Article

Are Agri-Food Systems Really Switching to a Circular Economy Model? Implications for European Research and Innovation Policy

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Abstract: The shift from a linear model to a circular model can significantly reduce the negative pressures on the environment and contribute to restoring biodiversity and natural capital in Europe. In this view, research and innovation (R&I) play a relevant role in setting the modalities of this transition. Therefore, the European Commission (EC) recently promoted dedicated research activity instruments in this vital area of the economy and in society as a whole. This paper aims to shed light on current public efforts on R&I supporting the transition to the CE (circular economy) model, opening a critical debate on the actual relevance of the CE in current R&I policy with its major research policy schemes in the recent programming periods of 2007–2013 and 2014–2020. Looking at the most significant EC programs sponsoring R&I, it seems that the will to increase the sustainability of the agri-food system and to foster the socio-technical transition towards circularity is evident but not very relevant. The data presented leaves some open questions concerning the effective commitment of European countries to promoting resource efficiency via R&I.

Keywords: agri-food; university-industry collaboration; circular economy; sustainability; research and innovation policy

1. Introduction

The World Economic Forum argues that a circular economy (CE), intended as an economic system that reduces waste, introducing continual use of resources, could be a \$4.5 trillion business opportunity [1]. However, only 9% of the global economy is circular at present [1]. Fortunately, companies are increasingly recognizing the value of shifting to a circular model of production of goods and services when it comes to being competitive. Company shareholders are becoming increasingly interested in these business strategies and public-private partnerships are being established to bring together circular government and business strategies [2]. The concept has also gathered momentum with policymakers, influencing governments and intergovernmental agencies at the local, national, and international level [3].

In Europe, the concern about the CE is growing and a very recent communication from the European Commission (EC) [4] focuses on this hot topic. The shift from a linear model to a circular model can significantly reduce the negative pressures on the environment and contribute to restoring biodiversity and natural capital in Europe. The Commission highlights that to fulfil the ambitious target of climate neutrality by 2050, as well as decoupling economic growth from resource use, the European Union (EU) needs to accelerate the transition towards a regenerative growth model. In this respect, the EC is particularly concerned about the agri-food sector. During the past 50 years, the agricultural industry has become more resource-intensive and now represents a critical

sector in Europe. However, the production of the food we eat today has become unsustainable from the environmental viewpoint [5,6]. Food production depends on fossil fuel, non-renewable mineral resources, the depletion of groundwater reserves and excessive soil loss. Despite this depletion of resources, coupled with the predilection in industrial policy for a resource-intensive and productivity-oriented model of agri-food production, food insecurity and malnutrition affect about half of the global population. The centrality of the agri-food sector in the shifting to CE relies on the consideration that both the livestock and agricultural sector represent a major cause of pollution all over the world, in lower as well as in middle- and high-income countries [7,8]. More specifically, the cattle industry uses, disproportionally, land, fresh water and energy while intensive agriculture (fostered by Common Agricultural Policy) has resulted in overuse of water, machines and chemical inputs [9]. Therefore, this sector plays a key role as part of an approach to foster the sustainability of the food system and to help achieving various sustainable development objectives at the same time.

In this view, there is growing consensus [10–12] about the fact the transition to a CE offers many opportunities for the entire agri-food system to become more resource-efficient, with positive food security implications. Starting from the consideration that it will be necessary to guarantee an adequate level of nutrition to an additional two billion people by 2050, and to reduce the negative impacts of agricultural systems, the agri-food sector presents a major opportunity for the development of a circular economy [13–16]. Accordingly, governments, businesses, research institutes and non-governmental organizations (NGOs) are exploring new ways to reuse products, their components or waste material via a CE and to restore more of their precious materials and energy [17]. However, there are still several barriers to the implementation of this model, which include gaps or incoherence in policy frameworks, a lack of awareness and capacities of the business operators, a still insufficient market demand for CE products and services, uninformed consumer choices, etc. [18]. Indeed, the development of a CE requires the adoption of closed loop systems which work towards the goals of improved economic and environmental sustainability [19].

