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Transforming Research and Innovation for Sustainable Food Systems—A Coupled-Systems Perspective

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Abstract: Current research and innovation (R&I) systems are not equipped to fully serve as catalysts for the urgently needed transformation of food systems. Though research on food systems transformation (first order: 'what?') and transformative research (second order: 'how to') are rapidly gaining traction in academic and policy environments, current efforts fail to explicitly recognize the systemic nature of the challenges associated with performing transformative second-order research. To recognize these manifold and interlinked challenges embedded in R&I systems, there is a need for a coupled-systems perspective. Transformations are needed in food systems as well as R&I systems ('how to do the "how to"'). We set out to conceptualize an approach that aims to trigger double transformations by nurturing innovations at the boundaries of R&I systems and food systems that act upon systemic leverage points, so that their multisystem interactions can better support food system transformations. We exemplify this coupled-systems approach by introducing the FIT4FOOD2030 project with its 25 living labs as a promising multilevel boundary innovation at the cross-section of R&I and food systems. We illustrate how this approach paves the way for double systems transformations, and therefore for an R&I system that is fit for future-proofing food systems.

Keywords: food systems; complexity; sustainability transitions; societal transformation; transdisciplinarity; research and innovation; boundary innovations

1. Introduction

Current food systems increasingly (re)produce a set of interlinked and persistent problems. Despite efforts to tackle these interlinked problems, profound transformation is yet to be realized (see, for example the EAT Lancet Report [1]). Currently, food systems account for 21%–37% of greenhouse gas emissions [2] and 70% of freshwater use [3], and lie at the heart of land-use conflicts, in both the global North and South [4,5]. Excessive agricultural pesticide and herbicide use further contributes to soil degradation and biodiversity loss [6] as 16% of pollinators are threatened with global extinction [7]. Unhealthy diets lead to the triple burden of malnutrition [8], with 11% of the world population being undernourished, 39% overweight, 13% considered obese, and 26% suffering from micronutrient deficiency [9–11]. Diet-related non-communicable diseases (NCDs), such as cardiovascular diseases, diabetes, and certain cancers, are on the rise globally and already lead to an estimated 40 million deaths per year [12].

In recent years, it has been recognized that food systems can best be understood as complex systems [13–19], pointing to the need to understand the dynamics of systems as a whole, rather than focusing only on their constitutive parts. Holistic conceptualizations of food systems therefore aim to move beyond traditional divisions between production-oriented and consumption-oriented approaches by emphasizing the need to include all relevant processes (e.g., food production, distribution, consumption), actors (e.g., farmers, researchers, consumers), policy sectors (e.g., health, agriculture, environment), governance levels (e.g., local, national, global), and functionalities (e.g., healthy diets, access to food, employment, fostering commensality, and cultural identity) in research and policy efforts. Such conceptualizations point to the need to move beyond linear models (such as value or supply chains) and circular food system models (such as food cycles) since they do not adequately capture the complex structural and dynamic properties of food systems [16,20]. The many interacting elements of complex (food) systems give rise to properties such as resilient or locked-in system states, adaptivity, emergent behavior, self-organization, and non-linear dynamics, such as systemic feedback loops, synergies, and trade-offs [16–19]. Such holistic food systems approaches are increasingly gaining ground in policy environments globally (see e.g., [21–24]).

In the domain of research and innovation (R&I), the emerging field of transition studies offers analytical tools for both understanding ('what?') and governing ('how to') sustainability transformations of complex societal systems [25–28]. These transformations—called transitions in transition studies—are characterized as non-linear processes of structural change [29,30] that entail a "profound change in various or all aspects of a system's functioning" [31] (p. 59) and lead to "far-reaching changes in the system along different dimensions: technological, material, organizational, institutional, political, economic, and socio-cultural" [26] (p. 956). Research on transformations of (agri-) food systems using a transition studies perspective is rapidly gaining traction [20,32–34].

In a recent work, Fazey et al. [35] refer to such transformation research and explore a characterization of first-order ('what?') and second-order ('how to') approaches. While first-order research is concerned with understanding the mechanisms of societal transformation, and generally considers researchers to be rather independent observers, second-order approaches aim to contribute to societal transformation through research as an intervention and acknowledge that the researcher is part of the system she aims to transform. Such transformative second-order research, according to Fazey et al. [35] (p. 54), "includes mode 2, transdisciplinarity, post-normal, participatory, sustainability science, and action research". Though it is increasingly recognized that such approaches might contribute effectively to societal transformations by generating societal impact [36], doing transformative research is not a straightforward endeavour and involves many challenges. For transformative second-order research, the challenges are especially problematic and relate to R&I processes, as well as to the associated systemic environments in which these processes are embedded [37–40]. Surprisingly, although scholars often emphasize the challenges they encounter in transformative efforts, they largely ignore the systemic nature of these challenges and do not provide systemic approaches to tackle them. We posit that if R&I is to live up to its full potential as a catalyst for food systems transformation, the challenges of doing second-order research need to be resolved (see also [41]). Henceforth, the goal of this conceptual paper is to develop an action-oriented approach to tackling those challenges by explaining 'how to do the "how to"'—which we call a coupled-systems transformation approach.

In pursuit of developing an approach to answer the 'how to do the "how to"' question, in Section 2, we first reflect upon food systems transformation literature through the lens of Fazey et al.'s categorization of two orders of transformation research, and we explore the manifold and interlinked challenges of transformative second-order research. Subsequently, in Section 3, we posit that such manifold and interlinked challenges are crying out for the adoption of a systemic perspective to R&I. To this end, we set out to conceptualize an approach that aims to trigger double transformations by nurturing innovations at the boundaries of R&I and food systems so that their systemic interactions can better support food system transformations. We exemplify this coupled-systems approach in Section 4 by introducing the EU FIT4FOOD2030 project as an instrument designed to foster double transformations. FIT4FOOD2030 is a Horizon 2020 project that supports the European Commission (EC) in the implementation of the FOOD 2030 policy framework. It aims to contribute to food systems transformation through research and innovation [18,21]. Finally in Section 5, we conclude this paper and present an outlook.

2. Two Orders of Food Systems Transformation Research

2.1. First Order: Understanding Mechanisms of System Transformation

Within transformation research, first-order approaches are the most dominant [35]. First-order approaches aim to understand and describe the mechanisms driving the dynamics of societal transformations. In doing so, they tend to consider research as "being conducted from without the subject of study, as if looking at the issue or system from the outside" [35] (p. 58), assuming that researchers can be independent observers of the system they study. According to Fazey et al. [35] (p. 58), this leads the focus of the research towards the "explanatory problem solving of natural and social science questions relating to social change and environmental sustainability" while assuming that researchers are the actors most fit to know what kind of knowledge needs to be produced for it to contribute to system transformation. It is then generally considered the responsibility of societal actors to utilize this knowledge towards system transformations. First-order research is important and valuable since it not only yields insights into mechanisms of transformation, but also helps to articulate the urgency of the required societal transformations.

