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Ecosystem Interactions and the Integration of Sustainability-Oriented Technological Innovation

An exploratory study of how interactions between actors shape and impact the adoption of sustainability-oriented technological innovation in an innovation ecosystem: a case study on the Swedish agri-food system

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Abstract

This thesis contributes to the understanding of sustainability-oriented technological innovation (SOTI) by applying an innovation ecosystem perspective. The aim is to explore how interactions between actors shape SOTI and how these interactions enable or constrain adoption in practice. To address this purpose, a qualitative case study was conducted within the Swedish agri-food innovation ecosystem, with particular attention to the integration of biotechnology-related solutions in agricultural practice. Empirical data was collected through semi-structured interviews with actors across the ecosystem, including primary producers, biotechnology firms, innovation support actors, intermediaries, and institutional actors.

The findings suggest that SOTI is shaped not only by the characteristics of the technology itself, but also by the interaction dynamics between ecosystem actors. Economic feasibility, trust and legitimacy, regulatory conditions, compatibility with farm practices, sustainability expectations, and market needs all influence whether innovation can move from development toward practical adoption. The study further shows that primary producers play a central role in this process, as they represent the point at which technological innovation must become usable, valuable, and compatible with everyday operations. Overall, this thesis argues that the successful integration of SOTI depends on the ecosystem's ability to create alignment between technological possibilities, economic realities, institutional conditions, and practical farm-level needs.

Keywords: Sustainability-Oriented Innovation, Technological Innovation, Innovation Ecosystem, Business Ecosystems, Ecosystem Interactions, Biotechnology, Innovation Adoption

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Abbreviation	**Reference**
SOI	Sustainability-Oriented Innovation
SOTI	Sustainability-Oriented Technological Innovation

1. Introduction

1.1 Background

Global agriculture plays a major role in feeding an increasing population that could reach 11 billion people by 2100 (United Nations Population Division, 2019), while simultaneously facing growing pressure to reduce its environmental impact (OECD, n.d.; P. K. Dubey et al., 2019). At the core of this challenge is primary production, which refers to “the production of basic material or crops” (Cambridge Dictionary, n.d.). Within this context, sustainable agriculture has emerged as an important objective and is defined as “farming in such a way as to protect the environment, expand natural resources, and make efficient use of nonrenewable resources” (USDA, n.d.).

Feed production, which provides nutrient-dense inputs for livestock and poultry, is critical for agricultural systems, but remains heavily dependent on imported inputs such as soy. This dependency raises concerns related to land degradation, deforestation, and broader sustainability challenges (Semper-Pascual et al., 2019; Andretta et al., 2021; Song et al., 2021). While the EU is partly self-sufficient, only 41% of feed protein is sourced locally (European Commission, 2024).

In response to these challenges, innovation, particularly technological innovation, has become an important mechanism for improving both productivity and sustainability within agricultural systems. Within this broader context, biotechnology and biosolutions can be understood as examples of technological innovation that may allow farms to enhance production quality and quantity while improving sustainability and self-sufficiency (FAO, n.d.; Dionglay, 2021; Das et al., 2023). Biotechnology refers to the use of biological systems, organisms, or processes to develop products and technologies (NTNU, n.d.), while biosolutions include applications such as bacteria, enzymes, fermentation, and fungi that can replace fossil-based inputs (Ministry of Foreign Affairs of Denmark, n.d.). However, biotechnology and biosolutions are not treated as the sole focus of this thesis. Rather, they provide an example of the wider category of sustainability-oriented technological innovation (SOTI) in agriculture.

Indeed, biotechnology can be linked to Sustainability-Oriented Innovation (SOI), as it aims to produce social and environmental value alongside economic returns (Adams et al., 2016; Government of the Netherlands, n.d.). It is also linked to technological innovation, which refers to a more iterative process that uses technology and science for innovation in production, development, and consumption (Rees, 2026; Scherer, 2001; Kline and Rosenberg, 1986). These developments illustrate how technological innovation is increasingly positioned as a response to sustainability challenges within agriculture, while biotechnology and biosolutions serve as one relevant example of this broader transition.

At the national level, Sweden is aiming to reduce agri-food emissions by 45% by 2050. This transition is expected to involve a shift toward a more circular and resilient food system value chain in order to improve food security and resilience to climate instability (Explore Sweden, 2025). Solutions to enable this transition include improvements in processing and manufacturing, such as circular technologies for feed and alternative protein sources.

However, the development and implementation of these solutions involve multiple actors across the agri-food system, including primary producers, firms, intermediaries, and institutional actors, whose activities and decisions are interdependent. As a result, the adoption of such innovations is not only shaped by their technical characteristics, but also by how these actors interact and coordinate across the system. Despite this potential, actors within the Swedish agri-food system remain hesitant toward biotechnology adoption due to concerns related to sustainability, uncertainty, and implementation challenges (Björnberg et al., 2015; Market Research Community, 2025). This highlights the challenges of translating technological innovation into practice.

1.2 Problematization

While new technologies in agricultural production present many opportunities for improving sustainability, efficiency and resilience, their implementation and adoption remain complex and uneven. Integrating technological innovation into agricultural systems requires changes not only at the technological level, but also in organizational routines, capabilities, and relationships across the value chain. It also requires alignment and coordination between multiple interdependent actors within the broader agri-food innovation system. In this context, two interconnected domains can be identified: the broader innovation ecosystem, where technologies are developed, and the agricultural value chain, where they are ultimately applied in practice. For innovation to be successfully implemented, these two domains must be connected and aligned. However, existing research has primarily focused on the technical and environmental benefits of such innovations. While innovation ecosystems and SOI have been examined separately, less attention has been given to how interactions between actors shape the adoption of SOTI.

This highlights a broader gap in understanding how technological innovation moves from development to adoption, particularly in contexts where actors differ significantly in knowledge, capabilities, and incentives. In sectors such as agriculture, where many actors are non-technical and operate within established routines, the adoption of new and potentially complex technologies may require coordination and alignment across multiple actors and levels. The interactions between actors shape how knowledge is shared, how technologies are interpreted, and how adoption decisions are made. In other words, innovation is not only the result of technological development, but also of interaction processes through which actors exchange resources, information, knowledge, and support.

In the context of our case study of the Swedish agri-food system, primary producers play a critical role in determining whether innovations are ultimately adopted, yet they are often not fully integrated into the innovation process. As a result, innovations that appear promising from a technical or environmental perspective may fail to translate into practice. Therefore, there is a need to better understand how interactions within innovation ecosystems shape SOTI, with a particular focus on how these interactions enable or constrain the adoption and integration of new innovations in practice.

1.3 Research Question and Purpose

The purpose of this thesis is to explore how interactions between actors shape SOTI within ecosystems. Additionally, the study seeks to understand how these interactions influence the adoption of innovation in practice.

As outlined in the literature, innovation is increasingly understood as a systemic and iterative process that extends beyond the boundaries of the firm and involves multiple actors. This is especially evident in the case of technological innovation, in which processes are shaped by interactions between technical, market, and institutional factors. Furthermore, SOI has been shown to emerge through system-level changes and coordinated activities across actors and sectors.

Building on this, an ecosystem perspective provides a useful framework for understanding how innovation emerges through interdependent actors. This requires co-evolving relationships, as well as the alignment of roles and activities. While existing literature highlights the importance of ecosystems in enabling value creation, less attention has been given to how ecosystem interactions between actors shape the adoption of innovation in practice.

Therefore, this study aims to address this research gap by examining how interaction dynamics influence innovation, and how they translate into real-world adoption. In order to fill this gap, we ask the following research question:

RQ: How do ecosystem interactions shape sustainability-oriented technological innovation?
Sub RQ: How do these interactions enable or constrain the adoption of innovation?

To address these questions, a qualitative multiple embedded case study will be conducted, examining interactions between actors within the Swedish agri-food innovation ecosystem. The research approach and actor selection will be further discussed in the methodology section.

1.4 Thesis Outline

Following the introduction, Chapter 2 reviews the literature relevant to sustainability-oriented technological innovation and innovation ecosystems. The chapter begins by discussing innovation as a broader concept and then narrows the focus to technological innovation and sustainability-oriented innovation. The chapter then introduces the ecosystem perspective, focusing on innovation ecosystems, actor roles, interdependencies, co-evolution, and ecosystem interactions. The literature review concludes with a theoretical synthesis, research gap, and a preliminary framework.

Chapter 3 presents the methodology of the study. This chapter motivates the qualitative case study design and explains the selection of the Swedish agri-food innovation ecosystem as the empirical case. It further defines the unit of analysis as the interactions between actors, rather than the actors themselves. Finally, it outlines the sampling strategy, data collection process using semi-structured interviews, data recording, transcription, thematic analysis, validity, reliability, ethical considerations, and the use of AI in the research process.

Chapter 4 presents the empirical findings. The chapter begins by introducing the empirical setting and describing the partner firm and case context. The findings are then structured around the main themes identified through the analysis, including economic feasibility, trust and legitimacy, ecosystem enablers and constraints, compatibility with farm practices, sustainability as both a driver and a tension, regulatory dynamics, and market needs as drivers of innovation.

Chapter 5 discusses the findings in relation to the literature and preliminary framework. It explains how ecosystem interactions shape sustainability-oriented technological innovation and how these interactions enable or constrain adoption in practice.

Finally, Chapter 6 concludes the thesis by answering the research question and summarizing the study's main findings.

2. Literature Review

This section reviews and discusses the existing literature and theories related to the proposed topic. In particular, an overview of innovation and ecosystems is discussed. In order to ensure breadth and depth, the literature review of these topics was conducted across different fields (Webster & Watson, 2002).

Following approaches to a literature review laid out by Bryman and Bell (2011) and Creswell and Creswell (2018), research was identified based on its connection to our topic, articles were reviewed in terms of credibility and relevance, and more recent contemporary contributions were added to complement older, more widely-cited research; finally, the selected research was critically discussed and structured thematically according to our chosen research topic.

2.1 Theoretical Foundations of Innovation

This section aims to develop an understanding of innovation by gradually narrowing its scope. It begins with a broad overview of innovation as a general concept, before focusing more specifically on technological innovation as a distinct form of innovation. Finally, the section introduces sustainability-oriented innovation (SOI), which extends technological innovation by incorporating environmental and societal considerations.

Together, these perspectives show that innovation cannot be understood as an isolated technological or firm-level process, but instead it emerges through the coordination and interactions of multiple interdependent actors. This provides the foundation for the following section on ecosystems, which offers a framework for understanding how such actors, relationships, and interdependencies shape innovation processes.

2.1.1 Innovation

Today, innovation is often associated with progress and technological advancement, and it is often viewed as a key driver of economic development, competitiveness, and productivity. In response to the new industrial revolution of the twenty-first century characterized by rapid technological transformation, firms continuously search for ways to innovate, and governments increasingly view innovation as a crucial policy objective for achieving economic growth and societal progress (Godin, 2016; Ross and Maynard, 2021). However, historically the term "innovation" did not always have a positive connotation. Prior to the twentieth century, innovation had nothing to do with creativity nor technology, but rather a negative and politically charged term used to describe changes perceived as threatening the established order, often likened to heresy or disruption (Godin, 2016).

The meaning of innovation began to shift during the nineteenth and twentieth centuries, as it became associated with industrialization and scientific progress (Godin, 2016). Early conceptualizations of innovation trace back to sociological theory, such as that of Gabriel Tarde. Tarde viewed innovation as social progress driven by the introduction of new ideas and subsequently their diffusion through imitation (Tarde, 1903).

Joseph Schumpeter, one of the most influential economists of the early twentieth century, conceptualized innovation as the introduction of "new combinations" that transform production processes and market structures (Schumpeter, 1934). According to Schumpeter (1942), innovation is imperative for firms to remain competitive during the cyclical process of "creative destruction," in which innovation displaces established firms and continuously reshapes economic structures. Under this view, innovation is closely linked with economic development. Similarly, Kogabayev and Maziliauskas (2017) define innovation as the "core action for the development and productivity of any economic activity." Johnston (1966) also emphasizes innovation's role in economic transformation by describing it as "the introduction of new and improved processes and products into the economy."

A key contribution of Schumpeter's work is the distinction between invention and innovation. He argued that invention refers to the creation of new ideas, while innovation involves their application and commercialization in the market (Schumpeter, 1934). Building upon Schumpeter's idea, Kahn (2018) argues that a mere invention does not equate to innovation; instead, innovation refers to an invention which has been successfully delivered to the market. Despite the fact that product innovation is perhaps most visible and therefore what commonly comes to mind when discussing innovation, Kahn (2018) identifies multiple forms of innovation outcomes, including *process, product, marketing, business model, supply chain,* and *organizational innovation*.

Chandler (2021) further connects innovation to business by positioning for-profit firms as being uniquely capable of transforming scarce resources into valuable services and products, and in doing so, as being uniquely capable of innovation. However, Chandler makes it clear that there is an interdependent relationship between business and society, as each business decision involves morals, ethics, and values (Chandler, 2021). Moreover, innovation does not occur spontaneously, but rather emerges from sources both inside and outside of the firm. Drucker (2002) outlines seven sources of innovation opportunities: *unexpected occurrences, incongruities, process needs, industry/market changes, demographic changes, changes in perception,* and *new knowledge.* This more holistic view is reflected in modern literature on innovation, which conceptualizes it as interdisciplinary, including social, behavioral, and institutional dimensions (Fagerberg, Mowery and Nelson, 2005).

Table 1: *Evolution of the Concept of Innovation*

Conceptual Stage	Conceptualization of Innovation	Source
Early View	Negative, disruptive, politically charged; associated with threats to the established order	Godin (2016)
Industrial Perspective	Associated with scientific progress and industrialization	Godin (2016)
Sociological Perspective	Social progress driven by the introduction of new ideas and their diffusion through imitation	Tarde (1903)
Schumpeterian Perspective	"New combinations" transforming production and driving economic development through creative destruction	Schumpeter (1934, 1942)
Economic and Process-Oriented View	Introduction of new and improved products and processes contributing to economic development	Johnston (1966); Kogabayev & Maziliauskas (2017)
Application	Innovation as the application and successful	Schumpeter (1934);

Perspective	commercialization of inventions	Kahn (2018)
Contemporary Interdisciplinary Perspective	Multidisciplinary, involving economic, social, behavioral, and institutional dimensions; innovation emerging from multiple internal and external sources	Fagerberg et al. (2005); Drucker (2002)

As shown in Table 1, the evolution of the concept of innovation shows a gradual shift from viewing innovation as a discrete outcome or firm-level activity toward understanding it as a broader, interactive, and multidimensional process. This contemporary perspective is particularly relevant for this thesis, as it suggests that innovation cannot be fully understood by focusing only on the firm or the technology itself. Instead, innovation is shaped by relationships between actors, the exchange of knowledge and resources, and the institutional and market conditions in which it takes place.

2.1.2 Technological Innovation

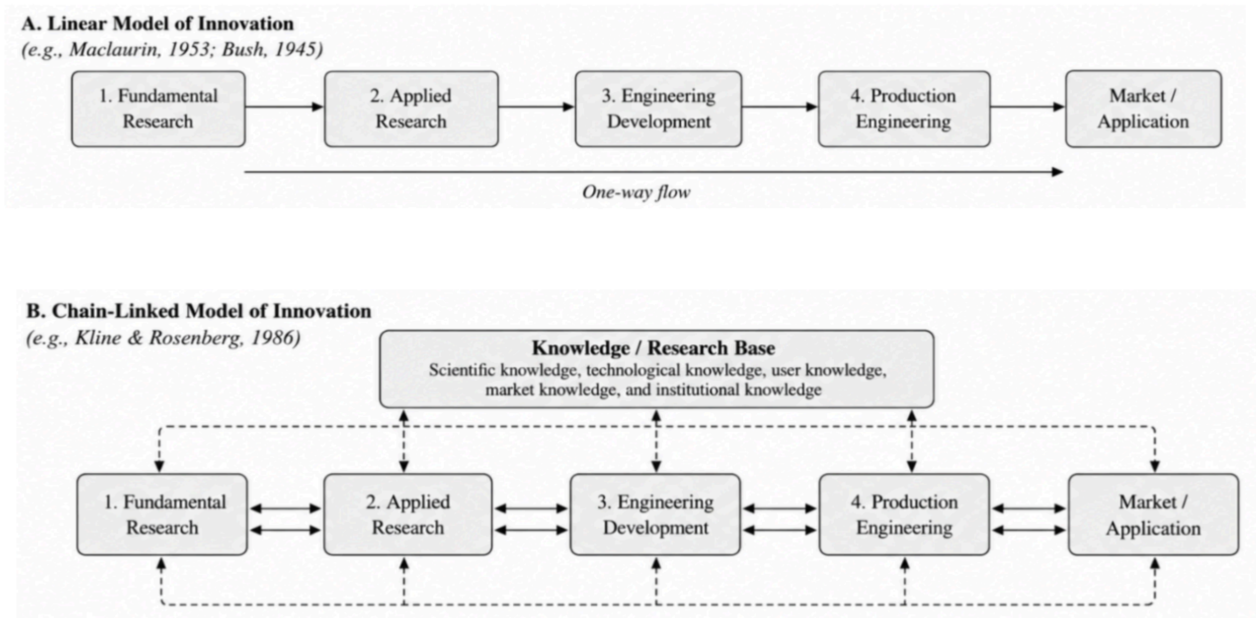
As a theoretical concept, the term "technological innovation" emerged after World War II as a way to specifically stress the application of technology (Godin, 2016). Rupert William Maclaurin, an economist at MIT, was one of the first to study the *factors* responsible for the rate of technological change, as well as the *conditions* required for technological development, within industries (Godin, 2008).