With this aim, research and innovation (R&I) can play a relevant role in setting the modalities of this transition, fostering the switch to more sustainable agri-food systems [20]. In this context, the EC is a relevant player in supporting agri-food companies in their efforts to conduct their business responsibly. The most relevant efforts focus on mobilizing investments in selected value chains, facilitating the formation of strategic value chain groups to promote the upscaling and replication of CE practices [21], and the design of regulatory frameworks [22–24]. The core EC instruments supporting R&I activities in the agri-food sector are the European Agricultural Fund for Rural Development (EAFRD), Horizon 2020 and, more marginally, LIFE, the funding instrument for environmental and climate action. These instruments complement private R&I funding, supporting the entire innovation cycle with the objective of bringing solutions to the market. Nevertheless, as noted in El Bilali [25], research on agri-food sustainability transitions is still extremely marginal and a gap exists in the scientific literature concerning the role of R&I in sustaining the transition to a circular model of agri-food production. In other words, despite the growing concern about the CE and the importance of R&I investments for this purpose, the extent of the commitment of the EC to promoting and supporting this transition through R&I is still uncertain. Therefore, the aim of this paper is to provide some crude estimates about current public efforts on R&I supporting the transition to the CE model, opening a critical debate on the actual relevance of the CE in current R&I policy with respect to other priority areas.

The structure of the study is as follows. After analyzing the central role of R&I in the agri-food sector, focusing on its impact on the adoption of the CE model in Section 2, the paper explains the link between the transition towards a CE and policy support in Section 3. In Section 4, it estimates the efforts of the EC in supporting the development of new technological solutions for the transition from a linear to a circular paradigm of economic development in the agri-food system with its major research policy schemes in the recent programming periods of 2007–2013 and 2014–2020. Finally, the study results, a discussion and some concluding remarks are presented in Section 5.

2. Agricultural R&I and Circularity

2.1. Circular Models in R&I

The CE can be defined as “a model of production and consumption, which involves sharing, leasing, reusing, repairing, refurbishing and recycling existing materials and products as long as possible [26] and the generation of waste minimized” [27]. The Ellen MacArthur Foundation [28], considers “the circular economy a systems-level approach to economic development designed to benefit businesses, society, and the environment.” In both these definitions, there is a precise reference to the optimum use and reuse of raw materials and products in the economy to conserve natural resources. This means that natural resources are used again in a way that adds the most value to the economy and causes the least amount of damage to the environment [29]. This applies to non-renewable resources, such as fossil fuels and metals, as well as renewable resources, such as agricultural produce and wood. Thus, CE is characterized by the removal or mitigation of wastes and subproducts in different production processes, and if this reduction is not possible, they should be integrated into the same productive processes or others of similar or different nature with the aim of avoiding negative externalities and protecting the environment [30].

CE business models fall in two groups: those that foster reuse and extending the service life through repair, remanufacture, upgrades and retrofits; and those that turn old goods into as-new resources through recycling the materials [31]. Currently, some countries, such as South Korea, China and the United States, have started research programs to foster circular economies by boosting remanufacturing and reuse. Meanwhile, Europe is just beginning on this path. In 2014, the EU published a strategy document titled “Towards a Circular Economy: A Zero Waste Programme for Europe”. Then, in 2015, it published the action plan titled “Closing the Loop – An EU Action Plan for the Circular Economy” [32] to guarantee a more resource-efficient future for Europe. In 2018, the monitoring framework for the CE was created to monitor progress and to identify success factors.

From the point of view of research funding, the Swedish Foundation for Strategic Environmental Research (Mistra) and the EU Horizon 2020 program, which published the first call for circular-economy research proposals in 2014, represent the first actions in this direction. A leading research institution with the specific mission “to accelerate the transition to a CE” is the Ellen MacArthur Foundation, which has published many reports and case studies on the CE issue [31]. The “2015 Circular Economy Action Plan” was a part of the EU industrial strategy and contained measures with the dual aim of: (i) making sustainable products the norm in the EU and (ii) empowering consumers. The former action means that products placed on the EU market should be designed to last longer and should be easier to reuse, repair and recycle. Meanwhile, the latter one is aimed at informing consumers about the reparability and durability of products [32].

