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Abstract

The mission of transforming global food systems into sustainable ones was declared at the 2021 United Nations Food Systems Summit. The rhetoric around this mission pushes a wide range of public, private and civic actors to take significant actions across a range of types of food systems, in order to ensure the achievement of this mission. Specific attention is drawn to the need for these food systems to be inclusive of alternative forms of knowledge, which are often produced outside of the conventional systems of research and innovation. In this article, we explore the challenge of generalising system innovations based on alternative ways of knowing by examining three cases of systems innovation in French food systems. We revisit the recent literature on transformative change, mechanisms of generalisation and intermediation in order to respond to a research gap about the operationalisation of system innovation generalisation. We suggest that four objects of intermediation – knowledge, value(s), infrastructure and rules – work to generalise system innovations. Through a comparative analysis of the intermediated movement of food systems from one situation to the next resulting in turning points along a trajectory, we offer new insights into how transformative change in food systems might occur.

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1 Introduction

On 23 September, 2021, Secretary General António Guterres closed the first United Nations Food Systems Summit (UNFSS) by claiming that "the journey has profoundly affirmed that our food systems hold the power to realise our shared vision for a better world."[1] Guterres added that transformative action requires the engagement and close participation of the people who drive our food systems. He mentioned specifically the need to draw expertise from scientific, traditional and indigenous knowledge; to value food as more than a mere commodity; "to shift and scale public and private financing for food, including for science and research" and to encourage "open, non-discriminatory, transparent, rules-based trade [..] for building more inclusive and resilient food systems."

This ambition is a tall order, and our ability and knowledge to comply with it are limited. Of course, we know that the world is not fed in the aggregate, but rather by people, animals and plants living, working and eating in very specific contexts. Moreover, we also know that there is no institutionalised 'we' that collectively feeds this world, but networks of actors who transform various types of knowledge about nature into energy, via food (Ericksen et al., 2010). These networks include, but are not limited to: inputs production, agricultural production, ecosystems services, storage, transport and logistics systems, food processing, food service, waste and recycling systems, energy and water systems, human and animal health and medicine, political systems, community rituals, art, religions and lifestyles that transect specific places (Sonnino and Milbourne, 2022; Allen and Prosperi, 2016). Finally, to achieve values like inclusivity, equity and resilience in a food system, like in any other socio-technical system, it matters who the people are that do this transforming as they come from different socio-cultural and economic situations (Bodenheimer, 2021; Kaljonen et al., 2023) and rely upon different ways of knowing (Haraway, 1988).

This means that food system transformation must operate at multiple scales of action and that new knowledge, techniques, rules, finance and actors must be able to circulate and anchor in many different locales around the world in order to effect transformative change (Kropp et al., 2020; Wigboldus et al., 2016; Schot and Steinmueller, 2018; Leeuwis et al., 2021). They also need to be translated and intermediated on their way across scales and spaces. This is indeed a grand societal challenge that has not been sufficiently addressed in the transitions literature (see: Hebinck et al., 2021). Much attention has been paid to experimentation with novel socio-technical food system innovations in a range of niches, but how to turn them into truly system-wide transformation seems to remain a mystery.

If we are to take the conclusions of the UNFSS seriously, then we need to better conceptualise and operationalise *how system innovations generalise in the face of unanticipated challenges so to create transformative change in food systems. This research need translates into two research questions, namely i) how to specify conceptually the pathways and mechanisms of generalisation, and ii) what role is played by various types of objects of intermediation in the generalisation process*.

In this article, we explore this challenge by i) proposing a conceptual framework, and ii) examining three cases of food system innovations in France. In section 2, we revisit the recent literature on transformative change, generalisation and intermediation. The gaps in these literatures show that a meso-level understanding of how actors interact pragmatically to transform their systems is under-theorised. We introduce "situated" intermediation as a means to negotiate turning points in transformative trajectories as a concept that can fill that gap. In section 3, we explain the methods used to analyse three illustrative case studies where situated knowledge and marginal actor inclusion are prioritised. Section 4 presents the socio-historical narratives of the three cases where turning points in transformative trajectories resulted from intermediation around objects of knowledge, value(s), infrastructures and rules. We discuss the importance of these findings in section 5, and conclude with reflections about what an understanding of generalisation as an intermediated trajectory might bring to the generalisation discussion that is the topic of this special issue, as well as to transformative innovation more generally.

[1] The Chair's Summary of the United Nations Food System Summit, New York, 23 September 2021. https://www.un.org/en/food-systems-summit/news/making-food-systems-work-people-planet-and-prosperity

2 Towards an understanding of transformative change as generalisation of system innovations

The theoretical and empirical puzzle addressed in this paper is how system innovations circulate and anchor (Elzen et al., 2012; Sengers et al., 2021) in diverse situations so that food systems might be transformed. We follow the practice theorists who have defined system innovations as the "co-evolution of innovations in material artefacts, socioeconomic conditions, organisational and institutional re-configurations, while simultaneously accounting for evolutions in collective and individual values, moral interpretations, lifestyles, social capital, body activities, emotions, or knowledge" (Rauschmayer et al., 2015: 216). Drawing on the work by Henderson and Clark (1990), these multiple dimensions can be interpreted in terms of the components and the (institutional) architecture of innovations, both of which need to change radically in the case of system innovations.

Historically, transformative system change has often been equated with revolutions (Lawson, 2016), but from the more modest perspective of food system transformation, scholars have referred to it as 'deep change' where there are practical, political, personal and interactional spheres of transformation (Weber et al., 2020). In transitions studies, transformative change refers to the need to change socio-technical systems so that innovation objectives (and policies) are aligned with ambitions to address societal challenges. "Socio-technical system transformation (or transition) is about changing skills, infrastructures, industry structures, products, regulations, user preferences and cultural predilections" (Schot and Steinmueller, 2018: 1562). de Haan and Rotmans (2018) further clarify that transformative change is "the consequence of deliberate, or even strategic actions of specific types of value-driven actors" (p. 276). Thus, transformative change is a type of change where a whole system is reconfigured into an articulated and desired future state of sustained interaction among many networks of actors. Due to complexity and uncertainty, it is necessary to experiment with various such configurations in order to come up with system innovations that have the potential to subsequently lead to transformative change.

