TÉCNICO LISBOA

Barriers Analysis for Supply Chain Collaboration in Industrial Symbiosis Networks: a case in the olive oil industry

Extended Abstract

Inês Figueira de Matos

May 2022

Abstract

In Portugal, the olive agro-industrial sector has tremendous socio-economic relevance and key implications on global employment and revenue. However, the impacts of increasing olive oil production and consumption on the environment are considerable, mainly due to the demand of large inputs of resources and the large amounts of by-products generated. In the vast majority of cases these by-products are unexploited, although they could be converted into a zero-waste supply chain, implementing waste-to-energy solutions throughout a circular economy (CE) perspective. Considering the latter, the research problem in this project concerns the conditions for developing stable industrial symbiosis (IS) relationships between involved entities, guaranteeing that the IS is beneficial for every party. Each player in the industrial symbiosis can benefit from this relationship in multiple aspects, for instance: more efficient use of resources, reduce waste, increase profits, share knowledge, thus reducing the firm's vulnerability in environments characterized by diverse levels of uncertainty. Earlier studies have presented drivers that support the introduction of new IS relationships in order to support CE, as well as common barriers that hinder its establishment. Hence, the olive oil industry is characterized, alongside a brief description regarding the olive oil management integrated supply chain. Then, a literature review on the problem's most relevant concepts is performed to provide a theoretical framework for the future work explored in the following sections. An empirical illustration of potential barriers towards the development of IS relationships is presented, including the several ones: Trust, Beliefs, Risk and Uncertainty, Economic and Operational, Skills and Technology, Governmental, Complexity and Responsibility. Then, methods to overcome the barriers and encourage a better implementation of CE across the supply chain were suggested.

Keywords: Olive oil, Supply Chain, Sustainability, By-products, Industrial Symbiosis, Barriers.

1 Introduction

The agri-food sector (AFS) in particular has been suffering from problems such as food shortage and waste accumulation across the supply chain. In fact, projections for 2050 indicate the emergence of growing scarcities of agricultural land (Esposito et al., 2020). To guarantee a more resilient tomorrow, stakeholders must be aware of upcoming trends, and possible disruptions, in their business strategy (McKinsey, 2021). Environmental responsibility, fair trade, and consumers' health are some of the current concerns. Consumers are more and more curious about the process that is behind the product they buy, from cradle to grave. Today, there is a chance for everyone to form properly informed decisions.

1.1 Sustainable Development and Circular Economy

Organizations as the FAO and the Ellen McArthur Foundation (EMF) have shifted the attention from optimizing production processes to responsible consumption, pushing the interest on the CE concept worldwide. In 2015, the Ellen McArthur Foundation together with McKinsey estimated that a CE approach could increase resource productivity by 3 percent by 2030, generating cost savings of around 600 billion euros a year and 1.8 trillion euros more in other economic benefits (McKinsey, 2019). CE approach has revolutionized the way agriculture and industry are involved with each other. From a typical supply chain that was designed to act as a 'take-make-waste' linear model. Where business continuity was supported on productive manpower and efficient operations, instead of being concerned with environmental or social impacts (EMF, 2015). The desired result is to have stakeholders with a more involved attitude in matters that focus on maintaining the balance between producing a good and ensuring its continuity. Despite the SC inherent sustainability risks, few organizations are aware of their sustainability issues, and the ones that are, rarely trigger collaborations with their suppliers in order to mitigate the risks. And, when businesses try to persuade their suppliers, they are most likely to face challenges ahead (McKinsey, 2019). The purpose of an olive oil's byproducts management system is to ensure the correct end or revalorization of these products' life cycle. This will require the promotion of

olive oil byproducts retread, recycle, or valorization with energy/material recovery, which can be solutions for effective waste management, to avoid other forms of disposal, harmful to both the environment and public health such as landfill disposal, as well as generating additional benefits for the company. SC key players should be able to efficiently interact with each other to maximize the collection of olive oil by-products from its sources and to avoid bottlenecks along with the network that keeps them from being recovered, creating unwanted accumulations of stock that later may disable olive oil production capacity due to legal reasons.

1.2 The olive oil Industry and Market

The Olive Oil industry faces constant demand, nevertheless, supply does not behave the same way, suffering from instability. This challenge can influence the industry's demand-supply balance, and thus its pricing and investment dynamics. The value chain distribution income between the different players is affected. This sector plays a very important role for a large part of the community since it employs around 1,2% of the total world active population, i.e., 35 million job positions. Per year, this industry generates approximately 9.500 million euros to 13.500 million euros, worldwide. Information is segmented by different continents. Nationally, the olive oil industry influences the agri-food business with a positive value of 144,405 million euros, counterbalancing the negative results (-3.460 million euros) previously presented in 2017 (Vilar, 2019). According to the latest statistics, the 2019/2020 national agricultural campaign released by SIAZ, presented a new historical maximum of olive oil production levels, reaching 140.5 thousand tons. The number of olives worked at the mills increased by 33% compared to the previous season, and its average olive oil yield increased from 13.4% to 15.2%. This resulted in a 51% increase in the volume produced. In summary, some of the aspects that have contributed to sector expansion were the positive developments in olive oil prices, national and international recognition of Portuguese olive oil quality, increase in domestic consumption per capita and exportations growth, leading to an important economic growth (GPP, 2019).