Building on Schumpeter's work, Maclaurin developed the first model of the process of technological innovation, which included four distinct stages: *fundamental research, applied research, engineering development, and production engineering* (Godin, 2008). This linear model of innovation is also reflected by Bush (1945), who states that scientific research is the starting point of innovation and application is the end point.

However, Kline and Rosenberg (1986) argued that "models that depict innovation as a smooth, well-behaved linear process badly misspecify the nature and direction of the causal factors at work." They argue that economists often view technological innovation as a "black box" of unknown internal processes (Kline and Rosenberg, 1986). On the other side of the equation, Kline and Rosenberg (1986) argue that technologists often focus too narrowly on the technical processes inside of the “black box” and thus ignore the role of market pressures and institutional factors that are required to successfully commercialize the technology.

Therefore, technological innovation is increasingly viewed as an iterative process. One such example is the “chain linked model” proposed by Kline and Rosenberg (1986), which conceptualizes innovation as a multi-directional process which connects multiple actors and feedback loops between multiple stages of research, development, and adoption. This is also shown in Figure 1, where the chain-linked model is contrasted with the linear model by emphasizing feedback loops between stages of innovation and the role of shared knowledge. This highlights that innovation depends not only on scientific and technological advances, but also on the coordination and interactions between technology developers, market demands, adopting actors, and the organizational and institutional structures that support, regulate, and shape the innovation process. For this reason, technological innovation cannot be fully understood within the boundaries of an individual firm, but instead requires a perspective that accounts for these interdependencies between multiple actors involved in the innovation process.

Figure 1: *Linear versus Chain-Linked Model of Technological Innovation Process*

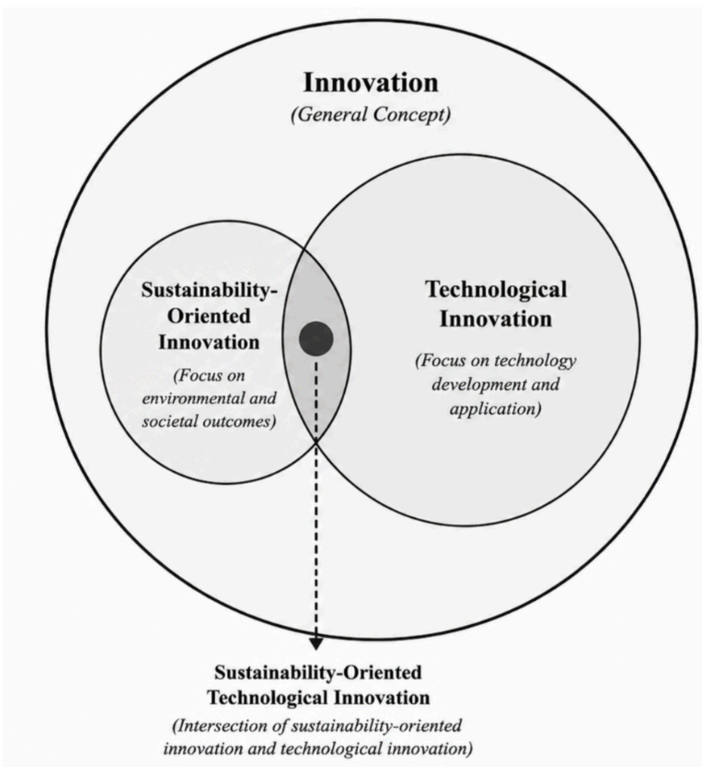


2.1.3 Sustainability-Oriented Innovation

As previously mentioned, there are many opportunities which may drive innovation, such as new technology or information, changing demographics, and market or process needs (Drucker, 2002). One such opportunity emerges from sustainability. Nidumolu, Prahalad, and Rangaswami (2009) call sustainability the new "key driver of innovation." According to Hart and Milstein (1999), sustainability represents a discontinuity which creates a new competitive landscape. Because of this, sustainability can be seen as a driver of creative destruction (Schumpeter, 1934). Therefore, rather than being viewed only as a constraint or compliance requirement, sustainability can also be understood as a source of innovation.

This shift from sustainability as an external pressure to sustainability as a source of innovation is commonly discussed through the concept of sustainability-oriented innovation (SOI). SOI refers to intentional changes in an organization's values, products, processes or practices that aim to create social and environmental value in addition to economic returns (Adams et al., 2016). While innovation represents the broader umbrella concept, this thesis focuses specifically on the overlap between technological innovation and SOI. This overlap is referred to here as sustainability-oriented technological innovation (SOTI), as illustrated in Figure 2. In this thesis, SOTI is therefore understood as technological innovation directed toward sustainability-related challenges.

Figure 2: *Sustainability-Oriented Technological Innovation*



As sustainability comes to the forefront, some firms will lose advantage as sustainability acts as a competency-destroying disruption; however, other firms will gain advantage as sustainability allows their existing strengths to become more valuable (Hart and Milstein, 1999). As these changes take place, innovators can view sustainability as an opportunity, rather than merely a constraint (Hart and Milstein, 1999).

This view is further developed by Nidumolu, Prahalad, and Rangaswami (2009), who argue that sustainability is the new frontier of innovation. They present five stages of SOI: *viewing compliance as an opportunity*, *making value chains sustainable*, *designing sustainable products and services*, *developing new business models*, and *creating next-practice platforms* (Nidumolu, Prahalad, and Rangaswami, 2009).

Adams et al. (2016) also present stages of SOI, which evolve from incremental compliance to systemic change. First, *operational optimization* involves reactive compliance and efficiency related to internal, technical innovations; this is often discussed as the starting point for innovation activity (Adams et al, 2016). Second, *organizational transformation* represents a cultural and strategic shift towards sustainability, involving the firm and its immediate stakeholders (Adams et al., 2016). Finally, the final stage is *systems building*, which includes systemic, cross-sectoral change at a societal level (Adams et al., 2016). Within this framework, the mechanisms of change are *strategy, process, learning, linkages*, and *organization* (Adams et al., 2016).

In line with this, Seebode, Jeanrenaud, and Bessant (2012) present a framework for managing innovation for sustainability. First, the "exploit" zone involves creating efficiency by using existing capabilities to make incremental sustainable improvements to cut costs or comply with regulations. The second zone is technology-driven and explores sustainable opportunities within the current boundaries of the firm. The third zone requires a change of perspective, as the company positions sustainability as core to its value and mission. In the fourth and final zone, firms and partners jointly transform markets, industries, and systems by "co-creating sustainable ecosystems." Reaching this level of co-creation of sustainable ecosystems requires systemic thinking, collaboration, learning, leadership vision, and culture change (Seebode, Jeanrenaud, and Bessant (2012). Potential barriers which can hinder co-creation of sustainable ecosystems include short-term profit pressures, siloed innovation which lacks collaboration, and resistance to change.

2.1.4 Linking Sustainability-Oriented Technological Innovation to Ecosystems

The preceding sections show that innovation has gradually moved from being understood as a linear and firm-centered process toward being understood as interactive, iterative, and shaped by multiple actors and sources of knowledge (Drucker, 2002; Kline and Rosenberg, 1986; Fagerberg, Mowery and Nelson, 2005). This shift is particularly important for SOTI, which combines technological innovation's emphasis on science and technology with SOI's focus on environmental, social, and economic value creation (Adams et al., 2016). These perspectives suggest that SOTI is shaped not only by technical development, but also by the wider conditions which enable or constrain its adoption.

For this reason, SOTI cannot be fully understood within the boundaries of a single organization. Since SOI can move beyond operational optimization and organizational transformation toward systems building, advanced sustainability innovation often requires firms and partners to jointly transform markets, industries, and systems through the co-creation of sustainable ecosystems (Adams et al., 2016; Seebode, Jeanrenaud, and Bessant, 2012). This suggests that SOTI depends not only on internal firm capabilities, but also on knowledge, learning, resources, and relationships that are distributed across the wider system in which the firm operates.

Therefore, the literature on innovation, technological innovation, and SOI points toward the need for an ecosystem perspective. SOTI is not only about developing a technical solution, but also about understanding how actors interact, exchange knowledge, share resources, manage risks, and align their activities around sustainability-related challenges. The following section therefore turns to the ecosystem literature, which provides a framework for understanding how actors, roles, relationships, and interdependencies shape innovation beyond organizational boundaries.

2.2 Ecosystems

2.2.1 Definition and Origins of the Ecosystem Concept

The concept of ecosystem was initially derived from biology and “describes the co-evolution of interdependent species, particularly in response to fundamental changes” (Moore, 1996). This term has evolved into “business ecosystem” which gained in popularity through Moore’s article and refers to "economic community supported by a foundation of interacting organizations and individuals" (Moore, 1996). Adner et al. (2017) share two views , ecosystem-as-affiliation which refers “to communities of associated actors defined by their networks and platform affiliations” and ecosystem as structure, viewing ecosystems as “configurations of activity defined by a value proposition”.

Business ecosystems definitions vary but remain within: interrelations between different actors who depend on each other and create value (Moore, 1996; Iansiti and Levien 2004; Sarafin, 2016; Jacobides et al. 2018). According to these authors, the business ecosystem would include multiple actors linked to each other and dependant on each other to create different type of value together : economic, service product (Moore, 1996; Iansiti and Levien, 2004; Sarafin, 2016; Jacobides et al. 2018, Teece, 2007).

Grandstrand and Holgersson (2020) compared definitions around innovation ecosystem and propose the following : “An innovation ecosystem is the evolving set of actors, activities, and artifacts, and the institutions and relations, including complementary and substitute relations, that are important for the innovative performance of an actor or a population of actors.”

Ecosystem definitions encompass different types of actors creating value and also highlight different aspects of the network such as roles, economic output, alignment and relationships that are evolving with time (Iansiti and Levien, 2004; Adner et al. 2017; Moore, 1996; Friedl, 2025) .

According to Gomes et al. (2018) and Valkokari (2015), the business ecosystem and innovation ecosystem can be distinguished.

2.2.2 The Innovation Ecosystem: Actors and Roles

Business ecosystem and Innovation ecosystem are two different concepts according to Valkokari (2015). Gomes et al. (2018) mention that value creation would refer to the innovation ecosystem while value capture would refer to the business ecosystem : “Business ecosystem relates mainly to value capture, while innovation ecosystem relates mainly to value creation.”. However, the business ecosystem is part of the innovation ecosystem according to Thomas and Autio (2020). Friedl (2025) is defining the innovation ecosystem as follows: “Innovation ecosystems are dynamic networks where universities, businesses, startups, and governments collaborate to fuel technological advancements, entrepreneurship, and economic growth”. Grandstrand and Holgersson(2020) compared definitions around innovation ecosystem and propose the following : “An innovation ecosystem is the evolving set of actors, activities, and artifacts, and the institutions and relations, including complementary and substitute relations, that are important for the innovative performance of an actor or a population of actors.” Friedl (2025) and Grandstrand and Holgersson (2020) both refer to an evolving group of actors creating innovation together through their relationship, collaboration and capabilities.

By defining the innovation ecosystem, Friedl (2025) is mentioning different actors such as “universities, businesses, startups, and governments”, to which Carayannis and Campbell (2009) add non government organizations. Other stakeholders related to the companies in the ecosystem can be added : customer, suppliers, institution, organizations etc (Moore, 1996; Iansiti and Levien, 2004; Sarafin, 2016; Jacobides et al. 2018, Teece, 2007; Sarafin, 2016).
Summarizing the entities of an innovation ecosystem, Gomes et al. (2021), refer to the actor definition of Adner (2017, p.43): “the entities that undertake activities”. The set of actors includes suppliers, deliverers, components, complementors, developers, technologies, support organizations, and customers (Dedehayir et al., 2018, as cited in Gomes et al. 2021). These actors include the upstream participants such as component suppliers and downstream participants such as the complementors, product developers .

Ecosystems actors have different, evolving relationships and roles and work together to cocreate technological/innovation value (Carayannis and Campbell, 2009). According to Sarafin (2016), actors in this ecosystem can be orchestrators and or participants in relation to actor roles in the value creation. Dedehayir et al. (2018), in a comparative study, decided to look into the different roles and activities that are present in the innovation ecosystem. The author divided the actors' role into four groups: "leadership roles ('ecosystem leader' and 'dominator'), direct value creation roles ('supplier', 'assembler', 'complementor', and 'user'), value creation support roles ('expert' and 'champion'), and entrepreneurial ecosystem roles ('entrepreneur', 'sponsor', and 'regulator')". Indeed, Dedehayir et al. (2018) and Sarafin (2016) both mention leader/orchestrator roles, which underlines the existence of central actors.

Dedehayir et al. (2018) examines the role of a central "ecosystem leader" at the origin of the innovation ecosystems and important for value creation. This central actor has an important role in the creation of the ecosystem and can be labelled as "ecosystem leader" (Iansiti and Livien, 2004; Cusumano, 2002; Iyer et al. 2006; Dedehayir et al. 2018). Indeed the leaders can also be referred to as "hub" or "keystone" firms, who provide stability and knowledge in the network (Iansiti and Livien 2004; Dhanaraj and Parkhe, 2006).

The leaders' activities fall into 4 categories, according to Dedehayir et al. (2018), governance, forging partnership, platform and value management. The value creation roles are: the supplier, assembler, complementor and user. Concerning the value support roles, the authors define the expert (generating the knowledge, sharing its expertise and enabling technology transfer) and the champion (building connection between actors and enabling access to local/ non local market). The entrepreneur ecosystem roles are the following, entrepreneur (start a new business, set up the network of actors involved and coordinate relationship between research and commercialization actors), the sponsor (responsible to provide resources and financing markets, codevelop products and linking entrepreneur to different actors) and the regulator (supporting entrepreneurial activities and fostering emergence of innovation ecosystem with political reform and regulations). These roles and modalities can change and evolve over time according to Dedehayir et al. 2018; Carayannis and Campbell, 2009; Roshani, 2025).

2.2.3 Interdependencies and Co-evolution

While there are different actors and roles present in an innovation ecosystem, the interrelation and interdependence needs to be understood. Jacobides et al. (2018), stated that modularity is needed for an ecosystem to function. The governance structure of the ecosystem influences actors' interactions and how they create value. Centralized ecosystems rely on dominant actors to coordinate, while decentralized ones allow more autonomous dynamics (Halinen and Törnroos, 2005). While some central firms control the ecosystem development by aligning stakeholders and ensuring strategic coherence, orchestrators manage interdependencies and foster collaboration among participants according to Gastaldi and Corso, 2016.

Different types of ecosystems change the roles of actors and interaction dynamic: centralized ecosystems, which rely on dominant actors driving activities and collaboration and decentralized ecosystems which allow autonomous and dynamic interactions (Halinen and Törnroos, 2005). In addition to this, Grandstrand and Holgersson, (2020), mention the possibility that, by creating innovation, it could be harmful for some of the actors if it could act as a substitution effect, in contrast with complementary effect. Indeed the evolution of an innovation ecosystem includes “collaborative/complementary and competitive/substitute relations” (Grandstrand and Holgersson, 2020; Adner and Kapoor, 2009). Yoon et al. (2022) established a description of the different relationship in a symbiosis, which is referred as “a relationship between participants such as prey and predator, can be interpreted as value creation and capture of symbionts” (Moore, 1993).