While change in general is a permanent aspect of society, transformative change typically needs to be triggered. Three types of triggers are applicable to food system transformations. A first type of trigger are crises (Grin et al., 2010), which can have their origins both outside of the food system (e.g., fuel shortage, war in the Ukraine) and inside it (e.g., Mad Cow Disease, mandatory GMO labelling). A second type of trigger is driven by the emergence of new approaches, techniques or practices that put into question prevailing ways of doing in food systems (e.g., post-growth paradigms and real utopias) (McGreevy et al., 2022). Initially explored and tested in specific niches – or free social spaces (Törnberg, 2018) – in order to demonstrate their benefits and to learn about their potentials, limitations and needs for complementarity innovations, these 'bottom-up processes' can take on momentum and transform entire socio-technical systems (Avelino et al., 2017; Kropp et al., 2020). Third, there can also be 'top-down' impulses in food systems such as environmental regulations (e.g. glyphosate bans) or major reforms (e.g. privatisation, divestiture of monopolies) that address the architectural or institutional dimensions of systems first, before follow-up innovations are initiated. All three types of triggers introduce interdependencies, uncertainties, complexities or controversies into systems that challenge system stability and create "situations of change" (Steyaert et al., 2007).

While these basic charactereristics of system innovations, transformations and their triggers are well established in the scientific literature, the processes of generalisation of system innovations, i.e. the processes and mechanisms through which they become anchored and taken up more widely are still not well understood. This research gap thus calls for an operational understanding not only of generalisation of system innovations at a meso-level of change where challenges manifest in specific situations that offer different directions for change, but also of the mechanisms to enable, facilitate and intermediate generalisation processes.

2.1 Generalisation as a way to amplify beyond scaling

In order to operationalise the concept of generalisation for transformation, we turn to some recent improvements upon the classic concept of technology diffusion.

Different forms of scaling (*up, out and deep*) have been introduced as a means to understand how technologies move from inventors to first users to more mainstream use (Breaugh et al., 2021). Since the 1990s, a

general consensus among innovation scholars is that the changing of scale of "meaningful innovation depends primarily on the spreading of a collective process from one network context to another" (Leeuwis and Aarts, 2011: 24). Wigboldus et al. (2016: 45) argue that most of the work to date using the concept of scale consists of "find[ing] out what works in one place and do[ing] more of the same, in another place." They argue that these frameworks ignore the complex realities of innovation processes that require ethical, value and rule adjustments that go beyond the technology itself, which is why many technologies and practices that are perceived as sustainable and inclusive when introduced in one specific place or scale (e.g., niche, project, farm) often challenges those same values when they move to different places and scales of application (Lawhon and Patel, 2013).

While Wigboldus et al.'s (2016) framework has advanced a suite of scaling aspects that capture system dynamics that can create lock-ins, this approach does not yet offer an operationalisation of how generalisation for transformation occurs. This critique is based on two main arguments. First, the authors assume that a professional analyses and assesses deficits and associated needs for intermediation, outside of the network of actors innovating and applying new technologies and/or practices. Second, Wigboldus et al. (2016)[2] adopt the multi-level perspective, which artificially separates the ways in which actors across food systems work together (or against each other) outside of protected spaces (Loconto et al., 2016). The word level suggests that there are hierarchies, which excludes the softer forms of influence involved when technologies spread and change society (Lam et al., 2020).

Partly in response to this need for empirical grounding, transition studies introduced the notion of generalisation pathways of experiments by focusing on what they call "embeddedness" (Sengers et al., 2019: 161). Sengers et al. (2021) claim that there are four generalisation pathways to embeddedness: 1) Replication-proliferation, 2) Expansion-consolidation, 3) Challenging-reframing, and 4) Circulation-anchoring. While the first pathway is what has been typically called scaling out, the second one is very much the classic notion of scaling up. These two pathways are well tried, and not fully explanatory, of how food system innovations generalise. They deal with the issues of renegotiating knowledge and rules within initiatives, but have the effect of extending the networks within which these initiatives are situated. The use of the term generalisation thus enables us to make a shift in the object of movement. No longer do we need to speak of a technological artefact, but a system innovation that carries its own material, knowledge, value(s) and rule(s) baggage can also begin to circulate and carve a path towards other localities of interaction. This allows us to operationalise the notion of transformative trajectories, which is a gap in this literature.

2.2 Turning points and transformative trajectories: recognising change

In transition studies, a number of scholars have begun to speak of the political science notion of 'small wins' (Termeer and Dewulf, 2018). It argues that small events accumulate over time to create the incremental change that eventually results in an identification of system-level leverage points and more deeply, a transformation of the underlying social contract (Huntjens and Kemp, 2022). Another stream of scholarship recognises the role of 'critical moments' in situations of conflict that create an enabling environment for change to occur (Yuana et al., 2020), and Avelino et al. (2017) include significant and symbolic events in their conceptualisation of 'game changers'. To join these scholars, and to connect their arguments with the abovementioned generalisation pathways arguments, we introduce the trajectory-turning point theory of change.

This theory of change, developed in the 1970s in the sociology of life course, claims that trajectories and turning points are mutually constituted (Abbott, 2001). A trajectory is the continuation of a direction, while a turning point is a disruption in a trajectory – a translation if we use the actor-network theory (ANT) terminology. A turning point cannot be understood without a trajectory (i.e., the norm), which in turn cannot be understood without turning points that (re)define its normative direction. A turning point is a 'narrative concept', which means that it has reference to two points in time. In line with ANT assumptions, this approach considers that change is the constant state of being in the world and the creation of the social is instantaneous. These instants – the momentary steps of confrontation among immediate past, present, and immediate future – are what constitute the narrative (Hernes, 2022). Thus, turning points have two defining features: 1) they are more than a temporary glitch; and 2) they cannot be predicted (Gotlib and Wheaton, 1997).

[2] Leeuwis et al. 2021 also relies upon the MLP to identify different levels of intervention for policy makers/researchers. The critique of 'protected spaces' is likewise relevant for these proposals. Our empirical examples demonstrate that generalisation works more in the sense of 'discursive spaces' and less in 'protected spaces'.

Following a 'relational ontology', food system tranformations require us to recognise that there are fundamental interdependencies among humans and non-humans on earth (Lidskog and Waterton, 2016) and that each action/reaction does not necessarily bring about a unidirectional change. Change can be multi-directional and asynchronous because each interaction in a network can either reproduce old patterns of interaction or introduce new ones. In the context of networked actors, this means that the past is encoded into the present in patterns of connection that we call (infra)structure and the production of the next moment happens from the basis provided by that (infra)structure and from visions of the future (van Lente, 2012). These arrangements always leave openings for actions, which, if they fit the situation, can change the longest-enduring (infra) structures quite quickly. Change thus occurs through generative mechanisms activated by addressing these openings.