When it comes to (agri-) food systems research, first-order approaches use a wide variety of conceptual frameworks. Below, we present an exploratory overview of recent literature, that aims to highlight this variety of frameworks in studying dynamics and transformations—or transitions—in (agri-) food systems. We rely on recent (2015–2019) key overviews of the field [27,28,42] in identifying several influential conceptual frameworks for understanding (mechanisms of) societal transformations. We then illustrate each of these frameworks with some empirical examples of research in the domain of (agri-) food systems, which were identified in a scoping exercise.

Research with a distinct socio-technical perspective, for instance, employs (historical) analyses to understand the dynamics of sustainable transformations by using the increasingly popular multi-level perspective (MLP) (see [26,28,29,34]). Such an analytical gaze can help, for example, to better understand the dynamics of agri-food regimes (e.g., [43]) and multi-sectoral interactions between health care and agriculture in care farming (e.g., [44,45]). It might also help to understand the role of pioneers in the emergence of organic agricultural practices (e.g., [46]), and to conceptualize the structural properties of diversified production systems (e.g., [47]). Socio-ecological perspectives that can be used to understand the complexity of systemic dynamics are also considered an important approach in transformation research [42] and focus on a range of empirical topics, from grasping the dynamics of dietary behaviours (e.g., [48]) to managing small-scale fisheries (e.g., [49]). Other qualitative analytical approaches that aim to understand the (technological) dynamics of food systems include technological innovation systems research (e.g., [50–52]), social practice approaches (e.g., [32,53,54]), and research focusing on the multitude of values involved in food systems transformation (e.g., [55,56]).

Another type of approach used in first-order transformation research relies on quantitative systems science. This includes the development of models and metrics for measuring sustainability, risks, and climate change, and their relation to (global) food system performance (e.g., [16,46,57–60]). Furthermore, there are schools of agro-economic research that focus on modelling cropping, farming systems, supply-chain dynamics, land-use, as well as those efforts focused on modelling consumption behaviour, nutrition (security), and their relation to food environments and health (e.g., [60–64]).

Finally, the role of governance, power, and agency is gaining increasing attention in the field (e.g., [26,28]). The analytical turn towards acknowledging the role of power is crucial, since recent work has indicated how understanding power and agency might help to understand systemic stasis and foster change [65,66]. Understanding power imbalances can, for instance, explain how regime actors contribute to enforcing status quo configurations in food systems [67,68]. Such an understanding also helps to indicate the shift in power from primary producers to input providers, large food companies, and retail [69,70]. Furthermore, empirical studies, for example, focus on how actors strategically draw upon their agency (e.g., in public procurement in UK universities catering systems [71]), but also focus on the role of non-human agency in system dynamics (e.g., in New Zealand wine production [72]).

2.2. Second Order: Intervening in and Contributing to Societal Transformations

Second-order efforts focus not only on unravelling systemic dynamics, but also contribute to system transformation through research as an act of intervention. Focusing research on both knowing and doing challenges multiple ontological and epistemological assumptions about what research 'should do' and moves beyond traditional linear and positivist approaches in the realm of R&I [35,39]. Second-order efforts acknowledge that researchers are inevitability part of the system they study and are therefore likely to always intervene in the system of interest as "one of the many actors in the process of change" [35] (p. 58). Second-order approaches also recognize the importance of interdisciplinarity and stakeholder engagement in developing the problem perceptions and shaping the research process, as well as contributing to transformations (transdisciplinarity). This leads to new roles for researchers engaging in second-order processes, as well as to a need for them to recognize normative aspects and to be reflexive regarding their own knowledge, values, and interpretations.

For food systems, transformative second-order research is considered to provide effective and useful contributions to understanding and governing, for example, the upscaling of, and knowledge exchange within, novel agro-ecological practices [73,74], the co-production of relevant (local) knowledge in organic agriculture [75], the creation of collaborative advantages for both farmers and researchers in participatory technology development processes [76–78], and the co-designing of governance strategies with small-scale fisheries [79,80].

To illustrate in more detail some of the key features of such transformative second-order efforts, and their use in different analytical approaches to guiding food systems transformation, we provide three examples that could be considered transformative second-order approaches, grounded in the principles of transdisciplinarity. The first example is an approach that originates from attempts to modernize and transform Dutch animal husbandry [81–83] through multi-stakeholder efforts: reflexive interactive design (RID). The RID approach was used recently to facilitate transformation of livestock systems on the Galapagos Islands [84] (p. 168) as "a way to structure a knowledge–practice interface in which reflection and dialogue are facilitated for managing (heterogeneous) knowledge and reflecting on practice". This action-oriented approach aims to have multi-stakeholder collaborations co-designing problem spaces, to focus on the (knowledge) needs of different actors, to conduct an analysis of the system, to develop shared visions of the system's future, and in the meantime to form a diverse reflexive network to foster structural systemic transformations.

Another example of a transdisciplinary approach developed first in Dutch agricultural R&I is reflexive monitoring in action (RMA, [85,86]). The RMA approach focuses on enhancing deep learning and reflexivity in transformative projects while at the same time fostering systemic transformations. In RMA, an actor (the 'reflexive monitor') aims to facilitate participants of the project to reflect upon the ambitions of the project and the current (unsustainable) practices (and how they are institutionally embedded), as well as to identify opportunities in the system that foster sustainable innovation [86] (p. 11). Within RMA, researchers can perform the role of the reflexive monitor, but that requires them to adopt a new role, which in turn requires specific skills and competences [35,87–89].

A final example considers transition management (TM; see e.g., [30,90]) approaches. This approach was employed, for instance, in the project Accelerating and Rescaling Transitions to Sustainability (ARTS), which aimed to understand and contribute to the role of (civil society in) urban sustainability transitions (including the role of food and urban agriculture) in five different city regions across Europe [91]. Rooted in a TM approach which focuses on "activities directed towards creating and furthering new practices in a sector" [92] (p. 76), there is a strong emphasis on the role of experimentation dubbed 'transition initiatives' [91] or 'transition experiments' [90]. In the case of Genk (Belgium) in the ARTS project, local transition arena for experimentation involving "co-creation and co-design of urban patterns of production and consumption [. . .], new solutions for urban challenges can provide a new boost in creativity and new ways to organize local governance and local economy" [91] (p. 182). TM efforts also explicitly require researchers and other actors to adopt new roles [93,94] in order to effectively steer towards systemic transformations.