Firstly, we will discuss viable revalorization processes alternatives for one of olive oil's production byproducts, olive pomace. Next, concepts related to **Industrial Symbiosis (IS), Supply Chains (SC), Supply Chain Management (SCM), and Circular Symbiotic Supply Chains (CSSC**) will be clarified in order to better understand the upcoming work. Also, which are the enablers for the creation of Industrial Symbiotic Supply Chains. Foremost, the major goal of this research is to identify significant blockers that may hinder the establishment of this type of relationship, or later, its endurance, within a SC, more specifically in the olive oil SC. Finally, additional developments for organizations interested in forming these relationships are recommended, as well as methods for determining whether a relationship(s) is beneficial to the parties involved.

2 Literature Review

Companies began to recognize that they could no longer operate as single entities, but rather as part of a network of enterprises collaborating to maximize consumer experience (Teixeira, 2019; Martin, 2011; Min, 2015). The main stakeholders in agri-food supply chains are usually farmers/producers, food industries, distributors, retailers, and consumers. In addition, several external entities, such as government agencies, non-profit organizations, food and industry representatives, and investment firms, serve as secondary partners. They may or may not participate in SC operations, but they frequently have a variety of effects on the business system that handle materials, data, and cashflows among different parties (Dania et al., 2018). In this case, the availability of industrial by-products is the result of a push process, which means quantity and the moment of time that it will be available is uncertain. As a result, there can be surpluses or shortages in different industries due to fluctuations in supply and demand and different seasonal characteristics (Morgan, M. G). Uncertainty in a SC can be related to demand versus supply, transportation plans, price fluctuations, quality level, and customer service. Considering downstream flow, the agricultural market is particularly volatile, heterogeneous, and extremely sensitive to economic and financial fluctuation in levels closest to the customer (demand elasticity) (Martinez, 2019).

2.1 Waste Framework

Observing the global economy, perhaps the food sector is one of the best potential creators of natural and regenerative capital rather than only exhausting it in the long term. For billions of years, organisms have evolved, flourished and, at the end of their cycle, become "fuel" for the beginning of a new cycle (Donner et al., 2020). The Ellen MacArthur Foundation (2015) has pointed out that the notion of a CE relies on three principles (Abreu & Ceglia, 2018):

1) Preserving natural capital by controlling finite stocks and balancing flows of renewable resources;

2) Optimizing resource yields by circulating products, components, and materials of the highest utility in both technical and biological cycles;
3) And, fostering system effectiveness by revealing and designing out negative externalities.

Food Waste (FW) is produced at every stage of the food SC, being more obvious at the retail and consumer stage, but this should not be ignored in other stages of the chain (Lin et al., 2013). FW can be defined as products or product components that the holder intends or is obligated to discard. Ideally, by implementing advanced valorization routes (CNCDA, 2017). Food by-products are secondary materials that arise from the cultivation and manufacturing stage or that are not edible (e.g. leaves, olive pomace), as well as consumer waste (e.g. packages) (Lin et al., 2013).

2.2 Sustainable Supply Chain

From an ecological-economic perspective, to be sustainable, means the development must be economically sustained (or efficient), socially fair (or inclusive), and ecologically thoughtful (or balanced) (Pearce & Atkinson, 1998). Having regard to this definition, sustainable management of a SC has to be aligned with shifting the focus from **labor productivity** to resource **productivity**. There are two reasons for increasing resource scarcity:

- Demand continues to exceed supply, this will quickly lead to stress over the resource.
- Resources' exploitation process will cause environmental influences, either positive or negative.

Manufacturers can use CLSC to benefit from retrieved and remanufactured products returned by consumers. In particular, refurbishment requires less energy consumption. In some cases, refurbished products may be more profitable and labor-intensive than producing new products (Chen et al., 2019). Also, the use of FW still has problems due to the following downsides and limitations: variable quantity, high water content, technical limitations, knowledge-based processing, skilled workforce, and the ability to transform it into valuable products (European Commission, 2018). Effective and inexpensive options are still being studied, legal and suitable infrastructure support for the transformation of perishable materials in the industry is still insufficient. The recognition and acceptance by the industry and the public are important obstacles that must be overcome in the future.

The government may have to intervene in the relationship between the producer and the consumer, if there is a need to reduce the consumption of a certain resource, on both sides (Di Maio et al., 2017). The Commission is currently focusing on restructuring regulation to facilitate the trade of by-products aiming to trigger a long-term culture ecology oriented proactive industries, as part of an action plan for its Circular Economy (European Commission, 2018). To help companies, European Union (EU) decided to develop some of the actions that may be stated quite briefly: Circular Economy Action Plan (CEAP), complementary to the European Green Deal, including the Climate agenda, Farm to Fork, Sustainable chemicals strategy, and Zero pollution strategy.

In the period of "local pollution per industry", where environmental progress in the industry has been largely initiated by the government. As we enter the period of "global social concerns" (globalization), this is no longer a pragmatic approach. There is an unquestionable necessity to focus from local to global and from industry to society. It is not enough to increase recycling and look at partial reformulations when considering a circular complex system. If the goal is to create a more sustainable economy, it is also important to look for a complete reduction in storage and resource consumption, in other words, reduce socio-economic metabolism while respecting the three dimensions of sustainability: profit, planet, and people. To do this, essential elements that impact the features and performance of collaboration, i.e. collaboration barriers, must first be identified, which may assist SC stakeholders in examining and managing the collaboration system for changes (Dania et al., 2018). Collaboration among organizations, as well as sustainable consumption and production, will be the next subjects for implementing sustainability in agri-food SC.