These concepts allow us to fill the gap in Sengers et al.'s (2021) discussion of generalisation as embedding. As we focus on trajectory, rather than scale, we are required to ask: what or who intervenes and disturbs these trajectories so that the system innovation itself changes direction? What pushes a system innovation away from its initial path, what puts it back on a prior path or a new path? Some clues that can be looked for are: "1) stability of the new direction; 2) resistance to efforts to re-establish a former trajectory; 3) transformation of identity to accommodate a new trajectory; and 4) evidence of a role commitment implied by a new direction" (Gotlib and Wheaton, 1997). In section 2.1 we learned that system transformation usually happens when the situation of interaction and the desired direction of action are temporarily unstable or contested (Pereira et al., 2020). In other words, the type of change, and to where it should lead the actors, is often not known at the outset even if there is consensus on the need for change. We suggest that these turning points can be identified empirically by looking at intermediated situations of change.

2.3 Objects of intermediation: recognising turning points

In their discussion of directionality failures in transformative change, Weber and Rohracher (2012) argue that failures occur when there is a lack of shared knowledge for making choices on alternative pathways. They argue that at times, processes of setting collective priorities fail, particularly when there is a breakdown in deliberation and when the diversity of opinions shifts the interactions towards conflict rather than convergence (cf. Kemp et al., 2022). Such situations - characterised by interdependencies, uncertainties, complexities or controversies – are ripe for intermediation (Steyaert et al., 2017). In these situations, we argue that challenges can be identified and intermediation can reconfigure the connections among actors around a new object, which in turn works to create new connections that extend the network.

The vast literature on intermediaries (e.g., van Lente et al., 2020; Howells, 2006; Klerkx and Leeuwis, 2008; Bergek, 2020; Kivimaa et al., 2019) tends to depict this work as a form of brokerage among stakeholders (often users and policy-makers) so that technologies or services can be adopted. The tendency has been to focus on the intermediating actor, either as a professional activity in a market context, or as a public and systemic intermediation activity (Kivimaa et al., 2019). Intermediaries are thus portrayed as either professional third-parties (e.g., brokers) who have no economic stake in the spread of an innovation, or actors who have other responsibilities in an innovation system but can learn the skill of intermediating (e.g., champions) and apply it in a situation when there is a need for intermediation. Recent work on behavioural change in the context of climate change suggests that the power of individual actors extends across the different roles people occupy, from community members to citizens (Whitmarsh et al., 2021: 76). However, intermediary functions do not necessarily need to be performed by humans; and the change that we observe is not necessarily the result of only human action (Callon, 1991). It is the latter insight that we feel has been neglected in the literature; too much focus has been placed on the work of the humans and organisations who intermediate and not upon the work of the objects of intermediation. We draw upon ANT's "object turn" to propose a new conceptual framework that can help operationalise the generalisation of system innovations. We suggest that to recognise these situations as turning points in trajectories, we should pay attention to the objects that enable actors to find a way out of the situation through material and embodied work (Marres, 2023).

Four key concepts emerge in the above-cited literature as being important for understanding both the generalisation of system innovations and transformative change: knowledge, value(s), infrastructure and rules. We suggest that these work as objects of intermediation because they both create the connections between heterogeneous and distributed actors in networks and define the meaning of these connections (Callon, 1991). First, the practices that actors use to intermediate knowledge concern how food system actors access and

communicate knowledge about sustainable production, distribution and consumption. Being able to differentiate how knowledge works differently as information, skills, judgement and wisdom (Gorman, 2002) offers us an analytical lens to explore how knowledge can become the object of intermediation in situations where uncertainties are minimised and complexity becomes the means to articulate action (Loconto, 2023). Thus to recognise a turning point, we should pay attention to when and how actionable knowledge emerges from interactions (cf. Janssen et al., 2023).

Second, value(s) intermediation deals with the desire of food system actors to produce both worth and social values through the generalisation of their system innovation. Empirically, we see that value(s) become(s) objects of intermediation as actors begin to link the evaluation of worth with the valorisation of the results of their work (Vatin, 2013). Often this occurs when actors create new standards that define their system innovation (Loconto, 2020). A turning point might then be recognised when a new term emerges that can reduce uncertainty by increasing interdependencies among actors in a network and limiting controversies by federating them behind a label .

Third, we cannot forget the material and knowledge infrastructures that limit the technical and organisational changes introduced by system innovations (Kornberger et al., 2019; Larkin, 2013). They are often among the first concerns that emerge from interactions. These infrastructures physically connect actors in networks and a turning point can materialise through the use of new linking devices that can reduce network complexity, calm controversy or build bridges to other networks.

Fourth, social innovations in food systems have always created their own rules to regulate internal interactions. The understanding that indicators and specialised organisations can change the interdependencies between actors is characteristic of regulatory intermediation (Abbott et al., 2017; Loconto, 2017). Central to the controversies that this form of intermediation attempts to situate are the legitimacy and trust of actors experimenting with innovative rules for working and exchanging. Turning points are thus found in the codification of rules for network interactions.

This conceptual framework thus operationalises the study of generalisation by focusing our analysis on identifying patterns of "situated" intermediation where change is triggered by the emergence of interdependencies, uncertainties, complexities or controversies. As we apply the above framework to the analysis of three empirical cases, we pay particular attention to the work of new actors (humans and non-humans) in the expanding networks so to recognise these objects of intermediation and their work in creating turning points.

3 Methods

We adopt an abductive approach (Atkinson et al., 2003) "as a method of coming to know" (Adams et al., 2009). Beginning in 2021, a group of 10 researchers launched a series of collective reflections about the work of intermediation in generalisation processes. A core theoretical piece on intermediation published by the first author, a seminar with intermediaries organised by the fifth author, and the call for participation in the workshop that led to this special issue were the catalysts for this collaboration. Each researcher brought a case that focused on systems innovations for sustainability that they had been studying and we analysed the cases by looking at the intersections of the challenges that required intermediation and the objects that enabled intermediation in specific situations. Following this first conceptual advance about the nature of the situations, we explored how challenges and objects interacted in three cases: market innovations for natural wine new protocols for testing pesticide toxicity, and new funding instruments for participatory research .