2.3. Challenges of Transformative Second-Order Research

Despite their potential to contribute to sustainable (food) systems transformation, the challenges of conducting transformative second-order research are manifold. Based on a scoping exercise, we argue that at least seven clusters of challenges can be identified, most of which are featured in reflections on transdisciplinary research.

First, the way in which knowledge production is (and has been historically) organized is limiting the uptake of transformative second-order research. Knowledge production is traditionally structured in silos of disciplines and sectors [52,95,96], leaving little room for the exploration of collaborations across disciplinary and sectoral silos. In addition, public and private partnerships fostering food systems transformation are still relatively rare [97].

Second, funding structures do not sufficiently support transdisciplinary and action-oriented research, which limits the uptake of such efforts and the transformative innovations that could originate from them. While the call for transformative research policy is emerging it is relatively new and most R&D funding is still traditional and linear [98]. For example, agricultural R&I investments in the EU are mostly targeted at food production and food security [99]. This means that other parts of food systems such as processing, logistics, and retail are underrepresented [52] and that the interconnectedness of the different elements within food systems is not sufficiently recognized and not reflected in current R&I investments [95]. Therefore, both first- and second-order approaches that take systemic perspectives and advocate systemic transformation are disadvantaged.

Furthermore, academic incentive structures do not support transformative collaboration, favouring disciplinary endeavours that are focused on high publication outputs in high-impact journals. According to Wiek et al. [100] (p. 22), the "dominant institutional structures that govern academic research, from funding schemes to promotion and tenure policies [...] are, in the majority of cases, not conducive to this new type of research, which limits the full development and impact of transformational sustainability research". This also means that "the disciplinary organization of scientific knowledge production remains largely unchanged" [101] (p. 70). These academic structures limit the impact of transformative research [102].

Fourth, (research) cultures across the globe do not sufficiently value the (outcomes of) transdisciplinary research, arguing that transdisciplinary research does not lead to objective or scientific knowledge or that the outcomes are not sufficiently legitimate [37,103]. This is exemplified by Schoolman et al. [102], who show that transformative research is often not published in high-impact journals; this is inherently related to the third challenge regarding incentive structures. This severe undervaluation leads Castree [104] to argue that we need a new social contract in order to re-legitimize the new role of research (that is, transformative research) in society. Although a number of studies have explored ways to appraise the outcomes of transition experiments (as examples of transformative research), coordinating efforts are widely lacking [105].

Fifth, transformative research is evolving as a field and there are clear methodological and conceptual challenges within transdisciplinary research itself. Major challenges in the field include a lack of coherent framing and positioning as a field [38] and a lack of coherent methods, with methods being used without being tailored properly to the relevant process phases or knowledge types [37,38,100]. In addition, there is a gap between 'best practice' transdisciplinary research and what is published in scientific journals [38]. Furthermore, knowledge integration in practice faces challenges related to social, organizational, communicative, cognitive, and technical aspects (e.g., [106]), and the role of reflexivity in transdisciplinary research is still under-conceptualized [107].

Sixth, it is challenging to engage all relevant stakeholders in transformative efforts and to continually keep them engaged [37]. Related to the low uptake of transformative food systems R&I is the limited active involvement of, for example, citizens and farmers [18,23,108]. Given their central role in food systems, it is important to further engage these actors in food systems R&I [99]. This is not straightforward since it is challenging to work "across differences in background, training, experiences, needs, ideologies, and interests [...] finding agreement on a consensual framework for the research, on methods, standards of work, and priorities, being confronted with different ontologies and epistemologies" [109] (p. 111) or even with distrust and institutionalized conflicts [110]. At the same time, such processes can be heavily constrained by the limited time and resources of non-academics who may need to engage in the co-production of knowledge [109].

Finally, we observe challenges in R&I practice since researchers and innovators lack the competences needed to engage in transformative second-order efforts, and so do policymakers (e.g., for collaborating across silos and embracing reflexivity and system thinking). Such engagement requires adopting roles in R&I processes other than those of traditional scientists, innovators, or policymakers. It requires new roles such as 'change agents' (researchers participating in practice to foster change), 'capacity builders' (supporting participants' transformative capacity building) and 'reflexive process facilitators' (facilitating transformative learning) (see e.g., [87,111]). Adopting these roles in practice is challenging because of differences in the understanding and expectations of each role and because of possible conflicts between them. As such there is an additional challenge for those taking up these roles, which points to the need for capacity building [88,112].

Taken together, these challenges are even more difficult to overcome due to their entangled, mutually reinforcing, and self-reproducing nature [39] (p. 203). Such a fundamentally interwoven set of challenges points to their truly systemic nature; they involve practices, structural and cultural dimensions of R&I efforts as well as the actors involved in R&I. As a means of dealing with another layer of complexity—in addition to the complexity of food systems and in order to explore possible solutions to overcome this new set of wicked challenges—we employ a systems perspective for food systems as well as the associated R&I systems that aim to serve as catalysts for fostering food systems transformation.

3. How to Do the How to? Conceptualizing Interventions for Triggering Double Transformations

3.1. Systemic Perspective on Research and Innovation: The Need for Double Transformations

It can be beneficial to acknowledge the systemic nature of the above-mentioned challenges and of R&I efforts more generally, since that allows us to understand the structural problems within these R&I systems that are related to their capacity to contribute to food systems transformation. A systemic take on R&I is rather common for those studying the interplay between science and society: scholars regularly speak of 'knowledge systems' [113,114], 'national innovation systems' [115], 'technological innovation systems' [116–118], 'science systems and innovation systems' [119], 'knowledge and innovation ecosystems' [120], 'agricultural innovation systems' [121], 'knowledge production and use systems' [39], 'knowledge and innovation systems' [122], 'agricultural innovation ecosystems' [123], or—to adopt an umbrella term, which we do—research and innovation (R&I) systems. Adopting a systemic perspective on R&I, we argue, gives rise to at least three questions: (1) 'what does a systemic take on R&I mean?', (2) 'what do R&I systems consist of?', and (3) 'what are the consequences of a systemic take on both R&I and food systems for conceptualizing how R&I can contribute to food systems transformation?'

First, reiterating the foundations of complex societal systems, we follow De Haan and Rotmans' [124] definition of a societal system as a part of society with a particular function that aims to fulfil a societal need. Functions of R&I systems can be, for instance, producing knowledge, communicating knowledge, innovating products or processes, disseminating research, informing policymakers, etc. Societal systems such as R&I systems consist of multiple interacting components: structures, cultures, and practices, as well as the actors involved in them [92,124]. The complexity of such systems is exemplified by their non-linear dynamical behaviour, which can be seen as the product of emergent self-organizing processes evolving from the interaction networks of the components in the system. Regarding R&I systems, this is in line with observations of the complex nature of "systems, networks, and sectors of innovation that is driven by increasingly complex, non-linear and dynamic processes of knowledge creation" [120] (p. 202).