There are 3 types of relationships, Mutualism, Commensalism and Parasitism. In Mutualism the actors strengthen their benefits and depend on each other for their survival, evolve together and enable value co-creation. Commensalism is described as one actor benefiting the other, while the other remains unaffected (can be observed between competitors) with a value that partially overlaps. Parasitism is referred to as one actor (parasite) benefitting while the other is being harmed (Yoon et al., 2022), which is linked to Grandstrand and Holgersson (2020) harmful ecosystem effect on some actors.

Ecosystems are also referred to as “networks”, according to D’Oliveira et al. (2017). These networks are composed of internal and external relationships (which enable more openness for innovation) according to Yan et al. (2020).

In their research, Thomas and Autio (2020), identified four characteristics that ecosystems have in common. The first is participants heterogeneity, where actors are often coming from different sectors and industries which links to the “multilateral set of partners" mentioned by Adner (2017). The second characteristic is Ecosystem output, referring to the different actors co-creating product and service to fit audience preference (Thomas and Autio, 2020). The third characteristic is participant interdependence. The fourth characteristic is technological interdependence and refers to the multiple actors operating within the ecosystem that exhibit co-specialization, generally shaped around a common platform or a modular architecture according to Thomas and Autio (2020).

The output from the ecosystem characterised by technological interdependence are made of components that are modular and that suppliers (who are connected together) provide. There is also a final component that is the integration choice and process made by the customer (Thomas and Autio, 2020; Autio; Jacobides et al., 2018).

According to Thomas and Autio (2020), there are other types of interdependence such as economics that refers to the value earned by each participant member of this ecosystem which depend on the compatible offerings of these actors together. It can be an economy of scope or scale and depend on external actors. (Thomas and Autio, 2020). The authors also mention cognitive interdependence which refers to shared belief and identity that link different actors with different expertise and maintain them aligned which is similar to Moore (1996), purposeful and aligned ecosystem. The last characteristic given by Thomas and Autio (2020), is that ecosystems have a non governance structure where roles are not always defined by contract. Thomas and Autio (2020), suggest that governance is non contractual and is made by aligning and managing the strategic interests of the ecosystem actors and enabling mutual trust to manage shared resources.

These interdependencies and co-evolution can either benefit one or multiple actors but it can also have no or a negative impact on other actors of the same ecosystem.

2.2.4 Ecosystem Interactions

Business interaction can be defined as: " a confrontation process that occurs between companies and which changes and transforms aspects of the resources and activities of the involved companies and of the companies themselves." and as "a process that takes place over time and where time is embedded into the process in several ways" (Ford et al. 2008). These interactions have 3 layers (activities, actors and resources) and 2 dimensions (time and space) according to (Ford et al. 2008). The 3 layers come from the ARA model, originated by (Håkansson and Johanson, 1992), which explains the outcomes of interactions through three layers: actor bonds, resource ties, and activity links. The actor part is about the bonds between actors and reflects the direction of the interaction, the activity is referring to the integration and coordination of activities that may arise between actors. The resource layer refers to how adapted and tied together the resource (tangible and/or intangible) are over time (Håkansson and Johanson, 1992; Ford et al. 2008).

While the ARA model presents the structural framework for understanding these layers, the actual content of these interactions can be explained by specific exchange elements. Håkansson (1982), in *International Marketing and Purchasing of Industrial Goods*, describes and categorizes these interactions into 4 elements. The first element, product of service exchange is core to the relationship with need and resources that shape the relationship. The second one, information exchange that can be technical, economic, or organizational and that shapes the exchange and relational understanding. This exchange can be done in an impersonal or personal way and can be more or less in depth. The third element is the financial exchange, with the quantity of money reflecting the economic relevance of the relationship. The social exchange is the last element, it reduces the uncertainty of two entities and is necessary between two transactions and participation in the trust building process. Valkokari et al. (2016) argue that innovation ecosystems are dynamic environments where the continuous interactions and actions of participants actively shape and build the co-created innovation. In this context, actors use resources to build and manage activities that happen in a broader network. These interactions are spatio-temporal with past experiences enabling actors to interpret current dynamics and ultimately, shape the direction of future purpose and interactions (Ford et al. 2008; Ngongoni, 2021).

According to Håkansson and Johanson (1992), interactions can also lead to conflict: "Yet interaction does not necessarily lead to co-operation; it can lead to conflict, and a barrier to interaction can be identified where one company fears the unreasonable exercise of power by another." Interactions represent a complex, dynamic process of social and technical exchange that are characterised by interdependence, trust and diverse types of interaction (commercial, high collaboration, hostile relationship etc). Barriers to interaction could arise because of environmental and market structure misalignment and instability, resources constraints and negative ROI of the interaction but also cultural/ social distance, agents (preventing direct interaction), technical and status incompatibility and mismatch and expectations and performance on new comers (Cunningham, 1982 in Håkansson (1982)). To simplify the barriers could be Internal (resource constraints, ROI) and "External/Relational (social distance, status mismatch).

The interaction process has aspects of: "Learning and teaching are present in interaction processes and this makes them useful parameters for evaluating any interaction by an actor" (Pucci et al. 2008). These learning/teaching outcomes are necessary for the knowledge transfer which leads to a potential innovation (Pucci et al. 2008). Indeed, also Valkokari et al. (2016) mention that: "The joint process before creation of the actual artefact (i.e., the innovation ecosystem) forms a key stage in which the translation of knowledge between research and practice occurs." which links back to Pucci et al. (2008) argument. This argument is also justified by Castaneda & Cuellar (2020) who mention that innovation occurs when there is knowledge sharing. (Pucci et al. 2008) framed the interaction between actors, population, communities or ecosystem. The central firm, depending on his fit with the other actors in its ecosystem will learn/teach (internal and external to the ecosystem), it will result in either parasitism (focal firm learns and does not teach to the ecosystem is belongs because of its competitivity), symbiosis (balanced learning/teaching by focal firm) and commensalism (focal firm learn and teach its ecosystem), which is linked to Yoon et al. (2022) and Grandstrand and Holgersson (2020) relationship types.

To summarize, according to Hakan Håkansson (1982), there are four types of interactions: product/service, information (technical, economic and organizational), financial, and social exchange. These interactions reflect the different layers of interdependence mentioned by Thomas and Autio (2020), where social trust and economic ties enable a more cohesive ecosystem. Collaboration is necessary for innovation, as it is enabled by knowledge transfer and can influence the firm's performance in the ecosystem (Granstrand and Holgersson, 2020; Valkokari et al., 2016; Pucci et al., 2008). While basic collaboration supports technology advancement, sustainable success depends on evolving from simple transactional exchanges into complex, mutualistic relationships. Eventually, these interaction dynamics provide the mechanism for heterogeneous actors to align their resources and activities, jointly creating systemic sustainable value rather than isolated firm-level gain (Hakan Håkansson, 1982; Granstrand and Holgersson, 2020).

2.3 Theoretical Synthesis and Research Gap

This research positions SOTI within the innovation ecosystem literature and addresses a gap in understanding how ecosystem interactions enable or constrain adoption in business practice. Existing research has examined technological innovation, SOI, and innovation ecosystems separately, emphasizing collaboration, interdependence, and value co-creation. However, less attention has been given to how ecosystem interactions specifically shape SOTI adoption in practice. This thesis contributes by connecting these areas of literature and applying them to the empirical context of the Swedish agri-food innovation ecosystem.

Existing literature shows that innovation has moved from being understood as a firm-centric and profit-centered activity toward being viewed as a dynamic process within networks of diverse actors. Literature on technological innovation introduces the technical dimension of innovation and is increasingly understood as an interactive process rather than a linear one. Finally, literature on SOI positions sustainability as a form of “creative destruction” that can create opportunities for co-creating new market platforms and value propositions, rather than only acting as a constraint.

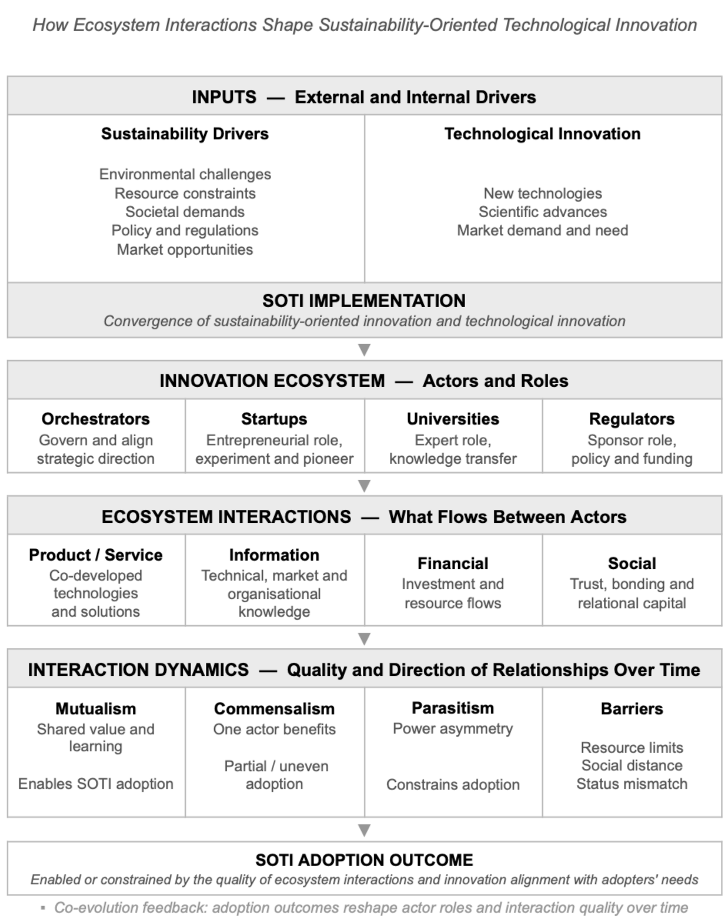
The ecosystem literature provides a framework for understanding innovation as a process shaped by networks of interdependent actors. The ecosystem concept has evolved from its biological origins into a way of understanding innovation networks that co-create value. This framework enables a better understanding of complex interdependencies, interactions, and collaboration between actors such as firms, universities, governments, and other organizations. These relationships change over time and are often governed through non-contractual forms of coordination. While business ecosystems focus primarily on value capture, innovation ecosystems are more oriented toward value creation and technological innovation. To enable this value creation, actors need to be aligned around a shared innovation purpose to support effective collaboration and relationships. Innovation ecosystems also involve different roles, such as orchestrators, complementors, and regulators. In addition, interdependence can be characterized as technological, economic, or cognitive. These interactions shape the success of the ecosystem and can be understood through symbiotic dynamics such as mutualism, commensalism, and parasitism. Actors' interactions must therefore support the effective exchange of resources, information, and knowledge over time to enable positive innovation outcomes.

To understand how ecosystem interactions shape SOTI, we propose a view of the ecosystem as an evolving group of actor roles, such as orchestrators, complementors, and regulators, that interact over time. These interactions involve product and service exchange, information exchange, financial exchange, and social exchange. They are governed not only by formal structures, but also by non-contractual responsibilities, trust, and the quality of actors' actions and relationships. The quality of these interactions has an impact on the ecosystem's direction: mutualistic dynamics, where dynamics enable knowledge transfer and "learning-teaching" outcomes necessary for innovation; parasitic dynamics, where parasitic and competitive behaviors constrain the collective ability to adopt sustainable practices; and commensalism, where only one actor benefits from the interaction.

To conclude, we suggest that the adoption of SOTI depends on the management of technical, economic, and cognitive interdependencies between ecosystem actors. Actors' interactions can enable the stability and resources needed for the adoption of technological innovation as a sustainable market solution. However, this also requires the alignment of heterogeneous actors around a common strategic purpose and forms of modular collaboration. Ultimately, the success of SOTI adoption is shaped by the ecosystem's ability to support healthy and collaborative relationships that evolve over time in response to environmental and societal challenges.

Based on this theoretical synthesis, Figure 3 presents the proposed framework guiding this thesis. The framework brings together the central concepts from the literature by showing how sustainability and technological drivers shape SOTI, and how actor roles, ecosystem interactions, interaction dynamics, and interdependencies influence whether SOTI moves toward adoption in practice.

Figure 3: *Proposed Theoretical Framework for Understanding How Ecosystem Interactions Shape Sustainability-Oriented Technological Innovation Adoption*



3. Methodology

3.1 Research Design

This study utilizes a qualitative research design in order to explore how interactions between actors shape SOTI. A qualitative study is appropriate because it allows for an in-depth exploration of how actors make sense of innovation, the meanings they attach to its adoption, and how these interpretations are shaped by their real-world business contexts (Creswell, 2009). Additionally, due to the exploratory nature of this research, a qualitative approach is suitable as the key variables are not yet clearly understood (Creswell, 2009; Morse, 1991).

This study follows an embedded case study structure in which the Swedish agri-food innovation ecosystem forms the overarching case and multiple actor groups and organizations are examined as embedded units within that case (Yin, 2018). This design is appropriate because the study is mainly interested in how actors interact with each other within the ecosystem, rather than evaluating one organization or comparing separate cases. More broadly, a case study design is appropriate for examining complex phenomena within their real-life context (Stake, 1995). Case studies are particularly useful when the boundaries between a phenomenon and its context are not clearly defined, as is the case with innovation processes across interconnected actors within an ecosystem. This is relevant for the present study because SOTI is not examined as an isolated technical outcome, but as a process shaped by relationships, coordination, and exchanges between actors across the agri-food system.

The study is theoretically guided by two connected areas of literature. First, the innovation literature frames technological innovation as an iterative and interactive process, rather than as a linear process of invention and implementation. Second, the ecosystem literature emphasizes that innovation emerges through interdependent actors, roles, resources, activities, and relationships. Together, these perspectives guide the research design by directing attention toward how actors interact, exchange knowledge, coordinate activities, and interpret the possibilities and constraints of SOTI.

3.2 Case Selection and Unit of Analysis

In order to gain an in-depth understanding of how interactions between actors shape SOTI, this study focuses on the Swedish agri-food innovation ecosystem as the empirical case. As outlined in the research design, the study uses an embedded case study design in which the Swedish agri-food innovation ecosystem is treated as the overarching case, while the organizations and actor groups included in the study are understood as embedded units within this wider case (Creswell, 2009; Stake, 1995; Yin, 2018). This structure is appropriate because the aim is not to compare separate cases, but rather to develop a detailed understanding of interaction dynamics within a specific ecosystem.

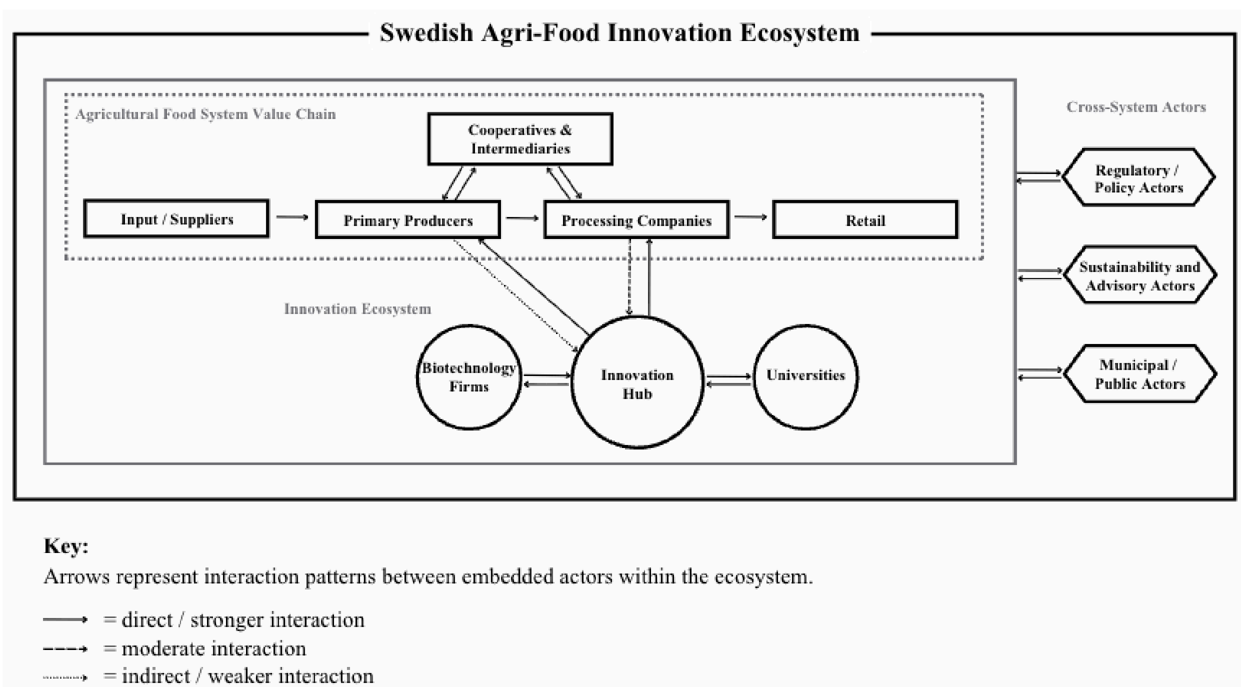
The Swedish context is particularly suitable for this study due to its strong policy focus on sustainability and innovation within the agri-food sector, as well as its ongoing efforts to transition toward a more circular and resilient food system (European Commission, 2026). These characteristics make Sweden a relevant empirical setting for examining SOTI. More specifically, the Swedish agri-food system provides a relevant case because it brings together sustainability challenges, technological development, and practical adoption issues within a sector where innovation depends on both technical feasibility and the willingness and ability of actors to implement new solutions in practice.

