918.4	1.44%	Cauliflowers	1,656.8	7.61%
Kiwi	29,234.7	14.45%	Celery	10.5	0.05%
Lemons	40.0	0.02%	Chicory	36.2	0.17%
Mandarins	267.6	0.13%	Courgettes	1,373.4	6.31%
Melon	7,513.8	3.71%	Cucumber	498.7	2.29%
Nectarines	28,065.1	13.87%	Curly endives	22.7	0.10%
Oranges	2,993.3	1.48%	Eggplants	1,784.0	8.19%
Peaches	6,362.2	3.14%	Fennels	522.2	2.40%
Pears	18,966.8	9.37%	Green beans	129.7	0.60%
Persimmon	5,128.9	2.54%	Leek	16.3	0.07%
Plums	46,886.1	23.17%	Lettuce	3,058.0	14.04%
Strawberries	542.7	0.27%	Lettuces	139.5	0.64%
Watermelon	8,958.6	4.43%	Mushrooms	305.4	1.40%

			Onions	8,516.7	39.11%
			Peas	45.1	0.21%
			Peppers	255.0	1.17%
			Pumpkins	68.6	0.31%
			Radicchio	16.0	0.07%
			Salsola soda	14.2	0.07%
			Savoy cabbage	394.7	1.81%
			Shallots	19.3	0.09%
			Spinach	37.0	0.17%
			Swiss chard	19.7	0.09%
			Tomato	1,076.3	4.94%
			White cabbage	486.7	2.24%
Total surplus fresh fruit products	202,315.8	100%	Total surplus fresh vegetables products	21,775.3	100%

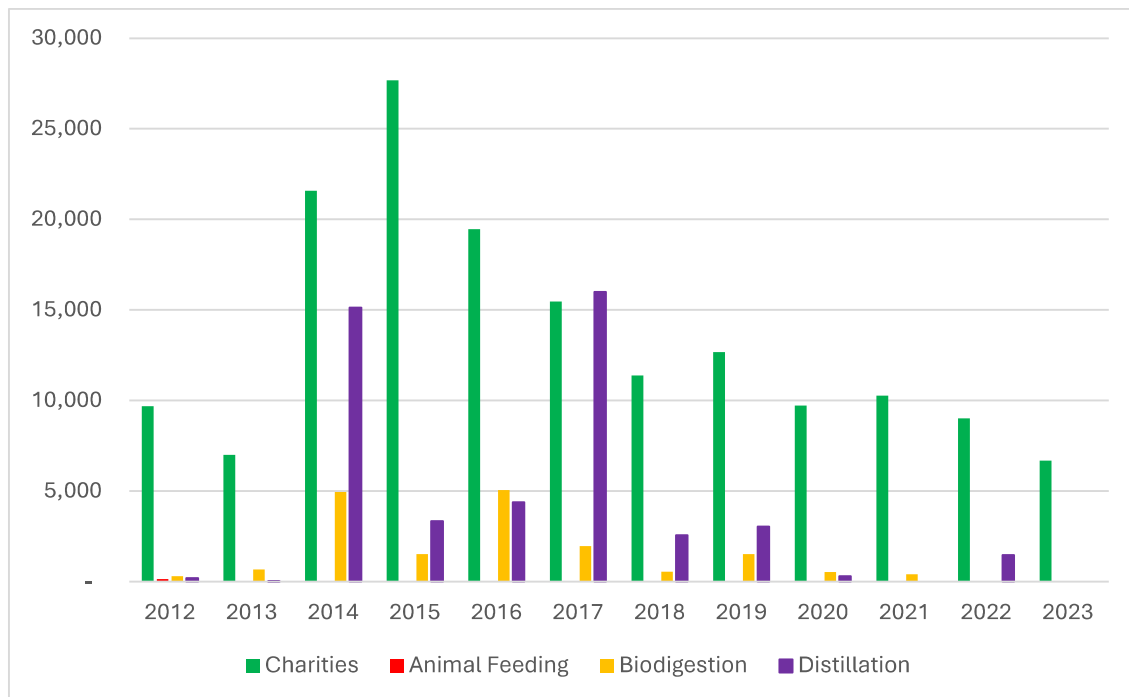
Plums contributed the highest volume of surplus (23.17%) of the total fresh fruit surplus (46,886.1 tons), followed by apples (18.37%), kiwi (14.45%), and nectarines (13.87%). These four categories represent over 70% of the total surplus in the fruit segment, mainly because their heightened susceptibility to market fluctuations and seasonal production cycles, which lead to surplus during peak harvest periods. Among vegetables, onions accounted for the largest share (39.11%) of the total vegetable surplus (8,516.7 tons). Other vegetables included lettuce (14.04%) and eggplants (8.19%). While the overall volume of surplus vegetables was smaller compared to fruits, several vegetable types showed recurring surplus trends, indicating persistent supply-demand imbalances within specific categories. Figure 3 illustrates the temporal distribution of surplus, revealing distinct seasonal trends, with the highest volumes observed during summer and early autumn, coinciding with peak harvest periods for many products.

Figure 7 - Trends of market withdrawal among the months during the period 2012 - 2023.



These trends are shaped by several factors, including the seasonality of high-value products that dominate surplus volumes and the impact of market crises during the period under observation as: the Russia ban on the import of certain F&V products between 2014 and 2018, the COVID-19 pandemic in 2020-2021 and the Ukrainian in 2022. These crises disproportionately affected summer and autumn products, amplifying surplus quantities during these periods. Redistribution efforts under the SIR platform have focused heavily on social utility, with approximately 80% of the surplus redirected to charitable organizations, aligning with the European Union's emphasis on reducing food waste and supporting vulnerable populations. The remaining 20% of surplus was allocated to valorization methods, including distillation (70%), biodigestion (25%), and animal feeding (5%), providing alternative avenues for surplus management (Figure 4).

Figure 8 - Fresh F&V surplus by destination (2012 – 2023, x 1,000 Kg)



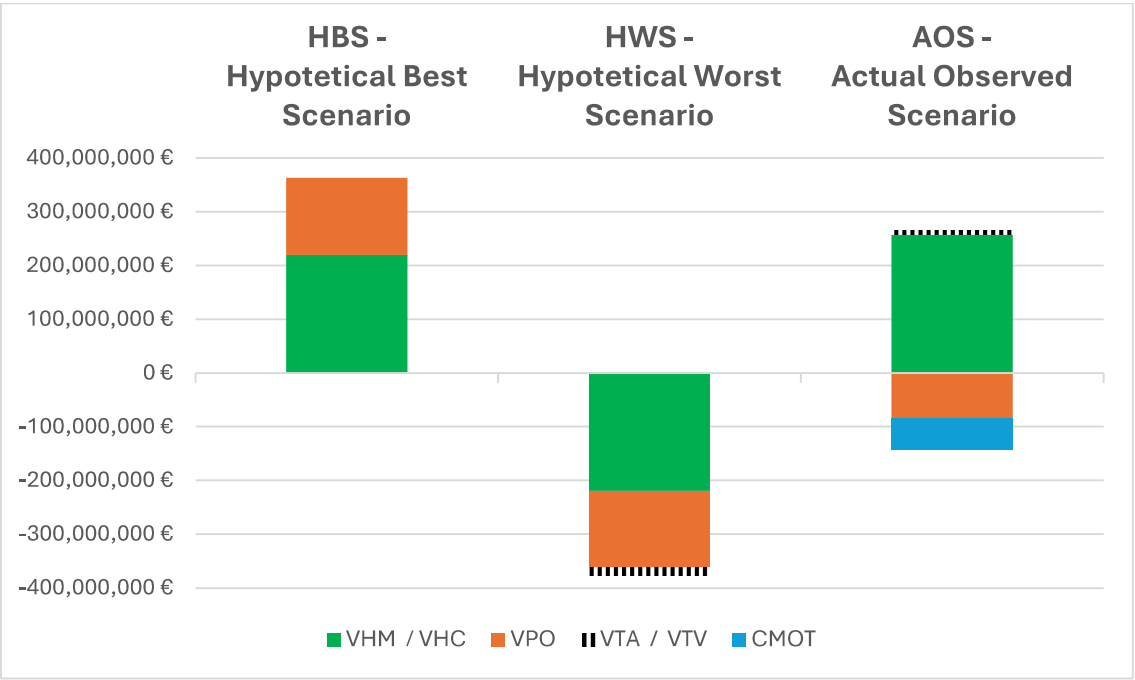
During the period under analysis three main market crises impacted on the fresh F&V sector in Europe. From 2014 to 2018, the European Union suffered a ban instituted from Russia on imports of certain F&V products (McEldowney, J., 2016). Considering that approximately 29% of EU exports of fresh F&V were destined for the Russian market, the SIR platform played a crucial role in redistributing part of the surplus to human consumption and valorization channels. However, as the withdrawal system was still in its early phases, the volumes redistributed to charities and valorized were similar during this period (Figure 4). Conversely, during the COVID – 19 crisis (2020 – 2022) the platform favored the redistribution to charities of the entire volume of fresh F&V to charities. Similarly, during the Ukrainian war (2022 – 2023), the platform achieved a 100% redistribution rate to charities in 2023, demonstrating the effectiveness of systemic improvements in optimizing surplus management (EU COM (2024) 12 Final).

5.3.1 Economic assessment and comparative scenarios

This section compares the outcomes of the economic assessment of value generated across the three scenarios under analysis. The HBS assumes the absence of market crises, representing a highly hypothetical condition rarely observed in the volatile fresh F&V sector. Conversely, the HWS represents a situation where market crises occur without any CMO interventions, highlighting the significant negative impacts associated with the lack of institutional support and redistribution mechanisms. Figure 5 provides an overview of

the value calculated among scenarios. This comparison stresses the importance of crisis mitigation mechanisms in preserving economic value, reducing waste, and minimizing environmental burdens. Without CMO interventions, the potential value of surplus products is lost, and the impact is further amplified by the financial and environmental costs of disposal.

Figure 9 - Comparison in the value generated across different scenario.



In the HBS, the total market value of the fresh F&V products commercialized generated an estimated gain of approximately €363 million, with no associated costs for surplus management or disposal. By contrast, in the HWS, the same volume of products is unsold and requires disposal, resulting in an additional cost for waste management, estimated at €9.2 million. Finally, in the current situation, the CMO regulation supported by the platform facilitates surplus redistribution, though a significant portion of the surplus is redistributed to charitable organizations, enabling producers to recover part of the expected value from their production. The remaining fraction undergoes valorization, including biodigestion, animal feeding, and distillation, decreasing the environmental cost compared to full disposal. The AOS partially mitigates the economic losses faced by producers, thereby reducing the net economic revenue while generating modest but positive returns. Redistribution channels offset the potential losses otherwise incurred by society in the absence of CMO support. The economic value of the surplus redistributed for human consumption is € 258 million, avoiding the economic loss observed in the HWS. The current scenario demonstrates potential for economic and social contributions

of CMO interventions. Table 16 provides an overview of the economic impact calculated using the SIR platform during different market crisis events between 2012 and 2023.