Second, following this line of reasoning, R&I systems consist, then, of structural components such as laws, funding structures, universities and research centres, laboratories, industry networks, scientific journals, ministries, cultural components such as the values and norms that relate to innovation and technology, ideas on the role of research in society, political environments, practices such as peer review, education, scientific processes, science–industry collaborations, mono-, multi-, inter- and transdisciplinary R&I processes, and of course a multitude of actors such as researchers, policymakers, consumers, producers, industry actors, and innovators. Although there is quite a lot of overlap between actors and other components in R&I systems and the thematic areas they work in (e.g., food, energy, health), there are also clear differences. For example, many countries have separate ministries, and therefore policies, policymakers, and cultures for R&I, decoupled from the sectoral ministries. The same can be observed in supranational entities like the EC, which at the time of writing (November 2019) has separate general directorates for research and innovation (DG RTD), agriculture (DG AGRI), and health (DG SANTE). These structures, cultures, practices, and actors together co-constitute the systemic functioning of R&I systems.

Finally, what consequences does a coupled systemic take have when it comes to the role of transformative R&I in realizing food systems transformation? The many challenges, as elaborated in Section 2.3, indicate that some of the desired functions of R&I systems are currently not being fulfilled, because the interactions between the components of R&I systems do not lead R&I systems as a whole to contribute efficiently to food systems transformation. Such a view has several implications for efforts aiming to alter the interactions between R&I systems and other societal systems. Those efforts should explicitly acknowledge:

- the systemic, complex, and dynamic nature of the challenges of transformative second-order research by introducing a coupled-systems perspective that connects the system of interest to a systemic perspective on R&I.
- that for R&I efforts to serve as catalysts for transformation in another societal system, there is a need for systemic reflection on the interactions between R&I systems and the system of interest. That in turn means that there is a need to explore double transformations. This echoes recent calls [125–127] to explore underlying mechanisms of inertia and the inter-systemic leverage points of transformative dynamics.
- that researchers and other actors are entangled in multiple systems at once, which means they also have to navigate in, actively and reflexively engage with, and act to transform multiple systems. This also requires researchers and innovators to transcend multiple logics, understand multiple systems, and establish transformative interactions between multiple systems.

Therefore, to answer our third question about the implications of this coupled-systems take on transformation, we argue there is a need for (R&I) efforts to realize transformations in R&I systems themselves as well as in the system(s) they aim to transform through transformative second-order efforts. A schematic overview of the two orders of transformation research, assumptions about the relation between the researcher and the system, and a visualization of an explicit coupled-systems perspective are depicted in Figure 1.

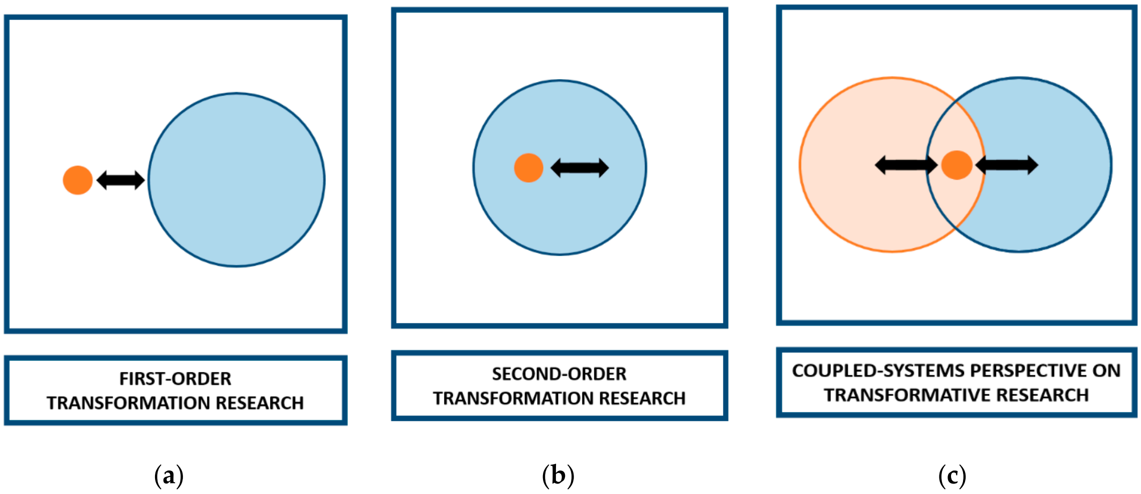

Figure 1. Schematic depiction of the different orders of transformation research and the relation between the 'researcher' (orange dot), the societal system of interest (e.g., the food system: blue circle), the R&I system (orange circle), and the flow of interactions (black arrows); (**a**) first order: the researcher as independent observer studies the system of interest; (**b**) second order: the researcher is engaged in the system of interest and tries to understand and transform it; (**c**) coupled-systems perspective: the researcher is engaged in the system of interest as well as in the R&I system; she acknowledges this multisystemic complexity and aims to understand and transform both systems by changing their interactions.

3.2. How to Do the How to: Designing Boundary Interventions on Leverage Points

Acknowledging the need for double transformations is one thing; achieving them is another. Before elaborating on how to empirically design a transformative intervention to trigger double transformations, let us first highlight two notions which we think can contribute to our understanding of the mechanisms through which transformative interventions can contribute to double transformation on a more fundamental level: (1) boundary innovations and (2) leverage points.

The first notion—'boundary innovations'—concerns the locus of the intervention and its relation to societal transformation. The importance of a cross-boundary innovation as an instrument for fostering sustainable transformation is increasingly recognized [45,123,128]. It refers to an innovation that "crosses systemic boundaries (that is the innovation interacts with different sectoral systems), but it also fundamentally changes the type of relation between those systems" [129] (p. 85), for example, it results in competition between different systems or in opportunities for creating symbiosis. Realizing symbiotic systemic interactions is challenging; actors or networks at such systemic boundaries are confronted with multiple sets of logics, actors, rules, practices, cultures, and structures [45,130]. Schot and Kanger [127], in their work on Deep Transitions, elaborate on the importance of coupling cross-systemic structures, functionalities, and logics to realize multisystem transitions. One explicit task of boundary innovations can be, then, to connect and align cross-systemic logics, practices, cultures, and structures (see also [129]). For example, Schot and Kanger [127] (p. 1054) consider coupling "a waste management system provid[ing] an input into the energy system" to be a functional coupling and these systems sharing an R&D facility as an example of structural coupling. Furthermore, Hassink et al. [45] point to the importance, capacity, and agency of actors engaged in cross-boundary innovations in overcoming the challenges of multisystem interactions. This relates to what we indicated in the previous section and highlights the importance of supporting actors involved in boundary innovations to reflexively navigate multiple systems and establish transformative interactions between multiple systems. This requires interventions that foster boundary innovations to employ methodologies that enhance learning and reflexivity. But while the concept of boundary innovation points to the locus of the intervention, it does not explicitly reveal how the involved actors should design instruments for fostering double transformations.