The case is therefore not limited to Swedish agriculture in a narrow sense, but instead focuses on the broader Swedish agri-food innovation ecosystem. This includes actors involved in the development, support, diffusion, interpretation, and adoption of SOTI. In this study, biotechnology is understood as one type of SOTI, as it involves the use of biological processes and technologies to develop solutions that may contribute to environmental, social, and economic value creation. In the empirical case, this includes technologies related to fermentation and bioreactors, which are explored as examples of technological innovation with potential relevance for feed, circular production, and agricultural sustainability.

The empirical boundaries of the case are defined by actors connected to technological innovation in the Swedish agri-food system. This includes actors who develop new solutions, support innovation processes, influence adoption conditions, connect actors across the ecosystem, or represent the practical context in which innovation is implemented. The study therefore considers actors across both the agricultural value chain and the wider innovation ecosystem, including primary producers, a biotechnology firm, a university-affiliated knowledge actor, sustainability-oriented intermediaries, an innovation support actor, and a public/institutional actor.

Figure 4 provides a conceptual representation of the Swedish agri-food innovation ecosystem as the overarching case and the organizations and actor groups included in the study as embedded units within this wider case. This simplified framework distinguishes between the agri-food value chain and the broader innovation ecosystem, while also highlighting cross-system actors that facilitate interactions between the two. The framework helps clarify the empirical boundaries of the case and supports the study's focus on how interactions between actors across different parts of the ecosystem enable or constrain innovation in practice.

Figure 4: *Conceptualization of the Swedish Agri-Food Innovation Ecosystem and Embedded Actor Interactions*



Biotech Heights functions as an entry point into the empirical case because of its role in connecting actors involved in biotechnology, sustainability, and agri-food innovation. However, the study does not treat Biotech Heights as the sole object of analysis. Rather, it is understood as one actor within the wider innovation ecosystem, as well as a useful access point for identifying other relevant actors and interactions. Within this wider ecosystem, the participating biotechnology firm serves as an example of an actor developing biotechnology-related SOTI. Its work with fermentation and bioreactor-based applications provides a concrete empirical example of how technological innovation may become connected to feed, side streams, circular production, and agricultural sustainability. This distinction is important because the purpose of the study is not to evaluate one organization or one technology developer, but to explore how ecosystem interactions shape SOTI in the Swedish agri-food system.

The case is also relevant because parts of the ecosystem are still emerging. Biotechnology-based solutions in agriculture, such as fermentation and bioreactor-based production, are relatively new and not yet fully established in everyday agricultural practice. This makes the case especially suitable for studying early-stage ecosystem dynamics, where actors are still developing roles, building relationships, interpreting the value of the technology, and negotiating the conditions for adoption and implementation.

Table 2 clarifies the connection between the theoretical concepts used in this thesis and their empirical application in the case. This is important because the study moves between abstract theoretical concepts, such as SOTI and innovation ecosystems, and a specific empirical setting involving biotechnology-related innovation in the Swedish agri-food system.

Table 2: *Application of Theoretical Concepts to the Empirical Case*

Theoretical Concept	Empirical Case Application
Sustainability-Oriented Technological Innovation (SOTI)	Biotechnology-related innovation, particularly fermentation and bioreactor-based applications connected to feed, side streams, and circular production

Innovation Ecosystem	The Swedish agri-food innovation ecosystem, including actors involved in the development, support, diffusion, interpretation, and adoption of SOTI
Technological Innovation Process	The movement of biotechnology-related innovation from development toward adoption and implementation in Swedish agricultural applications
Ecosystem Actors	Innovation hubs, biotechnology firms, primary producers, intermediaries, universities, public actors, and advisory actors
Innovation Hub / Ecosystem Facilitator	Biotech Heights, understood as an innovation facilitator within the wider ecosystem and as an entry point into the case
Technology Developer	The participating biotechnology firm, understood as an example of a technology developer working with biotechnology-related SOTI
Innovation Adopters and Implementers	Primary producers, understood as the actors through which innovation must become usable, valuable, and compatible with farm-level practice

3.3 Sampling Strategy and Participant Selection

Interviewees were selected using purposive sampling based on their involvement in the development, diffusion, support, or adoption of technological innovation within the ecosystem (Bryman & Bell, 2011). Purposive sampling is appropriate because the aim of the study is not to obtain a statistically representative sample, but to include information-rich participants who can provide insight into the interaction dynamics relevant to the research question.

A pilot interview was conducted in order to better understand the key actors of the ecosystem. Based on the insights from this interview, along with the study's theoretical framework and conceptualization of the agri-food innovation ecosystem, interviewees were selected to reflect distinct positions within the ecosystem. The study therefore includes primary producers, a biotechnology firm, a university-affiliated knowledge actor, sustainability-oriented intermediaries, an innovation support actor, and a public/institutional actor.

Each participant category was selected because of its connection to the development, support, interpretation, or adoption of SOTI. For example, the biotechnology firm is relevant because it develops technological solutions; intermediaries and innovation support actors are relevant because they facilitate connections and knowledge exchange; primary producers are relevant because they represent the practical setting where innovation may be implemented; and university and public/institutional actors are relevant because they shape knowledge, legitimacy, regulatory, economic, or organizational conditions around innovation.

While the study seeks to capture a range of perspectives, particular analytical attention is given to primary producers, as they represent the point at which technological innovation is adopted in practice. Therefore, a greater number of interviews were conducted with actors in or closely connected to this group in order to examine these interaction dynamics in greater depth. This is important because SOTI may appear promising from a technical or environmental perspective, but its success depends on how it is perceived, interpreted, and integrated by those expected to use it.

Table 3 provides an overview of the interview participants. It maps each participant to their position in the ecosystem, role, relation to the research study, and interview duration. This mapping helps ensure that the empirical material reflects the conceptual framework and includes perspectives from the agricultural value chain, the wider innovation ecosystem, and actors positioned between the two.

Table 3: *List of Respondents of Semi-Structured Interviews*

#	Date	Position in Ecosystem	Role in Conceptual Framework	Relation to Research Study	Duration
Pilot	April 10th	University / Researcher	Knowledge Provider	Provided background information on agriculture and food innovation systems and helped identify relevant ecosystem actors	45 mins

1	April 27th	Public / Institutional Actor	Regulatory / Policy Actor	Provided insight into European/Swedish regulation in particular the ones about genetically modified plants and agricultural innovation	50 mins
2	April 29th	Biotechnology Firm	Technology Developer	Provided insight into their biotechnology business and sustainability-oriented technological innovation and its potential agricultural applications	43 mins
3	April 30th	Sustainability-Oriented Intermediary	Sustainability Ecosystem Facilitator	Provided insight into sustainable agriculture settings and interactions between farmers and different actors such as municipalities and other food-system actors	1 hr 10 mins
4	May 5th	Innovation Support / Cross-System Actor	Innovation Connector	Provided insight into how actors of the ecosystem are linked farmers, researchers, and other actors to support/develop innovation and its adoption	1 hr 7 mins
5	May 12th	Primary Producer - Diversified Farmer	Adoption / Implementation Actor	Provided insight from a farmer's perspective about the practical conditions and barriers shaping innovation adoption at farm level	1 hr 12 mins
6	May 20th	Primary Producer - Traditional Farmer	Adoption / Implementation Actor	Provided insights about perception, experience and barriers for innovation adoption at farm level	1 hr 2 mins
7	May 20th	Primary Producer - Non-Profit Horticultural Farmer	Adoption / Implementation Actor	Provided insights concerning enablers and disablers for innovation adoption at farm level as well as perception and farmers condition for trying an innovations	30 min 25 sec
8	May 21th	Primary Producer - Aquaculture Farmer	Adoption / Implementation Actor	Provided perceptions about innovation, as well as enablers and disablers for its adoption	30 min

3.4 Data Collection

3.4.1 Interview Protocol

Primary data was collected through semi-structured interviews with open-ended questions with representatives from various areas across the ecosystem. This allows participants to describe their perspectives in their own words and allows for flexibility and probing questions (Creswell, 2009; Bryman & Bell, 2011). Semi-structured interviews are particularly suitable for this study, as they enable the researchers to explore complex interaction dynamics while maintaining the flexibility to adapt questions based on the specific experiences of each participant.

The interview guide was designed to gain insights into (1) actors' roles within the ecosystem, (2) their interactions with other actors, and (3) their experiences with the implementation of SOI. In line with the study's focus on interactions, particular attention was given to understanding how relationships, coordination, and knowledge exchange between actors enable or constrain the innovation process. The interview guide can be found in Appendix B.

The interview protocol was guided by the study's theoretical framework. The innovation literature informed questions related to technological innovation, SOI, adoption, implementation, and the perceived value or uncertainty of new technologies. The ecosystem literature informed questions related to actor roles, interdependencies, relationships, resource exchange, coordination, trust, and collaboration. This ensures that the interviews do not only collect general opinions about sustainability or technology, but specifically explore how ecosystem interactions shape SOTI.

Although all interviews followed the same overall thematic structure, the questions were adapted to each participant's position within the ecosystem. For example, interviews with primary producers focused more strongly on practical adoption, perceived usefulness, operational constraints, trust, and implementation conditions. Interviews biotechnology firms and intermediaries focused more on innovation development, ecosystem coordination, knowledge transfer, and collaboration. Interviews with public/institutional actors focused more on regulatory conditions, support structures, and system-level enablers or barriers. This flexible structure allowed the study to compare perspectives across actor groups while maintaining a shared analytical focus.

The interviews were conducted either in person or online, depending on availability, and typically lasted between 30 min and 70 minutes. During the interviews, follow-up questions were used to clarify participants' responses and encourage concrete examples. This is especially important because the study focuses on interactions, meaning that participants were asked not only what they think about SOTI, but also how they interact with other actors, what kinds of exchanges occur, and how these interactions influence adoption or implementation.

3.4.2 Data Recording and Transcription

The interviews were conducted online through digital video-conferencing platforms such as Google Meet or Microsoft Teams, which allowed verbal communication to be recorded and preserved as a reliable record for later analysis (De Sordi, 2024). Before each interview began, participants were informed about the purpose of the study, how the data will be used, and that the interview will be audio-recorded for transcription purposes. Explicit informed consent was obtained before recording begins, in line with qualitative research standards for ethical data collection (Creswell & Creswell, 2023).

All interviews were audio-recorded with the consent of participants and subsequently transcribed using Sunet Scribe. Transcription provides the basis for analysis by turning the interview material into textual data that can be coded and systematically compared across participants. Because this study involves specialized terminology related to agriculture, biotechnology, fermentation, bioreactors, SOI, and ecosystem interactions, the transcripts were manually reviewed by the researchers after transcription. This manual verification is important for correcting errors in technical terminology and ensuring a correct transcription of the interview as automated transcription may fail to accurately capture specialized or context-dependent meanings (De Sordi, 2024). The manual review of transcripts also functions as a reliability strategy, ensuring that the transcripts do not contain obvious mistakes before the coding process begins (Creswell & Creswell, 2023). The researchers also ensured a correct attribution by verifying the alignment between specific statements and the respective speakers to maintain the integrity of the dialogue.

In accordance with GDPR and ethical research principles, interview data was handled confidentially and used only for the purpose of this study. Participants and organizations were anonymized where appropriate through the use of general role descriptions. This is particularly important because the study includes actors from a relatively specific innovation ecosystem, where participants may discuss commercially sensitive technologies, organizational relationships, regulatory issues, or barriers to collaboration. Protecting participant anonymity helps reduce the risk of self-preservation bias and allows interviewees to speak more openly about their experiences, perceptions, and challenges (Creswell & Creswell, 2023; De Sordi, 2024).

3.4.3 Secondary Data

In addition to primary interview data, secondary data was used to contextualize the case, support the development of the interview guide, and help map the structure of the Swedish agri-food innovation ecosystem. These sources included public materials from Biotech Heights and the participating biotechnology company, reports and publications from the Swedish University of Agricultural Sciences (SLU), Swedish government publications on agriculture and farming statistics, European Union regulatory documents, public materials from agricultural authorities, industry reports, and selected news articles and press releases. Secondary data was particularly useful for understanding the roles of different actors, developments in the agri-food sector, and relevant examples of SOTI.

These sources supported contextual triangulation by allowing interview insights to be compared with publicly available information about the ecosystem and its actors (Bryman & Bell, 2011). Because secondary sources vary in reliability, priority was given to official government and EU regulatory sources, university publications, and reports from recognized institutions.

3.5 Data Analysis

The interviews were analyzed using thematic analysis, which allows the researchers to identify recurring themes and patterns in relation to technological innovation, SOI, and business and innovation ecosystems (Braun & Clarke, 2006). Thematic analysis is appropriate for this study because it provides a flexible method for identifying patterns across qualitative data while still allowing the analysis to remain connected to the study's theoretical framework. The analysis followed the six-phase approach to thematic analysis outlined by Braun and Clarke (2006), including familiarization with the data, initial coding, theme development, review of themes, definition and naming of themes, and final analysis.

The transcripts were turned into meaningful insights through labeling or coding relevant areas of text, grouping them into recurring themes, and reviewing patterns (Braun & Clarke, 2006; Ahmed et al., 2025). The analysis was guided by the theoretical framework, as well as by emergent insights from the data. This means that the coding process combines both deductive and inductive coding. Deductive codes were derived from the literature review and theoretical framework, particularly the sections on technological innovation, SOI, innovation ecosystems, actor roles, interdependencies, and ecosystem interactions. Inductive codes were developed from patterns that emerged from the interview material itself, allowing the researchers to capture unexpected themes or actor-specific perspectives that may not be fully explained by the existing literature.

The initial coding process began with a close reading of each transcript in order to identify statements related to innovation, sustainability, adoption, actor roles, relationships, resources, activities, and implementation. Relevant sections of text were coded according to the meaning of the statement. For example, statements about uncertainty, cost, technical feasibility, trust, regulation, knowledge sharing, collaboration, or farmer adoption were labelled with descriptive codes. These codes were then grouped into broader themes that reflect the study's research question, such as enablers of innovation, barriers to adoption, ecosystem coordination, knowledge exchange, and interaction outcomes. Table 4 presents the analytical coding framework used to organize the empirical codes into broader analytical categories and link them back to the theoretical framework. The table shows how codes from the interview analysis were grouped around technological innovation, SOI, actor roles, ARA dimensions, interdependencies, adoption conditions, and interaction outcomes.

Table 4: *Analytical Coding Framework*

Analytical Category	Codes from Analysis	Link to Theoretical Framework
Technological innovation	Time scarcity; Scaling barrier; Convenience and ease of use; Knowledge gap	Technological innovation
Sustainability-oriented innovation	Sustainability necessity; Sustainability opportunity; Cost of sustainability	Sustainability-oriented innovation
Actor roles	Advisor influence; Bridging actors; Coordinator; Actors legitimacy; Public-led policy	Innovation ecosystem actors and roles
Actor bonds	Personal relationships and trust; Peer-based trust; Knowledge gap; Actors legitimacy	ARA framework
Activity links	Advisor influence; Bridging actors; Coordinator; Need-based innovation; Adoption pressure	ARA framework
Resource ties	Knowledge gap; Advisor influence; Bridging actors; No external dependence; Farm heterogeneity	ARA framework
Interdependencies	Profit-driven motives; No external dependence; Cost of sustainability; Adoption pressure; Actors legitimacy	Ecosystem interdependencies
Adoption conditions	Economic hurdles; Profit-driven motives; Time scarcity; Convenience and ease of use; Regulation challenges; Regulation opportunities; Sustainability necessity; Sustainability opportunity; Cost of sustainability; Adoption pressure	Innovation adoption and implementation

Interaction outcomes	Advisor influence; Bridging actors; Coordinator; Personal relationships and trust; Peer-based trust; Need-based innovation; Farmer-led innovation	Ecosystem interactions

Using the Actors-Resources-Activities (ARA) framework by Håkansson and Johanson (1992) and Ford et al. (2008), interactions were analyzed across three dimensions: (1) actor bonds, (2) activity links, and (3) resource ties. This allows the study to examine how different interactions contribute to the implementation of SOTI. Actor bonds refer to the relationships between actors, including trust, familiarity, legitimacy, and social distance. Activity links refer to how actors coordinate or connect their activities, such as through collaboration, advisory support, joint projects, testing, regulation, or implementation processes. Resource ties refer to how actors exchange, adapt, or depend on resources, including technical knowledge, funding, infrastructure, data, biological materials, production capacity, or practical farming knowledge.