The data collected for these three cases are based on mixed qualitative methods (including document analysis, participant observations during 'industry' events, semi-structured and informal interviews) by the third, fourth, fifth and sixth authors in ongoing participatory research projects. The three research projects were focused on evaluating innovations linked to food systems that prioritized alternative ways of knowing. The publications of the original data from each of these projects, which also explain the data collection methods in detail, can be found in Annex 1. Specifically:

1. Between 2013 and 2021, the first author led a participatory research project with innovators in more than 20 countries, which focused on institutional innovations and the reconfiguration of value chains towards the creation of local food systems. Twenty-five cases were explored in this project and it inspired the writing of the natural wine case by the third and fifth authors, used in this article to represent an alternative way of knowing the value of nature.
2. From 2011 to 2022, the sixth author led a large-scale project of participatory and formative evaluation of the impact of research for agroecological transitions. Of the sixty cases analysed, the sustainable apiculture case was selected as representative of innovations that prioritise an alternative way of knowing complexity.
3. Since 2013, the fourth author has led research projects on the third sector of research, which prioritise non-institutionalised knowledge production in food, agriculture, health and education. She followed 35 specific projects during the 2019-2021 period and the case presented in this article represents a way to include alternative knowledge infrastructures in food systems.

As a group, we redrew the transformative trajectories for these three cases. We identified a series of situations that exhibited the characteristics of turning points, as described above. Through facilitated discussion we conducted a transversal analysis that enabled us to characterise the intermediation that had occurred and its role in the generalisation process.

4 Situated processes of intermediation

In this section we use three cases of system innovations for sustainability in French food systems to illustrate how situtations were intermediated so to move out of a challenging situation and redirect a transformative trajectory. Each case describes a series of situations where intermediation resulted in a turning point that opened up the network to include new actors and thus to generalise the system innovation.

4.1 Networking naturalness within food systems

As the demand from consumers of sustainably grown, pesticide- and additive-free food products soars, various associations form between consumers and producers to enable widespread access and create (alternative) markets for what used to be niche products. Even though standards and certifications have been established, conventional wine production remains one of the most pesticides-intensive food systems in the world. Thus, this case describes the intermediation process of generalising one such – rather controversial – product: natural wine. This case provides an example of the symbiosis of direct interactions and learning between producers and consumers. Natural wine has grown exponentially in terms of reputation and the number of actors participating in its network. This food system is based on values and marketing infrastructures that are different from the conventional wine system that has made French wine famous. As natural wine has generalised from an artisanal production niche in Bourgogne to a labelled product found in all major cities in the world, actors have intermediated the value of natural wine as the first point of entry to resolve the challenges that emerged in three situations of change.

Situation 1 – Since 1960s: De-facto and informal natural wine pioneers

Natural wine is a concept whereby production is based on traditional methods, typically without chemical inputs or additives like sulphites that contain, control and sanitize the wine. Just as pesticide use in wine growing is taboo, so is adding sulphites during vinification. The movement started informally among a small group of French producers who did not want to apply pesticides and additives when these grew popular in the 1960s. Natural wine has never been protected as a niche against market competition. Instead, small-scale independent producers have been using traditional production methods unnoticed for most of the 20th century. As natural wine is not based on institutionalised standards, it is subject to enduring controversy over the mutual learning between producers and consumers of its values.

The natural wine system has relied on peer-to-peer certification, learning, networks, transparency and collaboration to accelerate and develop into a thriving sustainable production system for consumers and producers with a shared belief-system. For natural wine, controversies emerged when natural producers needed to comply with industry or politically defined norms that value "conventional" qualities. Conventional wine producers have aimed for specific notes and traits in their wine, in contrast, natural producers use an alternative approach whereby they let the natural fermentation process give the wine its taste without (too much) interference. In some cases, natural wine develops novel notes as compared to conventional wine, which makes it hard to evaluate. 'Naturalness' in itself has emerged as a novel criterium to decide whether or not it is an indicator of quality or merely the taste of sour grapes. Beyond the coordination work that needed to generalise, producing wine without chemical additives while keeping homogeneous quality is a complex technical challenge. This problem has been present since natural wine emerged and only informal value intermediation among various actors within the sector has responded to this challenge.

Situation 2 – Since 1999: Movement consolidation through natural wine tasting events

The shared belief system among consumers and producers has been more regularly nurtured since 1999, where *La Dive Bouteille* hosted its first annual natural wine tasting with 15 producers and 100 attendees. This situation marks the beginning of the natural wine movement, providing a space for interaction and value sharing among consumers and producers. Since generalisation of the natural wine is not policy-driven, an increased interdependency among actors in the entire natural wine value chain is required. Thus, interdependencies among producers, with retailers/wholesalers (e.g., natural wine bars) and consumers emerged along with the formation of a new market. Whereas conventional wine quality and trends are often decided by the

allocation of appellations or designations of origin, there is less static and hierarchical direction-setting in the natural wine movement, which relies more on experimentation, both in terms of production and geographical origins (Bach Petersen, 2021). At the time, quality standards and labels for 'what is' and 'what is not' natural wine did not yet exist. Even today, actors must create consensus among themselves or identify a gatekeeper to 'set the boundaries' of natural wine. Informal events such as tastings and festivals play a key role in increasing knowledge and value sharing of natural wine both among producers and consumers.

The production and consumption of natural wine has rapidly developed in the past decade, in spite of being exposed to competition by conventional winemakers. For the movement, the core challenge revolved around the definition and quality of natural wine (rules intermediated outside of public or official standards). While certified organic wine has policy-driven standards to comply with in the production from vine to wine, natural wine is not based on such predefined standardisation (Alonso González and Parga-Dans, 2020). There has thus been a high level of uncertainty over the definition of natural wine and this left consumers uncertain of how to obtain a product that matched their expectations. Numerous associations exist and these have dissimilar definitions of what constitutes natural wine with some even allowing a limited use of sulphites (see Alonso González and Parga-Dans, 2020). Importantly, conventional wine lacks regulation as wine remains one of few consumable goods in supermarkets that are not required to list nutritional information. Simultaneously, labelling the grape or geographical origin is too expensive for natural wine producers since these are protected by associations, which means that mostly large-scale conventional producers can afford to list this information. Other labelling issues include the *quality* of the wine and the actual production methods, e.g., the Vin de France label can bar natural producers from stating both the larger geographical area and even the specific vineyard, if the taste is "atypical" (Zecevic, 2023).