The IS-oriented SC aims to effectively coordinate the supply and demand of by-products while creating a sustainable collaborative system. So, according to Nazli Turken (2020):

"A symbiotic supply chain is a network of traditional and symbiotic suppliers, manufacturers, distributors, customers, and logistics, marketing, and related systems with the dual goal of achieving customer satisfaction through offerings of value-adding products, by-products, and waste, and minimizing non-product output disposal and improving resource efficiency."

Traditional SC and Circular Symbiotic SC (CSSC) differ from one another in numerous aspects:

- One's non-product parts (e.g., industry waste/ by-products) or excess utilities will be another's production cycle input, this may cause uncertainty in terms of the diversity of the retrieved materials.
- A traditional SC strives to add value, meet customer needs, and maximize profitability, whereas a CSSC besides that also seeks to minimize the non-product parts that are going to be rejected and improve resource efficiency in the manufacturing phase (Turken & Geda, 2020).

For an efficient flow of materials, matters such as geographic, institutional, social, organizational, and interaction proximity can help promote the IS relationships. The proximity between companies is considered an important factor, as producers

tend to build up storage on waste biomass (bulk), which reduces the cost of participating in supplies and transport. Globalization can also have the opposite effect, reducing such interactions within local communities. A closed economy can lead to a return to localization (Abreu & Ceglia, 2018). Setting up an IS initiative is not easy, for example, the Expected Return on Investment (ROI) is lower than the typically required rate of return for a stakeholder to embark on an IS relationship project. For this reason, companies heavily rely on financial incentives from public agencies or private equity investors. These include payment mechanisms to beneficiaries (mitigation subsidies, carbon credit markets, low-interest loans) for initial investments related to the introduction of more efficient practices (FAO, 2016), or payment mechanisms to polluters to induce the introduction of damage reduction technologies/ practices. Fees and taxes for pollution according to the amount, the environmental costs are assumed as internal and should be accounted for when decision making concerning production is being made. Without such governmental incentives, or in the case of long payback periods, companies may be reluctant to participate (Herczeg et al., 2018). Suppliers' and buyers' core business is not trading by-products, IS relationships are different from traditional supply chain relationships, yet the majority of companies financially benefit from retrieving cheaper supply materials or avoiding disposal costs and generating additional profit from by-products sales (Turken & Geda, 2020). Companies are not always equally dependent on each other, leading to unbalanced involvement. If the waste or by-products supply (or demand) happens in crucial primary production activities, it is important to increase resilience by anticipating the occurrence of certain events, for example, a shortage or partner withdrawal, among others. For instance, the availability of industrial waste is the result of a push process, meaning that surplus or shortage can occur due to the variability in supply and demand, and the different seasonal characteristics in different industries (Herczeg et al., 2018). Figure 1 describes the role of IS in accordance with state authorities, implementing initiatives focused on promoting the transition from the traditional linear economy to CE.

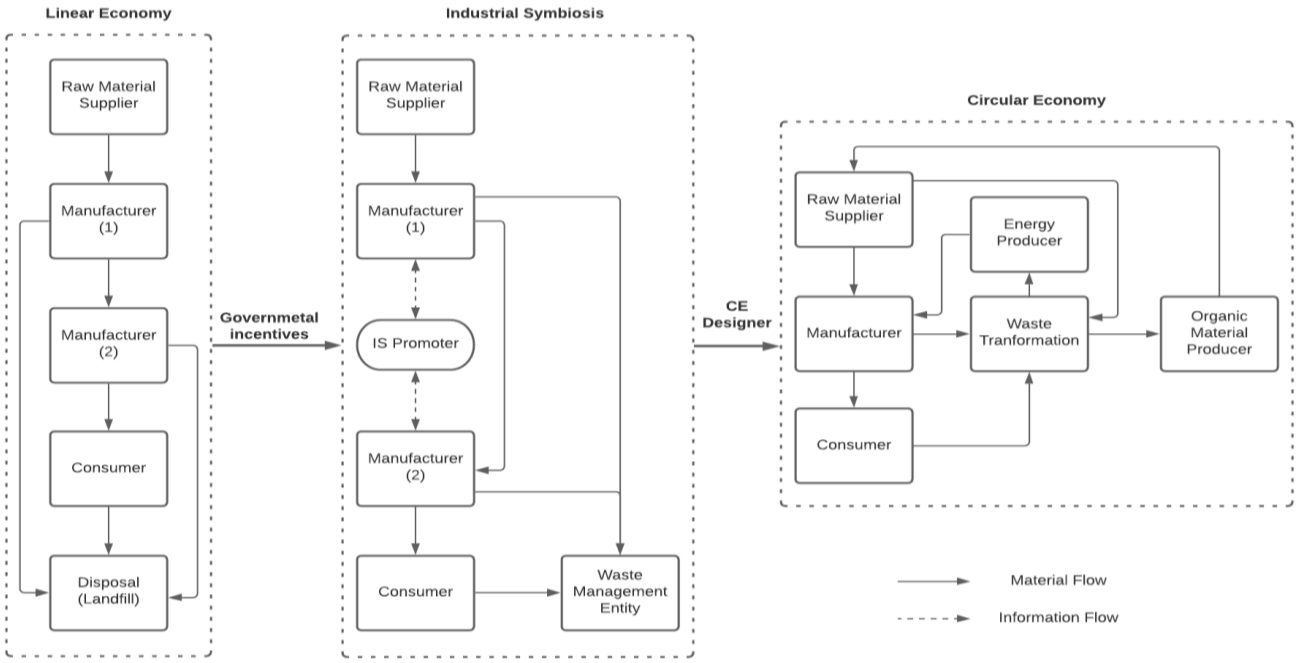

Figure 1- Transformation from a linear economy to a circular economy by means of industrial symbiosis, adapted from Abreu & Ceglia (2018)