Table 16 - Variation during the period 2012 - 2023 of the market withdrawals and quantification of the economic value of the fresh F&V products in each phase under different market crises

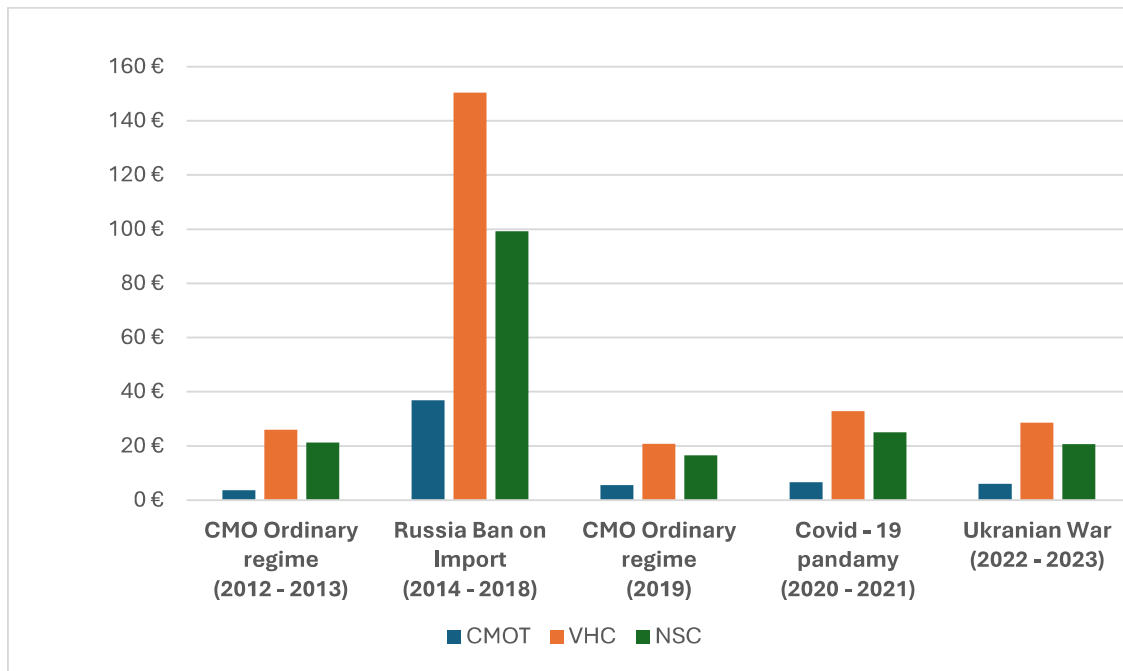
Market situation (2012 – 2023)	Q _{sc} - Surplus to Charities (x1,000 Kg)	Q _{sv} - Surplus to Valorization (x1,000 Kg)	V _{po} - Expected PO Value (M€)	CMO _c - Expenditure for free redistribution	CMO _v - expenditure on valorization	PO – Difference in the value gained by PO	V _{hc} - fresh F&V to charities (M€)	Emission due to dumping (tCO2eq)	Emission due to valorization (tCO2eq)	V _{ta} - Environment al cost for disposal (M€)	V _{tv} - Total environment al cost for valorization
CMO Ordinary regime (2012 - 2013)	16,660.16	1,317.65	9.3	3.37	0.23	5.7	25.98	34,275.78	2,246.72	1.03	0.07
Russia Ban on Import (2014 - 2018)	95,505.18	55,456.25	93.67	23.14	13.65	56.87	150.36	287,817.01	94,557.93	8.63	2.84
CMO Ordinary regime (2019)	12,667.40	4,545.34	10.46	4.19	1.31	4.96	20.76	32,817.11	7,750.22	0.98	0.23
Covid - 19 pandemic (2020 - 2021)	19,976.41	1,249.12	15.49	6.16	0.42	8.91	32.83	40,467.74	2,129.86	1.21	0.06
Ukrainian War (2022 - 2023)	15,675.41	1,463.83	14.81	5.56	0.41	8.84	28.53	32,676.98	2,495.96	0.98	0.07
Total	160,484.56	64,032.19	143.72	42.43	16.02	85.27	258.46	428,054.62	109,180.69	12.84	3.28

According to our results, the social value generated from redistribution far exceeds the environmental costs associated with valorization of a fraction of the withdrawn F&V products, confirming that the MW mechanism is a sustainability-oriented measure even when part of the fresh products is valorized. Only 29% of the surplus (equivalent to 64,000 tons) is not used for human consumption, and it is reallocated to valorization purposes. Valorization was largely used during the Russian import ban crisis (2014–2018), with a high environmental impact. During subsequent crises, the platform achieved an average redistribution rate of up to 95% of the surplus to charities, suggesting a growing efficacy in ensuring the redistribution of surplus products in a way that is effective in environmental terms. Without market interventions, the surplus would have been sent to landfills, generating avoidable emissions. These findings validate the MW mechanism as an effective tool to mitigate the economic impacts of market crises in the F&V sector while redistributing value to society. Furthermore, the results emphasize that innovative platforms like SIR are essential for aligning economic objectives with broader social and environmental goals.

5.3.2 Net Social Value quantification

The Net Social Value (NSV) index is used to quantify the economic, environmental, and social impacts of the surplus management process facilitated using the CMO's mechanism and the SIR platform. The NSV quantification incorporates multiple components, as described in Section 2.2. The total NSV for the period 2012–2023 is estimated at 182.76 M€ under the AOS. This result represents the tangible outcomes achieved through the synergy between CMO policies and the SIR platform, reflecting the value generated and redistributed among stakeholders. The NSV calculation demonstrates that socio-technical innovations leverage the expenditure under policy tools to enhance their efficiency. Indeed, the SIR platform's role highlights the leverage effect of socio-technical innovations in enhancing public spending. For every euro invested in the MW measure, the redistributed value to society is approximately three euros, as shown in Figure 6.

Figure 10 - Value distribution and leverage effect of the Net Social Value.



This ratio demonstrates that society is the primary beneficiary of value created through public policies, achieving a significant return on investment. Although the economic value gained by farmers is lower than the potential revenue observed under the HBS, the redistributive framework compensates for losses during crisis conditions. The CMO mechanism mitigates the economic impacts of market failures, ensuring that producers retain some value while prioritizing societal and environmental gains. These findings underline the critical role of structured interventions, and the role of the charities involved in optimizing surplus management, reinforcing the importance of innovative policy tools and technological platforms in addressing market crises in the European fresh F&V sector.

5.3.3 Limitations

The main limitation of this study is the regional scope constrained to the Emilia-Romagna region in Italy, a context characterized by strong institutional collaboration and advanced

logistical infrastructure. While this focus allows for an in-depth case analysis, it limits the generalizability of results to other European Member States with differing socio-economic, regulatory, and agricultural conditions. Future research should explore similar innovations in diverse contexts to assess the replicability and scalability of the SIR platform. Second, the comparative scenario-based approach, though methodologically robust, simplifies the complexity of real-world market dynamics. The hypothetical assumption of the HBC and HWC scenarios may not fully capture the nonlinear and evolving interplay between market crises, policy interventions, and stakeholder behaviours.

5.4 Conclusions

This study provides a comprehensive evaluation of the economic, environmental, and social impacts of the Common Market Organization market withdrawal mechanism, with a particular focus on the socio-technical innovation introduced by the SIR platform in Italy's Emilia-Romagna region. The findings demonstrate that the integration of the SIR platform with the CMO framework significantly improves the operational effectiveness of surplus redistribution. Under the AOS, over €258 million worth of fresh F&V were redistributed to charitable organizations, providing substantial social benefits by addressing food insecurity and reducing waste. The MW mechanism mitigated producer losses and avoided approximately €9.56 million in disposal costs, showcasing the environmental advantages of this integrated approach. Additionally, the valorization of surplus products through processes such as biodigestion, animal feeding and distillation contributed to lower environmental costs compared to full disposal, further aligning the mechanism with sustainability goals. The calculated Net Social Value (NSV) of €182.76 million for the period 2012–2023 highlights the transformative potential of socio-technical innovations in optimizing resource utilization. The SIR platform represents the potential offered by digital tools to amplify the efficiency of public funding by the digitalization of the surplus management process, reducing administrative burdens, and fostering greater coordination among stakeholders. Particularly, the platform enhanced the redistributive impact of the CMO mechanism, ensuring that societal and environmental benefits outweighed the costs associated with surplus management. Furthermore, the study reveals that for every euro invested in MW, society received a return of approximately three euros, confirming the high value of these interventions in addressing market failures. Despite these positive outcomes, the study also identifies limitations in the system's reach. Participation in MW remains constrained to a subset of

producer organizations, particularly those with higher production values and advanced operational capacities. Smaller PO often face barriers such as logistical challenges, administrative burdens, and limited financial resources, which restrict their ability to engage with the mechanism. These structural barriers call for tailored policy incentives, simplified procedures, and additional support to broaden participation and maximize the socio-economic and environmental benefits of MW. In conclusion, this research demonstrates the critical role of structured policy interventions, supported by digital innovations like the SIR platform, in addressing the challenges of surplus management in the fresh F&V sector providing a quantification of the different value generated in different steps of the value chain. The CMO mechanism, when complemented by technological solutions, provides a replicable model for mitigating market crises while aligning sustainability and food security objectives. Future research should focus on strategies to expand PO participation, refine socio-technical tools to ensure equitable access, and explore the long-term impacts of surplus redistribution mechanisms on environmental and economic resilience in agricultural systems. By addressing these challenges, policymakers can unlock the full potential of MW as a tool for achieving sustainable and inclusive food systems.

6.

Discussion and Conclusion

6.1 Summary of results

In the previous chapters, this thesis explored multiple perspectives on the adoption and scaling of socio-technical innovations within the F&V supply chain. By employing a mixed-methods approach, the study investigated stakeholders' motivations and innovation logics while providing a quantitative assessment of the potential impacts associated with innovation adoption.