Situation 3 – Since 2016: Increased popularity of natural wine: digitalisation and sustainability

While natural wine is not the dominant model of wine production, it has grown rapidly, promoting sustainable practices and influencing even conventional producers (Alonso González & Parga-Dans, 2020). This has been assisted by digital organising through the application *Raisin* since 2016, which has more than a quarter million downloads and 2,300 producers listed and mapped, while a separate map guides consumers to shops, bars and restaurants selling natural wine. According to Raisin, in 2010 there were slightly over 100 natural wine retailers in Paris (e.g., bars, shops, restaurants), which grew to 280 in 2017, 400 in 2022 and over 750 in 2023.[3] The tasting festival *La Dive Bouteille* went from 15 producers and 100 participants in 1999, and in 2015 the number of attendees had grown to 3,000 and over 5,000 in 2020 with around 250 producers.

The rise of natural wine is highly linked to consumers who are conscious about environmental and health impacts of consumption (Galati et al., 2019). Particularly the removal of pesticides and additives like sulphites in the production and processing of natural wine, reflect a 'new' type of consumer. This aspect increases the complexity of the natural wine system, particularly in relation to how it is valued. Consumers have a large role to play in intermediation, particularly in valuing of natural wine. However, the unique tastes of natural wine bring complexity to the generalisation, especially since organic wine – which makes similar claims to sustainability in its production and processing practices – is able to replicate the taste of conventional wine. This is achieved through the use of "approved" additives and sulphites.

Gatekeepers for generalisation are the direct consumer-retailer/wholesaler-producer networks and distribution channels, who set the boundaries of what is considered natural wine. Thus, as natural wine began generalising across France, the physical infrastructures that give form to the natural wine sector became objects of intermediation. The current mode of intermediation is highly collaborative, but there remain uncertainties on whether or not this will continue as natural wine further generalises and grows. For example, traditional wine distributors rely on expert judgements, prizes or most famously "Parker scores." Initiated by Robert Parker, a small elite of wine tasters score wines between 50-100 points. Considering the history of their *taste*, it is difficult to meritocratically reward the best natural wines. Furthermore, there has been a tendency for the

[3] Raisin lists those establishments where at least 30% of the wines are natural. Accessed, 28 October 2023, https://www.raisin.digital/fr/.

best natural winemakers not to brand themselves as such for fear of stigmatisation.

4.2 Knowing sustainability in pollinated food systems

Like other countries, France has been facing a general decline in bee colonies since the 1990s, the causes of which are still largely unknown. Sorting out the causes of bee mortality and assessing the potential responsibility of pesticides are two major issues for apiculture and the food system more generally. This case concerns the transition of a food system based on the extensive use of pesticides that are destroying bee colonies, to a more sustainable food system in which crop yields and quality are improved through bee pollinisation. The generalisation of a space for bees in pollinated agriculture – by removing pesticides – is explained by four situations of intermediation where alternative knowledge was advanced so to change the process of evaluation of the toxicity of pesticides.

Situation 1 - First test on toxicity of pesticides on larvae (1990 – 2006)

Gaucho®, a neonicotinoid produced by Bayer, began to be used in France in 1994 as a seed dressing for sunflowers. Some beekeepers mentioned the possible link between the pesticide and certain behavioral disorders in bees leading to colony dieback and asked for its ban. To raise awareness of the problem, the beekeeping unions organized a series of visible media events, which reach the general public quite quickly. The message was clear: the bees must be saved! At the beginning, Bayer was rather confident as it had a French marketing authorization (MA), based on the results of experimental tests. A series of studies conducted between 1998 and 2000 could not provide direct evidence of the negative effect of the imidaclopride on the changes in bee behavior, mortality, hive development and honey harvests. In 1999, the French government, raised the precautionary principle and decided to suspend the use of Gaucho® for the treatment of sunflower seeds. Bayer and seed companies contested these administrative decisions. The French government also banned its use on maize in 2004. A legal battle arose between the company, the beekeepers, the professional association and the French State. The ban was confirmed in 2006 (Albouy and Le Conte, 2020). The Gaucho® promoters stated that the general decline in bee colonies since the 1990s had a multifactorial origin, including: the emergence of new uncontrolled diseases and pests (*varroa*), the decrease of food resources and quality available to bees, and the presence of toxic substances in the environment. These multiple causes of bee mortality - and determining the potential responsibility of pesticides amongst these causes – rendered this situation quite controversial. Some actors in the food system began to intermediate the understanding of the complex toxicological effects of pesticides.

As part of this intermediation, the French Research Institute for Agriculture, Food and Environment (INRAE) started its research on bees and pesticides in the 1990s. The French research community developed a test on bee larvae where exposure to the pesticide was controlled. This test on larvae made it possible to establish, for a given product, the dose at which this product was toxic, including on adults, after larval exposure. This test was approved by France in 2007 and OECD in 2013. It has since become a standard reference test for the registration of new plant protection molecules. This standardised *in vitro* larvae method is designed to be easily transposed to approved laboratories in charge of pesticide evaluation. Two knowledge intermediaries – Testapi in France and Ibacon in Germany – use this test to help companies prepare their paperwork for homologation approval of their plant protection products. Here, intermediation around knowledge is extremely important for registering and regulating pesticides in order to protect the bees who are key intermediaries in pollinated food systems.

Despite the scientific progress, and the stabilisation of some of the relationships within the food system that enabled the spread of innovative testing methods, one particular challenge remained: The ability to study the effects of different molecules with tools that could monitor bee activity under field conditions, thus creating another situation ripe for intermediation.

Situation 2 – Restructuring the bee and public research sectors (2006 – 2010)

The fragmented bee sector acts in very different contexts (very small number of apiaries, multitude of beekeepers' practices, etc.). This fragmentation constituted serious blockages to change as it made raising a unified voice against the harmful effects of pesticides on bees extremely complex to manage. This resulted in further complexities that worked against the simple translation of scientific discoveries into public policy (i.e., a ban on specific molecules used in pesticides). The response from public actors (respectively the French

government and public research organisations) was to restructure the bee and research sectors through infrastructure intermediation.

In 2008, Martial Saddier (Member of the French Parliament) designed a plan for apiculture. He recommended, among other things the creation of the Technical and Scientific Institute for Bees and Pollination (ITSAP) to group the main actors of the bee sector and enable them to be better represented in public debates and to participate in research projects. In 2010, a Mixed Technology Unit grouping INRAE, CNRS, ITSAP, technical institutes and regional associations of beekeeping development was created to translate scientific knowledge into useful solutions for the beekeeping sector.