2.2. Innovation and Circularity in the Agri-Food Sector

The idea of promoting the optimum use and reuse of raw materials and products in agriculture is linked to the introduction of innovations, which is even more pressing if the challenges that climate change poses are considered. The scientific literature uses different definitions to describe innovations as environmentally friendly, which means that they reduce the negative impact of human activities [33]. Among these definitions, the notion of eco-innovation is probably the most complete, as it embraces economical, ecological and social aspects [34,35]. According to the definition of eco-innovation, any form of innovation can potentially increase sustainability and circularity in production processes [36–38]. Agriculture is typically characterized by process and incremental innovations that slowly increase land and labor productivity over the long run. However, its technological potential is often underrated, or to say it better, forgotten. In fact, despite the agricultural sector’s innovation potential, some contextual factors hamper innovation opportunities in this vital sector. According to Pavitt [39], innovation in agriculture is primarily targeted at cost reduction and suffers from low appropriability, as well as the low use of intellectual property. In agriculture, there is no homogeneous technological regime [40,41]

because innovation activity in this sector needs to be analyzed while also accounting for innovation in other industries directly linked to it. Knowledge flows from external sources, such as the suppliers of fertilizers, pesticides and agricultural equipment [42], and scientific institutions determine the technological regimes of agricultural companies more than in other so-called traditional sectors of the economy. In addition, induced innovations—those stemming from changes in relative factor prices, which will result in a more effective realization of the new technical potential [43] are relatively important [44].

The symbiosis between agriculture and food processing, that resulted from past decades of industrial development, inevitably makes more complex the analysis of innovation activity in agriculture. The food processing industry has been relying not just on raw materials, such as agricultural products, but also on specialized suppliers of equipment and chemical products [38] to promote innovative processes. Market opportunities push companies to exploit scientific advancements, adapting them to respond to consumers' needs [45] and in many cases, food companies must collaborate with research institutions in developing innovations. In fact, university-industry collaborations in the food industry greatly enhance innovation opportunities [46,47] and the probability of success of new food products [48].

The introduction of a CE in agriculture means the utilization of minimal amounts of external inputs in the production of agricultural commodities. It also means closing the nutrient loops in agri-food production, from livestock to cropland farming; reducing negative discharges, such as waste and emissions in the environment; and valorizing agri-food waste. Therefore, research on circularity in agriculture can support the development of innovations that can increase resource efficiency in this resource-intensive sector, where unsustainable agricultural practices pose a serious risk to human health and to the planet's ecosystems [49].

While the introduction of innovations addressing the CE model can bring many benefits to the agri-food sector, innovation in agriculture has been fundamentally linked to land and labor productivity growth, ignoring for centuries the problem of circularity. Several economic studies [50,51] evidenced how, over the past century, an incredible increase has occurred in total factor productivity in the agricultural systems of industrialized countries [52]. This was due not only to returns to scale but also to the technological progress brought about by generous public investments in R&D [53,54].

The role of R&D is incorporated into Roling's [55] Agricultural Knowledge and Information System (AKIS), an approach that the EC, the FAO, the World Bank and other international organizations share. This principle is based on the collaboration between people and institutions to promote reciprocal learning as well as generate, share and utilize technologies in agriculture [56]. It places great emphasis on the role of research and technological transfer, which have augmented agricultural productivity [57,58], increased harvests, lowered prices and increased welfare and demographic growth. This was possible, thanks to large public investments in research centers [59,60].

Therefore, scientific inputs contribute to many industrial innovations in the agri-food sector [61–63]. The technological environment in which agri-food companies operate is characterized by an extensive range of technologies, exploiting many innovations in the area of food preservation, such as freezing and chilling technologies; information technologies and automation solutions; and new developments in drying, heat processing and packaging in a controlled and modified atmosphere [64].

New advances in core scientific fields, such as biotechnology, microelectronics, nanotechnology and computer science, are awaiting transfer in the near future [62]. However, circularity poses new, daunting technological challenges that cannot be faced without government support. Although the shift to a CE has become an increasingly important component of the EU's development strategy, no consensus has yet been reached on the depth of the transformation that this implies [65]. The socio-institutional and productive change involved in the transition to a CE requires the support of an appropriate innovation system [66].

3. The Current Situation

From Linear to CE through R&I

Increases in temperature, rainfall variation and the frequency and intensity of extreme weather events are adding pressure to the global agriculture system, which is already struggling to respond to rising demands for food and renewable energy. Climate change is exacerbating the challenges that the agriculture sector faces, thus negatively affecting both crop and livestock systems in most regions.