3 Methodological Approach

3.1 Supply Chain Symbiotic Relationships

The importance of SCM will be highlighted in this chapter, where it is expected that sustainable practices will be incorporated into all levels of the chain through the emergence of multiple IS relationships, by actively encouraging the major players to remove barriers that are still on the way of establishing these relationships. Hopping that as a result, the entities involved in the process of delivering a specific product to the end consumers are better equipped to play a critical role in sustainable development, both in the direct and indirect SC. Figure 2 shows chapter's methodology.

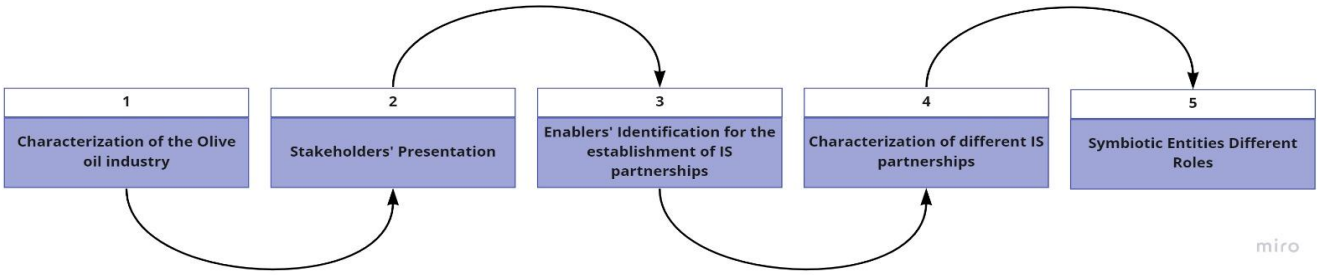

Figure 2- Supply Chain Symbiotic Relationships Characterization Methodology

Section 1 - Characterization of the Olive oil industry

Motivation: In Portugal, approximately one million tons of olives are processed per agricultural campaign year, which operates seasonally from November to February, with an increasing trend. Resulting in large quantities of olive pomace, the disposal of which is obliged by law. In order to prevent the buildup of potentially harmful material to the environment. A greater variety of processes and recovery locations is emerging, in order to not jeopardize the normal operation of mills. The following table demonstrates the classification of the system's outputs and their respective destination (Table 1).

Table 1- Characterization of olive oil activities, outputs and destination

Activity	Output	Destination
Olives Cultivation	Leaves, branches, bad quality olives	Waste Management: Energy or Organic Material Recovery
	Olives	Olive Oil Production
Olive Oil Manufacturing	Olive oil	Olive Oil Commercialization
	By-products (e.g., olive pomace)	Waste Management
Olive Oil Commercialization	Revenue	Consumer

Section 2 - Key Players Presentation

A description of the stakeholders present in different stages of the SC, directly and indirectly (Figure 3). Characterizing the relationships created between the entities is a crucial initial step in subsequently enhancing the partnership. It was developed a list of stakeholders, including those persons and entities who will influence the capacity to accomplish the study objectives. A wide range of actors need to get involved in cooperative actions (EMF, 2019):

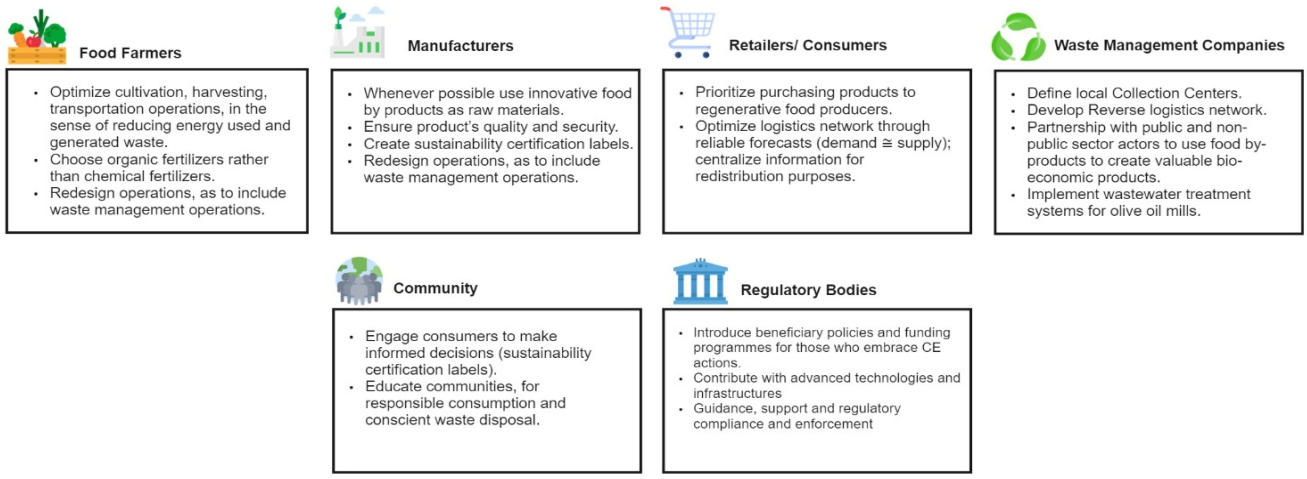

Figure 3- Key Player Representation

Section 3- Enablers' acknowledgment for the development of IS relationships

- **Ecological:** Scarcity of resources with potentially permanent environmental repercussions if sustainable manufacturing techniques are not embraced in emerging nations (Moktadir et al., 2018). Implementing an ISNs while relying on CE techniques will allow reducing the need for chemical fertilizers applied to crops, plus reducing the need for non-renewable