The creation of the Technical and Scientific Institute for Bees and Pollination (ITSAP) and the reorganisation of the French research competencies have been determining factors in bringing together complementary skills and facilitating the setting up of collaborative projects.

Situation 3 – Isolating the toxicity of pesticides and new bans (2010 – 2013)

Around 2010, an interdisciplinary French research consortium developed an innovative tool based on the installation of RFID microchips on the backs of bees. The development of the RFID technology made it possible to control the entry and exit of each individual bee from the hive. This work showed that exposure to a dose well below the lethal dose of thiaethoxam led to a much higher disappearance of bees than in the control lot. The combination of scientific knowledge with technological engineering and beekeepers' skills in successive collaborative projects enabled the actors to separate the responsibility of the environmental factors affecting bees' behaviour from other factors.

These results, published in *Science* by Henry et al. (2012), along with another English study, had a major media impact and led to the banning of Cruiser® in France in 2012. In 2013, a European Commission moratorium-imposed restrictions on the use of three neonicotinoids deemed harmful to bees: clothianidin, imidacloprid and thiamethoxam. The intermediation among the different knowledges, including journalism, produced conclusive evidence to effect a change in the rules that finally banned these molecules. In 2018, France banned neonicotinoid-based products (derogations could be granted until July 2020). Likewise, the European Commission banned the use of clothianidin, imidacloprid and thiamethoxam at the European level.

Situation 4 – The hive return test and changing the rules about pesticides use (2018 -....)

Since very recently, one of the difficulties in studying the effects of these different molecules has been the inability of tools that could monitor bee activity under real-life field conditions. Even if the toxic effects of pesticides on bees, especially on their behaviour, could be shown it was often difficult to transpose them to the behaviour of an entire colony living in a field. The evaluation methods had to evolve and incorporate novel knowledge. Based on the RFID method, French scientists developed "the hive return test". After 5 years of circular testing that was conducted by a network of public and private laboratories, "the hive return test" was finally deemed sufficient to be homologated as the standard rule by the OECD in 2021. The development of the 'hive return test' was possible thanks to existing public research infrastructures (especially at INRAE) and long-term investments in this research field (RFID devices). It is the first method, validated within the set of regulatory tests, where the parameter studied (return success) is measured on bees in free flight, in real conditions. This test is a step towards understanding the complex toxicological effects that can affect the functioning of the colony. The continuous development of hybrid knowledge about how pesticides harm bees enabled a generalisation of this particular configuration of a pollination-based food system beyond France. This in turn enabled a wider range of actors to know how to create new rules that are used to determine when particular molecules could be banned.

4.3 Including marginal actors in food systems

The dominant system of research and innovation is often referred to as a triple helix where State, academics and firms are allied in processes and policies. Analysts hypothesize that a more effective system for transitioning to sustainability may be generalised, if a fourth helix is opened to civil society actors (Robinson et al., 2020). Among those actors are third sector organizations (TSO), including associations[4] TSOs are considered

[4] In France, associations are a proxy for the third sector since they represent 80 % of this sector's organisations(Barré R (2020)

key actors in grassroots innovation for sustainability transitions in multi-level institutional environments. In the food system, they facilitate the inclusion of concerned groups in agroecological innovation, that is, as consumers, small-scale farmers, and environmental groups. This third case recounts essential events leading to changes in the rules and infrastructures of the research and innovation system that are necessary for inclusiveness. We describe four situations that were ripe for intermediation, and explain how different actors contributed to networking and advocacy, the legitimation of third sector actors, and the recognition of knowledge that was previously ignored. This trajectory also brings in elements of the broader context of science with/for society policies that are central to current policy approaches that support agroecological transitions (Barbier et al., 2023) and closes the narrative with the experimentation of policies that finance research and innovation by TSOs.

Situation 1 – The triple helix and third sector organisations in research and innovation (before 2010)

In 2010, TSOs were not considered as full-fledged actors in agricultural innovation systems (AIS) despite the fact that the concept of science with/for society had appeared in the European framework research programmes quite early in the 2000s. This concept refers to the idea that research and innovation should be conducted in a way that is responsive to the needs and interests of society. Adopting this approach can involve engaging with various stakeholders, including the third sector and citizens, throughout the entire innovation process. Engagement refers to shared values among the actors. Major research and innovation policies excluded TSOs. This was reflected in the French National Research Agency (ANR) financing rules (i.e., only research organisations and small enterprises could be co-funded) and the pre-eminence of the ideology of the (knowledge) deficit model (of citizens). In addition to being excluded from the research and innovation networks (and food systems more broadly), the research and innovation activities of the third sector was fragmented and invisible. The challenge was therefore to transform public policies to obtain funding for TSOs. This required state and regional lobbying efforts.

Situation 2 – Building the epistemic community (2010 – 2017)

In order to intermediate the rules governing research and innovation, a core group of science and technology studies (STS) scholars and pioneers in the TSOs begin organising themselves. They began to build an epistemic community of interested actors who were researching and innovating around sustainability transitions. Their idea was to create an organisation that could represent TSOs in discussions with the public research institutes. First, the core group raised the visibility of their knowledge with public research organisations by pulling together existing evidence about food systems that are inclusive of alternative ways of knowing (e.g., farmer-driven research). For instance, a member of the core group (and of the authors' research team) contributed to the report on « participatory sciences and research » written by the president and director general of INRA[5]. The report calls for opening up spaces for knowledge production outside of the institutions of research in order to ensure that future food systems are sustainable (Houllier and Merilhou-Goudard, 2016). Because of this recognised importance of TSOs in food system transformations, INRAE became a founding member of the Alliss platform (an alternative and participatory think tank) in 2014.

The secretary general that was selected to coordinate Alliss extended the network included in the platform through events and collective projects that brought together science and society actors, particularly around innovations in food, agriculture, housing and health. However, the fragmentation of a dizzying array of TSOs challenged the capacity of Alliss to find a common voice for advocacy. Thus, the writing of a white paper was introduced as a way to intermediate this challenge.

Situation 3 – Intermediating to legitimate the third sector and experiential knowledge (2017-2019)

In January 2017, the white paper entitled "Taking knowledge society seriously" (Akrich et al., 2017) was presented to the French National Assembly under the auspices of members of parliament and via the invitation of several representatives of the research organisations. This report was inspired by the eponymous report published for the Directorate General for European Research and Innovation (Felt et al., 2007), to which

Pour une recherche scientifique responsable. *Natures Sciences Sociétés* 28(1): 45-50.