Therefore, we employ the second notion—'leverage points'—to operationalize and focus the direction of transformative interventions. One major challenge for multisystem transformations lies in the identification of "the mechanisms, processes and actors, which influence the evolution of a sociotechnical system and may or may not be part of it" [125] (p. 2). We therefore deploy the notion of leverage points to operationalize how boundary innovations can aim to redirect the interactions between R&I systems and food systems. The importance of identifying and acting upon leverage points for complex societal systems transformation was introduced by Meadows [131]. Leverage points are "places within a complex system where a small shift in one thing can produce big changes in everything" (ibid, p. 1). In a recent revaluation of her work, Abson et al. [132], as well as Fischer and Riechers [133], follow and adapt Meadows' hierarchy of places of intervention in complex systems to achieve sustainability transformations. They identify 12 orders (in four realms) of intervention on leverage points, from very 'shallow' Parameters or Materiality (altering rewards and material flows) via Processes (changing feedbacks), and Design (redefining goals, information flows, and self-organization) to the most impactful 'deep leverage points' in the realm of Intent (changing mindsets and paradigms). Such a conceptualization is useful since it helps to identify where intervention can be most effective and where it is perhaps hardest to realize and serves to provide "a common entry point for academics from different disciplines and other societal stakeholders to work together" [133] (p. 115). The hypothesis Fischer and Riechers [133] present is that if the interactions of leverage points are taken into account properly, this might lead to clever intervention strategies being implemented at 'chains of leverage points' (both deep and shallow), potentially leading to transformative dynamics.

To summarize, and based on the above discussion, one approach to tackling the 'how to do the "how to"' question could be

- to foster boundary innovations at the cross-section of R&I systems and food systems
- that aim to trigger double transformations by identifying specific leverage points and intervening at these points in R&I systems (and food systems)
- with the objective of better aligning the inter-systemic interactions between them
- so that R&I systems can serve as more effective catalysts of food systems transformation.

The dynamics of a coupled-systems approach to fostering double transformations through boundary interventions is schematically depicted in Figure 2.

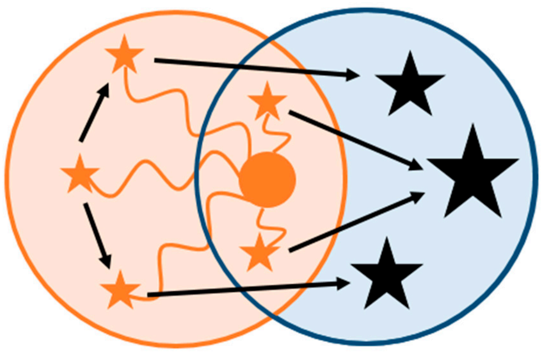

Figure 2. Schematic depiction of the dynamics of a coupled-systems approach: a cross-boundary innovation (orange dot) located at the boundaries of the R&I system (orange circle) and the food system (blue circle) identifies and intervenes on chains of leverage points in R&I systems (orange stars) that aim to change the inter-systemic interactions so that R&I systems can more effectively contribute to food systems transformation (black stars).

4. An Example of How to Do the How to: The FIT4FOOD2030 Approach

'Fostering Integration and Transformation for FOOD 2030' (FIT4FOOD2030) is a Coordination and Support Action project funded through Horizon 2020 (2017–2020) for further development and implementation of the EC's FOOD 2030 policy framework [21,134,135]. In line with the aim of FOOD 2030, FIT4FOOD2030's mission is to contribute to the transformation of European food systems through R&I to make them 'future-proof', i.e., sustainable, resilient, responsible, diverse, competitive, and inclusive. The three-year project has 16 partner institutions across Europe, including universities, research funders, technology and innovation platforms, industry networks, and science engagement organizations. The transdisciplinary consortium therefore represents the quadruple helix, including stakeholders from the domains of research, policy, industry, and civil society [120] and acts at the boundaries of food systems and R&I systems in the EU. At the time of writing, the project is still ongoing. Therefore, our elaboration mainly focuses on illustrating the design and mechanisms, not on the final outcomes of the project.

The project builds on the above-mentioned reasoning in stressing that though R&I systems in Europe have contributed to providing solutions to food systems' problems, they are currently unfit to fully contribute to large-scale sustainable transformations. The project cites the challenges of fragmented funding structures: little involvement of societal stakeholders, citizens, and primary producers in food systems R&I, a lack of competences of researchers and policymakers to facilitate such involvement, modest and fragmented private R&I investments, and academic incentive structures that hinder transdisciplinary collaborations [134–136]. It is not surprising that these challenges are similar to those formulated in Section 2.3 that represent the challenges of transformative second-order efforts.

The main objective of FIT4FOOD2030 is to tackle these challenges through the establishment of a sustainable, multi-stakeholder FOOD 2030 Platform, mobilizing a wide variety of stakeholders from different sectors at the levels of cities, regions, countries, and Europe. The FOOD 2030 platform aims to contribute to

- strengthening R&I policies' coherence and alignment to respond to a variety of actors' needs,
- building competences of current and future researchers, entrepreneurs, policymakers, and society at large, and
- raising awareness in support of the initiatives and action plan.

To guide the realization of these main objectives, the project designed three structures to foster transformation at three different levels: (1) an 'EU Think Tank' that acts as a link between the EC and member states and associated countries, with global outreach; (2) 'Policy Labs' on the national level that mobilize stakeholders in order to align R&I policies and investment schemes and integrate existing networks; and (3) 'City Labs' and 'Food Labs' on the local and regional levels that develop and pilot hands-on (in)formal training for students and professionals by bringing a wide diversity of actors together. An overview of the FOOD 2030 Platform is presented in Figure 3.