This framework helped move the analysis beyond a general discussion of "collaboration" by specifying what kind of interaction was taking place and how it influenced innovation. For example, when a farmer describes whether they trust a biotechnology firm or intermediary, this was coded as an actor bond, while connections facilitated by an intermediary were coded as an activity link. When actors exchange technical expertise, funding, inputs, or practical knowledge about farm-level implementation, this was coded as a resource tie.

Interactions were also analyzed based on whether they enabled or constrained innovation. Enabling interactions included trust-building, shared learning, access to resources, technical support, regulatory clarity, or coordination between innovation developers and primary producers. Constraining interactions included misalignment between actors, lack of trust, unclear value propositions, limited resources, regulatory uncertainty, weak communication, or a gap between technological development and practical farm-level needs.

The analysis also involved comparing perspectives across different actors in order to identify similarities and differences, and where their perspectives converged or diverged. This cross-actor comparison is important because the study examines organizations and actor groups as embedded units within the broader case, while focusing analytically on how interactions between these actors shape SOTI.

The final stage of analysis connected the identified themes back to the research question. Themes were reviewed in relation to how ecosystem interactions shape SOTI, and how these interactions influence the adoption or implementation of innovation in practice. In doing so, the analysis seeks to show how technological innovation is shaped not only by technical characteristics, but also by the relationships, resources, activities, and interdependencies that connect actors across the ecosystem.

3.6 Validity and Reliability

Validity and reliability were important considerations in this study, as qualitative case study research depends on transparency in how data is collected, interpreted, and connected to the research question (Bryman & Bell, 2011; Creswell & Creswell, 2018). While this study was designed to include perspectives from multiple actors across the innovation ecosystem, time constraints limited the number of potential participants and purposive sampling is not exhaustive, meaning some relevant actors may not have been included and the study has limited generalizability (Cook & Campbell, 1979). However, the purpose of this study was not statistical generalization, but rather to develop an in-depth understanding of interaction dynamics within a specific ecosystem. Additionally, although most interviewees were identified and contacted independently by the researchers, access to one biotechnology firm was facilitated through Biotech Heights. This may have influenced the inclusion of this specific actor perspective, but the broader sample was primarily shaped by the researchers' own purposive sampling and outreach.

We attempted to mitigate validity concerns by using secondary sources to provide contextual triangulation, ensuring interviewees agree with interviewer interpretations, and using detailed descriptions when discussing findings, as well as by incorporating perspectives from multiple actor groups within the ecosystem to enhance credibility (Creswell, 2009; Bryman & Bell, 2011). In addition, follow-up questions and clarifications during the interviews helped reduce the risk of misunderstanding participants' meanings, while direct quotes were used in the findings to show how the identified themes were grounded in participants' own accounts.

Reliability was strengthened by conducting the interviews and analysis in a structured and transparent way, as reliability depends on the consistency and clarity of the research process (Bell, Bryman & Harley, 2019). A semi-structured interview guide was used across interviews, while still allowing questions to be adapted to each participant's role in the ecosystem. The interviews were transcribed and manually reviewed, and the analytical coding framework provided a systematic structure for linking empirical codes to the theoretical framework.

3.7 Ethical Considerations

Ethical considerations were addressed through informed consent, voluntary participation, the right to withdraw at any time, and confidential handling of interview data (Bryman & Bell, 2011). Before participating, interviewees were informed about the purpose of the study and how the data would be used. Because the study includes actors from a specific innovation ecosystem, participants and organizational information were anonymized where appropriate. While Biotech Heights is named due to its role as an innovation hub and entry point into the case, the participating biotechnology firm, individual interviewees, and specific identifying details about their organizations are anonymized where appropriate.

3.8 Artificial Intelligence Contribution Statement

AI tools, including Gemini and ChatGPT, were used in a supportive and enhancing way throughout the thesis process. These tools were used for structure enhancement, sentence refinement, and mistake checking, including grammar. They were also used to help improve the formation of the interview questions and to support the development of the theoretical framework. AI was further utilized to ensure a good flow of information and coordination between different parts of the thesis by providing feedback and suggestions on what to improve and how to ensure a more logical flow, especially in the literature review. AI was also used to reformulate some themes during the data analysis process and to ensure that the theme names were well formulated and concise. All AI-generated suggestions were critically reviewed, revised, and approved before being included in the thesis. The tools were used as supportive aids in the writing, editing, and refinement process. However, the ideas, arguments, empirical interpretations, and conclusions originated from the authors. All substantive decisions regarding the research design, theoretical framing, empirical analysis, interpretation of findings, and conclusions were made by the authors.

4. Empirical Findings

4.1 Setting

The following section presents the findings collected by eight semi-structured interviews from diverse actors of different organizations/businesses. The empirical section serves as setting a basis answer for the research questions of this thesis which is to understand how different ecosystem interactions shape SOTI.

First, a short background about the context is provided for each individual respondent in order to establish a good understanding and overview on the ecosystem studied. Second, the 7 core themes derived of the data will be explained: (1) Economic Feasibility, (2) Trust and Legitimacy, (3) Ecosystem Enablers and Constraints, (4) Compatibility With Farm Practice, (5) Sustainability as Driver and Tension, (6) Regulation Dynamics and (7) Market Need Drives Innovation. Third, the data and findings of the interview are presented with a summary tab and with a coding of main themes and insights of the primary data. The section enables the readers to get an organised overview of the data and diverse information in order to better understand the empirical findings and to make sense of it.

4.2 The Partner Firm and Case Description

To provide a better overview of the different actors interviewed and their business, a short description of each organization and their participant is given.

This research is conducted with the partner organization: Biotech heights. Biotech Heights is an innovation hub that is led by Tetra Pak and Lund University. It is a collaborative hub for research and innovation in the biotechnology industry in Sweden. Different actors collaborate together such as the public sector, academia and other industry actors in order to advance biotechnology innovations and to implement these into new sectors and industries. It specialized particularly in bioprocess and fermentation (Biotech Heights, 2025). Their mission is that, by 2035, people will eat fermented food everyday.

Public / Institutional Actor: This public actor is an expert in agriculture, fisheries and rural areas. They operate in Sweden and participate in political decisions concerning these sectors as well as follow and analyse its evolution while collaborating with the Government. They have a mission to profitably and sustainably produce food in Sweden as well as ensuring animal welfare. The two respondents of this organization, provided insights about European and Swedish regulation, specifically about Genetically Modified Plants and more general innovation within agriculture.

Biotechnology Firm: This actor is a biotechnology firm that is a partner of Biotech Heights. They are operating in the food sector in Sweden and propose a bioreactor that would turn sidestreams into high nutrition value ingredients for crops, feed and so on, using fermentation. Their goal is to serve primary producers to help them transform their streams, directly at the farm, into nutrient rich ingredients. The respondent provided insights from a biotechnology firm perspective and shared its relation with farmers, the opportunity of their technology for farmers and the interactions with diverse actors in the ecosystem. The respondent also provided information concerning their firm history, challenges and ambitions.

Sustainability-Oriented Intermediary: This actor is a Swedish foundation that is promoting sustainability in the food system and regenerative agriculture. They promote information, education and research about these topics. They work with public actors, support and advise them and their strategic development for their transition towards a sustainable food system. The respondent provided insights concerning sustainable agriculture, interactions between farmers and diverse public actors of the Swedish food system.

Innovation Support / Cross System Actor: This actor serves as an innovation support within a Swedish network for agriculture, aquaculture and rural development. This network helps connect farmers, researchers, and other actors to support the development and adoption of new technologies and innovation. This actor also serves as a knowledge sharing and connector between diverse actors of the food system. They enable discussion and knowledge transfer between researchers and farmers. The respondent provided insights about the relationship and links between farmers, researchers and other actors within the ecosystem. He also provided tips for innovative firms to discuss and approach farmers in a more meaningful way.

Primary Producer - Diversified Farmer: This actor is a diversified farmer with interests in regenerative practices and an holistic approach to agriculture, innovation and technology. The farm produces meat, eggs and other fruits and owns a shop where they sell directly to customers and is located in Sweden near Göteborg. The respondent shared insights concerning his perception and experience of contact with other actors of the food system and about his view on innovation, sustainability and what could be done concerning the support and adoption of innovations in agriculture.

Primary Producer - Traditional Farmer: This actor is a small primary producer and considers himself as a traditional farmer located in Sweden in the region of Skåne. The owners are retired but still have some activities such as growing different types of vegetables and greens, managing diverse animals and also providing different types of experiences in their farm for the public. The respondent is a first generation farmer who provided insights about his perception of innovation and sustainability. The respondent also shared opinions on innovation adoption and common practices of farmers in his area as well as his interactions with other members of the food system.

Primary Producer - Non-Profit Horticultural Farmer: This actor is also a primary producer, more specifically a non-profit horticultural farm in Sweden. Flowers, fruits, vegetables and herbs are produced and have over 450 volunteers. The actor is doing some projects that are EU based as well as some research work collaboration and consider themselves as very innovative and sustainable. The respondent shared insights about her role at the farm, relation and collaboration with other members of the food system and provided perceptions and opinion about trying different types of innovation and about her view on sustainability in the agricultural sector.

Primary Producer - Aquaculture Farmer: This actor is a primary producer that is doing aquaculture in Sweden. This actor is cultivating fish in land and in fresh water and consider themselves very innovative and sustainable within aquaculture. Also, this actor is not really in relation with other actors of the food system or with other farmers. The respondent provided insights on his situation and the aquaculture in Sweden as well as sharing his perception about innovation, possible enablers and disablers and about how it could be adopted in practice and the risk associated with it.

4.3 Economic Feasibility

The data revealed that economic feasibility drives adoption. Indeed under this theme, the analysis identified four sub themes which are the following: cost as a main barrier, economic incentives and profit motivation, time pressure and heavy workload and commercialization gap.

Concerning cost as a main barrier, many respondents identified it, farmers themselves but also diverse actors from the ecosystem. Indeed both the sustainability-oriented intermediary and the innovation support / cross-system actor identified multiple times the cost issue and its impact on innovation adoption. The sustainability-oriented intermediary stated: *"economic survival remains central"* and the innovation support / cross-system actor mentioned *"economics are the primary hurdle for farmers"*. This opinion was widely shared by other respondents and by the different farmers. The diversified farmer mentioned repeatedly that cost was a big issue in agriculture: *"the biggest problem for most farmers ... is money"* and *"it's all about costs"* which links back to the other actor's perspective. The other farmers also underlined the cost problem as a common issue, they expressed low investment possibilities and the need for compensation when trying a new innovation. The aquaculture farmer also mentioned cost, in addition to other issues that could affect innovation: *"Money and knowledge"*. Indeed, the data revealed, for the vast majority of the participants (5 out of 8), that innovation is linked to capital needs and is a big barrier for innovation adoption and implementation. The data showed the need for an innovation to be economically viable, which was a major point made by the farmers interviewed.

In relation to the cost barrier, the data showed that economic incentives and profit driven innovation could be a motivation for the farmer to adopt it. Indeed all the farmers respondent mentioned the profit motive and the innovation support / cross-system actor, supported this opinion too: *"Farmers are more responsive to: grants, subsidies or concrete financial incentives".* Indeed, this incentive/profit was also mentioned by the farmers interviewed unanimously. The following quotes illustrate this perspective: *"Profit-driven again"* (diversified farmer), *"Certainly, they're all interested in just making more money."* (non-profit horticultural farmer). While farmers are quite different when it comes to values, way of working, production and even geographical area, they all shared the same belief concerning economic incentives as a motivation for innovation adoption. They also agreed with the innovation support / cross-system Actor that farmers adoption is highly influenced by financial returns and incentives.

Under the same core theme, time pressure and workload was raised from the data analysis. Indeed, few respondents mentioned the time constraint of farmers and impact on their relation with innovation. The biotechnology firm mentioned: "*these people don't have time"*, which is a view also shared by the farmers themselves: *"farmers are definitely busy and carry a quite heavy burden"* (the diversified farmer). The non-profit horticultural farmer also shared this view and expressed : *"we do not get any time compensation"*, when talking about farmers experimenting with technology and innovation. The aquaculture farmer, another type of primary producer, also mentioned the time constraint: *"I mean, people spend most of the time making ends meet and they don't have so much spare time".* For farmers, time scarcity appears to limit their interest and availability to interact with new technologies and innovation. The different types of primary producers interviewed share the same point of view and all have the same issue with their time, which negatively impacts their interaction with innovation. The biotechnology firm also raised this point, as they are directly impacted. This issue appeared to be well known in the industry and be a major problem affecting more than the farmers alone.

Finally, the data showed that for the technology developer, the ecosystem enabled early stage innovation but lacked support for the commercialization process. Indeed, the biotechnology firm mentioned that, as a startup, there is a need for more support for the go to market stage: *"There* *are lots of grants for when you start but not for commercialization"* and *"I would like to see actors linking startups with grants, trying to make the last step to commercialization"*. The data revealed that support is lacking to better support market scaling for innovation which directly negatively impacts innovation development and adoption, the biotechnology firm finished her statement with: *"That's what I would like to see more in order to strengthen the innovation ecosystem in Sweden"*. The data found that it could be a major improvement for the ecosystem to establish actors that are supporting these startups and innovation firms as its commercialization accompaniment is weak.

To conclude this section, it was found that some barriers to innovation adoption and development are cost and time constraints and additional support for commercialization but that, with incentives for farmers and support during the innovation market phase, these barriers could be balanced.

4.4 Trust and Legitimacy

The analysis found that trust and legitimacy shape adoption. Under this, four sub themes have been identified: real relationship, institutions and legitimacy, suspicion of outsiders and peer credibility.

Regarding relationships, it has been mentioned by many respondents that relationships are necessary for innovation. Indeed respondents, from the technology firm to the innovation support / cross-system actor to the farmers, stated that personal connection and interactions with other actors in the ecosystem are very important. The biotechnology firm mentioned: *"I see that E (innovation hub) is really trying hard, working ... So for us, this is super important"* when talking about their relation to the innovation hub and link to other governmental actors.
The innovation support / cross-system actor also highlighted that contact really matters for innovation development: *"most important trust-building connection point within the ecosystem"*, *"Innovation diffusion depends on social embeddedness and relationship-building"*. The respondents identified some relationship being more impactful than others: *"Advisory relationships may matter more than direct firm-to-farmer outreach",* and explaining their role *"These actors appear to function as: intermediaries, translators, validators and trusted*

communicators" (innovation support / cross-system actor). These actors seemed to appear as trustworthy for farmers, which shows potential "central actors".

The farmers all expressed that personal connection is important for them when it comes to collaborate with another actor: *"it always comes down to relationships and communications between humans"* (diversified farmer) and *"That's why we often like to work on a small scale, oftentimes starting up entrepreneurs ... because we have this direct relationship with them. And the trust relationship"* (non-profit horticultural farmer) and *"good collaboration, I mean, it's relationship building"* (aquaculture farmer). Strong relationships seemed to appear as mandatory for the respondents, especially for collaboration and business within the ecosystem.

In addition to that, the analysis revealed the link between institutions and legitimacy as a bridge for innovation development and implementation. Indeed, few respondents considered certain actors in the ecosystem more influential than others. The biotechnology firm, for example, identified a University (Swedish University of Agricultural Sciences) as a legitimate institution for farmers: "*they want to know that this is SLU stamped. Why? Because those farmers, they have been studying at SLU themselves. So this is like a quality control*". The sustainability-oriented intermediary stated: *"the legitimacy universities provide"* and *"farmer; institutional approval alone creates trust among farmers".* The innovation support / cross-system actor also stated that farmers themselves act as a source of trust. Different actors recognised universities, farmer advisors (as mentioned in the previous paragraph) and farmers as legitimate and trustworthy members in the ecosystem that can impact views and adoption of innovation.