[5] National research institute for agriculture, food and environment

some of the founding members of Alliss had contributed. Over 100 organisations had been involved in the collective writing of the white paper, whose publication was sponsored by three public research organisations. The white paper was subsequently used for advocacy work to turn recommendations into formalised rules and to structure the fragmented sector. The aim was to provide recommendations to create knowledge infrastructures that included TSOs, and thus to legitimate the research and innovation conducted by civil society actors working outside of the dominant institutions.

In June 2018, Le Mouvement Associatif (speaking for a network gathering over 50 % of the registered associations in France), included the Alliss white paper recommendations in a report entitled "For an ambitious associative life policy and the development of a society of commitment." They presented it to the Prime Minister, the Minister in charge of Associative Life, and the High Commissioner for the Social and Solidarity Economy. Their objective was to "have the resources to understand more finely the realities of associative life and its contributions to sustainability, but also the issues and changes with which associations must deal." One of the recommendations referred to the need for subsidising research and innovation activities by TSOs.

On January 20, 2020, other strategic actors of the dominant order pleaded for the institutional recognition of TSOs during a vigil of arms organised at the National Assembly prior to the parliamentary debates on the pluriannual law that governs research and higher education. Even though CNRS[6] and the MESRI[7] resisted this form of interference from civil society in research, both were represented at the vigil. In preparation, Alliss organised 3 symposia, one in Paris (2015) and two in other regions of France (Occitanie 2017 and Bretagne 2020) to bring together TSOs and academics. This allowed the generalising of normative concepts such as participatory research, third sector (TSO) and research intermediation. Therefore, these activities produced common knowledge and values, the result of this intermediation was a new rule for TSO who was considered to be a legitimate actor (deserving of state funds) in innovation processes.

Situation 4 – Experimenting changes in rules and infrastructures (2019-2021)

In 2019, a new policy was first experimented to subsidise associations who conduct knowledge brokering. This experimentation is the first implementation of the recommendations put forward in the 2017 white paper. It was thus the first infrastructural change that included experiential knowledge in innovation promotion. It was funded by the Ministry of Education as the adaptation of an existing policy instrument dedicated to associations granted the State label "youth and popular education" (JEP) Fonjep)[8]. This aid supports the employment of a qualified employee for 3 years, renewable twice. Three calls were published from 2019 to 2021 resulting in the selection of 60 grant winners working on sustainability transitions.

Ten of the grant winners worked on sustainable food systems. For example, an agroecology and organic network in Occitanie received financing for a living lab in urban agriculture and local food provisioning. There were also several nature conservation societies contributing to biodiversity observatories that were financed. The grant provided economic stability and time necessary to co-produce knowledge, infrastructures, and legitimacy within their food systems. This could induce changes in the skills, organisation, and activities of the other actors in their network. That is, they created (or developed pre-existing) learning tools and intermediation devices (depending on the phase of the associations' project): surveys and databases, virtual platforms and living labs, training programs and observatories, books and journals. They started new research projects, expanded pre-existing networks, created new ones and participated in other actors' projects. This intermediation work by the funding instrument (facilitated knowledge exchange among projects, within the associations and between organisations. The result has been organisational and methodological changes in INRAE and the TSOs themselves, with the creation of new hybrid infrastructures that connect them (e.g., living labs and observatories).

Since 2019, grassroots actors involved in projects and institutional entrepreneurs within the Alliss platform have intermediated additional challenges. These challenges emerged and were intermediated in local and international situations such as in the hybrid steering and selection boards, and among grant winners. INRAE was represented at both boards. The boards developed criteria of eligibility for the selection of projects and ensured that the public policy was not diverted from its objective of valuing alternative knowledge for innovation. Criteria were negotiated between the historical beneficiaries of Fonjep financing and Alliss. We observed

[6] National center for scientific research

[7] Ministry of Higher education, research and innovation

[8] Fonjep is the acronym used to refer to the JEP funds (fond pour la jeunesse et l'éducation populaire)

how the members of Alliss not only worked to reframe the call, but also intervened during the selection process. Meanwhile, the Alliss secretariat pursued its advocacy work. It was successful in expanding the epistemic community and maintaining its influence in institutional circles. The intermediation in this regulatory space was a partial success. While the new Research and innovation act passed in 2020 had not included TSOs as full-fledged stakeholders, they became eligible to receive ANR financing in 2022.

Today, TSOs still remain largely invisible in research and innovations in comparison to the recognition given to universities and public authorities. However, the most recent call for proposals by the ANR focused on science with/for society, received 200 proposals from a very wide range of TSOs and research organisations working on sustainability transitions beyond Alliss. This demonstrates a generalisation beyond food systems of the efforts initiated by food system actors to be inclusive of alternative ways of knowing.

5 Four objects of intermediation for generalisation

We now turn to looking across the three series of situations in order to identify which objects of intermediation enabled actors to move out of a challenging situation into a new one. We then examine the turning points that we observed and we discuss what this means for understanding the generalisation of systems innovation.

5.1 The four objects of intermediation

The natural wine case is rather straightforward. In a first situation, *de facto* and informal wine producers needed to construct a series of interdependencies in order to survive – without a protected niche – in a very competitive food system. They negotiated these interdependencies by developing a networked approach to generalisation. They intermediated knowledge, and then infrastructures, in order to overcome both the required interdependencies and unnecessary complexities that challenged the generalisation of the new "natural" value. In 2000, the natural wine movement began to develop, attracting more consumers and developing a fairly recognisable niche. Complexities and controversies emerged in this phase around the identifiable (and standardisable) characteristics of natural wine. In a second situation, intermediation around values emerged to complement ongoing knowledge and infrastructure intermediation. Starting in 2015, the increased popularity of natural wine was carried through digitalisation advances and greater consumer interest in sustainable agriculture. Uncertainties emerged into the generalisation process as existing forms of certification, labels and marketing did not fit with the values that needed to generalise with the product. All actors in the network independently held in person meetings across the country. The commitment to informal exchange without a commercial end, allowed rules intermediation in a third situation. This began to clarify and codify the natural wine quality through a commitment to informal exchange without a commercial end via in person meetings.

