Circular economy and resilience: convergences and deviations in the case of agri-food supply chains

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Abstract. Agri-food supply chains have a multitude of roles for the mankind. Among others, they encompass the primary, secondary and tertiary sectors of the economy; they are responsible for feeding the planet; they are associated with various environmental and social impacts. Therefore, their operation, efficiency and performance are crucial in many contexts. In this paper we investigate the transitions of agri-food supply chains towards two different goals: circular economy and resilience. Circular economy has been a focal priority in the EU and global agenda, which aims at redefining the patterns that have been associated with linear economy models in order to meet environmental, social, and economic challenges of our era. On the other hand, supply chain resilience is the capacity of supply chains to be prepared for unexpected risk events, act and recover promptly to probable disruptions, and return to their original position or move to a better ideal condition. In particular, we focus on the enablers and barriers for both goals and identify possible convergences and deviations. The former are expected to lead to win-win opportunities, whereas the latter will lead to trade-offs.

1. Introduction

Many countries across the world rely heavily on the agri-food sector, which is one of the largest employers in the world, employing millions of people. It also accounts for a sizable portion of both production and consumption, being responsible for feeding the planet.

There is a high level of fragility in the agri-food sector as a result of its current structure. Some examples of stressors could be related to the environmental problems such as the climate change or soil degradation and pest outbreaks, economic and political, referring to issues such as population growth, rapid urbanization and consumer behavior. Moreover, societies increasingly recognize their global responsibility regarding consumer and dietary behaviors, as well as their vulnerability to impacts from disruptions of agri-food supply chains [1] or sudden shocks like the COVID-19 pandemic which may have immediate and acute effects [2].

There are certain indicators suggesting that the agricultural world production, in order to meet the demands of the population, must increase by 70% by 2050 [3]. In order to meet this goal there are only two possibilities that Velasco-Muñoz et al. [4] suggest. The first possibility is to extend the cultivated land, which was approximately 37% of the total available surface in 2017 and the second is to increase
the production in the areas that are the current producers that can result to an extension of the cultivated land up to 38%, if the water consumption is increased up to 53% globally.

In this paper, we look at how agri-food supply chains are evolving toward two different goals: circular economy and resilience. The EU and worldwide agendas have made circular economy a priority, with the goal of rethinking the patterns associated with linear economy models to solve the environmental, social, and economic issues of our day. Supply chain resilience, on the other hand, refers to a supply chain’s ability to plan for unforeseen risk occurrences, respond quickly to potential disruptions, and return to their original position or move to a better ideal state.

2. The model of circular economy in the agri-food supply chains

Circular economy is an emerging paradigm which strives to modify human and organizational behavior and practice patterns. Circular economy aims at improving the way organizations are producing goods [5,6]. The model of circular economy is a generic model of the entire economy and is an alternative approach to both production and consumption and its main opponent is the commonly used linear model. A switch towards a circular model aims to set an end to the extraction of new resources followed by the mentality of use, make, dispose [4] aiming at reaching sustainability objectives. The Ellen MacArthur Foundation [7] has indicted the principles and a definition of a circular economy to be the following three. The first will be designing out waste and pollution, the second is keeping products and materials in use, and the final is regenerating natural systems. Thus, it can be defined as ‘an economic system of closed loops in which raw materials, components and products keep their quality and value for the longest possible and systems are fueled by renewable energy sources’. The way the economy currently operates is a result of the industrial development of systems over the last 250 years. Therefore, the transition to a circular economy is uncharted territory for all business sectors and each of them is faced with particular barriers, challenges and opportunities.

Following the current events, it is obvious that food systems are getting more and more exposed to drivers of change some of them being very sudden shocks and others being stressors with a long term effect making them more vulnerable [8,9]. The agri-food sector is crucial for the mankind as a matter of course, since it is connected with human existence [10]. On the other hand, agriculture is one of the main consumers of resources since it is accountable for the 90% of land- and water-related environmental impacts, and also contributes to the human toxicity due to farm workers’ exposure to pesticides [4,7]. Some measures such as the productivity and the availability of the agricultural land are exposed to climate conditions [1], which reminds us the importance of environmental protection.