The data stressed that, while some actors enhanced the trust of farmers, others made them more skeptical. For many respondents, people external to farming are mostly creating distrust and also demonstrated a knowledge gap between them. The public / institutional actor underlined that: " *I think it's got a lot to do with the lack of knowledge about the subject throughout the general public in Europe*", when asked on what could be responsible for farmers' skepticism. Other actors interviewed explained that in order to address that, people should listen to farmers more. This knowledge gap perspective was also shared by the different farmers, saying that the gap is coming from the public, the technology firms and from academia. They also mentioned a gap between the farmers themselves and regarding topics such as sustainability and innovation. The analysis showed, however, that the lack of trust is due to several reasons as the traditional farmer mentioned: *"Because they are afraid. I mean, I can honestly say that I was a bit reluctant to talk to you too. Because I didn't know who you were. Why do you want to talk to me? Do you want to scam me? Or do you want to sell me products? Is there a hidden agenda? That is definitely a problem. That's a trust issue".* More generally, the data showed a lot of distrust within the ecosystem and was partially identified by the lack of proximity, knowledge and contact different actors have together.

The analysis also raised that credibility and trust could be coming from farmers themselves. Trust and legitimacy were mentioned by a few respondents from the agricultural ecosystem. The sustainability-oriented intermediary mentioned the importance of farmer innovators, which was supported by the innovation support / cross-system actor: *"Farmer-developed innovation carries credibility that external innovation may lack"*, "*the farmer's prior credibility and practical experience mattered. Trust increased because the innovation came from 'one of them' ".* This was also confirmed and expressed by the non-profit horticultural farmer: *"farmer led innovation and technology ... where we can make sure that it's in our interest".* Overall, the trust could be coming from various sources according to the innovation support / cross-system actor who stated: *"Trust may instead emerge through: farmer networks, demonstrations, practical experience and peer credibility".* The analysis demonstrated that farmers are more receptive when innovation comes from other farmers and when it feels familiar to them, an essential element for innovation adoption.

To summarize, peer credibility and institution legitimacy are key for innovation implementation and for farmers' trust.

4.5 Ecosystem Enablers and Constraints

The data analysis demonstrated that actors can act as enablers and disablers for innovation.
Under this theme, four elements have been identified: advisors as influencing actors, connectors, ecosystem fragmentation and coordinating actors.

Respondents mentioned the importance of advisors in the ecosystem. Indeed, the innovation support / cross-system actor indicated multiple times the advisors'role: *"advisors as the most important trust-building connection point within the ecosystem"* as they enable more trust for the farmers: *"Farmers listen to trusted advisors more than companies".* Their role was also described by the innovation support / cross-system actor: *"These actors appear to function as: intermediaries, translators, validators, and trusted communicators".* Different farmers also identified these advisors and the fact that they are close to farmers. Indeed, according to them, there are a lot of advisors for farmers that are coming from different organizations and who are quite influential and impact their views on innovation.

Other actors of the ecosystem are considered as connectors. The data raised bridging actors, enabling connections and points of contacts within the ecosystem: actors that most of the respondents identified. The biotechnology mentioned the innovation hub as a connector strengthening the biotech landscape in Sweden and pressuring policies, which, as a startup, they don't have access to. They also raised SLU (University) as a connection between academia and the farming industry and served as a direct contact with farmers.

Other actors have been cited by different respondents such as different networks and public actors: *"Ekologiskt Lantbruk Ekodagarna Foundation for sustainable food system"* (sustainability-oriented intermediary), *"CSA (Community Supported Agriculture) distributes risk between farmers and consumers, creates closer social relationships, and improves sustainability while supporting farm survival"* (sustainability-oriented intermediary), but also local communities: *"There's a lot of it is done by the (BYLAG) local communities, something called the village communities."* (the traditional farmer). The non-profit horticultural farmer also mentioned the EU agroecology network and other EU initiated programs, which appears to work as a link between different actors. One of the primary producers also mentioned the Swedish Board of Agriculture as its only external and supporting actor. The data presented different connectors in the ecosystem, from Sweden but also biggest scale actors and their respective roles for different actors, influencing innovation development and adoption. Adding to that, the study also found a wide and spread ecosystem, as few respondents stated: *"the innovation ecosystem is* *huge"* (biotechnology firm) which makes it harder to coordinate for some actors *"One of the issues that I see is that there are many actors. And agendas are, like, far from sync. You know, the innovation ecosystem is huge. I've seen it expand for many years. And it's endless"* (biotechnology firm), demonstrating a very complex system.

While other respondents didn't explicitly mention it, they argued it by citing different actors and roles within the ecosystem, reflecting the magnitude of it. However, farmers mostly interact with customers and not so often with firms or other members of the ecosystem, apart from the non-profit horticultural farmer who mentioned: *"at an international level, we collaborate with different universities"* which reflect the extent of the ecosystem. The data revealed a very broad ecosystem that the diverse organizations and firms acknowledge but that some farmers don't really see as they are not interacting with as many actors.

Concerning the relation between actors, the analysis showed the hurdle of coordination and communication between them but also raised the few actors that are considered as coordinators. The biotechnology firm identified innovation hubs as coordinators but also recognised a general coordination struggle in the ecosystem: *"So, I know that some of the actors really try their best to coordinate. But it becomes impossible".* The biotechnology firm also considered themselves as their own coordinator. During our interview with the innovation support / cross-system actor, it appeared that they work close to agricultural innovation and appeared to be a bridge for research, innovation and coordination with practical farming realities. Farmers also shared this role and very explicitly mentioned that they are coordinating other actors' interaction. In addition to that, the diversified farmer, for example, also stated that: "*sometimes it feels like we do other people's jobs",* showing the importance of defined connectors. The non-profit horticultural farmer working at a big farm with a very organized structure (working as a community) also identified herself as a coordinator: *" I'm a little bit the spider in the web, so I'm always kind of in the room and listening and then I'm trying to connect actors".* This metaphor described perfectly the coordinator role certain actors have and more generally the need for connector in order to enable better communication and flow in the ecosystem.

The analysis showed the importance of collaborative ecosystems with actors' role and how it can affect innovation and presented a current coordination struggle.

4.6 Compatibility With Farm Practice

The analysis raised that innovation compatibility with farms is mandatory. Under this theme, four themes have been identified: simplicity and usability, farmers self-reliance and farm individuality.

The data showed that innovation should be convenient and easy to use for the farmers. Many respondents mentioned technology practicability as necessary for adoption. Indeed, the technology firm, stated that, from a research they conducted, the technology needs to be easy to use: *"We started with market research, actually, to understand what was the need of the farmers. And then they were very clear, it has to be cost competitive, and it has to be easy to operate",* in addition to that, the respondent also mentioned that it needs to be compatible with the farm in which it operates: *"You can easily operate it. You can easily clean it. You know, it's compatible with farming operations"*, overall, they stated that technology should be convenient, adaptable and practical for farmers. This view was also shared by the sustainability-oriented intermediary, which added that innovation should also be easily compatible with their existing operation systems. Finally, from a farmer perspective, after sharing views on innovation, the non-profit horticultural farmer indicated that: *"innovation that makes everything more efficient, more attractive to farmers",* which showed that the innovation efficiency is core to a better innovation acceptance from farmers. Many actors in the ecosystem seemed to all align on the usability of innovation.

In addition to that, the data found that innovation shouldn't create more dependency on external actors, it should enable more autonomy. The non-profit horticultural farmer highlighted the fact that if innovation was adopted it shouldn't create more dependency on another firm, which is closely linked to innovation convenience, it can be seen as a risk which causes a situation where the farmer is "stuck" with the specific innovation, making it less attractive for them. This reliance would prevent the farm from adapting if needed. In addition to that, this respondent, specifically, mentioned the importance of being able to rely on itself when it comes to innovation adoption: *"we don't want to be dependent on the company"* and *"systems that are in itself not ... creating dependencies"*. This respondent showed that farmers value autonomy and are reluctant to technologies that create long-term dependency on external firms and ultimately stated: *"low tech, small tech, human based tech solutions"* (non-profit horticultural farmer).

If one farmer had a really strong opinion on his view with innovation, it is not necessarily the case of all farmers, indeed farm heterogeneity makes them all very different in their relation to it. Many respondents answered that there is not one type of farmer: *"Every farm is different. Differences include: soil,climate, crops, bacterial composition, operational structures, scale, and economics"* (sustainability-oriented intermediary). In addition to that, the innovation support / cross-system actor mentioned that:*"Agricultural innovation must adapt to local biological and operational conditions"* and *"There is likely no universal agricultural innovation solution"*. The analysis raised that while every farm is different, it also confirmed that innovation must fit and be adaptable to every farm.

The data showed that an innovation, in order to be adopted, should be convenient, adaptable and enable self reliance for the farmer.

4.7 Sustainability as Driver and Tension

The data presented sustainability as both an enabler and disabler for innovation adoption. Under this, three themes have been identified: green necessity, green opportunity and sustainability as a barrier.

A very large majority of respondents mentioned the importance of sustainability. Different types of actors from the ecosystem seemed to share the same view. Indeed, from the public / institutional actor with: *"And that I think is of great importance to improve sustainability"*, to the biotechnology firm with: "*It's about resilience in Europe. It's about sustainability"*. This actor also mentioned that the younger generation valued new sustainable solutions in their operations. From the data, it was also found that Europe also appeared to be favorable for sustainability according to the biotechnology firm: *"The more that Europe is pushing for sustainability all over the place and laws and whatsoever, it's better for us"*, which was considered good for them.

Most of the farmers interviewed had a sustainable approach to farming, according to the interviews, they mentioned sustainability as: *"existential"*, *"the foundation of farming"* (non-profit horticultural farmer). Others explained that without it, we will poison the planet. The sustainability-oriented intermediary also underlined the importance of sustainability, but also the economic downfall that comes with it. Sustainability inclusion in farming seemed to make a lot of different actors in the ecosystem agree, even though some of them mentioned that this is not the priority for all.

In addition to this sustainability necessity, it can also be an opportunity for some sustainable technology provider, such as the biotechnology firm stated: *"the sustainability agenda in Europe is not a bottleneck"*, *"it's absolutely fantastic"* and *"I see this as a rocket for us"* which support this idea of sustainability as a chance.

While sustainability can be seen as an opportunity, the data showed that for some actors, it can also appear as a barrier. Indeed, the innovation support / cross-system actor stated: *"Farmers do not necessarily prioritize sustainability goals directly"*. The reason why it was not, was because of the economic hurdle of farmers, the innovation support / cross-system actor brought that: *"Economic realities outweigh abstract sustainability ambitions"*. The aquaculture farmer also stated that sustainability can also be a barrier for some businesses because other, less sustainable businesses, often have the monopoly in some practices: *"I mean, for us, if you look at the seafood industry, we have a sustainable business idea and we want to do it on land. But in Sweden, 99-95% of all the fish comes from caskets in the sea. And those farmers see a trade-off for sustainability as a threat"*. These established actors perceive the shift to more sustainability as a "threat" or a "risk", leading to active resistance against industry-wide change. Again respondents brought up the profit and economic issue that can be linked to sustainability.

To summarize, the analysis found that sustainability can be beneficial for some actors and some innovation, as farmers perceive it as necessary but is sometimes still subject to resistance from other actors in the ecosystem.

4.8 Regulation Dynamics

The data analysed found that the regulation can be seen as an enabler but also as a disabler. This theme was divided into three parts: regulation as a challenge, regulation as an opportunity and bottom-up governance

Concerning regulation as a challenge, the data revealed that regulation is often seen as a challenge. It is the case because of the complexity and process of regulating itself. Indeed, the public / institutional actor stated that: *"the last time I saw it, it took about, I think, six years to get an application through the approval system…it was like many million euros, I think it was",* this illustrates the reality of regulation within the industry. This actor expressed the cost, complexity and time regulation needs. The biotechnology firm also mentioned that it is very complicated to push the regulation as not everyone has a weight on policy and regulation. The non-profit horticultural farmer also shared that policy is becoming more and more strict in the sector. According to these respondents, policies are perceived more as a challenge than something positive for change and represent a barrier to innovation for some actors.

If regulation is perceived as a challenge, it can also be seen as an opportunity. Indeed, the policy/regulation actor mentioned that with an upcoming law, they can expect to use gene-edited plants more easily, but also that it'll be easier and less costly to put the product on the market, which seems to be very positive for the GMO commercialization. In addition to this, the biotechnology firm, also shared this positive view about regulations being in favor of what they want to commercialize: *"The more that Europe is pushing for sustainability…it's better for us, green companies"* and *"So I mean there are a lot of things related to regulation, to sustainability, to agriculture, and grants that farmers could get",* showing a lot of enthusiasm for it.
Upstream actors mainly see policy change as an enabler for innovation to be implemented within the ecosystem.

Regulations dynamics is not only coming from policy makers and organizations according to the data, it was found that it comes from the downstream actors too.
The public / institutional actor mentioned the policy being influenced by the public voice and others: *"having seen how work is done with this new regulation, it is, I mean, it's of course a mix*

... there's certainly a lot of input from the bottom", the actor also raised that the public is implicated and that researchers, organizations and others in the sector also participate. It implies that lots of people actually have an influence on how regulation is shaped but also indirectly on the innovation adoption. Indeed, the non-profit horticultural farmer explicitly noted that: *" I'm working with policy. I'm a board member of an EU agroecology network "* , illustrating this argument.

To conclude, regulation has a positive and negative impact on innovation implementation and adoption but can be influenced by other actors in the ecosystem.

4.9 Market Need Drives Innovation

The analysis raised that market needs is a driver for innovation, under this, were divided into three sub themes: customer designed, market pressure for adoption and farmer innovation.

The data showed that few respondents mentioned that innovation should be developed according to farmers' needs. Indeed, the biotechnology firm stated multiple times the importance of satisfying and framing innovation around the customer need:*"you start the company out of a customer need".* This actor shared her experience and work as a startup and innovator and really made sure to highlight this specific point. The non-profit horticultural farmer also supported her statement by saying:*"I think there can be innovations that make our lives very much easier, but it needs to fit our needs in a way",* which complement the technology developer point of view. From the innovator perspective and from the farmer's perspective, both shared the same opinion on the fact that innovation should come from needs.

In addition to that, the analysis revealed that sometimes the market makes pressure for innovation adoption too. The non-profit horticultural farmer, working with few innovators and willing to try new things at her farm, mentioned that: *"But I don't necessarily think that that's something that everyone wants, but that's more what the market forces us to go for"*. This quote showed that innovation can also be pushed towards certain farmers if the market constrains them to adopt it. It is not because there is innovation adoption that it means that it is actually what farmers want.

Innovation is not only coming from external firms, indeed the analysis also identified farmers as innovators. Some respondents mentioned the implication of farmers in the innovation ecosystem. The sustainability-oriented intermediary, for example, stated that: *"innovation frequently emerges bottom-up through practical farming experience"*, which showed that farmers are already perceived as innovators and according to this actor, the most important one. The innovation support / cross-system actor also indicated that not only farmers can be innovators but also be a source of trust, which links back to peer legitimacy. Ultimately, the diversified farmer stated that without the involvement of a farmer, innovation is likely to fail.

To sum up, the data showed that innovation had to address farmers' needs and not be pushed against them. In addition to that, if combined with the participation of farmers in the process, it can enhance trust and increase chances for adoption.

4.10 Overview of Empirical Findings

The empirical findings have shown rich empirical takeaways organized by themes and sub themes and their assigned empirical insights. An overview of these findings have been presented in Table 5 below.

Figure 5 complements Table 5 by showing how the seven major themes appeared across interviews, supporting a cross-actor comparison of theme presence and main areas of emphasis. It highlights that several themes were shared across actor groups, while emphasis differed. Primary producers especially emphasized economic feasibility, practical compatibility, sustainability, and trust, whereas the regulatory-policy actor and biotechnology firm emphasized regulatory conditions, sustainability, market need, and ecosystem-level coordination. Sustainability-oriented intermediaries and innovation-support actors emphasized trust, legitimacy, coordination, and ecosystem roles.