energy sources, and even promote organic enrichment and improvement of soil structure contributes to reducing the amount of water required due to induced soil retention capacity thanks to organic fertilizers application. Eliminating a potential source of pollution, and creating value where previously was a cost are some of the examples of an ecological enabler of establishing IS (David Catita, et al. 2021).

- **Competition:** The food industry is a very competitive economic environment and fast passed. The pressure from competitors to go green may be a major driver of sustainable manufacturing production processes.
- **Customer Awareness:** Customers are increasingly choosing environmentally friendly items as a result of information from the government or increased public awareness. This fact can force industries to embrace more sustainable strategies.
- **Legal authorities**: Can reduce regulatory barriers and promote two-way discussion on the impact of legislation on IS, as well as provide conditions for faster government legal response. For example, increasing the percentage of products that can be reclassified as non-waste.

Section 4 - Characterization of different IS partnerships

The desired outcome is for the parties involved in the exchange to share mutual benefits and extend the diffusion of ISNs to new sectors, where the cooperative exchange of resources is not currently happening in a symbiotic and consistent way. **Self-organized symbiotic relationships:** appear from spontaneous decisions made over time by self-driving but interrelated enterprises, with no entity or central control mechanism guiding or regulating the whole system, like a deliberator organization or the state. Chertow (2007) classified three different types of Industrial Symbiotic Systems according to distances between each other:

i) Eco-parks and is recognized as the "classic" inter-firm relationship between enterprises placed adjacent to one other inside a designated common area.

ii) Inter-firm cross-network of enterprises with symbiotic relationships that are located within the same region but do not share the same area as the first.

iii) Firms that collaborate across wider distances.

Central entity facilitating relationships within the SC: the central authority must be accountable for ensuring that these established collaborations do not affect one's primary company. Once there is a central authority entirely managing the network, the process of establishing possible symbiotic connections is accelerated, cross-ventures between various and independent enterprises are more likely to arise (Albino et al., 2016). This intermediary may offer administrative and regulatory assistance, help to pursue incentive policies, and share their expertise with businesses at the initial stage of a system. They can be present in several forms, for instance, as a contract, as a facilitator who looks for eventual optimal matches through a set of options or simply as knowledge agents (e.g, through a procurement platform where different individuals can gather and exchange ideas on different topics) (Capelleveen et al., 2018; Freitas & Magrini, 2017; Notarnicola et al., 2016). Furthermore, they operate as a knowledge channel across industrial clusters, as mediating "neutral participants," they promote interaction and collaboration among stakeholders with differing and often divergent ideas and share their lessons learned from past experiences. The **first** step is to acknowledge that you want to participate in the development of a symbiotic network. What will push companies into pursuing integration with one another is the idea that it will increase SC efficiency as a whole while being secure that the single company's performance will still be maintained. At least 3 distinct enterprises must interconnect and collaborate in order to exchange at least 2 different resources before they can be recognized as part of an IS, said Chertow (2007). The 3:2 heuristic reveals the importance of dealing with several players, creating a complex system as opposed to a direct one-way transaction. The **second** step to establishing relationships is always networking or procurement. After procuring, the **third** step is choosing a partner from a pool of potential companions may be a difficult undertaking. It is crucial to collect information on the characteristics of partners: industry, size, acknowledgment of the circularity strategic value, waste categorization and quantification, waste recovery policies, waste value chain- reintroduction in another chain, and awareness of the ecosystem

concept. Nevertheless, the selection of symbiotic partners is not an easy task, since it is more idealized rather than realistic, because some partners may not want to form a symbiotic network. Aside from selection, the appropriate number of partners must be defined, because of the more diverse and larger the number of optimal, willing, and stable partners, the better the firm's symbiotic readiness (Agudo et al., 2022).

Section 5 - Key Players Roles

Understand the context and distinguish which entities are involved, both in a traditional logistics management and waste management perspective. Secondly, present each individual's role taken in the chain, as well as the level of the chain in which they are involved along with their major concerns (Figure 4).