The analysis in Chapter 3 demonstrates the central role of stakeholder perceptions in shaping strategies to reduce food loss within the fruit and vegetable supply chain. The study, applying the Q-methodology, identified four distinct stakeholder groups, each with unique motivations and priorities. The first Factor prioritizes economic efficiency, emphasizing cost reductions and productivity gains as key drivers of food loss mitigation efforts. The second Factor focuses on environmental sustainability, advocating for practices that minimize waste and resource use, thereby aligning closely with broader sustainability objectives. Factor 3 highlights the importance of social equity, emphasizing redistribution as a means to support vulnerable populations and address systemic inequalities in food access. Finally, Factor 4 grouped the point of view of most of the POs in the sample focusing the discussion on the need of investments in risk management and the optimization of value chain operations. The chapter reveals that while stakeholders broadly agree on the urgency of reducing food loss, significant differences in priorities can create barriers to co-innovation. To further enrich the analysis and respond to the need for actor-specific insights, the chapter also considers the connection between the sorted statements and the typologies of stakeholders involved. The sample includes representatives from Producer Organizations (POs), Associations of Producer Organizations (APOs), institutional actors, research experts, and commercial buyers, each with distinct roles in the F&V value chain. The analysis of factor loadings and qualitative comments during the sorting process revealed how certain actor categories consistently emphasized specific types of innovations. For example, POs and APOs representatives frequently prioritized statements related to operational efficiency, redistribution logistics, and market access. In contrast, institutional and research actors tended to rank higher those statements addressing long-term systemic change, education, and regulatory support. Although the sample size and methodology do not allow for inferential statistical testing across actor groups, this qualitative pattern strengthens the interpretative robustness of the findings and illustrates how organizational positioning influences the

perceived effectiveness of innovation strategies. This connection between actor type and statement preference reinforces the value of Q-methodology for capturing the diversity of strategic orientations within complex agri-food systems. As emerged from the study, conflicts often arise around the allocation of responsibilities and costs, with stakeholders expressing divergent views on who should bear the financial burden of implementing sustainable practices. By identifying areas of consensus and divergence, the chapter contributes to a deeper understanding of the social and cognitive dynamics that drives co-innovation approaches in the agri-food sector. These insights are essential for designing inclusive and participatory strategies that address the complexity of food loss prevention systems.

Chapter 4 adopts a quantitative approach through duration analysis to investigate the dynamics of adopting food redistribution technologies. This method analyses the factors influencing the adoption process over a 10-year period (2012–2022) of a socio-technical innovation in the form of a digital platform, namely the Sistema Informativo Ritiri (SIR) platform, in Italy. Using panel data from 135 Italian POs operating in the F&V sector, the study evaluates the impact of contextual factors such as economic conditions, policy incentives, and external shocks on the innovation adoption process. A statistical model is provided at the end of the study to report the critical barriers and facilitators to the diffusion of food redistribution technologies resulting from the duration analysis, contributing to the broader discourse on innovation diffusion within institutional settings. The inclusion of a temporal dimension in the analysis allows for a deeper understanding of the dynamics of adoption. Unlike cross-sectional studies, duration analysis captures not only whether a redistribution technology is adopted, but also when this adoption occurs. This distinction is crucial in sectors like agri-food, where external events (such as policy changes, pandemics, or market disruptions) can significantly alter the incentives or constraints faced by actors. By modelling the probability of adoption over time, the method uncovers temporal patterns that would otherwise remain hidden, such as acceleration effects following institutional reforms or delays linked to administrative burdens. These findings underscore the value of time-sensitive policy design and the need for continuous institutional support to maintain momentum in innovation diffusion. The chapter thus enhances the theoretical and practical relevance of duration analysis by demonstrating its ability to reveal the evolving interplay between institutional structures and technological uptake, offering critical insights into how redistributive systems can be more effectively governed and scaled. The results reveal that successful adoption is not

solely dependent on technological innovation but requires a supportive institutional infrastructure that aligns with the operational realities of the agri-food sector. These findings contribute to the literature on the diffusion of innovations by illustrating the complex interplay between institutional structures and technological adoption, offering practical insights for policymakers and practitioners seeking to enhance the effectiveness of redistribution systems.

Chapter 5 focuses on evaluating the socio-economic and environmental impacts of surplus management mechanisms within the framework of the CMO regulation in Europe. The study employs a scenario-based methodology to quantify the Net Social Value (NSV) generated by digital redistribution platforms, namely the Sistema Informativo Ritiri (SIR) in Italy. The results demonstrate that socio-technical innovations significantly enhance the efficiency and equity of surplus redistribution. By improving operational coordination and reducing logistical inefficiencies, these innovations contribute to substantial reductions in food waste. The findings also reveal significant social benefits, including improved access to surplus food for underserved populations and enhanced economic opportunities for smaller producers and distributors engaged in redistribution programs. Environmental benefits are another critical outcome, with reductions in greenhouse gas emissions associated with food waste disposal being a prominent impact. However, the chapter also highlights challenges to the scalability of these innovations, particularly the need for inclusive governance mechanisms that ensure equitable access for all supply chain actors. The findings demonstrate that socio-technical innovations can act as powerful enablers of sustainability transitions when supported by robust policy frameworks and stakeholder engagement. By providing empirical evidence of the benefits generated by these mechanisms, the chapter advances the understanding of how surplus management practices can align environmental, social, and economic objectives, offering actionable recommendations for enhancing their impact.

In regard to the transition towards sustainable food systems, the results of these chapters collectively demonstrate that the adoption and scaling of socio-technical innovations depend on aligning stakeholder motivations, institutional frameworks, and technological tools. These findings reinforce the importance of a holistic and integrated approach to addressing food waste and surplus challenges. By situating the results within the broader theoretical framework of sustainability transitions, the thesis highlights the need for inclusive, participatory, and adaptive strategies to overcome systemic barriers and foster long-term innovation adoption in the F&V sector.

6.2 Theoretical Contribution

This section provides a broader reflection on the conceptual insights drawn from the findings of this thesis, offering new perspectives on the systemic challenges and opportunities in the transition towards sustainable food systems. In particular, the analysis highlights how the dynamics of adoption, innovation, and collaboration inform the academic knowledge about the steps forwards to the sustainability transitions.

One of the key insights from this research is the need to approach food loss and surplus management as inherently systemic issues rather than isolated problems. The findings across the chapters reveal that inefficiencies in waste and surplus management are deeply radicated within structural and institutional frameworks that govern agri-food supply chain. This challenges the traditional perspective of treating food waste reduction as a purely operational concern and emphasizes the role of broader systemic reforms. As a reference, the adoption of redistribution technologies (Chapter 4) and the implementation of socio-technical innovations (Chapter 5) demonstrate that addressing these challenges requires cross-sectoral collaboration and policy integration. This perspective shifts the focus from immediate technical advancement to the long-term transformation of the value chain structures. Integrating these findings within the "Sustainable Food Management and Innovation Hierarchy" framework discussed in Chapter 1.3, the research highlights how interventions at different levels of the hierarchy, ranging from intervention to improve the adoption of innovation for prevention and redistribution, are mutually reinforcing when supported by integrated socio-technical innovations. This perspective explicitly acknowledges that the effectiveness of cooperative innovations is amplified when these are implemented within a coherent, hierarchical framework, thus shifting the focus from immediate technical advancement to the long-term transformation of value chain structures.

Also, the research outcomes highlight the dual role that institutions play in facilitating and constraining sustainability transitions. While institutional support, such as funding mechanisms or policy incentives, can enable innovation and adoption, institutional logics often act as barriers. As emerged from the discussion across chapters, rigid regulatory frameworks can delay the adoption of redistribution technologies, creating tension between innovation goals and operational realities. This duality emphasizes the need for dynamic institutions that can adapt to the evolving demands of the supply chain needs while maintaining stability and fairness for all the society. Conceptually, this insight calls for a rethinking of governance mechanisms to balance innovation with equity and

inclusivity in waste and surplus management practices. In alignment with the innovation "Sustainable Food Management and Innovation Hierarchy" framework, these findings underscore the necessity of flexible institutional arrangements that support collaborative innovation strategies and foster socio-technical system transitions across different hierarchical levels, particularly at the critical interface between prevention and redistribution strategies.

Another conceptual advancement lies in reframing stakeholder collaboration not merely as a supporting element of sustainability transitions but as a central catalyst for systemic change. The findings from the research chapters, reveal that co-innovation opportunities arise when stakeholders align their priorities through shared goals and mutual trust. However, this alignment is often hindered by perceptual and cognitive differences, which require structured frameworks for stakeholder engagement. The Q-methodology analysis conducted in Chapter 3 particularly highlights how subjective stakeholder perspectives significantly influence the adoption of sustainability innovations, reinforcing the theoretical argument that aligning stakeholders' cognitive frames and motivational drivers is critical to unlocking co-innovation potential within agri-food systems. As a result, this thesis contributes to the conceptual understanding of stakeholder collaboration by emphasizing the importance of trust-building mechanisms and participatory processes that go beyond traditional consultative models.

The research also expands the conceptual understanding of adoption in the context of sustainability transitions. Adoption is traditionally framed as the uptake of specific practices or technologies by individual actors. However, this thesis demonstrates in Chapter 4 that the adoption process of innovations is a multi-layered process influenced by institutional, cognitive, and socio-economic factors. This conceptual shift broadens the understanding of adoption as a collective process that involves multiple actors operating within interconnected systems. Incorporating these insights within the innovation hierarchy framework reinforces the idea that successful adoption at higher hierarchical levels (such as prevention and redistribution) is dependent upon the coordinated and collective actions of various stakeholders, influenced by a complex interplay of socio-economic dynamics.

This is also confirmed by the case study analysed in Chapter 5, highlighting that socio-technical innovations, such as the SIR platform, are critical facilitators between policy frameworks and operational realities. In addition, by quantifying the socio-economic and environmental impacts of surplus redistribution, the research demonstrates that such

innovations can deliver measurable benefits while addressing systemic inefficiencies. This conceptualization positions socio-technical systems as more than mere technological solutions; they are dynamic frameworks that integrate policy, governance, and stakeholder engagement to achieve sustainability objectives. This perspective advances the discourse on socio-technical systems by illustrating their potential to bridge the gap between high-level policy goals and ground-level implementation. Thus, the research clearly positions socio-technical innovations within the "Sustainable Food Management and Innovation Hierarchy" framework, as key enablers for operationalizing higher-order objectives of food waste prevention and efficient surplus redistribution, demonstrating their critical role in supporting holistic sustainability goals.