A recent estimate suggests that overall, food systems cost society \$12 trillion dollars in health, economic and environmental costs—20% more than the market value of food systems [67]. Therefore, it is no wonder that one of the defining challenges of the 21st century is to discover new ways to accommodate the continuous increase in the living standards of a world population estimated to reach nine billion by 2030 and 10 billion by 2050 [68]. This must be done in the context of limited natural resources without jeopardizing the sustainability of the global environment [69] and moving towards an inclusive CE system [70].

This shift relies on many changes (towards more sustainable agriculture practices, to food waste reduction, etc.) and requires integrated and coherent policies supporting innovations that allow for climate-friendly productivity. Such productivity stimulates the take-up of innovative technologies with sustainable and climate-friendly goals [71,72]. This also requires technological, organizational and institutional changes to the knowledge base of existing production systems [73,74].

Currently, there is a great deal of interest in the concept of a CE in the EU [75]. The CE potential for innovation, job creation and economic development is huge: estimates indicate a trillion-dollar opportunity [69]. However, the EU economy is still largely linear, thus resulting in the inefficient use of natural resources and avoidable environmental and human health impacts [76]. In 2017, the EU's circular material use rate was 11.2% [77], whereas at world level, in 2020, only 8.6% of the global economy is circular [78], with the gap widening compared with previous years.

The socio-technical transition to a CE relies on the pillars of environmental benefits [79]. These include cost savings and the creation of new markets, which provide additional economic benefits of CE practices, for example, in terms of job or wealth creation. However, as many scholars have argued [80–83], the main obstacle to this transition is the growing need for innovation, which involves not only research on new technologies but also clear indications on how to use them, policy support in the definition of appropriate regulatory frameworks, and the provision of the right incentives to technology adoption. As argued by Proserpio et al. [84], the suffix socio- highlights the great change that this shift needs and that, going beyond the simple technological dimension, requires deep changes in practices and institutional and cultural structures. Transitions are, therefore, complex and long-term processes comprising multiple actors either from the institutional or from the entrepreneurial and civil environment.

Ghisellini and Ulgiati [85] argue that legislative support and governmental support are fundamental in the initial phase of the implementation of a CE. In addition, a lack of governmental support is one of the main barriers that companies—particularly small to medium-sized companies—must overcome to adopt a circular approach [86]. New investments and alliances between companies seem to be necessary, although companies with vested interests will be inclined to try to hold back the transition [29]. Specifically, De Cleene and Bora [72] identify four categories of incentives: (i) public investment and policy pathway; (ii) business model innovation pathway; (iii) institutional investment pathway; and (iv) consumer behavioral change pathway. In addition, these kinds of incentive mechanisms in food systems will have a greater impact if complemented by incentives from other sectors [72]. In terms of policies, systemic approaches to innovation and technological change have resulted in broad policy recommendations primarily addressing framework conditions [87]. The potential for both economic and environmental transformation has motivated policy interventions to drive this change, particularly in regions such as China and Europe, where a CE has been an established goal for more than a decade [88]. Many countries show a strong interest

in inclusive circular economic growth and long-term sustainability. They are interested in looking into supporting policies, norms and standards to reach the challenging Sustainable Development Goals of the 2030 Agenda. However, notwithstanding this widespread interest and a growing body of academic research in this field, knowledge gaps remain between the aspiration of a truly CE and the widespread adoption of its most promising strategies [88]. As the transition to a CE requires significant efforts in R&I, the Framework Programs for Research and Innovation (FP) can be deemed excellent tools for providing incentives for the economic actors to develop and enhance the CE system. More specifically, the Horizon 2020 program supports innovative projects for waste prevention and management, reduction of food waste, innovative remanufacturing, sustainable process industry, industrial symbiosis and the bioeconomy [89].

4. Current Investments in R&I and the Path Ahead

4.1. R&I on Circularity in EC-Sponsored Research

In Europe, the EC has always been extremely concerned about the agricultural sector and has distributed generous funding in an attempt to support farms and preserve rural communities. Nevertheless, the need to introduce a CE model in the agri-food sector, as a whole, is placing more pressure on the design of effective policy design. According to the EC, about 88 million tons of food are wasted annually in the EU [90]. Food is lost or wasted along the entire food supply chain—on the farm, in processing and manufacture, in shops, in restaurants and canteens, and at home—with relevant economic, environmental and social impacts. The adoption of a CE model indirectly supports waste reduction, minimizing the use of resources. According to the EC [91], a CE can bring major economic benefits, contributing to innovation, growth and job creation.