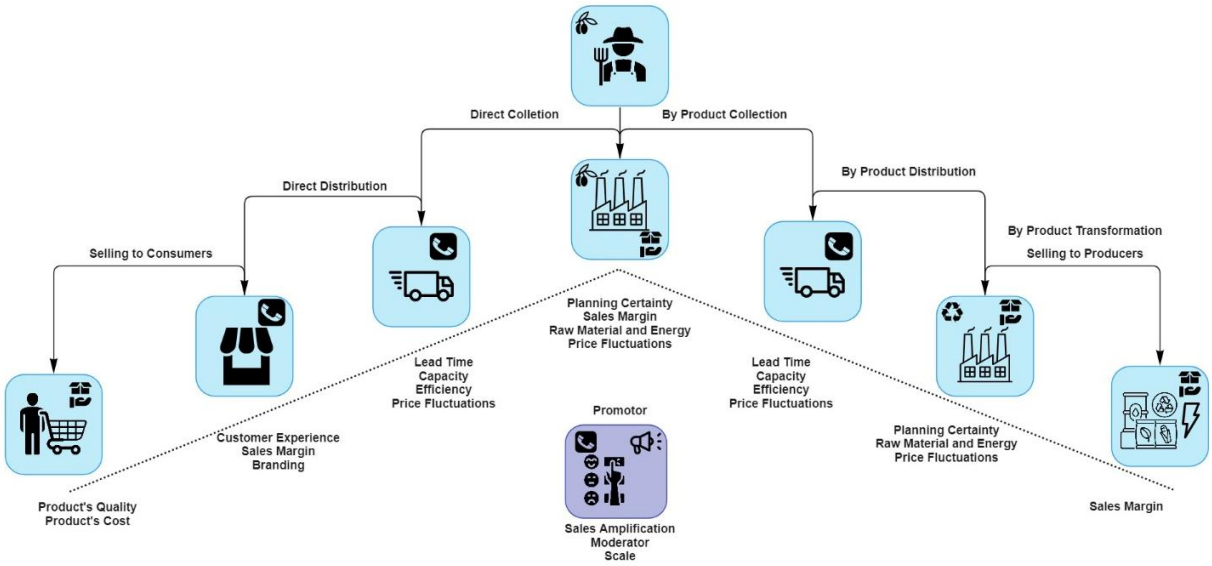

Figure 4- Olive Oil and Byproduct SC entities and major concerns

3.2 Supply Chain Symbiotic Relationships' Barriers Approach

The following framework was followed (Figure 5):

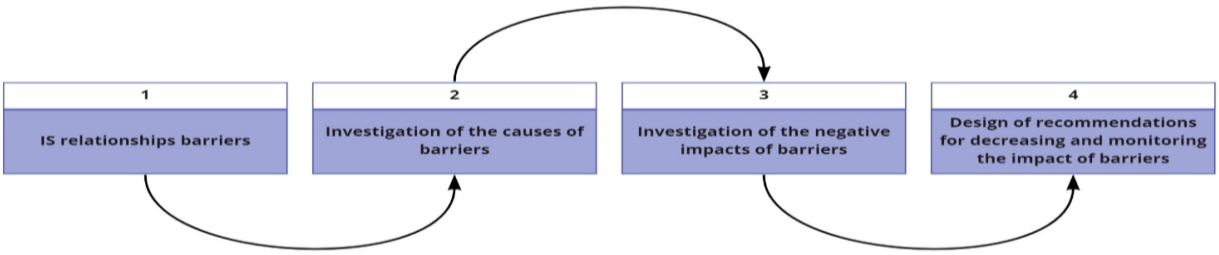

Figure 5- Barriers Identification Framework

Step 1 - Barriers Identification

Relevant barriers to the establishment of IS SC relationships will be exposed. This chapter was highly influenced in Luthra et al. (2022.)

Step 2 - Investigation of the causes of barriers

Gathering relevant causes for emerging barriers when establishing IS SC relationships.

Step 3 - Investigation of the negative impacts of identified barriers

Considering relevant scenarios for the case study, which will stress possible benefits or inconveniences.

Step 4 - Overcoming barriers

Several solutions will be suggested. Also, it aims to identify several points that will guide partnership beginners on how to grow these relationships and measure their partnership benefits. The following presents a brief summary of the identified barriers, its potential causes, major impacts and solutions (Table 2).

Table 2- Brief Summary of the identified barriers, its potential causes, major impacts and solutions