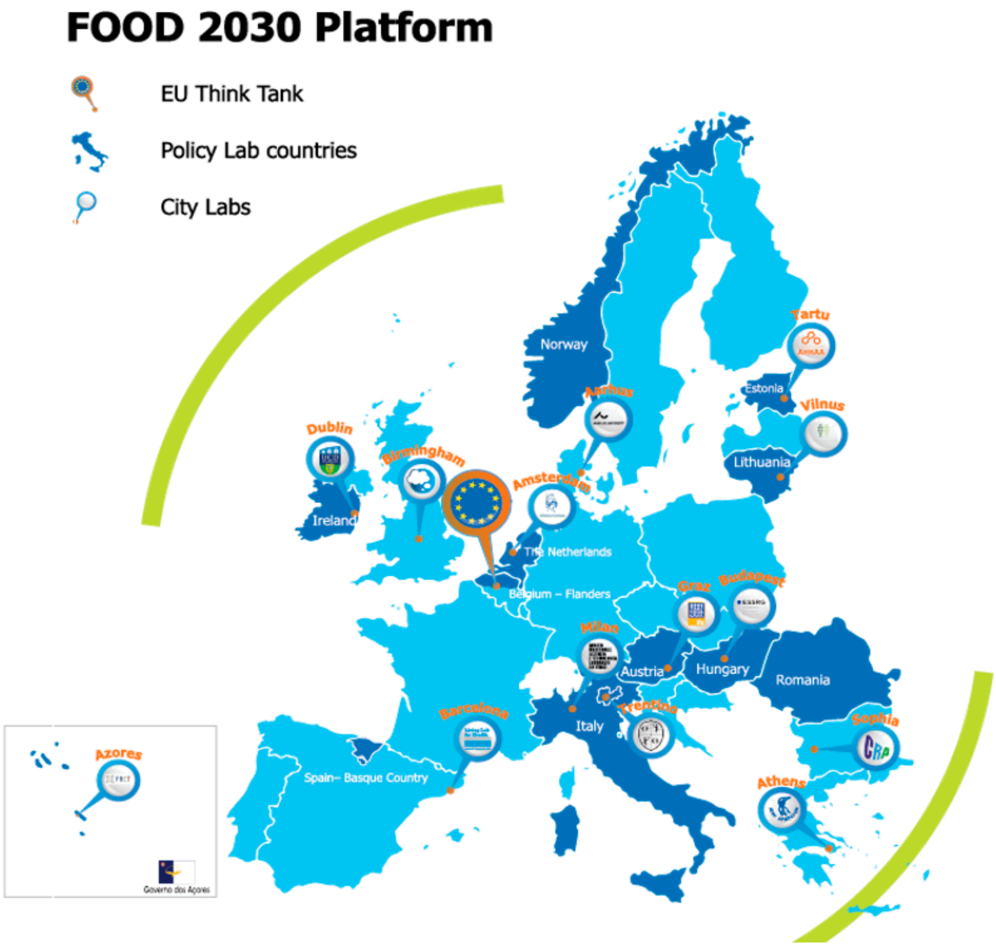

Figure 3. An overview of the multilevel, multi-stakeholder FOOD 2030 Platform that the FIT4FOOD2030 project has established, indicating the 11 national Policy Labs, the 14 local City and Food Labs and the EU Think Tank.

4.1. Designing Boundary Innovations in Practice

Through this example, we posit that the design and establishment of the FIT4FOOD2030 project and its Platform and activities can be seen as an effort to trigger double transformations. Here, the FIT4FOOD2030 project is an experiment that crosses the boundaries of European R&I systems and food systems. As a boundary innovation it deploys several instruments, with associated key elements that aim to intervene at leverage points in order to realize profound transformation. The overall architecture of the leverage points, the challenges they aim to address, and what specific instruments the project uses to intervene are depicted in Table 1.

Note that all these leverage points are within the realm of 'deep leverage points', aiming to transform the structural design and (paradigmatic) intent of R&I system components. However, some of the main instruments—or key elements of the main instruments—can be seen as interventions on more shallow leverage points (such as processes or parameters; e.g., organizing 120 workshops, establishing new feedback loops of 'information' about designing learning processes) that together co-constitute interventions on deeper levels. It can be argued that successful intervention on the deeper leverage points enables the project to more effectively organize interventions on the shallower leverage points as well. This exemplifies the point of Fischer and Riechers [133] that different leverage points (deep and shallow) can interact and therefore enable or constrain each other.

Table 1. Overview of the FIT4FOOD2030 design, including leverage points, addressed challenges, main instruments, and key elements within those instruments.

Deep Leverage Points	Addressing Challenges	FIT4FOOD2030 Main Instruments	FIT4FOOD2030 Key Elements
Engaged FOOD 2030 Platform	All	FOOD 2030 Platform	• Lab approach • (Tools for) system analysis and facilitating activities in (FIT4FOOD2030) living labs
Competence Development	Lack of stakeholder engagement; lack of competences needed for transformation	7 City Labs 7 Food Labs	• Establishment of local networks to engage stakeholders and ensure sustainability • Workshops with stakeholders (on visioning, system analysis, pathways for transformation, and mandate for change) • Co-creating, testing, and implementing 18 educational modules • Influencing local/regional R&I/food policy agendas • Mutual learning and exchange between the labs
R&I Policy Alignment and Coherence	Academic silos; fragmented funding structures; hindering of academic incentive structures	11 Policy Labs EU Think Tank	• Establishment of national networks to engage stakeholders and ensure sustainability • Workshops aligning different ministries on national levels (on visioning, system analysis, pathways for transformation, experimentation) • Co-creating R&I policy experiments such as o national transformative R&I agendas or visions o nationally aligned R&I strategies across ministries o funding programmes for transformative food systems R&I
Raising Awareness	Unsupportive research cultures; aims to contribute to tackling all other challenges	EU Think Tank Communication and Dissemination Strategy	• Policy briefs by the EU Think Tank targeting policymakers [41,137] • Strategies for engagement through the self-sustaining FOOD 2030 Platform • Online repository of tools for transformation • Channels: webinars, newsletters, deliverables, scientific articles, website, social media
Enhancing Transformative Capacity of R&I Processes	Challenges internal to transdisciplinary processes	Methodological Development and Monitoring	• Continual learning, monitoring, and evaluation via RMA and DLA approaches • Tools for system understanding, visioning, and building pathways for transformation • (Tools for) guiding experimentation • Supporting Community of Practice (CoP) of labs, their coordinators and the project consortium through mutual learning and training sessions

In the following section, we highlight how this reflexive approach, with the main instruments of the project (City, Food, and Policy Labs) being experimentation spaces, while at the same time conducting experiments themselves can be seen as a multilevel boundary intervention approach.