In conclusion, by integrating these conceptual insights, this thesis contributes to a more comprehensive understanding of the dynamics driving sustainability transitions in the fruit and vegetable supply chain. It moves beyond isolated analyses of stakeholder behaviour, institutional frameworks, or technological adoption, offering a systemic perspective that highlights the interconnections between these elements. These reflections not only inform academic debates on sustainability transitions but also provide actionable insights for designing more effective and inclusive policies and practices in surplus management and food loss prevention. Finally, the integration of these findings within the "Sustainable Food Management and Innovation Hierarchy" emphasizes the importance of adopting an integrated and hierarchical approach to sustainability transitions, advocating for comprehensive policy frameworks and stakeholder collaboration strategies that simultaneously address the interrelated challenges of food loss prevention, surplus optimization, and resource recycling.

6.3 Policy recommendations

The findings of this thesis emphasize the importance of integrated, adaptive, and targeted policy interventions to facilitate sustainability transitions within the European fruit and vegetable sector. Considering the analysis conducted in the research chapters, the following policy recommendations are proposed to address critical challenges and promote actionable pathways for systemic change. These recommendations are contextualized within the "Sustainable Food Management and Innovation Hierarchy" framework presented in Chapter 1.3, highlighting the need to align policy measures with the prioritization of waste prevention, surplus redistribution, and valorization strategies also taking into account the technological advancement in the context of socio-technical innovation adoption.

The results of Chapter 3 highlighted the four different groups of stakeholders' cognitive and motivational factors that influence their decision to adopt innovative practices. In this regard, the agreement areas from participants are towards policies that aim to facilitate the diffusion of digital technologies, as multi-stakeholder platforms that promote collaboration, knowledge exchange, and inclusive decision-making processes to address divergent priorities and overcome systemic barriers. Specific policy recommendations include the establishment of regional innovation hubs where stakeholders can co-design tailored solutions to address inefficiencies in the supply chain. Additionally, the implementation of targeted financial incentives to support collective investments in advanced technologies, logistics optimization, and quality management systems is essential. Moreover, educational and technical training programs are required to enhance stakeholder capacity, bridging knowledge gaps and fostering shared commitments toward sustainability goals. These measures will not only align stakeholders' priorities but also mitigate conflicts, enabling scalable and inclusive co-innovation strategies to tackle food loss effectively. Such measures directly contribute to strengthening the upper tier of the "Sustainable Food Management and Innovation Hierarchy" framework (waste prevention) by facilitating the proactive identification and management of inefficiencies through collaborative innovation.

In Chapter 4, the focus shifts to the adoption of food redistribution technologies and the role of institutional and contextual dynamics in their diffusion. The findings reveal that adoption remains uneven across regions due to barriers such as regulatory complexity, infrastructure disparities, and the impact of external shocks, including economic crises and the COVID-19 pandemic. To address these challenges, policymakers should develop

enabling environments that facilitate the diffusion of redistribution technologies and sustainable systems. This includes the development of streamlined regulatory frameworks that reduce administrative burdens and compliance complexities, particularly for small-scale farmers and producers' organizations. Targeted regional investments are also crucial for strengthening infrastructure and ensuring equitable access to digital platforms and real-time monitoring tools. Furthermore, the research highlights the need for resilience strategies that enable rapid adaptation to external shocks, ensuring efficient surplus management even under volatile market conditions. By aligning policy incentives with local operational investment, policy should improve the development of redistribution systems, strengthening the capacity of operators to reduce food waste delivering social and economic benefits across regions. These interventions correspond to the second level of the innovation hierarchy (redistribution) by facilitating the equitable and efficient reallocation of surplus, while also addressing the structural and contextual factors that inhibit broader adoption.

Finally, Chapter 5 demonstrates the transformative potential of socio-technical innovations in enhancing surplus management within the framework of the Common Market Organization regulation. The research reveals that the SIR platform enabled the redistribution of approximately 15,000 tons of surplus food annually for a value of over € 20 million per year. This value reflects the combined economic, environmental, and social benefits of redistribution actions when pushed by a strong governance systems and technological tools. Economically, the redistribution efforts provided €15 million worth of surplus food to charitable organizations, enhancing food security for vulnerable populations and reducing food-related inequalities. To fully harness these benefits, policy frameworks shall prioritize a mutual approach that integrates the legislative framework with surplus prevention strategies and socio-technical innovations. Financial support for preventive measures (such as investments in predictive tools, demand forecasting technologies, and real-time monitoring systems) should be expanded to complement existing redistribution mechanisms. The SIR platform has demonstrated its capacity to mitigate economic and social impacts of market crises, streamline surplus management operations, and redistribute value to society through charitable organizations. Such evidence confirms the strategic role of digital and organizational innovations that enhance the widespread diffusion of socio-technical innovation while reinforcing both the prevention and redistribution actions claimed by the "Sustainable Food Management and

Innovation Hierarchy", optimizing the dual objectives of food security and waste minimization.

Policy recommendations lie in the requirement of aligning the European and national legislative framework with sustainability goals, as outlined in the Green Deal and the Farm to Fork Strategy. Financial incentives under the CMO regulation, including full coverage of redistribution costs for charitable purposes, are pivotal in motivating POs to engage in market withdrawal activities. However, administrative complexities and logistical burdens remain barriers to broader participation, suggesting a need for simplified procedures and greater structural support, especially for smaller POs. To this end, the hierarchical structure provided by the "Sustainable Food Management and Innovation Hierarchy" framework should guide policy prioritization: policy instruments should support top-tier interventions first (e.g., prevention), without neglecting the complementary roles of redistribution, recycling and valorisation. Furthermore, the findings advocate for a policy paradigm shift that prioritizes surplus prevention alongside redistribution. While the redistribution mechanisms have successfully reduced waste and enhanced food security for vulnerable populations, they primarily address symptoms rather than root causes of inefficiencies in the supply chain. Policy measures must therefore integrate preventive strategies with redistribution systems to foster long-term sustainability. This aligns with the innovation hierarchy, which explicitly ranks prevention as the most desirable outcome, indicating a need for policy redirection that reflects this prioritization through investment and regulatory alignment. Scaling up digital platforms like the SIR system across European Member States is essential to enhance governance efficiency, ensure equitable access for all supply chain actors, and foster harmonized implementation. Additionally, policies should emphasize the integration of redistribution mechanisms with charitable initiatives, strengthening food security for vulnerable populations while minimizing environmental impacts associated with food waste. Standardizing the integration of such platforms into national CAP and CMO operational programs, guided by a harmonized interpretation of the hierarchy, could significantly improve consistency and equity across Member States. By fostering stakeholder collaboration and leveraging digital tools, the study demonstrates that socio-technical innovations can maximize the impact of public spending. Policymakers are encouraged to expand the adoption of such platforms across Member States to replicate the demonstrated economic, social, and environmental benefits, ultimately advancing the transition toward sustainable food systems in the F&V sector. In conclusion, these policy

recommendations, grounded in the “Sustainable Food Management and Innovation Hierarchy” framework, advocate for a shift from fragmented and reactive interventions to strategic, coordinated, and hierarchical actions that embed socio-technical innovations as the core enablers of systemic change.

6.4 Limitations and further research

This thesis has provided valuable insights into the adoption and scaling of socio-technical innovations for food loss prevention and surplus management within the fruit and vegetable (F&V) supply chain. However, several limitations must be acknowledged to guide future research and enhance the applicability of the findings. The analysis of stakeholder perspectives in Chapter 3, while comprehensive, was limited to upstream actors within the Italian F&V value chain, potentially restricting the generalizability of the findings to other regions or sectors. Expanding future studies to include downstream stakeholders, such as retailers and consumers, across diverse geographic contexts could offer a more holistic understanding of socio-technical dynamics. The analysis reported in Chapter 4 using the duration analysis provided valuable insights into the adoption of redistribution technologies over a 10-year period but was constrained by its temporal scope, which did not account for long-term trends or evolving regulatory landscapes. Longitudinal studies addressing these gaps could illuminate the impact of emerging challenges, such as geopolitical crises or climate change, on innovation adoption. In Chapter 5, the focus on economic and social benefits of surplus management mechanisms left environmental impacts, such as carbon footprint reductions, underexplored. Incorporating life-cycle assessments or other environmental modelling approaches in future research would strengthen the empirical links between socio-technical innovations and sustainability goals. Additionally, the complexity of measuring co-innovation outcomes due to varying stakeholder priorities presents a challenge that future studies could address by developing standardized metrics or evaluation frameworks. Finally, while the findings highlight the potential of socio-technical innovations to align economic, social, and environmental objectives, barriers to scalability and policy integration remain significant, including fragmented governance structures and resistance from smaller-scale actors. Future research should explore mechanisms for enhancing scalability, such as public-private partnerships and adaptive policy frameworks, while also investigating consumer behaviour, market dynamics, and digital tools that can foster real-time collaboration. By addressing these limitations and pursuing these directions, future studies can contribute to the broader goal of building resilient, inclusive, and sustainable agri-food systems.

Summary

This thesis examines the transition toward sustainable fruit and vegetable systems, with a particular focus on food loss and waste prevention through the development of surplus management strategies within the European agri-food sector. The fruit and vegetable supply chain faces significant challenges related to inefficiencies, waste generation, and uneven resource distribution to fully achieve a sustainable transition. These inefficiencies are not only environmental and economic issues but also social concerns, as they intensify food insecurity and resource inequities. To address these challenges, this research employs a multi-method approach to analyse the interplay and dynamics of stakeholder behaviour, institutional frameworks, and socio-technical innovations. The study is structured into three core chapters, each exploring a critical dimension of the problem. The conceptual framework that ties the research chapters is the “Sustainable Food Management and Innovation Hierarchy framework”, an original structure which provides a structured basis for evaluating the prioritization, integration, and effectiveness of innovations and policies at different levels of intervention: prevention, redistribution, and recovery considering the different type of technologies that are at the core of socio-technical innovations.

Chapter 3 aims to analyse the cognitive and motivational factors influencing stakeholder decision-making in food loss prevention strategies. Using Q-methodology, the study identifies four stakeholder perspectives for addressing waste prevention and surplus management: (1) economic efficiency, prioritizing cost reductions and operational optimization; (2) environmental sustainability, emphasizing resource conservation and waste minimization; (3) social equity, focused on redistribution to support vulnerable populations; and (4) collaborative innovation, advocating for systemic changes through stakeholder cooperation. These perspectives reveal significant divergences in stakeholder priorities, which create barriers to co-innovation. The findings underscore that achieving agreement and alignment towards shared objectives is essential for fostering collaboration and designing inclusive strategies.