The application of circular economy in the agri-food sector seems to be very crucial in all the above principles [11,12]. There is this great trilemma of environmental denomination, food scarcity, and food wastage, which needs to be considered immediately where the proposed approach to a solution is the adoption of green recovery strategies. It is estimated that approximately 1/3 of the food produced is wasted worldwide, leading to loss of valuable natural resources [13]. Naturally, there is a high demand of food and consumption due to population growth and varying food habits. In addition, matters such as contamination, storage, loss, and security are in the center of attention. Therefore, a holistic approach in all research fields is needed in order to integrate the values and the strategies with risk analysis and application of optimization studies in every step of the agri-food supply chain [14].

To switch towards a circular model, there needs to be cooperation in order to develop and apply the knowledge, creating new innovative technological and sustainable processes, products and services. Applications described generally by the term Industry 4.0 can help reach this demands [15,16]. Focusing on the implementation of circular economy to agri-food systems includes adopting practices and technologies that cut down on spending new natural resources, the use of generative resources, measures that prevent any loss of natural resources from the system and finally adopting methods that encourage reusing and recycling of any unavoidable loss [4].

In an extensive research Gedam et al. [13] researched the indicators of food supply chains and narrowed it down to the biggest barriers of implementing the circular economy model being the lack of innovation and technology, the inability to calculate the exact amount of food waste, the bad design
of the supply chains and lack of optimization and finally the high cost of investments in the already developed methods. It is very crucial to focus on these factors in order to work towards a circular system [13]. Starting from implementing resource-efficient processes while redesigning out the losses. Implementing the developed tools to assess the environmental impact of the processes. In a circular system there are several stages that intertwine and all activities are connected [14].

The model of circular economy is applicable in all sectors of the economy. Firstly, taking into consideration the primary production, which immediately connected to the environment, applying the rules of circular economy can help tackle important environmental issues such as soil degradation and natural resources exploitation. Moving into the secondary production which includes the food manufacturing redesigning with a goal to minimize any waste and at the same time keep the products in use for as long as possible and finally the tertiary sector, can support in the adoption of circular economy by creating economies of scale, with minimized costs and sustainably use of resources.

In addition, it is clear that a cooperation between stakeholders is important on organizational and institutional level. Firms should take the risk of investing in the new models of production and create an atmosphere of sharing technologies and knowledge to enhance the circularity of their production systems. Finally, the key role to this transition is held by policy makers that should design and enforce new legislative framework that favors businesses to implement this promising production model.

It is evident that the agri-food sector has raised sustainability concerns due to the large amount of waste production and the consumption of energy and natural resources. Circular economy can play a key role by promoting sustainable production methods, by minimizing waste across production, since output materials can be reused, and by using waste as input for new products. Some indicative examples of the application of circular economy in the agri-food sector are presented in the sequel.

The valorization of unavoidable food waste is a matter that holds the attention of the scientific community as it can be used to produce food additives, since food waste is rich in nutrients, as well as in the pharmaceutical industry [17,18]. Valorization of agri-food waste coming from wine and olive oil production in the vein of circular economy has been studied in [18]. By-products of olive oil production are being analyzed for carotenoids and bioactive compound production while wine by-products are being processed to produce compounds such as squalene and bioactive phenolic compounds from parts of the fruit such as the seeds. All these products can be used as additives to produce other products and hold a great position on creating a link between industries while implementing the zero-waste concept in order to minimize waste and close material loops. Circular economy can also find application in new product development, where unavoidable waste or production of by-products can be used in order to produce new type of products such as biofuels and bioplastics [19] solving the problem of plastic waste production. Food waste materials are being studied to be the input materials for energy production. Waste bio-refineries have the potential to produce green energy and to work under zero waste production technologies [20]. An extensive study on orange peels has been conducted in [21] using them as raw material to produce biogas, bio-ethanol bioelectricity etc. but also flavonoids for pharmaceutical use by applying a variety of treatments.

3. Resilience of agri-food supply chains

In a globalized setting, competition occurs not just between firms, but also across supply chains, value chains, and stakeholder value networks. Thus, there are more complicated and challenging chances to obtain and/or increase competitive advantages through engaging in novel approaches in all supply chain stages [22]. Furthermore, convergences in many areas of the economy give further chances for reorganizing the design, organization, and operation of sectors.