MAIN THEME	SUB-THEME	CODE NAME	ANALYTICAL INSIGHT
Economic feasibility	Cost barrier	*Economic hurdles*	Innovation is adopted when it is economically viable.
	Economic incentive and profit motivation	*Profit-driven motives*	Farmers' adoption is influenced by financial returns.
	Time pressure and heavy workload	*Time scarcity*	Time scarcity limits interest and contact with new technologies and innovation.
	Commercialization gap	*Scaling barrier*	The ecosystem supports early-stage innovation better than market scaling.
Trust and legitimacy	Real relationships	*Personal relationships and trust*	Adoption depends on trust built through direct human contact and interactions.
	Institutions and Legitimacy	*Actors legitimacy*	Institutions and farmer implication reduces skepticism and increases credibility.
	Suspicion of outsiders	*Knowledge gap*	Distance and knowledge gap create resistance for initial contact and adoption of innovative/technology firms.
	Peer credibility	*Peer-based trust*	Farmers are more receptive when innovation comes from farmers and feels familiar.
Ecosystem enablers and constraints	Advisors as influencing actors	*Advisor influence*	Advisors strongly shape farmers' perspectives as legitimate and useful.
	Connectors	*Bridging actors*	Diverse actors play a big role as connectors in the ecosystem.
	Ecosystem fragmentation	*Widespread ecosystem*	Fragmentation increases the coordination challenge.
	Coordinating actors	*Coordinator*	Only a few actors seem to coordinate themselves.
Compatibility with farm practice	Simplicity and usability	*Convenience and ease of use*	Adoption requires practical fit with everyday farm routines.
	Farmers self reliance	*No external dependence*	Farmers value autonomy and are reluctant to technologies that create long-term dependency on external firms.
	Farms individuality	*Farm heterogeneity*	Adoption depends on each farm individually.
Sustainability as driver and tension	Green necessity	*Sustainability necessity*	Sustainability is presented as fundamental to farming's survival.
	Green opportunity	*Sustainability opportunity*	For some actors, sustainability policy actively supports innovation.
	Sustainability as barrier	*Cost of sustainability*	Sustainability is not a due for all farmers.
Regulation dynamics	New regulation as a challenge	*Regulation challenges*	New regulation is getting stricter and could work as a barrier for some actors.
	New regulation as an opportunity	*Regulation opportunities*	New regulation could lower barriers for smaller firms and researchers.
	Bottom-up governance	*Public led policy*	Regulation is highly influenced by bottom-up actors and voices.
Market need drives innovation	Customer designed	*Need-based innovation*	Innovation is mostly from needs.
	Markets pressure for adoption	*Adoption pressure*	Market pressures often push innovation adoption.
	Farmers innovation	*Farmer-led innovation*	Farmers remain important innovators.

Table 5: *Thematic Framework of Enablers and Constraints in the Swedish Agri-Food Innovation Ecosystem.*

Major theme	Pilot Knowledge Provider	I1 Regulatory / Policy Actor	I2 Technology Developer	I3 Sustainability Ecosystem Facilitator	I4 Innovation Connector	I5 Diversified Farmer	I6 Traditional Farmer	I7 Non-Profit Horticultural Farmer	I8 Aquaculture Farmer
Economic feasibility drives adoption			⚫	⚫	⚫	🔴	🔴	🔴	🔴
Trust and legitimacy shape adoption		⚫	⚫	🔴	🔴	🔴	🔴	🔴	🔴
Ecosystem actors enable or constrain innovation diffusion	🔴	⚫	🔴	🔴	🔴	⚫	⚫	⚫	⚫
Compatibility with farm practice is crucial		⚫	⚫	🔴	🔴	🔴	🔴	🔴	🔴
Sustainability is both driver and tension		⚫	🔴	⚫	⚫	🔴	🔴	🔴	🔴
Regulation as enablers and disablers		🔴	🔴			⚫		⚫	🔴
Market need and farmers drive innovation			🔴	🔴	⚫	⚫	⚫	🔴	⚫

Note: A black circle indicates that the theme was present in the coded material for that interviewee. A red circle indicates that the theme was one of the interviewee's main areas of emphasis. Blank cells indicate that the theme was not clearly identified in the coded excerpts. The pilot interview is included as contextual background.

Figure 5: *Presence of Major Themes Across Interviews*

5. Discussion

This chapter discusses the empirical findings of the study in relation to the existing literature and theoretical framework and aims to address the research questions. The aim is to examine how ecosystem interactions shape Sustainable Oriented Technological Innovation, and how these interactions enable or constrain the adoption of innovation in practice. The discussion is structured around the core themes identified in the empirical findings, which are interpreted through the lens of the literature on technological and sustainable innovation, innovation ecosystems and ecosystem interactions.

5.1 Ecosystem Interactions as a Main Element for SOTI

While shaping SOTI refers to how interactions influence the development and direction of innovation, adoption enablers or constraints refers to whether those interactions translate into practical implementation at the farm level. A central element in the theoretical framework is that innovation is the result of multiple coordination and interactions of diverse interdependent actors and not merely just a linear or firm-level process (Kline and Rosenberg, 1986; Fagerberg, Mowery and Nelson, 2005).

The findings happened to reinforce this argument. Indeed; across most of the respondents, the analysis highlighted that in the Swedish agri-food system, innovation is deeply relational. It depends on trust, coordination of activities, resource exchange and knowledge transfer that the actors have between them. For the different actors of the ecosystem (farmer, innovation hub, technology firm, innovation network …), none of them operate alone, they all have some sort of contact and interrelation with other actors, which confirm and support the existing literature.
This finding is supporting Valkokari et al. (2016) argument that the innovation ecosystem is composed of diverse interactions that shape and co create the innovation in a very dynamic setting.

In addition to that, the data also showed that the quality of interactions between actors vary a lot from one actor to another. Building on that and by utilizing the ARA framework by Håkansson and Johanson (1992) and Ford et al. (2008), the data can be interpreted across three categories: actor bonds, activity links, and resource ties.

Actor bonds relate to the trust and legitimacy derived from actors' relationships, this appeared quite a lot in the data, which support that technology itself is not enough if trust doesn't exist. Other farmers and actors in the ecosystem also stressed that personal relationships are essential to their willingness to interact with new technologies. This aligns pretty well with Håkansson's (1982), social exchange concept as a way to create trust between actors. The data also suggested that, by the absence of strong relationships or proximity, actors felt distrust and were quite reluctant to interact with external actors. This, again, supports Håkansson and Johanson's (1992) argument that weak actors' bonds can lead to poor or even conflictual cooperation.

Activity links can be considered enabling or disabling and refer to the coordination of activities between actors. Actors such as innovation hubs have been identified as quite important and strong connectors in the ecosystem. Indeed they appeared to enable communication with politicians and have a certain influence on regulatory actors, which startups cannot have. Furthermore, advisors were identified as key actors multiple times, indeed they appear to be trust building and working as a translator between firms and farmers. This seems to be supporting Dedehayir et al. (2018) idea of "champions", supposed to enable access to the market and create connections with actors. On the other hand, activity links were found to be spread and fragmented, which shows the coordination challenges that happen in large, decentralized ecosystems (Halinen and Törnroos, 2005). This fragmentation limits an effective development of SOTI into practice and brings another layer to the existing literature.

Resource ties refers to the exchange of resources (inputs, knowledge, financial…) between actors. The data revealed this as uneven within the ecosystem. The analysis shows, for example, a lack of financial resources for farmers, a lack of knowledge from the public and between different actors and more generally resources unevenly shared and exchanged leading to limitations concerning interaction with innovation which impact adoption. The imbalance in resources leads to structural obstacles that hinder mutualistic interactions. According to Grandstrand and Holgersson (2020), innovation ecosystems involve both cooperation and competition and evidence indicates that unequal resource distribution among participants often results in parasitic or one-sided relationships, rather than the reciprocal arrangements needed to support long-term innovation uptake (Yoon et al., 2022). The data aligns quite closely with the existing research on the effect of resource exchange on relationships.

5.2 Trust, Legitimacy and the Social Interactions for Adoption

It can be argued that both trust and legitimacy are key to understanding why SOTI adoption has been successful, not merely ancillary concepts. In each category of respondents analyzed, it is clear that technology acceptance on the part of farmers is greater if the new technology comes from a source deemed credible and trustworthy, supporting previous work on the topic. Key organizations that were seen as credible included SLU, the Swedish University of Agricultural Sciences. As one individual stated, farmers would like assurances that new technologies have "the SLU stamp". This highlights the university's role as a recognized expert within the innovation landscape: an institution that not only produces and shares knowledge but also validates the reliability of technological advancements (Dedehayir et al., 2018).

Peer credibility emerged as an essential element when creating trust. Some respondents noted that innovations developed or encouraged by other farmers appear more credible than innovations generated externally. This correlates with the existing literature on interactions within ecosystems, which underscores social interaction as one of the factors that contribute to establishing trust between interacting parties (Håkansson, 1982). It also confirms Adams et al.'s (2016) argument about how the organizational transformation stage in the case of SOTI requires changes not only in terms of technology but also in terms of culture and relationships. The likelihood of adopting innovations is likely to decrease substantially if they are introduced without social interaction, i.e., without trust, approval, or institutional support, which well illustrates the weight of social interaction in SOTI adoption .

The mistrust that farmers exhibited towards any outsider who was not known to them had significant consequences as well. This lack of trust and distance forms the basis of what Håkansson (1982) refers to as a relational barrier to interaction as explained by Cunningham (1982), as it is grounded on cultural and social differences as opposed to incompatible economic and technological factors. These results indicate that bridging the social gap between innovators and primary producers may be as important as enhancing the economic or technological value of the innovation.

5.3 Economic Feasibility as a Structural Constraint

Based on empirical results, economic feasibility has been revealed as a key structural factor limiting the adoption of SOTI. For all four respondents representing primary producers, economic factors were found to be the main limitation. The above-mentioned result supports other research that highlights the importance of economic factors over sustainability despite the pro-environment attitude of the actor (Adams et al., 2016; Hart & Milstein, 1999).

The conflict was put into perspective by some respondents. As noted by Nidumolu, Prahalad and Rangaswami (2009), sustainable innovations are more likely to be applied if there is economic gain from the application especially when there are issues regarding compliance, efficiency, or competitiveness involved. However, based on the data gathered, it seems that the farmers in Sweden have yet to reach a point in which sustainability becomes economically feasible to them and therefore cannot be applied in an integral manner.

Time constraints further accentuate this structural limitation. Some respondents commented that the farmers work under a lot of pressure and do not have much time to interact with any other actors, assess new technology or innovations. This becomes relevant to the context of interactions literature where it highlights that deep interactions for ecosystems are essential and require time investment (Ford et al., 2008). The absence of time results in transactional and superficial interactions that lack deeper interactions essential for effective learning and technology uptake. In essence, the actors who are central to SOTI implementation are those who are the least capable to get engaged into the interactions process.

This gap is pointed out by the biotechnology firm who also demonstrates the existence of structural inequality in ecosystem support. There are support and opportunities in Sweden provided for R&D and new startups. However, there are no actors that provide any support to ensure successful scaling up after technological development. This is quite consistent with the chain-linked approach to innovation suggested by Kline & Rosenberg (1986). According to the authors, innovation is dependent not only on scientific discoveries, but also on a combination of different processes in the marketplace, organization, and institution. In other words, innovation cannot be successfully conducted without adequate coordination of various activities.

5.4 Compatibility, Autonomy and Farm-Level Conditions for Adoption

As seen, being compatible with current practice on farms is a requisite condition for the adoption of SOTI but not a sufficient one. According to the biotechnology firm, their technology was purposely developed to be price competitive and user-friendly based on farmers' suggestions. Moreover, the sustainability-oriented intermediary emphasized that innovation should be adapted and complement existing practices. This supports the general notion that innovations cannot be viewed independently of the environment in which they are adopted since the decision to adopt is influenced by both technological aspects and the context into which the innovation will be introduced (Kline & Rosenberg, 1986; Adams et al., 2016).

Autonomy is another aspect highlighted by the findings. A farmer explicitly emphasized his desire for innovation that does not make him dependent on any outside firm. This focus on independence is in line with the notion of the non-contractual governance arrangements within ecosystems outlined by Thomas & Autio (2020), whereby actors remain strategically independent despite their interdependence. Farmers particularly could see dependence upon external technology as a potential source of risk to their farms amid climate uncertainty.

The farm variation was identified as a cross-cutting constraint. The various respondents stated that farms vary greatly in relation to the scale, soil, climate, crops grown, structure, and economic situation. This issue has profound importance for the development of ecosystems. This issue implies that adoption of SOTI cannot rely on standardization of innovative solutions. On the contrary, it implies interaction, which can occur only when there is sufficient time, necessary knowledge, and strong connections between innovators and farmers.

5.5 Sustainability and Regulation as Dual Forces

The results portray sustainability as both a motive and a challenge in the ecosystem. First, the results indicate that sustainability serves as a motivating factor as well as an innovative force. The various respondents in the ecosystem, such as policymakers, biotechnology companies, sustainability brokers, and farmers, all indicated a common dedication to the issue of sustainability as a moral value. This is consistent with the notion put forward by Hart & Milstein (1999), who claim that sustainability opens up a whole new competitive field in which sustainability may be a driver for creative destruction.

On the other hand, the data collected highlights the issue that sustainability causes conflict, especially for stakeholders who work under limited finances. Sustainability is an ideal that farmers wish to achieve but cannot in their present economic status, as suggested by the findings made by Adams et al. (2016), who noted that SOI implementation gets stuck during the stage of operational optimization due to lack of incentives and resources needed for radical transformation. As stated by the aquaculture farmer, sustainability-based innovations can be met with resistance because they are viewed as competition.

The same could be said about regulatory dynamics. On one hand, regulation served as a hindrance especially to small companies and innovation start-ups facing complicated and expensive regulatory approval procedures while, on the other hand, it served as a tool that can potentially facilitate things with regard to new EU legislation concerning genetically edited plants that can reduce barriers for new technologies or sustainable innovation in agriculture. Notably, based on the collected data, it should be pointed out that regulation is not merely an activity performed from above. Thus, one farmer highlighted her involvement in EU regulatory discussions, while the public / institutional actor reported considerable bottom-up contribution coming from farmers, businesses, and scientists to the process of developing regulation.

5.6 Towards a Relational Model of SOTI Adoption

As a whole, the evidence shows that the adoption of SOTI in the Swedish agri-food industry is not primarily dependent on the technical nature of innovations, but rather on the level and nature of ecosystem interactions related to innovations. This conclusion coincides well with the main thesis of the theoretical model: that ecosystem interactions, as an exchange of products/services, information, finance, and social capital (Håkansson, 1982), is the major way to transfer SOTI into implementation.

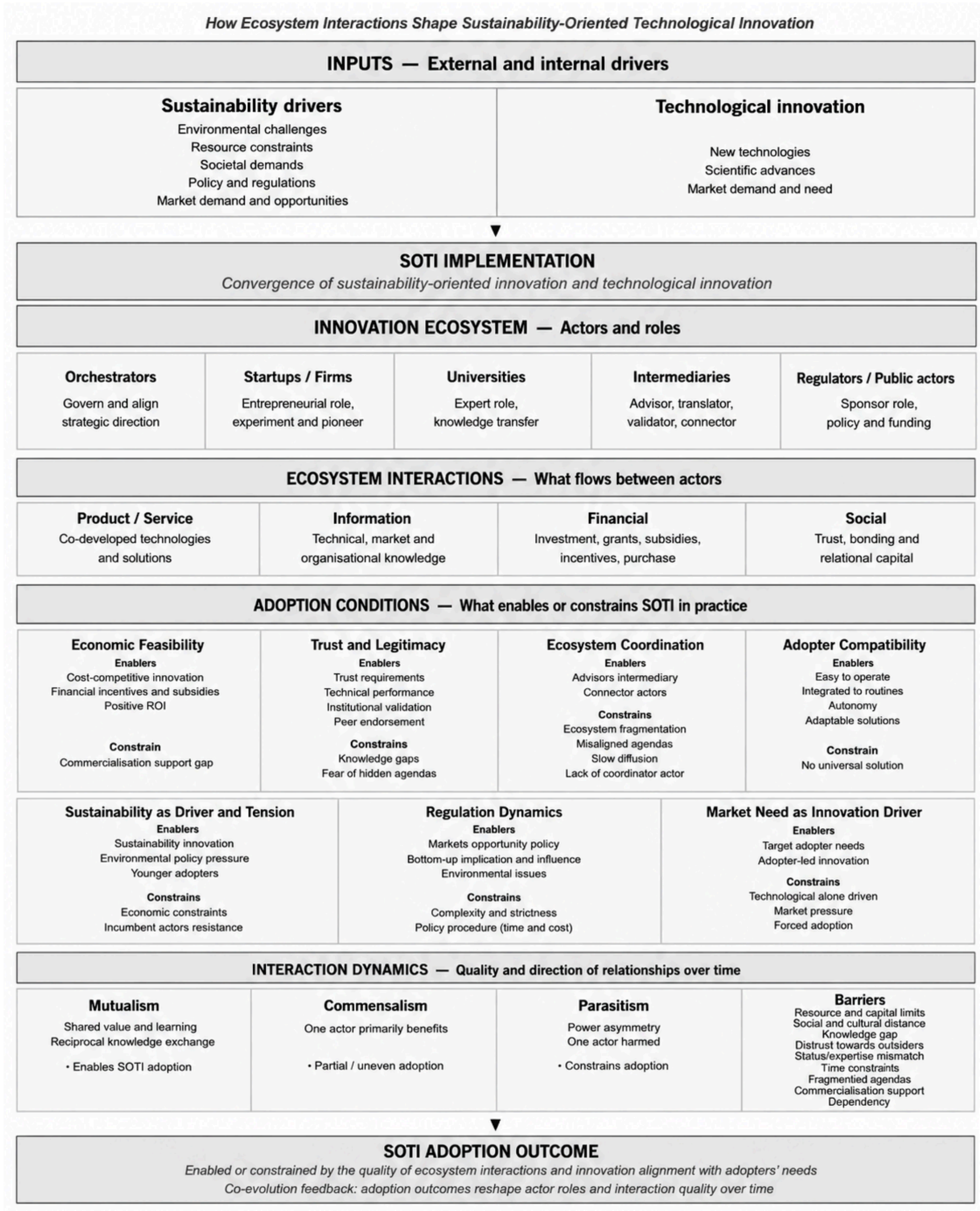
The data and analysis raised three critical factors that make the adoption of SOTI possible through the existence of ecosystem interactions. First, the interactions need to be characterized by relational embeddedness and trust. If actors within the system enjoy some degree of personal relations, peer respect, and institutional power, then there is a higher possibility of adoption of innovations. Second, the interactions have to be economically grounded. Since SOTI will be difficult to adopt without generating economic gains from it, then the ecosystem interactions should include elements of incentives and financial gains as well. Third, the interactions should be adaptive to farm-level conditions since each farm will have different requirements.