In 2020, the EC has adopted a new Circular Economy Action Plan—one of the main blocks of the European Green Deal, Europe's new agenda for sustainable growth. This new action plan promotes “initiatives along the entire life cycle of products, targeting for example their design, promoting CE processes, fostering sustainable consumption, and aiming to ensure that the resources used are kept in the EU economy for as long as possible [4].” This plan identifies food, water and nutrients as being among the main key product value chains in the promotion of circularity. It stresses how the food value chain is responsible for significant resource and environmental pressures, and how 20% of the total food produced is lost or wasted in the EU. To increase circularity in this vital value chain for Europe, the EC will propose targeting food waste reduction and consider specific regulatory measures to increase sustainability (e.g., limiting single-use packaging), as well as promote water reuse and wastewater treatment.

The 2015 version of the plan partially relied on Horizon 2020 to sponsor research projects on relevant topics and mentioned the food value chain as a sector of concern, urging the reduction of food waste. The new action plan stresses that Horizon Europe and LIFE will complement private innovation funding and will support the entire innovation cycle with the aim of bringing solutions to the market. Smart specialization strategies implemented with the European Regional Development Fund complement these two instruments. Marie Skłodowska Curie Actions, which can support the development of skills and training in this area, also complements them. The plan makes no specific reference to funding instruments for sustainability in the agri-food value chain.

4.2. The EAFRD and the FPs

The agri-food sector will benefit in the future from general advancements in digital technologies (e.g., tracking deliveries will reduce waste and extend shelf life), with Horizon 2020 currently supporting their R&I. However, if we look specifically at the agri-food sector, at present, the main instruments for R&I in sustainability in agri-food are the EAFRD, which is one of the two funds financing the Common Agricultural Policy (CAP), and the FPs.

Recent measures to adapt to climate change have led to some positive results. These include supporting sustainability in agri-food production, a major source of pollution, and reducing biodiversity. For example, the 2013 CAP reform was aimed at strengthening agricultural competitiveness and explicitly promoted sustainable farming and innovation. The reform introduced direct payments to farmers, conditional on limited crop diversification [92]. From 1990 to 2010, agricultural productivity growth was maintained. The greenhouse gas emissions of Organization for Economic Co-operation and Development agricultural producers have declined by 44M tons of CO₂ equivalents thanks to more efficient fertilization and input uses that have reduced emissions. However, the introduction of new technologies in the agri-food industry might give this relevant sector of the economy a new lease on life. In addition, it may delay the inevitable shift to a fundamentally different model of agriculture based on more diversified ecological systems. This will curb emissions as well as increase biodiversity and sustainability while enabling the industry to compete with monoculture systems. In fact, during the past 30 years, cuts to government research funding budgets have strained research institutions, which have partially compensated this gap with private funding [93], increasing productivity at the cost of focusing on fewer types of tradable crops [94]. The focus has often been on technological innovation (particularly for input-responsive crop breeding) to drive productivity increases.

The EU is already taking measures to ensure the sustainable intensification of agriculture. The EAFRD is the funding instrument of the CAP that supports rural development strategies and projects. It is also a part of the European Structural Investment Funds (ESIF). The EAFRD budget for the 2014–20 period amounts to around €150 billion (Figure 1) that will be spent through the implementation of rural development programs that run until the end of 2023.

Figure 1. Total budget 2014–20: EAFRD, EUR million. Source: Our elaboration on EC (European Commission) [94] data.

The EAFRD has six priorities, and in the view of the EC, each of these priorities should contribute to the cross-cutting objectives of innovation as well as climate change mitigation and adaptation. Priority 1 aims specifically at fostering knowledge transfer and innovation in agriculture, forestry, and rural areas with a focus on the following areas:

- Focus Area 1A—fostering innovation, cooperation, and the development of the knowledge base in rural areas;
- Focus Area 1B—strengthening the links between agriculture, food production and forestry and research and innovation, including for the purpose of improved environmental management and performance;
- Focus Area 1C—fostering lifelong learning and vocational training in the agricultural and forestry sectors.