4.2. Multilevel Boundary Intervention: Labs as Instruments for Transformation

The main loci of intervention within the project are 25 labs, on national and regional/local levels. These labs build on the concept of living labs. While acknowledging that there are many views on what exactly constitutes a living lab [138,139], we extrapolate our approach to living labs from Bergvall-Kårrborn et al. [140] (p. 9): that they facilitate "open and distributed innovation processes engaging all relevant partners in real-life contexts, aiming to create sustainable values". There are many different kinds of 'open innovation networks' [141,142] that share the common characteristics of (1) involving diverse actors as co-creators on equal grounds and (2) experimenting in real-world settings [143]. The FIT4FOOD2030 project has various kinds of labs, which were established after multiple open calls and selected for their innovative capacity and their motivation to engage stakeholders in order to contribute to transformation. The labs serve as couplings between food systems and R&I systems operating at different levels and explicitly link functionalities, structures, and actors. Therefore, different kinds of labs work on distinctly different sets of leverage points and take different organizational shapes [134,135].

Firstly, FIT4FOOD2030's City and Food Labs are examples of (peri-) urban living labs, which are rapidly gaining ground as instruments for fostering sustainability transitions on local (urban) levels [144–146]. To avoid a narrow urban focus, given the importance of connecting urban and rural areas when it comes to food systems transformation [18,147], the labs are encouraged to have a peri-urban focus on metropolitan regions more broadly. The seven City Labs are embedded in science engagement organizations such as science shops, science museums, and science centres. These labs build multi-stakeholder networks that aim to engage in continual dialogues and collaboration on the visioning of (1) a future-proof food system, (2) the role of R&I in a future-proof food system, and (3) the competences (knowledge, attitude, and skills) required for individuals engaged in R&I processes relating to a future-proof food system [148]. In a later stage of the project, an additional seven Food Labs were recruited. These take on a different role and are following another timeline. While the trajectories of the City and Food Labs differ as a result of different contextual factors (e.g., the number of food-system related-initiatives in a specific region and the institution and design of the lab itself), all labs aim to contribute to building competences for the R&I processes of a future-proof food system by developing, testing, and implementing educational modules through playful co-creation with their locally established multi-stakeholder networks (cf. [149]). These modules can be targeted towards different stakeholders (e.g., schoolchildren, students, researchers, policymakers, entrepreneurs, or the general public) and are based either on light-learning (e.g., one- or two-hour workshop) or on deep-learning approaches (e.g., academic course lasting several weeks). Competences targeted within these modules include key competences needed for sustainability transformations [150,151] such as futures- and value-sensitivity, systems and strategic thinking, multi-actor collaboration, and integrated problem solving. Besides module development, local food systems transformation is stimulated via the development of local food-related R&I agendas to support innovative and integrative food policies and partnership building [148].

The project has also introduced Policy Labs. These labs are situated on the national or regional level and are coordinated mainly by governmental policymakers; they are supported by multiple national ministries related to food and R&I. These labs work towards R&I policy coherence: "the process where policymakers design a set of policies in a way that, if properly implemented, they can potentially achieve a larger goal" [152] (p. 750), which can be organized at the levels of (1) objectives, (2) strategies and mechanisms, and (3) outcomes [153]. The 11 FIT4FOOD2030 Policy Labs engage in transition experiments that aim to construct novel institutional innovations or pathways for national governments to follow to reorganize their R&I system, and in particular its interaction with food systems. The labs and their evolving networks serve as transition arenas [30] (p. 157), which "provide room for long-term reflection and prolonged experimentation". The timeline of the Policy Labs consists of three action phases: (1) system awareness and system understanding, (2) future outlook and agenda setting, and (3) policy experimentation. Parallel to these process phases is the continual activity of building engaged multi-stakeholder networks. In addition, reflexive learning and monitoring processes are supported by the project, and these are both important activities in transition experiments [154]. By explicitly linking incumbent regimes and dominant actors to societal stakeholders and policy experimentation, these labs provide an interesting opportunity to co-create pathways that lead towards novel R&I systems that support sustainable food systems transformation.

The City, Food, and Policy Lab processes also contribute to transformative competence building among the lab coordinators and the different stakeholders involved. The development of transformative competences is considered an important leverage point for creating a sustainable impact [36] and it is important for stimulating actors to adopt different actor roles (see Section 4.3).

Finally, the EU Think Tank, comprising a transdisciplinary team of experts, aims to connect the EU level with the global, national, and regional levels by integrating and linking the labs' results to the EU level, thereby potentially acting as a transformative network in itself. The EU Think Tank aims to stimulate the required transformation in food systems R&I in particular by identifying and highlighting promising pathways to stimulating the development of innovative European, national and regional R&I funding systems, as well as identifying what types of first- and second-order research these systems need to stimulate to deliver food systems transformation.

4.3. Four Pillars of Transformative Learning

For City and Food Labs, as well as Policy Labs, learning within and between labs forms an important part of the process and guides efforts to upscale experiments and practices. Firstly, the project follows a multilevel approach to establishing learning among and between multiple levels: peer-to-peer, experiential, and experiment-to-experiment learning regarding lab activities and outputs between lab coordinators, within the transdisciplinary consortium, and between consortium members, the labs, and their activities and outputs too. An overview of this multilevel learning process is presented in Figure 4.

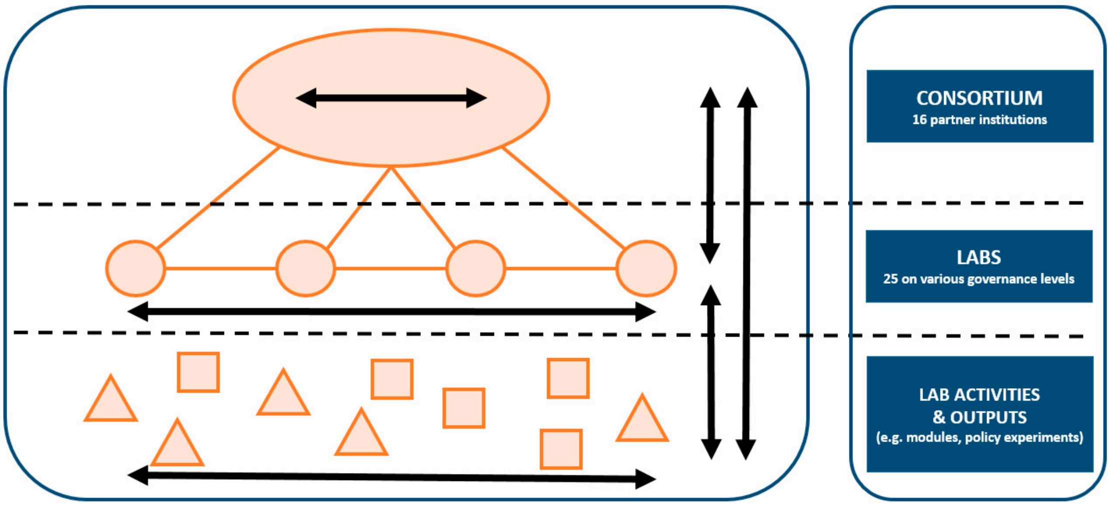

Figure 4. Three levels of experimentation in FIT4FOOD2030 exemplifying the multilevel learning design. The black arrows indicate the learning processes taking place in the project.