Several attempts have been made to define the term resilience. One of them is included in the Sustainable Development Goals of the United Nations and defines resilience as ‘the capacity of a system to absorb disturbance, undergo change, and retain the same essential functions, structure, identity and feedbacks’ [23]. The concept of resilience has a high potential to increase food security [24–26] and sustainability of the food systems as it can be associated with the ability to provide
sufficient, appropriate and accessible food to all in the face of various severe and even unforeseen disturbances e.g. the COVID-19 pandemic and the climate change [25–27].

Resilience of socio-ecological systems refers to the ability of a social system, intertwined with an ecological system, to predict, cope and bounce back after a disturbance [28]. Resilience is mentioned in several Sustainable Development Goals of the United Nations [23], in some it is mentioned explicitly while in other cases it is implied, making it a very current and popular topic in the academic and the policy discourse [29]. For example, there is an extensive reference where by 2030 we should ensure that there will be sustainable food production systems and implementation of the resilient agricultural practices in order to increase the productivity and production, that help maintain ecosystems, strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters, and progressively improve land and soil quality [23,29].

In order to build resilience into agri-food systems an alteration is required on how we view the complexity and interconnectivity of the various activities, how the resources for the production are used, how the products are stored and transported, the processes that take place along the manufacturing, the retail and food service, and finally how the products are consumed [30–32].

The resilience of agri-food systems has gained traction in science, policy and civil society debate both in the European Union and worldwide [28]. Most focus on agricultural production or other specific stages in the food value chain but others focus on particular components of resilience, for example the adaptability and transformability, the cascading effects in regime shifts, or on particular outcomes and contexts, e.g. food security in emergency situations [2,33]. This overview of the supply chain makes it clear for the previous linear model of production, commonly known as the farm-to-fork representation of activities, to be the subject of a total transformation [34,35].

There is a large amount of waste, in the form of final products but also in the form of various resources across the whole chain of the agri-food system. Several methods related to bioeconomy can support in closing materials loops [20,36,37]. Approximately, these amounts of waste, together with the necessity of high production efficiency to cover the nutritional needs of the population, could possibly exceed the maximum capacity of the primary resources of the planet earth. Considering this statement, there is an immediate need for an alternative system view to combat the challenge of creating food security together with high resource efficiency [38]. A very important outcome of achieving food security except from bringing high productivity of nutritious food but also reinforcing stability to changes in weather and markets, resilience to stresses and shocks, and equity in supply [38]. The term resilience is often connected to the word “sustainable”. Even if these two terms are different, development can be created when both resilience and sustainability are achieved. This is something that can also be noted in the case of circular economy being often used interchangeably in the literature with sustainability [6,29].

Tendall et al. [2] broke down the agri-food systems’ resilience into these 4 components, the first one is robustness, which describes the capacity of the system to withstand any disturbance in the first place before food security is lost. The second component is the redundancy, which is the extent to which the elements of the system are replaceable, and it is affecting the capacity to absorb the perturbing effect to fight the disturbance and avoid as much food insecurity as possible. The third component is the flexibility and thus rapidity (or system reactivity) with which the system is able to recover when security is threatened. The fourth and final component is the resourcefulness and the adaptability, which determines just how much of the lost security is recovered. Together, these capacities form the basis of the agri-food system resilience action cycle.

4. Is there common ground for circular economy and resilience in agri-food supply chains?

To examine how circular economy and supply chain resilience interact, the barriers and enablers which are involved in the agri-food supply chain will be set in focus. As suggested by [13] and [39] they can be categorized as follows: Economic and Financial / Organizational-Operational / Technology / Supply Chain – Logistics / Environmental / Institutional - Public Policy.
These categories of barriers or enablers will be put into deliberation on how they can possibly interfere with the criteria of a resilient supply chain, as described by Harris and Spiegel [40].

- Awareness, which describes the knowledge of the existing assets, liabilities and vulnerabilities in order to adjust to shocks.
- Diversity, which describes the ability of the system to alternate between resources when some elements of it are challenged.
- Integrated, which refers to the ability to share information across the system and be transparent.
- Self-Regulating, which refers to the ability to bounce back on itself safely after a shock without any extreme malefaction or after a failure.
- Adaptive, which describes the flexibility of a system to a change in a circumstance, behaviors and alternate between existing resources.
- Inclusive & Equitable, was added to describe the social aspect of the food system.