Focus Area 1A is designed to foster innovation, cooperation, and the development of the knowledge base in rural areas. It offers to EC Member States the opportunity to provide to their stakeholders a package of soft measures related to advice, training, cooperation and knowledge transfer. The target is to dedicate a modest 3.9% of the total planned public expenditure, intended as the sum of EAFRD funding, Member States matching funds, plus any national top-ups, to:

- Total public expenditure is Measure 1—Knowledge transfer,
- Measure 2—Advisory services, and
- Measure 16—Cooperation.

Notwithstanding the efforts to promote adaptation to climate change and sustainability, the direct allocation of funds to R&I activity seems to be very low, amounting to some €3.6 billion. This represents approximately 2.4% of the total budget [95]. The main measure addressing R&I (Measure 16.2) focuses on cooperation: aid for pilot projects, and developing new products, practices, processes and technologies. Therefore, it mostly focuses on innovation and not specifically on solutions for circularity. Thus, the EAFRD favors support for innovation rather than research. However, it inevitably does promote research activity; as from an operational viewpoint, it is very hard to evaluate the technology readiness levels (TRLs) of innovative solutions in small companies, discriminating between what actually is input activity (research) and output activity (innovation). Thematic areas linked to a CE, such as environmental protection and resource efficiency, or a low-carbon economy, represent some 30% of the total funding allocation. Dedicated R&I activities are extremely limited.

However weak the support obtained from the EC may seem, it must be admitted that this has improved considerably compared with the previous programming period. The EAFRD total budget for the period of 2007–13 was a little more than €96 billion, and the total allocation for the Measure 124, promoting “cooperation for development of new products, processes and technologies” [96] was about €334M, representing approximately 0.34% of the total budget [96]. It must be noted that these figures refer to the whole R&I budget, which is allocated to projects and activities on circularity in a limited way.

The primary instrument in terms of resources for the promotion of R&I in Europe is Horizon 2020, the latest iteration of the FP. Horizon 2020 implements the Innovation Union, a Europe 2020 flagship initiative aimed at securing Europe’s global competitiveness. It features three pillars and two specific objectives corresponding to its main priorities, as well as several thematic areas. The area ‘agriculture and forestry’ is organized around four headings, all more or less directly linked to circularity for the thematic areas addressed: increasing production efficiency and coping with climate change while ensuring sustainability and resilience; providing ecosystem services and public goods; the empowerment of rural areas, including support for policies and rural innovation; and sustainable forestry.

Horizon 2020 has a total budget of some €79 billion for the programming period of 2014–2020, of which around €3.7 billion is for the Societal Challenge 2 (SC2) on “food security, sustainable agriculture and forestry, marine, maritime and inland water research and the bioeconomy”. It is substantially more generous compared with the FP7, which had a budget of €50 billion for the period of 2007–2013.

For the purposes of the study, the project data of Horizon 2020 were extracted from the Community Research and Development Information Service (CORDIS), which does not include a classification for the area of a CE in agriculture. To identify the projects in this area, we extrapolated the 416 projects in the area ‘food and natural resources’ and searched for all projects more closely related to a CE. This was done by searching for relevant keywords (circular; reuse; valorization; waste; cradle; raw; sustainable; renewable) in project abstracts that Horizon 2020 and FP7 sponsored. The results of this exercise are presented in Table 1.

The area ‘food and natural resources’, despite its relevance in EC policy papers, represents less than 2% of both FPs. The search for keywords evidenced that 80 projects on circularity exist, which represent about 19.2% of the total number of projects on food and natural resources, whereas

in FP7, just 68 existed (14.8%). Overall, in both programs, the projects on circularity in the agri-food sector represented some 0.2% of the total number of sponsored projects, leaving open questions about the effectiveness of efforts to promote circularity in the agri-food sector before it is too late.

The analysis of both EAFRD and FP data calls for more decisive efforts in the area of circularity both in terms of resources allocated and in terms of creation of a targeted funding area. The agricultural sector alone is at the center of the challenges associated with population growth, food security, climate change and resource scarcity. Precision agriculture utilizes the capabilities of information technology systems to optimize the application of agricultural inputs, and especially in areas such as livestock production [97], can enhance dramatically the control over the application of input fertilizers and agrochemicals, which is essential to achieving sustainable agricultural production. Similarly, the ad hoc use of biomass plants for electricity production (e.g., for powering the public lighting of small communities) [98] can reduce the use of fossil fuels. Therefore, if circularity is to stay at the heart of EC policy, it is recommended to create dedicated calls for R&I activity in agri-food and in its wide value chain, pooling resources from the main EC policy instruments.