Learning, reflexivity, and monitoring comprise four complementary pillars. First, an important part of facilitating learning between the labs is the formation of communities of practice (CoPs) [155,156]. A CoP is a learning community of actors who share a similar passion, a sense of urgency or interest.

This informal learning network stimulates reflection in action, out-of-the-box thinking, flexibility and adaptivity in action planning and taking, and the development of collaborative relationships. Through mutual engagement, CoP members create innovative solutions and new practices.

Second, the formation of a CoP and learning are stimulated through multiple training sessions for Lab coordinators. During these training sessions, competences are trained that are needed for the different roles that coordinators can adopt during the Lab activities (such as reflexive monitor, process facilitator, honest broker) and coordinators are familiarized with the tools that are used to facilitate transition experiments. These include tools for system analysis, stakeholder engagement, network building, visioning, and developing roadmaps and transformation pathways, as well as tools for the scaling up and sustainability of lab activities and outputs.

Third, an important method for ensuring continual learning between lab coordinators is the dynamic learning agenda (DLA): an open and interactive learning method for facilitating reflexivity in change processes [157]. Topics covered in monthly online DLA sessions vary from reflecting upon strategies that aim to engage stakeholders and the challenges of running lab activities to sharing experiences of identifying systemic barriers to transformation or formulating visions.

Finally, as an overall methodology for monitoring and evaluation, FIT4FOOD2030 relies on the reflexive monitoring in action (RMA) approach as introduced in Section 2.2. RMA facilitates learning and reflection within experiments, like the labs and their activities. It does so by encouraging participants to keep reflecting on the relationships between the ambitions of the project and the (institutionalized) practices used as well as the developments in the system that offer opportunities for realizing the ambitions of system transformation. Within RMA, the monitoring is not an ex post activity, but an integrated part of the entire transformation process itself. Additionally, the insights gained from the monitoring are tried out and experimented with in the project's new activities. It therefore allows for identification and implementation of interventions in the experiment, based on a selection of tools (see further below) and the preferences of the actors and/or monitor [85,86].

When combined, these four pillars of enhancing learning and transformation aim to contribute to the stability, success, and, ultimately, the sustainability of the labs as well as their (upscaling of) experiments.

5. Concluding Remarks and Outlook

In this paper we argued that in order to tackle the manifold and interlinked challenges related to doing second-order ('how to') transformative research that contributes to food systems transformations, there is a need for a coupled-systems perspective to realize double transformations in both R&I systems and food systems ('how to do the "how to"'). We set out to conceptualize an approach that aims to trigger double transformations by nurturing innovations at the boundaries of R&I systems and food systems that act upon systemic leverage points so that their multisystem interactions better support food systems transformations. We exemplified this double systemic approach by introducing the FIT4FOOD2030 project as a promising multilevel boundary innovation at the cross-section of R&I systems and food systems.

By emphasizing the need for interventions at system boundaries, where actors engage in transformative second-order efforts in order to stimulate the reconfiguration of R&I systems, we hope to inspire transformation practices in three ways. First, while non-transformative and first-order transformation research are valuable and crucial if we want to better understand the mechanisms of system dynamics and articulate the urgency of persistent problems in global food systems, our approach focuses on the importance of optimizing R&I systems to better support second-order transformative efforts. Second, where thematic policy interventions (regulations, taxes, etc.) as well as bottom-up initiatives remain extremely important to stimulating food systems transformation, our conceptualization adds the need to intervene at the boundaries of R&I systems and food systems to unlock the potential of R&I as a true catalyst for food systems transformation. Finally, we encourage more transformative researchers to adopt an explicit coupled-systems perspective and to work towards realizing double transformations.

With regard to our empirical illustration, an innovative and adaptive multisystem and multilevel innovation, such as the FIT4FOOD2030 project, naturally gives rise to new challenges and questions. Major challenges, and the opportunities for learning that they lead to, relate to the question of how interventions targeting different leverage points (deep and shallow) could be optimally aligned to increase effectiveness and create real transformative change. As the project is still ongoing, it is highly adaptive in moving towards achieving double transformations, as well as to meeting the (local) needs of the labs. Those local needs include developing strategies to ensure the sustainability of the activities and outputs of the labs in terms of future funding and institutionalization of the networks, modules, and policy experiments.

Moreover, boundary innovations such as FIT4FOOD2030 could provide insight into the effectiveness of the (combination of) instruments that aim to target deep leverage points for transformation on different (governance) levels. Furthermore, insights into how the multilevel nature of such interventions influences their transformative capacity might give rise to a better understanding of how multilevel governance arrangements in R&I systems can be designed (e.g., in relation to funding programmes). In addition, such innovations might lead to a better understanding of how to more effectively link R&I efforts to thematic food policies. The need to develop integrated food policies is increasingly emphasized in both policy environments and academia (see e.g., [24,158]). Strategies for multilevel interventions can therefore feed into policy debates on, for example, the common agricultural policy (CAP) in the EU but can also inform national and local governments regarding developing integrated food policies that foster sustainable and healthy food systems.

Another interesting opportunity for enhancing our understanding of *doing* multilevel boundary innovation lies in the plurality and variety of the living labs involved in the project. In this plurality lies also the challenge of balancing labs' autonomy and the context-specific nature of experimentation on the one hand and generalizing results as well as ensuring the transferability of lab outputs, such as specific policy experiments and educational modules, on the other hand. Future research—as well as monitoring, evaluation, and learning within the project—might also yield new insights into understanding how coordinators learn in a CoP, what competences are required for which roles in multilevel boundary innovations, how power dynamics shape the emergence of local networks, and how strategies for continual engagement of stakeholders play out in theory and practice. In these respects, the FIT4FOOD2030 project is an experiment that is just starting.

While the persistent problems in food systems are severe and ever increasing, it is promising that new conceptualizations of food systems as complex systems, as well as transformative research agendas, are getting traction in academia and in policy environments. If R&I systems truly aim to contribute to sustainable food systems transformation, researchers, policymakers, and other actors should not hesitate to reflect not only upon their own role, but also upon the role of the multisystemic environments they are operating in. Such an explicit double gaze paves the way for double systems transformations and therefore for R&I systems that are fit for future-proofing food systems.

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