Identification of barriers in symbiotic relationships	4.2.4.1 - Level of Trust and Commitment	1	Trust is directly correlated with the probability of maintaining a relationship and the level os transparency.
		2	A company's commitment is related with the dependency in its partners to perform its activities. Trust in other partners is expected to be low/non-existent when a company has no experience in IS relationships or no reputation in the field.
		3	The unavailability of data might result in increased uncertainty, worst rollout negotiations and less planning certainty.
		4	Find a facilitator in which all parties trust to share crucial information, e.g.: sharing information trough a secured online platform; Implement ISO 27001 and ISO 8000; Sign an agreement concerning privacy terms.
	4.2.4.2- Distintic Beliefs	1	Each company has its own autonomous planning and management procedures.
		2	The wider the geographical distance between each company's headquarters, the larger is the mental gap.
		3	Disparities in mentalities cause internal management and performance measurements. Which makes decision-making more challenging.
		4	Partners should define pain points, identify clear targets, priorizatize interests, define criteria and respective weights
	4.2.4.3- Risk and Uncertainty	1	What was once one's risk, will now become a diffused risk throughout all concerned stakeholders. Firms are vulnerable in environments characterized by diverse levels of uncertainty.
		2	Internal organization uncertainty, internal supply chain uncertainty, external supply chain uncertainty
		3	Diverse
		4	Outsourcing; Study operational variables and parameters (distances, capacities, input/output volumes); Insurance; Contract agreements; KPIs; ISO 31000; among others
	4.2.4.4- Economic and Operational Infeasibility	1	Assessing possible financial returns and the resources required to achieve the expected return is a very challenging process
		2	Power and position asymmetry influence resource and benefit allocation
		3	Operational inefficiency can cause products' shortages and surplus, lack of capacity, product flow constraints, which can represent negative impacts for economic dimension.
		4	Models for Supply Chain Network Design and Planning to optimize topics such as the number, location of the plants, routing and production plans. For economic feasibility, suitable indicators to examine the achievement of set targets are suggested.
	4.2.4.5- Level of Skills and Technology	1	Partners' temporal advances of technology differ. One of the biggest challenges is the quick development pace of technologies and new researches. Not every partner has the capability to follow the progress.
		2	Lack of investment and lack of interest
		3	if technologies become obsolete water pollution, greenhouse gas emissions, green transportation, and sustainable industrial processes
		4	Workshops and training, 4.0 Industry
	4.2.4.6- Government regulations	1	Despite any changes to the management structure, a company will continue to respect every legal obligation. Exchanges can be particularly problematic if still these cannot legally be exchanged.
		2	The bureaucracy may not CE strategy-friendly due to the fact that it can be extensive and expensive
		3	If regulamentation is not correctly reviewed before transforming or commercialising, it may represent a negative impact on operating performance, financial situation and legal matters
		4	Waste Classification as to understand need of the legal process for authorizing revalorization alternatives and commercialization; Declassification of waste; Licensing
	4.2.4.7- Complexity and Responsibility	1	Duplication of tasks for leaders/individuals, makes them reluctant in participating in a partnership due to its complexity.
		2	Ambiguity in data, diverse stakeholder engagement, increasing operational complexity, human subjectivity in judgments, linguistics, multiple sources of risk, sophisticated technology, and skill acquisition.
		3	It may jeopardize the normal flow of core activities
		4	Participate in workshops and offer time, personnel, and financial resources to find, appraise, implement, and run synergies

4 Conclusions and recommendations for future work

Apparently, olive oil's consumption, production, and export have been increasing over the years and it is believed that it will continue to do so on a global scale. There is a growing concern to transform this sector into a more sustainable one, so that the industry can sustain itself for upcoming generations, in terms of resources, revenues, and employability rate for the European countries. The present dissertation intends to promote the IS study in the olive oil's industry, specifically in the Portuguese market. IS is only attainable at a group level, and it can be one of the key strategies for managing resources and waste from stakeholders such as businesses, communities, policymakers, institutions, and organizations. Therefore, synergies between different stakeholders can help maximize waste utility, through energy production, and organic transformation, among others. The assessment of the relationships effectiveness has been based more on empirical observations rather than on theoretical judgments. Firms are vulnerable in environments characterized by diverse levels of **uncertainty** especially working with multiple partnerships from different sectors. Also, the level of **trust** can influence a company's transparency. This can be supported by adapting the level of **skills** and **technology**, that can be leveraged with the correct investments and top open-minded management. The barriers regarding the **distinct beliefs** and the intrinsic **operational** and **economic** objectives of a company can highly influence the decision-making process in terms of judgments and timings. The amount of effort necessary to achieve major changes in operations represents **complexity** of newly formed relationships. Furthermore, the duty of each organization is proportional to the quantity and complexity of operations, which is expected to greatly increase. Furthermore, **government** regulation in areas where waste management policies have not evolved towards more ecological approaches might still be seen as a strong barrier. In order to protect, restore, and enhance environmental quality the government can implement strategies such as government subsidies, demystification of waste classification, financial assistance, tax relief, and others. The above empirical observations demonstrated that the influence of particular barriers and motivating factors varies enormously depending on the context. Thereby, the assessment of compatibility, between processes or companies, is mandatory, because while assessing possible barriers, the companies' compatibility may be questioned. Every system's environment has to be properly studied, externally and internally, before designing a SCCS strategy. The parts engaged in establishing a synergetic relationship should not directly replicate the strategy from one context to another. A business strategy that is successful in a specific context may fail in a more complex one. Overall, the identification and arrangement of certain barriers with potential solutions and performance indicators, that would reduce barriers' impacts, was extremely difficult. The lack of research connecting some of the SC concepts with the IS strategy was noticeable. Furthermore, the main goal of this study was to highlight the gap in SC research with complex IS relationships and propose future research directions.

5 References

Abreu, M. C. S. de, & Ceglia, D. (2018). On the implementation of a circular economy: The role of institutional capacity-building through industrial symbiosis. Resources, Conservation and Recycling, 138(July), 99–109. https://doi.org/10.1016/j.resconrec.2018.07.001

"Agriculture Sector: Preparing for Disruption in the Food Value Chain." McKinsey & Company. McKinsey & Company, May 8, 2021. https://www.mckinsey.com/industries/agriculture/our-insights/agriculture-sector-preparing-for-disruption-in-the-food-value-chain.

Albino, V., Fraccascia, L., & Giannoccaro, I. (2016). Exploring the role of contracts to support the emergence of self-organized industrial symbiosis networks: An agent-based simulation study. Journal of Cleaner Production, 112, 4353–4366. https://doi.org/10.1016/j.jclepro.2015.06.070

Bové, Anne-Titia, and Steven Swartz. "Starting at the Source: Sustainability in Supply Chains." McKinsey & Company. McKinsey & Company, May 11, 2019. https://www.mckinsey.com/business-functions/sustainability/our-insights/starting-at-the-source-sustainability-in-supply-chains.