Chapter 4 assess the adoption dynamics of food redistribution technologies, focusing on the factors that influence their diffusion over a ten-year period. Using duration analysis methodology, the chapter evaluates the impact of both systemic barriers and enabling conditions that influenced the decision-making process of a sample of Italian producers' organization in the F&V sector. The results indicate that adoption rates are significantly influenced by external shocks, such as the COVID-19 pandemic and geopolitical crises,

which have highlighted the urgency of using the diffusion of digital solutions to mitigate the negative effect of crisis. However, barriers such as regulatory fragmentation and infrastructural disparities persist, particularly for smaller producers. On the other hand, localized investments and institutional support, exemplified by higher adoption rates in supportive regions, emerge as critical enablers. The chapter concludes that adaptive policy frameworks and regionalized strategies are crucial for overcoming structural challenges, enhancing the scalability and equity of redistribution technologies.

Chapter 5 evaluates the socio-economic and environmental impacts of surplus management mechanisms, using a case study of a digital redistribution platform to assess its effectiveness in enhancing operational efficiency and delivering social benefits. The study employs scenario-based methodologies to quantify the Net Social Value (NSV) generated by surplus redistribution activities and to assess how socio-technical innovations enhance the efficiency, equity, and sustainability of surplus management systems. The findings demonstrate the transformative potential of digital tools in addressing logistical inefficiencies, fostering equitable redistribution, and mitigating environmental impacts. However, challenges related to scalability and administrative complexity remain significant. The discussion emphasizes the importance of aligning policy frameworks with operational realities to maximize the impact of such innovations, highlighting their ability to integrate environmental, social, and economic objectives.

Together, the chapters of this thesis present a comprehensive framework for analysing and addressing systemic inefficiencies in the European fruit and vegetable sector. This thesis makes a contribution to the academic discourse on sustainability transitions by demonstrating how targeted interventions and innovative governance mechanisms can bridge the gap between policy objectives and practical implementation. By providing both theoretical insights and actionable recommendations, the research lays the groundwork for designing robust strategies that align economic, environmental, and social objectives. From an economic perspective, the evidence presented confirms the transformative potential of a well-coordinated policy and innovation ecosystem. Socio-technical solutions, when supported by inclusive governance and stakeholder cooperation, not only reduce inefficiencies but also generate measurable socio-economic and environmental value. The results emphasize that achieving sustainability in the agri-food sector requires a paradigm shift that prioritizes circular economy principles and equitable resource allocation as core components of future strategies. The “Sustainable Food Management and Innovation Hierarchy” provides the unifying structure through which these insights

are integrated and operationalized, offering a roadmap for prioritizing interventions and amplifying systemic impact. Finally, this thesis underscores the urgency of such transitions and provides a roadmap for policymakers, practitioners, and researchers to drive meaningful and lasting change in the fruit and vegetable supply chain.

References

- Addams, H., & Proops, J. (2000). *Social Discourse and Environmental Policy: An Application of Q Methodology*. Edward Elgar Publishing Limited
- Afif, K., Rebolledo, C., & Roy, J. (2022). Drivers, barriers and performance outcomes of sustainable packaging: a systematic literature review. *British Food Journal*, 124(3), 915–935. <https://doi.org/10.1108/BFJ-02-2021-0150>
- Al Zaabi, S., Al Dhaheri, N., & Diabat, A. (2013). Analysis of interaction between the barriers for the implementation of sustainable supply chain management. *The International Journal of Advanced Manufacturing Technology*, 68(1–4), 895–905. <https://doi.org/10.1007/s00170-013-4951-8>
- Albizzati, P. F., Tonini, D., Chammard, C. B., & Astrup, T. F. (2019). Valorisation of surplus food in the French retail sector: Environmental and economic impacts. *Waste Management*, 90, 141–151. <https://doi.org/10.1016/j.wasman.2019.04.034>
- Alcon, F., de Miguel, M. D., & Burton, M. (2011). Duration analysis of adoption of drip irrigation technology in southeastern Spain. *Technological Forecasting and Social Change*, 78(6), 991–1001. <https://doi.org/10.1016/j.techfore.2011.02.001>
- Alexander, C., & Smaje, C. (2008). Surplus retail food redistribution: An analysis of a third sector model. *Resources, Conservation and Recycling*, 52(11), 1290–1298.
- Al-Obadi, M., Ayad, H., Pokharel, S., & Ayari, M. A. (2022). Perspectives on food waste management: Prevention and social innovations. *Sustainable Production and Consumption*, 31, 190–208. <https://doi.org/10.1016/j.spc.2022.02.012>
- Aparicio, S., Urbano, D., & Audretsch, D. (2016). Institutional factors, opportunity entrepreneurship and economic growth: Panel data evidence. *Technological Forecasting and Social Change*, 102, 45–61. <https://doi.org/10.1016/j.techfore.2015.04.006>
- Aramyan, L., Grainger, M., Logatcheva, K., Piras, S., Setti, M., Stewart, G., & Vittuari, M. (2021). Food waste reduction in supply chains through innovations: a review. In *Measuring Business Excellence* (Vol. 25, Issue 4, pp. 475–492). Emerald Group Holdings Ltd.
- Avelino, F., Wittmayer, J. M., Pel, B., Weaver, P., Dumitru, A., Haxeltine, A., Kemp, R., Jørgensen, M. S., Bauler, T., Ruijsink, S., & O’Riordan, T. (2019). Transformative social innovation and (dis)empowerment. *Technological Forecasting and Social Change*, 145, 195–206. <https://doi.org/10.1016/j.techfore.2017.05.002>

- Avolio, G., Blasi, E., Cicatiello, C., & Franco, S. (2014). The drivers of innovation diffusion in agriculture: Evidence from Italian census data. *Journal on Chain and Network Science*, 14(3), 231–245. <https://doi.org/10.3920/JCNS2014.x009>
- Ayala, V., Caldwell, J. I., Garcia-Silva, B., Shah, D., Garcia, V., & Kuo, T. (2022). Increasing Surplus Food Redistribution to Improve Food Access Through a Partnership Between Public Health and a Technology-Based Company. *Journal of Health Care for the Poor and Underserved*, 33(4supp), 7–24.
- Barry, J., & Proops, J. (1999). Seeking sustainability discourses with Q methodology. *Ecological Economics*, 28(3), 337–345. [https://doi.org/10.1016/S0921-8009\(98\)00053-6](https://doi.org/10.1016/S0921-8009(98)00053-6)
- Batterink, M. H., Wubben, E. F. M., Klerkx, L., & Omta, S. W. F. (2010). Orchestrating innovation networks: The case of innovation brokers in the agri-food sector. *Entrepreneurship and Regional Development*, 22(1), 47–76. <https://doi.org/10.1080/08985620903220512>
- Bauer, F. (2018). Narratives of biorefinery innovation for the bioeconomy: Conflict, consensus or confusion? *Environmental Innovation and Societal Transitions*, 28, 96–107. <https://doi.org/10.1016/j.eist.2018.01.005>
- Bellemare, M. F. (2015). Rising food prices, food price volatility, and social unrest. *American Journal of Agricultural Economics*, 97(1), 1–21.
- Benyam, A. A., Soma, T., & Fraser, E. (2021). Digital agricultural technologies for food loss and waste prevention and reduction: Global trends, adoption opportunities and barriers. *Journal of Cleaner Production*, 323, 129099. <https://doi.org/10.1016/j.jclepro.2021.129099>
- Bilska, B., Wrzosek, M., Kołozyn-Krajewska, D., & Krajewski, K. (2016). Risk of food losses and potential of food recovery for social purposes. In *Waste Management* (Vol. 52, pp. 269–277). Elsevier Ltd.
- Bocken, N. M. P., Short, S. W., Rana, P., & Evans, S. (2014). A literature and practice review to develop sustainable business model archetypes. In *Journal of Cleaner Production* (Vol. 65, pp. 42–56).
- Bojnec, Š., & Ferto, I. (2008). European enlargement and agro-food trade. *Canadian Journal of Agricultural Economics*, 56(4), 563–579. <https://doi.org/10.1111/j.1744-7976.2008.00148.x>
- Bolwig, S., Tanner, A. N., Riemann, P., Redlingshöfer, B., & Zhang, Y. (2021). Reducing consumer food waste using green and digital technologies. UNEP DTU Partnership.

- Boons, F., Montalvo, C., Quist, J., & Wagner, M. (2013). Sustainable innovation, business models and economic performance: An overview. *Journal of Cleaner Production*, 45, 1–8. <https://doi.org/10.1016/j.jclepro.2012.08.013>
- Bossle, M. B., Dutra De Barcellos, M., Vieira, L. M., & Sauvé, L. (2016). The drivers for adoption of eco-innovation. *Journal of Cleaner Production*, 113, 861–872. <https://doi.org/10.1016/j.jclepro.2015.11.033>
- Brown, S. R. (1993c). A Primer on Q Methodology. *Operant Subjectivity*, 16(3/4). <https://doi.org/10.22488/okstate.93.100504>
- Brown, S. R. (1996). Q Methodology and Qualitative Research. *Qualitative Health Research*, 6(4), 561–567. <https://doi.org/10.1177/104973239600600408>
- Brown, S. R., Steven R., & Stephenson, W. (1980). *Political subjectivity: applications of Q methodology in political science*. Yale University Press.
- Bruxelles, 22.1.2024 COM(2024) 12 final Annexes 1 to 2 allegati della relazione della commissione al parlamento europeo e al consiglio il ricorso alle misure di crisi adottate a norma degli articoli da 219 a 222 del regolamento OCM
- Bryngelsson, D., Wirsenius, S., Hedenus, F., & Sonesson, U. (2016). How can the EU climate targets be met? A combined analysis of technological and demand-side changes in food and agriculture. *Food Policy*, 59, 152–164. <https://doi.org/10.1016/j.foodpol.2015.12.012>
- Burton, M., Rigby, D., & Young, T. (2003). Modelling the adoption of organic horticultural technology in the UK using duration analysis. *Australian Journal of Agricultural and Resource Economics*, 47(1), 29–54. <https://doi.org/10.1111/1467-8489.00202>
- C.R. Doss (2006). Analyzing technology adoption using microstudies: limitations, challenges, and opportunities for improvement, *Agric. Econ.* 34 (3), pp. 207–219.
- Caldeira, C., De Laurentiis, V., Corrado, S., van Holsteijn, F., & Sala, S. (2019). Quantification of food waste per product group along the food supply chain in the European Union: a mass flow analysis. *Resources, Conservation and Recycling*, 149, 479–488. <https://doi.org/10.1016/j.resconrec.2019.06.011>
- Camanzi, L., Malorgio, G., & Azcárate, T. G. (2011). The role of producer Organizations in supply concentration and marketing: A comparison between European countries in the fruit and vegetable sector. *Journal of Food Products Marketing*, 17(2–3), 327–354.
- Canali, M., Amani, P., Aramyan, L., Gheoldus, M., Moates, G., Östergren, K., Silvennoinen, K., Waldron, K., & Vittuari, M. (2017). Food waste drivers in Europe, from identification to possible interventions. *Sustainability (Switzerland)*, 9(1).