However, in the absence of such conditions, when interaction is transactional or economically unsustainable or has nothing to do with the farm process, there will be parasitic relationships or commensal relationships but not mutual relationships (Yoon et al., 2022), thereby making the whole integration of the system unable to adopt sustainable technology. This study further supports the notion that the creation of sustainable ecosystems needs systems thinking, collaboration and alignment among participants by Seebode et al. (2012) because those conditions do not fully exist within the Swedish agri-food innovation ecosystem.

A revised framework has been developed to illustrate the contribution of our thesis, indeed, while the data aligned with most of the theoretical framework and previous studies, the data and analysis added layers. Fundamentally, SOTI adoption is a relational ecosystem process shaped by alignment between technology, resources, actors, institutions, and farm-level conditions. Within this updated model, another actor has been identified as well as its respective role. In addition to that, the study provided a more detailed adoption condition layer, which was taken from the recurring themes of our analysis. The themes displayed in the final framework show a real addition to previous study by establishing different innovation adoption enablers and disablers but also suggesting practical implications for different firms and members of the ecosystem.

Furthermore, concerning the transferable takeaways from the thesis, it can be found in the revised framework (Figure 6) as it has been built with a more general view on innovation and sustainability that was widely shared by the respondents, highly applicable to ecosystems with comparable actors and institutional landscapes. Regarding what is unique to the Swedish landscape, it would be more about the innovation of the new generation of farmers and their willingness to try new solutions that could make their operation more sustainable. Also, Swedish farmers appeared to have a good knowledge on diverse sustainability and innovation topics that could be quite advanced in opposition to other regions of the world (supported by the innovation firm, who qualified Swedish farmers as quite educated).

Figure 6: *Revised Theoretical Framework for Understanding How Ecosystem Interactions Shape Sustainability-Oriented Technological Innovation Adoption*



6. Conclusion

This thesis explored how ecosystem interactions shape sustainability-oriented technological innovation (SOTI), and how these interactions enable or constrain adoption in practice. Based on a qualitative case study of the Swedish agri-food innovation ecosystem, the thesis argues that SOTI cannot be fully understood through the characteristics of the technology itself. Instead, it is shaped by the wider ecosystem in which actors develop, support, interpret, regulate, and adopt innovation in practice.

The revised framework developed from the findings shows that SOTI adoption is shaped through several connected layers. Sustainability drivers and technological innovation create the conditions for SOTI adoption, but these inputs do not lead directly to adoption. Rather, they move through an innovation ecosystem made up of actors with different roles, including orchestrators, firms, universities, intermediaries, regulators, public actors, and primary producers. Within this ecosystem, adoption is shaped by what flows between actors, including product and service exchange, information exchange, financial exchange, and social exchange.

The findings show that these ecosystem interactions become practically significant through seven adoption conditions: *economic feasibility, trust and legitimacy, ecosystem coordination, adopter compatibility, sustainability as both a driver and a tension, regulation dynamics,* and *market need as an innovation driver*. These conditions determine whether SOTI becomes cost competitive, credible, coordinated, usable, institutionally supported, and aligned with adopter needs. The revised framework therefore shows that adoption is not shaped by one single factor, but by the interaction between technological, economic, social, institutional, market, and farm-level conditions.

The framework also shows that the quality and direction of interaction dynamics matter over time. Mutualistic interactions can support shared learning, reciprocal knowledge exchange, and SOTI adoption, while fragmented, poorly aligned, or asymmetric interactions can constrain adoption. The central issue is therefore not only whether a technology works, but whether the ecosystem enables it to become economically viable, legitimate, coordinated, compatible with everyday practice, and aligned with regulatory and market conditions.

6.1 Theoretical Implications

In line with innovation literature, this thesis finds that innovation is not a linear process moving directly from invention to adoption, but an iterative and interactive process shaped by multiple actors, feedback loops, and sources of knowledge (Drucker, 2002; Kline and Rosenberg, 1986; Fagerberg, Mowery and Nelson, 2005). The findings extend this perspective by showing that, when technological innovation is connected to sustainability goals and agricultural adoption, innovation moves toward practice only when actors across the ecosystem interpret, support, adapt, and legitimize it.

The findings also support SOI literature, which argues that sustainability-oriented innovation involves environmental, social, and economic value creation and may require system-level change (Adams et al., 2016; Seebode, Jeanrenaud, and Bessant, 2012; Nidumolu, Prahalad, and Rangaswami, 2009). However, this thesis nuances that literature by showing that sustainability value does not automatically translate into adoption. In the Swedish agri-food context, sustainability can drive innovation, but it can also create tension when it conflicts with economic feasibility, practical compatibility, autonomy, or adopter needs. This suggests that SOTI adoption depends not only on sustainability potential, but on whether the ecosystem can align sustainability goals with farm-level realities.

In line with innovation ecosystem literature, this thesis finds that innovation is shaped by interdependent actors, roles, resources, activities, and relationships (Moore, 1996; Iansiti and Levien, 2004; Granstrand and Holgersson, 2020; Dedehayir et al., 2018). However, the revised framework adds that multiple actors alone do not enable adoption. Rather, ecosystem actors influence SOTI through product/service, information, financial, and social exchanges, which become practically significant through adoption conditions such as economic feasibility, trust and legitimacy, ecosystem coordination, adopter compatibility, regulation dynamics, and market need. The framework therefore extends ecosystem literature by showing how ecosystem structure is translated into adoption conditions.

Finally, the findings build on interaction and ARA literature by showing that actor bonds, activity links, and resource ties shape how actors coordinate, exchange knowledge, build trust, and access resources (Håkansson and Johanson, 1992; Ford et al., 2008). More specifically, actor bonds influence trust, legitimacy, and willingness to engage; activity links influence coordination, testing, advisory support, regulation, and adoption; and resource ties influence access to knowledge, funding, infrastructure, biological materials, and practical farming knowledge. The thesis therefore moves beyond the general claim that collaboration matters by showing how specific interaction flows create adoption conditions and shape adoption outcomes over time.

6.2 Practical Implications

The revised framework has practical implications for actors involved in sustainability-oriented innovation ecosystems, particularly in the Swedish agri-food context. First, actors developing SOTI should involve primary producers early and meaningfully in the innovation process. The findings show that adoption depends not only on whether a technology is sustainable or technically promising, but also on whether it is economically feasible, practically compatible, and aligned with farmers' routines, risks, and autonomy. Primary producers should therefore be treated not only as end users, but as important sources of practical knowledge about adoption conditions.

Second, intermediaries, innovation hubs, advisors, universities, and support actors can help connect the innovation ecosystem with the agricultural value chain. By translating knowledge, building trust, validating technologies, and facilitating collaboration, these actors can reduce distance between technology developers, public actors, and primary producers. Since product/service, information, financial, and social exchanges influence whether SOTI becomes credible, coordinated, and usable in practice, adoption should be approached as a process of dialogue, adaptation, validation, and relationship-building.

Third, policy and support structures should address the adoption conditions that constrain SOTI in practice, including economic feasibility, regulatory uncertainty, limited resources, risk, lack of knowledge, and compatibility with existing farm practices. If SOTI is expected to contribute to a more circular and resilient agri-food system, actors across the ecosystem must also make adoption feasible for primary producers. This requires support not only for early-stage innovation development, but also for commercialization, testing, demonstration, farmer compensation, and market adoption.

6.3 Limitations and Future Research

This thesis is subject to several limitations that provide opportunities for future research. First, the study is based on a qualitative case study of the Swedish agri-food innovation ecosystem. While this approach allowed for an in-depth understanding of ecosystem interactions, the findings cannot be assumed to represent all agri-food systems or all forms of SOTI. Future research could compare different national or sectoral contexts in order to examine how the adoption conditions identified in the revised framework vary across institutional, cultural, and market settings.

Second, the study included a limited number of interviews with selected actors across the ecosystem. Although the sample included a public/institutional actor, a biotechnology firm, intermediaries, an innovation support actor, a university-affiliated knowledge actor, and primary producers, it cannot capture the full diversity of perspectives within the Swedish agri-food system. Access to primary producers was especially challenging. Numerous farmers were contacted through email, LinkedIn, phone calls, and Facebook, but many stated that they were unable to participate because the study coincided with one of the busiest periods of the farming year. Farmers who did participate were also hesitant to refer the researchers to other farmers because they did not want to add to their peers' workload during this period. As a result, the number and range of farmer perspectives included in the study was limited. Future research could therefore include a larger number of primary producers and conduct interviews during a less intensive period of the agricultural year. It could also include additional actors such as cooperatives, processors, retailers, investors, policymakers, and advisors.

Third, this thesis initially used biotechnology-related innovation and biosolutions as a concrete context for examining SOTI. However, during the interview process, several respondents engaged more meaningfully with broader questions about innovation, sustainability, ecosystem interactions, and adoption than with narrowly defined questions about biotechnology or biosolutions. As a result, the empirical focus developed toward SOTI more broadly. While this allowed the study to capture wider ecosystem dynamics, it also means that the findings are less specific to one clearly bounded technology. Future research could therefore apply the revised framework to one specific SOTI in greater depth in order to understand how interactions evolve from development to testing, adoption, commercialization, and scaling.

Finally, because this study captures interaction dynamics at one point in time, future research could use longitudinal methods to examine how trust, legitimacy, regulatory conditions, economic feasibility, and market need change over time. This would be especially useful for studying early-stage technologies that are still moving from experimentation toward broader adoption.

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Appendix

Appendix A: Pilot Interview Guide

1. Introduction
    a. Is it okay if this interview is recorded and transcribed?
    b. Could you describe your research in relation to Swedish food and feed systems?

2. Theoretical Framing and Research Focus
    a. Do you think an ecosystem perspective is appropriate for analyzing innovation in this context?

3. Understanding the Swedish Food and Feed System
    a. Can you explain how the Swedish food and feed system works in simple terms?
    b. Who are the main actors in this system?
    c. How do these actors interact across the value chain?
    d. Are there any important interdependencies or tensions (e.g., food vs feed)?

4. Roles of Key Actors
    a. Who are the most influential actors in the system?
    b. How do actors like cooperatives (e.g., Lantmännen), processing companies, and retailers influence farmers?
    c. How is power distributed across the value chain?

5. Innovation Adoption at the Farm Level
    a. How open to innovation are farmers in practice?
    b. What determines whether farmers adopt new technologies or solutions?

6. Business Models and Implementation
    a. What is required for farmers to adopt new solutions in practice?
    b. What role do profitability and efficiency play in adoption decisions?
    c. How important are services (e.g., training, support) in enabling adoption?

7. Barriers and Enablers of Innovation
    a. What are the main barriers to adopting innovation (e.g., resources, knowledge, time)?
    b. What enables adoption (e.g., incentives, efficiency gains, sustainability goals)?
    c. How do policy and regulation influence these processes?

8. Scaling and Ecosystem Coordination

a. What challenges exist when scaling innovation in the Swedish food system?
b. How do different actors (e.g., processing companies, cooperatives) support or hinder scaling?
c. What is missing in terms of collaboration or coordination?

9. Recommendations for Interviewees
a. Which actors would you recommend we interview?
b. Which perspectives are most important to include?
c. Would it make sense to focus on a specific region (e.g., Skåne)?

Appendix B: Interview Guide

1. Introduction
a. Is it okay if this interview is recorded and transcribed?
b. Could you briefly describe your role and how you engage with different actors in the food and feed system?

2. Technological Innovation
a. How would you define innovation in the context of the Swedish food and feed system?
b. From your perspective, how are these types of innovations typically developed?
c. What distinguishes sustainable from more traditional innovations in agriculture?
d. Would you say innovation in this space is mostly driven by:
i. technology push (from firms/research), or
ii. demand pull (from farmers, regulators, or consumers)?

2.1 Sustainability-Oriented Innovation
a. To what extent is sustainability a driver of innovation?
b. Are innovations mainly developed for sustainability reasons, or also for economic and operational benefits?
c. How do you see these innovations affecting agricultural operations in practice? What kinds of changes do they lead to?

3. Ecosystem Structure and Actors
a. How would you describe the structure of the Swedish food/feed ecosystem?
b. Who are the most important actors involved in developing and scaling innovation?
c. Who are the most influential actors and how so in the Food/Feed systems, and how do they influence the system?
d. What role does your organization play in:

    i. connecting actors
    ii. facilitating collaboration
    iii. supporting innovation development

3.1 Ecosystem Interactions

a. Can you describe the interactions you have with other actors in the system?
b. How do different actors (e.g., firms, farmers, intermediaries, institutions) interact in practice?
c. Who do you interact with most frequently, and for what purpose?
d. What kinds of resources or knowledge are exchanged in these interactions?
e. How do these interactions influence the development or implementation of innovation?
f. How do farmers typically first become aware of new innovations?
g. Are there particular interactions or collaborations that are especially important for moving innovation forward?
h. Are there interactions that do not work well? Why?
i. Are there particular bottlenecks or coordination challenges in these interactions?
j. Would you describe these interactions as more:
    i. Collaborative
    ii. Transactional
    iii. Dependent
    iv. One-sided
k. Can you walk us through a specific example of an interaction that led to a successful (or unsuccessful) outcome?

4. Innovation Adoption and Implementation

4.1 Ecosystem Support for Adoption

a. How do interactions between actors support the adoption of innovation by primary producers?
b. What kinds of collaborations are most useful for enabling adoption, and why?
c. What actors are closest to primary producers, and what roles do they play?
d. What kinds of support are most important:
    i. Knowledge
    ii. Financial incentives
    iii. Partnerships
    iv. Infrastructure
    v. Other?
e. Are there specific actors that play a key role in helping farmers adopt new technologies?

4.2 Innovation Integration in Practice

a. From your perspective, what does it mean for an innovation to be successfully implemented in practice?
b. What kinds of changes are typically required at the farm level?
    i. Operations
    ii. Routines
    iii. Investments
    iv. Relationships with other actors
    v. Other?
c. Do you see examples where innovations fail, not because of the technology, but because they do not fit existing practices or structures?
d. Could you give examples of successful innovation adoption in primary production and describe how it was implemented?

4.3 Enabling and Constraining Factors

a. What are the main barriers to adopting innovation in practice?
    i. Knowledge
    ii. Cost
    iii. Risk
    iv. Regulation
    v. Culture
    vi. Other?
b. Do these challenges differ across:
    i. Different types of farms
    ii. Early adopters versus more traditional producers

5. Conclusion

a. Is there anything we haven't asked that you think is important for understanding this topic?