In order to inspect how circular economy and resilience can intertwine the barriers and enablers as mentioned by [13] and as described by [39] will be examined simultaneously with the criteria of building resilience in food systems described by Harris and Spiegel [40] subsequently.

To begin with the economic and financial dimension of agri-food supply chains, implementing the circular economy mentality by closing the material loops will enhance the re-use of materials and minimize the high demand of new resources resulting in lowering raw material prices. From a different aspect it promotes an economic development connected to job creation [13,39]. On the other side, the cost of investment on new technologies such as recycling, energy creation and repurposing are usually high. This part of circular economy is strongly connected to the characteristic of diversity of building resilience since it encourages the re-use and strives away from incorporating new materials which in case of shocks can be hard to obtain [24,40].

Operational and organizational implementation of circular economy include the actions of the firm towards this matter which include redesigning of the production by incorporating recycling, reverse logistics and product alterations. The case of agri-food production is complex due to the perishability of the products, the difficulty in planning and forecasting of agriculture production and the abundance of fast moving products [8,34]. In order to build resilience, an integrated system of information sharing between the stages of production should be adopted which can support on minimizing the uncertainties and better management [25,40].

Technology has a key role in supporting the transition to a circular economy. Innovative solutions in the fields of product development which incorporate new materials and zero waste techniques or predictive data analysis can enable the transition to a circular model [12,13,39,41]. While there is plenty of space in this field, the lack of these innovations result in big waste production and generally in unsustainable behavior with environmental and economic impacts [14]. The ability to adapt can be built through technological innovations supporting a resilient agri-food supply system [2,40].

Currently, supply chain and logistics hold the ropes for most of the business operations. Redesigning with a circular model can offer multidimensional benefits by offering competitive advantages by waste minimization or by activating safety mechanisms in case of disruptions such as weather conditions affecting production or sudden shocks such as a pandemic [13,39]. Enhancing this characteristic can support in creating better self-regulating systems and also incorporate the important characteristic of being inclusive and equitable which is also important to maintain food security [25,40].

The model of circular economy holds the greatest potential in enabling environmental protection by restoring the natural resources by minimizing input materials and protecting renewable resources while increasing the quality of agricultural production [13,39]. The current linear model creates large amounts of emissions and is associated with soil degradation and resources depletion, making in a necessity to immediately change mentality [42]. By making this change, resilience is enhanced as a result of re-adapting the procedures with new and alternative resources [40,43].
Finally, moving towards institutional enablers, which hold the ability to interfere with all the aforementioned cases, it is mandatory to provide the legislative and regulatory framework in order to push companies towards implementing cleaner production techniques and incorporate sustainable production models such as circular economy which can be beneficial and supportive to all dimensions of agri-food supply chains [13,39]. Unfortunately, unawareness, lack of knowledge and doubtfulness about how circular economy can help restore and improve in all dimensions push back on the transition. All characteristics of resilience can be met when stakeholders adapt their procedures to be in line with the pillars of circular economy [40,44].

5. Concluding remarks
Agri-food supply chains, due to the nature of the materials, the processes, the demands of consumers and the fact that food is a basic human right are considered of very high importance and complexity. The agri-food supply chain is affected by many factors in each stage of the production, and this is a reason that makes the transition towards sustainability a very crucial matter and both adopting the model of circular economy and building resilience can have a strong impact towards this transition [45].

Circular economy is a promising model; as discussed in academic research and policy development adapting to this approach could be beneficial in several ways. When circular economy is fostered, what we are considering is a change of mentality on the production methods, meaning switching towards new techniques that promote the reduction of waste production in every step of the agri-food supply chain, the use of fewer new resource materials and products that are kept in use, striving away from the linear mentality of single use and, finally, contributing to the regeneration of natural systems. Resilience on the other side is an appealing characteristic of systems and is currently in the foreground especially in the case of agri-food supply chains. This characteristic is met in a system as a result of enhancing some specific traits.

In this paper we addressed circular economy as a paradigm that should be implemented for all the aforementioned benefits and resilience as a characteristic that needs to be strengthened across the agri-food supply chain. We concluded that there is common ground for them and that they can mutually support each other in order to accelerate the alteration of the current production mentality which affects all pillars of sustainable development. Towards this end, a cross-industry collaborative approach is necessary and of utmost importance.

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