- Casson, A., Ferrazzi, G., Guidetti, R., Bellettini, C., Narote, A. D., Rollini, M., Piccardo, A., Volturo, E., Cosentino, M., & Limbo, S. (2024). Wholesale fruit and vegetable market in Milan: Turning food surpluses into environmental gains. *Journal of Cleaner Production*, 462. <https://doi.org/10.1016/j.jclepro.2024.142625>
- Ciccullo, F., Cagliano, R., Bartezzaghi, G., & Perego, A. (2021). Implementing the circular economy paradigm in the agri-food supply chain: The role of food waste prevention technologies. *Resources, Conservation and Recycling*, 164, 105-114. <https://doi.org/10.1016/j.resconrec.2020.105114>
- Coppola, A., & Ianuario, S. (2017). Environmental and social sustainability in Producer Organizations' strategies. *British Food Journal*, 119(8), 1732–1747. <https://doi.org/10.1108/BFJ-11-2016-0553>
- Cuppen, E. (2012). Diversity and constructive conflict in stakeholder dialogue: Considerations for design and methods. *Policy Sciences*, 45(1), 23–46. <https://doi.org/10.1007/s11077-011-9141-7>
- D'Amato, D., Droste, N., Winkler, K. J., & Toppinen, A. (2019). Thinking green, circular or bio: Eliciting researchers' perspectives on a sustainable economy with Q method. *Journal of Cleaner Production*, 230, 460–476. <https://doi.org/10.1016/j.jclepro.2019.05.099>
- D'Emden, F. H., Llewellyn, R. S., & Burton, M. P. (2006). Adoption of conservation tillage in Australian cropping regions: An application of duration analysis. *Technological Forecasting and Social Change*, 73(6), 630–647. <https://doi.org/10.1016/j.techfore.2005.07.003>
- De Jong, B., Boysen-Urban, K., & Fricko, O. (2023). Assessing the economic, social and environmental impacts of food waste reduction targets. Publications of the European Commission. Retrieved from <https://publications.jrc.ec.europa.eu/repository/bitstream/JRC133971/JRC13397101.pdf>
- de Laurentiis, V., Caldeira, C., & Sala, S. (2020). No time to waste: assessing the performance of food waste prevention actions. *Resources, Conservation and Recycling*, 161.
- de Souza, M.; Pereira, G.M.; Lopes de Sousa Jabbour, A.B.; Chiappetta Jabbour, C.J.; Trento, L.R.; Borchardt, M.; Zvirtes, L. A (2021). Digitally Enabled Circular Economy for Mitigating Food Waste: Understanding Innovative Marketing Strategies in the Context of an Emerging Economy. *Technol. Forecast. Soc. Change*, Vol. 173, n. 121062
- Deloitte (2014). Comparative Study on EU Member States. Legislation and Practices on Food Donation. Available at <
https://www.eesc.europa.eu/sites/default/files/resources/docs/comparative-study-on-eu-member-states-legislation-and-practices-on-food-donation_finalreport_010714.pdf>

- Diaz-Ruiz, R., Costa-Font, M., López-i-Gelats, F., & Gil, J. M. (2019). Food waste prevention along the food supply chain: A multi-actor approach to identify effective solutions. *Resources, Conservation and Recycling*, 149, 249–260. <https://doi.org/10.1016/j.resconrec.2019.05.031>
- Dieteren, C. M., Patty, N. J. S., Reckers-Droog, V. T., & van Exel, J. (2023). Methodological choices in applications of Q methodology: A systematic literature review. *Social Sciences and Humanities Open*, 7(1), 100404. <https://doi.org/10.1016/j.ssaho.2023.100404>
- Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives (Text with EEA relevance). Official Journal of the European Union. <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32008L0098>
- Doukidis, G. I., Matopoulos, A., Vlachopoulou, M., Manthou, V., & Manos, B. (2007). A conceptual framework for supply chain collaboration: Empirical evidence from the agri-food industry. *Supply Chain Management: An International Journal*, 12(3), 177–186. <https://doi.org/10.1108/13598540710742491>
- Dumont, A. M., Gasselin, P., & Baret, P. V [P. V.] (2020). Transitions in agriculture: Three frameworks highlighting coexistence between a new agroecological configuration and an old, organic and conventional configuration of vegetable production in Wallonia (Belgium). *Geoforum*, 108, 98–109. <https://doi.org/10.1016/j.geoforum.2019.11.018>
- E.M. Rogers, *Diffusion of Innovations*, V ed New York, 2003.
- Esposito, B., Sessa, M. R., Sica, D., & Malandrino, O. (2020). Towards circular economy in the agri-food sector. A systematic literature review. In *Sustainability (Switzerland)* (Vol. 12, Issue 18). MDPI. <https://doi.org/10.3390/SU12187401>
- European Commission (2014) Report from the commission to the european parliament and the council on the implementation of the provisions concerning producer organisations, operational funds and operational programmes in the fruit and vegetables sector since the 2007 reform, Brussels, COM (2014) 112 final
- European Commission (2023, November). EU Platform on Food Losses and Food Waste. Recommendations for Action in Food Waste Prevention. (2023). Retrieved from: https://food.ec.europa.eu/safety/food-waste/eu-actions-against-food-waste/eu-platform-food-losses-and-food-waste_en.
- European Commission (2023, November). *EU Platform on Food Losses and Food Waste. Recommendations for Action in Food Waste Prevention*. (2023). Retrieved from: https://food.ec.europa.eu/safety/food-waste/eu-actions-against-food-waste/eu-platform-food-losses-and-food-waste_en

- European Commission, Directorate-General for Research and Innovation (2023), Bizzo, G., Lledó San Mauro, F., Lueth, D. et al., Food 2030: Green and resilient food systems - conference outcome report, 4-5 December 2023, Brussels, Bizzo, G.(editor), Lledó San Mauro, F.(editor), Lueth, D.(editor), Lutzeyer, H.(editor), Luvarà, G.(editor), Meloni, G.(editor), Molina Villanueva, J.(editor), Pellegrino, G.(editor), Scalia, R.(editor), Schoumacher, C.(editor), Publications Office of the European Union, 2024, <https://data.europa.eu/doi/10.2777/959042>
- European Commission. (2018). Evaluation of the Impact of the Common Market Organisation for Fruit and Vegetables. European Commission Staff Working Document COM(2018) 370 final. Retrieved from <https://eur-lex.europa.eu>
- European Commission. (2019). The European Green Deal (COM(2019) 640 final)
- Falkowski, J., & Chlebicka, A. (2021). What product mix do they offer and what marketing channels do they use? – Exploring agricultural producer organisations’ heterogeneity. *Journal of Rural Studies*, 85, 1–12. <https://doi.org/10.1016/j.jrurstud.2021.05.002>
- Feder, G., & Umali, D. L. (1993). The Adoption of Agricultural Innovations A Review. In *Technological forecasting and social change* (Vol. 43).
- Finizia Antonella, & Manfredi Gabriella. (2024). Indicatori Ismea-Metodologia. Available at: <https://www.ismea.it/flex/files/D.333e12bb3982b42b5cac/Metodologia_indici_prezzi_all_origine.pdf>
- Food and Agriculture Organization of the United Nations (2019). The state of food and agriculture 2019: Moving forward on food loss and waste reduction. Rome, CC BY-NC-SA 3.0 IGO.
- Franco, S., & Cicatiello, C. (2021). Levering waste taxes to increase surplus food redistribution at supermarkets: Gains and scenarios in Italian municipalities. *Waste Management*, 131, 1–9.
- Frijters, P., Haisken-DeNew, J. P., & Shields, M. A. (2011). The increasingly mixed proportional hazard model: An application to socioeconomic status, health shocks, and mortality. *Journal of Business and Economic Statistics*, 29(2), 271–281. <https://doi.org/10.1198/jbes.2010.08082>
- G. Feder, R.E. Just, D. Zilberman, Adoption of agricultural innovations in developing countries: a survey, *Econ. Dev. Cult. Change* 33 (2) (1985) 255–298.
- G. Green, D. Sunding (1997). Land allocation, soil quality, and the demand for irrigation technology, *J. Agric. Res. Econ.* 22 (2), pp. 367–375.

- Galli, F., Cavicchi, A., & Brunori, G. (2019). Food waste reduction and food poverty alleviation: A system dynamics conceptual model. *Agriculture and Human Values*.
- García Azcárate, T. (2018). Research for AGRI Committee – The sectoral approach in the CAP beyond 2020 and possible options to improve the EU food value chain. European Parliament Publication.
- Garrone, P., Melacini, M., & Perego, A. (2014). Opening the black box of food waste reduction. *Food Policy*, 46, 129–139. <https://doi.org/10.1016/j.foodpol.2014.03.014>
- Geels, F. W. (2019). Socio-technical transitions to sustainability: a review of criticisms and elaborations of the Multi-Level Perspective. *Current Opinion in Environmental Sustainability*, 39, 187–201. <https://doi.org/10.1016/j.cosust.2019.06.009>
- Georghiou, L., Edler, J., Uyarra, E., & Yeow, J. (2014). Policy instruments for public procurement of innovation: Choice, design and assessment. *Technological Forecasting and Social Change*, 86, 1–12. <https://doi.org/10.1016/j.techfore.2013.09.018>
- Ghisellini, P., & Ulgiati, S. (2020). Circular economy transition in Italy. Achievements, perspectives and constraints. *Journal of Cleaner Production*, 243, 118360. <https://doi.org/10.1016/j.jclepro.2019.118360>
- Grimm, J. H., Hofstetter, J. S., & Sarkis, J. (2014). Critical factors for sub-supplier management: A sustainable food supply chains perspective. *International Journal of Production Economics*, 152, 159–173. <https://doi.org/10.1016/j.ijpe.2013.12.011>
- Gupta, H.; Kumar, S.; Yadav, D.; Verma, O.P.; Sharma, T.K.; Ahn, C.W.; Lee, J.-H. (2021). Data Analytics and Mathematical Modeling for Simulating the Dynamics of COVID-19 Epidemic—A Case Study of India. *Electronics*, 10, 127. <https://doi.org/10.3390/electronics10020127>
- Gustavsson, J., Cederberg, C., Sonesson, U., van Otterdijk, R., Meybeck, A., 2011. Global Food Losses and Food Waste - Extent, Causes and Prevention. FAO, Rome.
- Gutiérrez, J. A., & Macken-Walsh, Á. (2022). Ecosystems of Collaboration for Sustainability-Oriented Innovation: The Importance of Values in the Agri-Food Value-Chain. *Sustainability (Switzerland)*, 14(18), 11205. <https://doi.org/10.3390/su141811205>
- Gutiérrez, J. A., & Macken-Walsh, Á. (2022). Ecosystems of Collaboration for Sustainability-Oriented Innovation: The Importance of Values in the Agri-Food Value-Chain. *Sustainability (Switzerland)*, 14(18). <https://doi.org/10.3390/su141811205>