Table 1. Number of projects in recent Framework Programs.

Programme	All Domains	Food and Natural Resources	Share	On Circularity	Share
Horizon 2020	28,634	416	1.5%	80	19.2%
7th FP	25,778	461	1.8%	68	14.8%
Total	54,412	877		148	

Source: Our elaboration on CORDIS (Community Research and Development Information Service) data.

5. Discussion and Concluding Remarks

The current economic linear system is failing in terms of environmental, social and economic sustainability. Human activities are causing climate change, and this is pushing the transition to a CE. A CE offers an opportunity to reinvent the economy, thus making it more sustainable and competitive. The use of new and innovative products, processes and business models can generate higher incomes for producers while keeping consumer prices affordable and improving the delivery of environmental and social benefits.

As stated in the Introduction, the aim of the paper is to shed light on the European policy for innovation fostering the socio-technical transition at the basis of the CE and to open a critical debate on the actual relevance of the adoption of a CE model in current R&I policy.

Based on our brief analysis of EC policy documents, the transition towards a CE represents an important strategic step, entailing a shifting from ‘necessity’ (efficiency in the use of resources, and the rational management of waste) to ‘opportunity’ (designing products to make what is currently a waste become a resource for a new production cycle). As highlighted in this paper, the transition from linear to CE models is so complex (for the multiplicity of elements and dimensions involved in the process) that it requires very strong and wide support in terms of R&I. Starting from the consideration that the necessary shift towards circularity must be accomplished via a technological transition, that is, by a set of innovations from many points of view, this study has focused on the funding of research projects aimed at promoting sustainable and CE innovation in the agri-food system. A CE very much depends on technical innovations that increase efficiency in resource use, the substitution of fossil fuel-based products and the recycling rate of the production system. In terms of environmentally friendly innovations, any form of innovation could bring an increase of sustainability in production processes. In the agri-food sector, there is a widespread awareness that clean technology and eco-innovation are the keys to creating a win-win situation and that this shift requires integrated policies and different kinds of incentives. Therefore, research has a role to play in unravelling the links between the complexity of food systems and their efficiency, resilience and sustainability, which governments must promote and sustain.

However, looking at the most significant EC programs sponsoring R&I, it seems that the will to increase the sustainability of the agri-food system and to foster the socio-technical transition towards circularity is evident but not very relevant.

More specifically, we look at data related to the amounts of money allocated and the projects funded for R&I projects with the EAFRD and the FPs in the agri-food sector. Here, we find that the issue of circularity, while widely trusted in policy papers, plays a marginal role in R&I activity. The R&I issue becomes particularly critical if we consider that the global circularity gap is widening instead of shrinking. Therefore, to reverse this negative trend embedded deep within the ‘take-make-waste’ tradition of the linear economy, a strong need exists for change and for the adoption of transformative and correctional solutions.

Although it is not the intention of this paper to highlight doubts about the appropriateness of EC policy in this vital issue for society, the data presented leaves some open questions concerning the effective commitment of European countries to promoting resource efficiency via R&I. Despite the policy intent to foster the adoption of a CE model, a decisive step towards a real transition will be represented by the political will. This will, coupled with funding R&I activities, is needed to reduce the high level of uncertainty associated with all innovations, including policy uncertainty. In our opinion, future research should provide empirical evidence regarding the actual impact of EC initiatives on the circularity in the European agri-food systems. Future research should also call attention to the contribution of advancements in R&I beyond the anecdotal evidence that a few success stories have provided.

However, we are aware that the real transition will not depend only on the financing of specific projects on the topic of CE in agri-food systems, but also from the financing of other projects which, although not apparently attributable to the CE, are the basis, together with a regulatory framework, of the social innovation much desired for the shift to take place.

Therefore, the added value of the paper relies on the debate and on the reflection about the real intent of the EC to promote scientific progress and innovation that could let the transition forward circular models. Indeed, as highlighted in the study, this transition needs a great turning point that, starting from innovation strictly meant as technology development, also affects a real socio-technical transition.

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