Chertow, M., & Ehrenfeld, J. (2012). Organizing Self-Organizing Systems: Toward a Theory of Industrial Symbiosis. Journal of Industrial Ecology, 16(1), 13–27. https://doi.org/10.1111/j.1530-9290.2011.00450.x

David Catita, Paula Sarmento, Ana Ilhéu, Cristina Sempiterno, R. F. (2021). Uma solução sustentável.\

Dania, W. A. P., Xing, K., & Amer, Y. (2018). Collaboration behavioural factors for sustainable agri-food supply chains: A systematic review. Journal of Cleaner Production, 186, 851–864. https://doi.org/10.1016/j.jclepro.2018.03.148

Di Maio, F., Rem, P. C., Baldé, K., & Polder, M. (2017). Measuring resource efficiency and circular economy: A market value approach. Resources, Conservation and Recycling, 122, 163–171. https://doi.org/10.1016/j.resconrec.2017.02.009

Djanian, Mikael, and Nelson Ferreira. "Agriculture Sector: Preparing for Disruption in the Food Value Chain." McKinsey & Company. McKinsey & Company, May 8, 2021. https://www.mckinsey.com/industries/agriculture/our-insights/agriculture-sector-preparing-for-disruption-in-the-food-value-chain.

Chen, C., Zhang, G., Shi, J., & Xia, Y. (2019). Remanufacturing network design for dual-channel closed-loop supply chain. Procedia CIRP, 83, 479–484. https://doi.org/10.1016/j.procir.2019.04.132

Donner, M., Gohier, R., & de Vries, H. (2020). A new circular business model typology for creating value from agro-waste. Science of the Total Environment, 716, 137065. https://doi.org/10.1016/j.scitotenv.2020.137065

European Commission. (2018). A sustainable Bioeconomy for Europe: strengthening the connection between economy, society and the environment. https://doi.org/10.2777/478385

EMF. (2015). Towards a Circular Economy: Business Rationale for an Accelerated Transition. Ellen MacArthur Foundation (EMF), 20.

EMF. (2019). Cities and Circular Economy for Food. Ellen MacArthur Foundation, 1–66.
https://www.ellenmacarthurfoundation.org/assets/downloads/Cities-and-Circular-Economy-for- Food_280119.pdf.

Esposito, B., Sessa, M. R., Sica, D., & Malandrino, O. (2020). Towards circular economy in the agri-food sector. A systematic literature review. Sustainability (Switzerland), 12(18). https://doi.org/10.3390/SU12187401

FAO. (2016). *Livestock & climate change*. File:///Users/Inesmatos/Downloads/The Role of Online Information-Sharing Platforms on the Performance of Industrial Symbiosis Networks.PdfFood and

GPP. (2019). Azeite. Globalagrimar. Retrieved from https://www.gpp.pt/images/globalagrimar/estrategias/Azeite_FichProdEstrat_2019.pdf

Herczeg, G., Akkerman, R., & Hauschild, M. Z. (2018). Supply chain collaboration in industrial symbiosis networks. Journal of Cleaner Production, 171, 1058–1067. https://doi.org/10.1016/j.jclepro.2017.10.046

Lin, C. S. K., Pfaltzgraff, L. A., Herrero-Davila, L., Mubofu, E. B., Abderrahim, S., Clark, J. H., Koutinas, A. A., Kopsahelis, N., Stamatelatou, K., Dickson, F., Thankappan, S., Mohamed, Z., Brocklesby, R., & Luque, R. (2013). Food waste as a valuable resource for the production of chemicals, materials and fuels. Current situation and global perspective. Energy and Environmental Science, 6(2), 426–464. https://doi.org/10.1039/c2ee23440h

Luthra, S., Sharma, M., Kumar, A., Joshi, S., Collins, E., & Mangla, S. (2022). Overcoming barriers to cross-sector collaboration in circular supply chain management: a multi-method approach. Transportation Research Part E: Logistics and Transportation Review, 157(May 2021), 102582. https://doi.org/10.1016/j.tre.2021.102582

"Mapping the Benefits of a Circular Economy." McKinsey & Company. McKinsey & Company, March 14, 2019. https://www.mckinsey.com/business-functions/sustainability/our-insights/mapping-the-benefits-of-a-circular-economy.

Moktadir, M. A., Rahman, T., Rahman, M. H., Ali, S. M., & Paul, S. K. (2018). Drivers to sustainable manufacturing practices and circular economy: A perspective of leather industries in Bangladesh. Journal of Cleaner Production, 174, 1366–1380. https://doi.org/10.1016/j.jclepro.2017.11.063

Morgan, M. G. and M. Henrion. Uncertainty: A Guide to Dealing with Uncertainty in Quantitative Risk and Policy Analysis.

Pearce, D., & Atkinson, G. (1998). The concept of sustainable development: an evaluation of its usefulness ten years after Brundtland. Working Paper - Centre for Social and Economic Research on the Global Environment, PA 98-02, 95–111. https://doi.org/10.1007/bf0335389

Turken, N., & Geda, A. (2020). Supply chain implications of industrial symbiosis: A review and avenues for future research. Resources, Conservation and Recycling, 161(November 2019), 104974. https://doi.org/10.1016/j.resconrec.2020.104974

Vilar, J. et al. (2019). Alentejo: A liderar a olivicultura moderna internacional. 95. https://www.oliveoiltimes.com/wp-content/uploads/2019/12/portugal-olive-growing-report.pdf