- H.M. Souza Filho, T. Young, M.P. Burton (1999). Factors influencing the adoption of sustainable agricultural technologies: evidence from the State of Espirito Santo, Brazil, *Technol. Forecast. Soc. Change* 60 (2) 97–112.
- Herzberg, R., Schneider, F., & Banse, M. (2023). Policy instruments to reduce food loss prior to retail – Perspectives of fruit and vegetable supply chain actors in Europe. *Waste Management*, 170, 354–365. <https://doi.org/10.1016/j.wasman.2023.09.019>
- Hosmer, D. W., Lemeshow, S., & May, S. (2008). *Applied Survival Analysis: Regression Modeling of Time-to-Event Data*. Wiley-Interscience.
- Howells, J. (2006). Intermediation and the role of intermediaries in innovation. *Research Policy*, 35(5), 715–728. <https://doi.org/10.1016/j.respol.2006.03.005>
- Iñigo, E. A., & Albareda, L. (2016). Understanding sustainable innovation as a complex adaptive system: A systemic approach to the firm. In *Journal of Cleaner Production*, 126, 1–20. <https://doi.org/10.1016/j.jclepro.2016.03.036>
- Iofrida, N., De Luca, A. I., Gulisano, G., & Strano, A. (2018). An application of Q-methodology to Mediterranean olive production – stakeholders’ understanding of sustainability issues. *Agricultural Systems*, 162, 46–55. <https://doi.org/10.1016/j.agsy.2018.01.020>
- Ishangulyyev, R., Kim, S., & Lee, S. H. (2019). Understanding food loss and waste-why are we losing and wasting food? *Foods*, 8(8), 297. <https://doi.org/10.3390/foods8080297>
- ISMEA, 2021, *L'Italia e la Pac post 2020: Contributo all'analisi di contesto e all'individuazione delle esigenze del settore Ortofrutta*
- Jaitiang, D., Luther, G. C., Tung, S. J., & Takagi, C. (2022). Agricultural stakeholders’ priorities using Q method for initiation of an innovation platform in Nan, Thailand. *Journal of Public Health and Development*, 20(2), 196–213. <https://doi.org/10.55131/jphd/2022/200215>
- Jenkins, S.P. (1995). Easy estimation methods for discrete-time duration models. *Oxford Bulletin of Economics and Statistics* 57 (1): 129-138.
- Kalbfleisch, J. D., & Prentice, R. L. (2002). *The Statistical Analysis of Failure Time Data*. Wiley-Interscience.
- Kauffman, R. J., Techatassanasoontorn, A. A., & Wang, B. (2012). Event history, spatial analysis and count data methods for empirical research in information systems. *Information Technology and Management*, 13(3), 115–147. <https://doi.org/10.1007/s10799-011-0106-5>

- Kim, S. H., & Park, H. J. (2011). Effects of social influence on consumers' voluntary adoption of innovations prompted by others. *Journal of Business Research*, 64(11), 1190–1194. <https://doi.org/10.1016/j.jbusres.2011.06.021>
- Kleinbaum, D. G., & Klein, M. (2012). *Survival Analysis: A Self-Learning Text*. Springer.
- Klewitz, J., & Hansen, E. G. (2014). Sustainability-oriented innovation of SMEs: A systematic review. *Journal of Cleaner Production*, 65, 57–75. <https://doi.org/10.1016/j.jclepro.2013.07.017>
- Knickel, M., Neuberger, S., Klerkx, L., Knickel, K., Brunori, G., & Saatkamp, H. (2021). Strengthening the role of academic institutions and innovation brokers in agri-food innovation: Towards hybridisation in cross-border cooperation. *Sustainability (Switzerland)*, 13(9), 4899. <https://doi.org/10.3390/su13094899>
- Krishnan, R., Yen, P., Agarwal, R., Arshinder, K., & Bajada, C. (2021). Collaborative innovation and sustainability in the food supply chain- evidence from farmer producer organisations. *Resources, Conservation and Recycling*, 168, 105253. <https://doi.org/10.1016/j.resconrec.2020.105253>
- Lemaire, A., & Limbourg, S. (2019). How can food loss and waste management achieve sustainable development goals? *Journal of Cleaner Production*, 234, 1221–1234. <https://doi.org/10.1016/j.jclepro.2019.06.226>
- Loučanová, E., Paluš, H., & Dzian, M. (2017). A course of innovations in wood processing industry within the forestry-wood chain in Slovakia: A Q methodology study to identify future orientation in the sector. *Forests*, 8(6), 210. <https://doi.org/10.3390/f8060210>
- Lowe, P., Phillipson, J., & Lee, R. P. (2008). Socio-technical innovation for sustainable food chains: roles for social science. *Trends in Food Science & Technology*, 19(5), 226-233
- M. Caswell, E. Lichtenberg, D. Zilberman (1990). The effects of pricing policies on water conservation and drainage, *Am. J. Agric. Econ.* 72 (4) 883–890.
- Magalhães, V. S. M., Ferreira, L. M. D. F., & Silva, C. (2022). Prioritising food loss and waste mitigation strategies in the fruit and vegetable supply chain: A multi-criteria approach. *Sustainable Production and Consumption*, 31, 569–581. <https://doi.org/10.1016/j.spc.2022.03.022>
- Manda, J., Khonje, M. G., Alene, A. D., Tufa, A. H., Abdoulaye, T., Mutenje, M., Setimela, P., & Manyong, V. (2020). Does cooperative membership increase and accelerate agricultural technology adoption? Empirical evidence from Zambia. *Technological Forecasting and Social Change*, 158. <https://doi.org/10.1016/j.techfore.2020.120160>

- Mandolesi, S., Nicholas, P., Naspetti, S., & Zanoli, R. (2015). Identifying viewpoints on innovation in low-input and organic dairy supply chains: A Q-methodological study. *Food Policy*, 54, 25–34. <https://doi.org/10.1016/j.foodpol.2015.04.008>
- Matzembacher, D. E., Vieira, L. M., & de Barcellos, M. D. (2021). An analysis of multi-stakeholder initiatives to reduce food loss and waste in an emerging country – Brazil. *Industrial Marketing Management*, 93, 591–604. <https://doi.org/10.1016/j.indmarman.2020.08.016>
- McEldowney, J., 2016. The Russian Ban on Agricultural Products.
- Ménard, C. (2014). Embedding organizational arrangements: Towards a general model, *Journal of Institutional Economics*, 10(4), pp. 567-589.
- Menard, C., & Valceschini, E. (2005). New institutions for governing the agri-food industry. *European Review of Agricultural Economics*, 32(3), 421–440.
- Meyer, B.D. (1990). Unemployment insurance and unemployment spells. *Econometrica* 58 (4): 757-782.
- Midgley, J. L. (2014). The logics of surplus food redistribution. *Journal of Environmental Planning and Management*, 57(12), 1872–1892. <https://doi.org/10.1080/09640568.2013.848192>
- Midgley, J. L. (2014). The logics of surplus food redistribution. *Journal of Environmental Planning and Management*, 57(12), 1872–1892.
- Mourad, M. (2016). Recycling, recovering and preventing “food waste”: Competing solutions for food systems sustainability in the United States and France. *Journal of Cleaner Production*, 126, 461–477. <https://doi.org/10.1016/j.jclepro.2016.03.084>
- Mylona, K., Maragkoudakis, P., Miko, L., Bock, A. K., Wollgast, J., Caldeira, S., & Ulberth, F. (2018). Viewpoint: Future of food safety and nutrition - Seeking win-wins, coping with trade-offs. *Food Policy*, 74, 143–146. <https://doi.org/10.1016/j.foodpol.2017.12.002>
- Naspetti, S., Lampkin, N., Nicholas, P., & Zanoli, R. (2009). Organic supply chain collaboration: a case study in eight EU Countries. *Journal of Food Production Marketing*, 17, 141-162. <https://doi.org/10.1080/10454446.2011.548733>
- Nasso, M., Blasi, E., Pezzoli, F., & Cicatiello, C. (2024). Investigating Co-Innovation strategies to prevent food loss in the fruits and vegetables sector. *Journal of Cleaner Production*, 467.
- Nicholas, P. K., Mandolesi, S., Naspetti, S., & Zanoli, R. (2014). Innovations in low input and organic dairy supply chains-What is acceptable in Europe? *Journal of Dairy Science*, 97(2), 1157–1167. <https://doi.org/10.3168/jds.2013-7314>

- Notarnicola, B., Tassielli, G., Renzulli, P. A., Castellani, V., & Sala, S. (2017). Environmental impacts of food consumption in Europe. *Journal of Cleaner Production*, 140, 753–765. <https://doi.org/10.1016/j.jclepro.2016.06.080>
- Organisation for Economic Co-operation and Development (2018). Oslo Manual 2018 - The Measurement of Scientific, Technological and Innovation Activities. <https://doi.org/10.1787/9789264304604-en>
- Pancino, B., Blasi, E., Rappoldt, A., Pascucci, S., Ruini, L., & Ronchi, C. (2019). Partnering for sustainability in agri-food supply chains: the case of Barilla Sustainable Farming in the Po Valley. *Agricultural and Food Economics*, 7(1). <https://doi.org/10.1186/s40100-019-0133-9>
- Papargyropoulou, E., Fearnough, K., Spring, C., & Antal, L. (2022). The future of surplus food redistribution in the UK: Reimagining a ‘win-win’ scenario. *Food Policy*, 108.
- Papargyropoulou, E., Lozano, R., K. Steinberger, J., Wright, N., & Ujang, Z. bin. (2014). The food waste hierarchy as a framework for the management of food surplus and food waste. *Journal of Cleaner Production*, 76, 106–115. <https://doi.org/10.1016/j.jclepro.2014.04.020>
- Pérez-Mesa, J. C., Serrano-Arcos, M. M., Jiménez-Guerrero, J. F., & Sánchez-Fernández, R. (2021). Addressing the location problem of a perishables redistribution center in the middle of Europe. *Foods*, 10(5). <https://doi.org/10.3390/foods10051091>
- Pietrangeli, R., Eriksson, M., Strotmann, C., Cicatiello, C., Nasso, M., Fanelli, L., Melaragni, L., & Blasi, E. (2023b). Quantification and economic assessment of surplus bread in Italian small-scale bakeries: An explorative study. *Waste Management*, 169, 301–309. <https://doi.org/10.1016/j.wasman.2023.07.017>
- Pietrangeli, R., Herzberg, R., Cicatiello, C., & Schneider, F. (2023a). Quality Standards and Contractual Terms Affecting Food Losses: The Perspective of Producer Organisations in Germany and Italy. *Foods*, 12(10), 1984. <https://doi.org/10.3390/foods12101984>
- Porter, S. D., Reay, D. S., Bomberg, E., & Higgins, P. (2018). Production-phase greenhouse gas emissions arising from deliberate withdrawal and destruction of fresh fruit and vegetables under the EU’s Common Agricultural Policy. *Science of the Total Environment*, 631–632, 1544–1552.
- Porter, S.D., Reay, D.S., (2016). Addressing food supply chain and consumption inefficiencies: potential for climate change mitigation. *Reg. Environ. Chang.* 16:2279–2290.
- Prentice, R. and Gloeckler L. (1978). Regression analysis of grouped survival data with application to breast cancer data. *Biometrics* 34: 57-67.

- Principato, L., Trevisan, C., Formentini, M., Secondi, L., Comis, C., & Pratesi, C. A. (2023). The influence of sustainability and digitalisation on business model innovation: The case of a multi-sided platform for food surplus redistribution. *Industrial Marketing Management*, 115, 156–171.
- Raak, N., Symmank, C., Zahn, S., Aschemann-Witzel, J., & Röhm, H. (2017). Processing- and product-related causes for food waste and implications for the food supply chain. *Waste Management*, 61, 461–472.
- Regulation (EU) No 1308/2013 of the European Parliament and of the Council of 17 December 2013 establishing a common organisation of the markets in agricultural products and repealing Council Regulations (EEC) No 922/72, (EEC) No 234/79, (EC) No 1037/2001 and (EC) No 1234/2007
- Reina-Usuga, L., de Haro-Giménez, T., & Parra-López, C. (2020). Food governance in Territorial Short Food Supply Chains: Different narratives and strategies from Colombia and Spain. *Journal of Rural Studies*, 75, 237–247. <https://doi.org/10.1016/j.jrurstud.2020.02.005>
- Salunkhe, D. K., & Wu, M. T. (1974). Developments in technology of storage and handling of fresh fruits and vegetables. *Critical Reviews in Food Technology*, 5(1), 15–54. <https://doi.org/10.1080/10408397409527170>
- Samoggia, A., Monticone, F., & Esposito, G. (2022). Governance in the Italian Processed Tomato Value Chain: The Case for an Interbranch Organisation. *Sustainability (Switzerland)*, 14(5). <https://doi.org/10.3390/su14052749>
- Scalvedi, M. L., & Rossi, L. (2019). L' osservatorio sulle eccedenze, sui recuperi e sugli sprechi alimentari Ricognizione delle misure in Italia e proposte di sviluppo Rapporto della prima annualità forestali e del turismo. CREA - Centro di Ricerca Alimenti e Nutrizione
- Schanes, K., Dobernig, K., & Gözet, B. (2018). Food waste matters - A systematic review of household food waste practices and their policy implications. *Journal of Cleaner Production*, 182, 978–991. <https://doi.org/10.1016/j.jclepro.2018.02.030>
- Schipmann, C., & Qaim, M. (2010). Spillovers from modern supply chains to traditional markets: Product innovation and adoption by smallholders. *Agricultural Economics*, 41(3–4), 361–371. <https://doi.org/10.1111/j.1574-0862.2010.00438.x>
- Smith, B. G. (2008). Developing sustainable food supply chains. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 363(1492), 849–861. <https://doi.org/10.1098/rstb.2007.2187>
- Sneegas, G., Beckner, S., Brannstrom, C., Jepson, W., Lee, K., & Seghezzo, L. (2021). Using Q-methodology in environmental sustainability research: A bibliometric analysis and

systematic review. *Ecological Economics*, 180, 106864.
<https://doi.org/10.1016/j.ecolecon.2020.106864>

- Solano Hermosilla, G., Antonioli, F., Ciaian, P., Pinedo Gil, J. and Fernandez Casal, L., Adoption of sustainability innovations by operators in the EU food supply chain, Publications Office of the European Union, Luxembourg, 2023, doi:10.2760/010598, JRC133931.
- Alcon, F., de Miguel, M. D., & Burton, M. (2011). Duration analysis of adoption of drip irrigation technology in southeastern Spain. *Technological Forecasting and Social Change*, 78(6), 991–1001. <https://doi.org/10.1016/j.techfore.2011.02.001>
- Spring, C. A., & Biddulph, R. (2020). Capturing waste or capturing innovation? Comparing self-organising potentials of surplus food redistribution initiatives to prevent food waste. *Sustainability (Switzerland)*, 12(10).
- Stewart, J.M. (2001). The impact of health status on the duration of unemployment spells and the implications for studies of the impact of unemployment on health status, *Journal of Health Economics*, 20(5), pp. 781-796. 10.1016/S0167-6296(01)00087-X
- Sundin, N., Bartek, L., Persson Osowski, C., Strid, I., & Eriksson, M. (2023). Sustainability assessment of surplus food donation: A transfer system generating environmental, economic, and social values. *Sustainable Production and Consumption*, 38, 41–54. <https://doi.org/10.1016/j.spc.2023.03.022>
- Surucu-Balci, E., & Tuna, O. (2022). The role of collaboration in tackling food loss and waste: Salient stakeholder perspective. *Journal of Cleaner Production*, 367, 133126. <https://doi.org/10.1016/j.jclepro.2022.133126>
- Taylor, D. H., & Fearne, A. (2009). Demand management in fresh food value chains: A framework for analysis and improvement. *Supply Chain Management*, 14(5), 379–392.
- Teigiserova, D. A., Hamelin, L., & Thomsen, M. (2020). Towards transparent valorization of food surplus, waste and loss: Clarifying definitions, food waste hierarchy, and role in the circular economy. *Science of the Total Environment*, 706, 136033. <https://doi.org/10.1016/j.scitotenv.2019.136033>
- Thyberg, K. L., & Tonjes, D. J. (2016). Drivers of food waste and their implications for sustainable policy development. *Resources, Conservation and Recycling*, 106, 110–123. Elsevier. <https://doi.org/10.1016/j.resconrec.2015.11.016>
- Tirivayi, N., Nennen, L., Tesfaye, W., & Ma, Q. (2018). The benefits of collective action: Exploring the role of forest producer organizations in social protection. *Forest Policy and Economics*, 90, 106–114. <https://doi.org/10.1016/j.forpol.2018.01.010>

- Tort, Ö. Ö., Vayvay, Ö., & Çobanoğlu, E. (2022). A Systematic Review of Sustainable Fresh Fruit and Vegetable Supply Chains. *Sustainability* (Switzerland), 14(3), 1573. <https://doi.org/10.3390/su14031573>
- Trotter, P. A., Becker, T., Renaldi, R., Wang, X., Khosla, R., & Walther, G. (2023). The role of supply chains for the sustainability transformation of global food systems: A large-scale, systematic review of food cold chains. *Journal of Industrial Ecology*, 27(6), 1429–1446. <https://doi.org/10.1111/jiec.13445>
- Van Den Berg G (2001). Chapter 55 - Duration Models: Specification, Identification and Multiple Durations, Editor(s): James J. Heckman, Edward Leamer, *Handbook of Econometrics*, Elsevier, Volume 5, Pages 3381-3460, ISSN 1573-4412, ISBN 9780444823403, [https://doi.org/10.1016/S1573-4412\(01\)05008-5](https://doi.org/10.1016/S1573-4412(01)05008-5).
- van Oorschot, J. A. W. H., Hofman, E., & Halman, J. I. M. (2018). A bibliometric review of the innovation adoption literature. *Technological Forecasting and Social Change*, 134, 1–21. <https://doi.org/10.1016/j.techfore.2018.04.032>
- Velázquez, B., & Buffaria, B. (2017). About farmers' bargaining power within the new CAP. *Agricultural and Food Economics*, 5(1).
- Vellema, S., & Van Wijk, J. (2015). Partnerships intervening in global food chains: The emergence of co-creation in standard-setting and certification. *Journal of Cleaner Production*, 107, 105–113. <https://doi.org/10.1016/j.jclepro.2014.03.090>
- Vermunt, D. A., Negro, S. O [S. O.], van Laerhoven, F., Verweij, P. A., & Hekkert, M. P [M. P.] (2020). Sustainability transitions in the agri-food sector: How ecology affects transition dynamics. *Environmental Innovation and Societal Transitions*, 36, 236–249. <https://doi.org/10.1016/j.eist.2020.06.003>.
- Vittuari, M., de Menna, F., Gaiani, S., Falasconi, L., Politano, A., Dietershagen, J., & Segrè, A. (2017). The second life of food: An assessment of the social impact of food redistribution activities in Emilia Romagna, Italy. *Sustainability* (Switzerland), 9(10). <https://doi.org/10.3390/su9101817>
- Watts, S., Stenner, P., 2012. *Doing Q Methodological Research: Theory, Method and Interpretation*. London, Sage.
- Webler, T., & Danielson, S. (2009). *Using Q Method to Reveal Social Perspectives in Environmental Research*. www.seri-us.org
- Wesseler, J. (2022). The EU's farm-to-fork strategy: An assessment from the perspective of agricultural economics. *Applied Economic Perspectives and Policy*.

- Wooldridge, J. M. (2012). *Introductory Econometrics: A Modern Approach*. South-Western, Cengage Learning.
- Zabala, A., Pascual, U., & García-Barrios, L. (2017). Payments for Pioneers? Revisiting the Role of External Rewards for Sustainable Innovation under Heterogeneous Motivations. *Ecological Economics*, 135, 234–245. <https://doi.org/10.1016/j.ecolecon.2017.01.011>
- Zhao, G., Liu, S., Wang, Y., Lopez, C., Ong, A., & Chen, X. (2023). Reducing food waste from social innovation perspective: a review of measures, research gaps and future directions. In *International Food and Agribusiness Management Review* (Vol. 26, Issue 2, pp. 199–223). Wageningen Academic Publishers. <https://doi.org/10.22434/IFAMR2022.0006>

*Quant'è bella giovinezza che si fugge tuttavia! Chi vuole esser lieto, sia, di doman non c'è
certezza.*