Looking at the other two cases, we can trace the emergence and actions of these four objects of intermediation. For example, the generalisation of the bee-inclusive food system emerged and converged within controversy. In a first situation, the core controversy was between the researchers, regulators and companies who could not agree about the causes of harm to bees, questioning the justifications for banning specific products. Knowledge intermediation led to the development of new tests that could prove the causes of colony collapse, but it also led to the identification of interdependencies and complexities that challenged the further generalisation of the use of these tests and thus the development of sustainable apiculture as a valued practice. Addressing the interdependencies thus became the object of further knowledge intermediation in order to develop collaborative research in real conditions. At the same time, the fragmented apiculture sector complexified the generalisation process. Infrastructural investments, particularly establishing the Bee Technical Institute, intermediated this second situation and enabled convergence of the generalisation process. This was solidified through rule intermediation and homologation of the "return to hive test" based on RFID technology that was adopted in 2021. The controversy following this final intermediation, which questioned the level of knowledge necessary to fully recognise the legitimacy of this new technology that supported sustainable apiculture.

In the generalisation of TSO, the knowledge that was valued by the dominant institutions offered the original challenge. In a first situation, knowledge intermediation thus emerged within a period of deep uncertainties about the legitimate inclusion of non-institutionalised actors in research and innovation for sustainability transitions. The challenge was to understand and specify what knowledge was needed to be produced, and to legitimate experiential knowledge that is valued in participatory research. The creation and diffusion of

the white paper was the object of knowledge intermediation. As participatory research generalised more broadly across France, this process was challenged by complexity and deeply embedded interdependencies. Complexity appeared both in terms of the fragmentation of actors that did not have the means to collaborate effectively, and in the challenge of bringing the wide range of actors together under an umbrella of common values for sustainability issues. Knowledge intermediation was conducted through collective writing actions, meetings, and focus groups conducted to understand the needs of actors and include more disparate actors in co-creation. In a second situation, intermediation was thus carried out on the two fronts of infrastructure and values. This resulted in (partly failed) attempts to restructure the sector, in effective distributed actions among grassroots actors involved in projects, and in successful mobilisation of institutional entrepreneurs. The interdependencies among ministries and sectors were not taken seriously into consideration in the beginning. This challenged the ability of actors to fund their research and innovation. It alsocontinued to challenge the generalisation of the system and required codifying TSOs and the notion of social economy (and social innovation) to establish legitimate rules. In a third situation, controversy emerged once the rules were intermediated as not all actors in the research sector were willing to recognise the TSOs as full research partners, and not all TSOs were willing to act for change. Rule intermediation is still ongoing to change the regulations for research and higher education in order consolidate the generalisation of an hybrid epistemic community for sustainability transitions in France that includes and values 3rd sector knowledge. Observatories and popular education trainings remain objects of knowledge and infrastructure intermediation.

As the above three narratives demonstrate, we see the four objects of intermediation circulating within the food systems and emerging to do the intermediation work in rather different situations. While the sequencing of these types of intermediations may differ from case to case, we can link these intermediations to the four conditions of turning points (Gotlib and Wheaton, 1997) (Table 1). If you look across the three cases, knowledge and rules emerged to stabilise the new direction, while infrastructures and rules offered resistance. Identity transformation and the evidence of role commitment were intermediated by all four objects. What is important to note, is that in order for a turning point to emerge (i.e., for the four conditions to be met), we have identified more than one situation that was intermediated for each case. What this means, is that each situated intermediation may not be sufficient for a turning point to be identified, but it is the series that build upon the results of prior intermediations that offer the conditions for turning points in transformative trajectories.

Table 1: Intermediated turning points

Four conditions of turning points	**Natural Wine**	**Bees**	**TSO**
Stability of the new direction	Scores intermediating rules	Field tests intermediating knowledge about colony collapse	Intermediating knowledge through the white paper, symposia and working groups
Resistance to efforts to re-establish a former trajectory	Intermediating infrastructures through digital apps	Bee Technical Institute as the result of infrastructural intermediation	Rule and infrastructural intermediations through institutional entrepreneurship and grassroots activism
Transformation of identity to accommodate a new trajectory	Fermenting agents intermediating value	Sustainable apiculture as the result of value intermediation	Financing TSOs as infrastructure intermediation
Evidence of a role commitment implied by a new direction	Festivals as objects of knowledge intermediation	Homologation of the return to Hive Test as rule intermediation	Value intermediation through distributed grassroots activism

Taken together, these three cases help to explain how sustainable food systems are generalising in France. Emerging from quite different situations, and passing through others, we detect a pattern of intermediation that offers an explanation of generalisation of system innovations. First, these cases are important in illustrating that food systems are not simply food supply chains or formal AIS – but rather complex systems that include actors from research, civil society and the private sector. All of these actors produce knowledge that serves to generalise system innovations from the first circle of inventors (Whitmarsh et al., 2021: 76; Nielsen

et al., 2021; Parag and Janda, 2014). Second, these differences reinforce the importance of situated knowledge and the fact that change was catalysed each time challenges emerged to destabilise a given situation. In our cases, destabilisation was always tied to a re-stabilisation in a new direction of change after passing these intermediated turning points. Finally, and perhaps most importantly, the range of actors that actively intermediated the challenges that emerged in order to restabilise a new food system configuration were different from one situation to the next. They are not always formal knowledge brokers, nor professionals (Sutherland et al., 2023; Steyaert et al., 2017). Instead, the actors doing intermediation work were both human and non-human. The human actors were furthermore specifically interested in effecting change in the food systems that they intermediated in order to respond to grand societal challenges. The non-human intermediaries took on lives of their own by connecting actors across scales and parallel networks. Thus, while these cases demonstrate that generalisation requires knowledge intermediation (Loconto, 2023), we find that values, infrastructures and rules were also important (non-human) objects of intermediation that contributed to turning points in each cases' trajectory.

5.2 Implications for generalisation

From the above analysis, we can draw out two key learnings that advance our understanding of generalisation and the role of intermediation within it. First, it is clear that the needs for intermediation are linked to challenges that are posed during different phases of a generalisation process. Thus, while diffusion of innovation and theories of scaling have typically portrayed these processes as a progression of use (of a particular novel technology, product or service), generalisation should be considered as a dynamic process of intermediated network management, more similar to institutional innovation than to scaling of technologies (Hargrave and Van De Ven, 2006). However, we do notice that there is movement from one form of intermediation to another, which suggests that the situated knowledge and other aspects of the situations should not be underrated (Leeuwis and Aarts, 2011). Our data suggest that a successful generalisation is the result of intermediations around specific objects that can occur sequentially, but also in parallel. These parallel intermediations are often not synchronised. The accumulation of these situated intermediations seem to provide the conditions for turning points to emerge in transformative trajectories.

Second, while there is in some cases only one object of intermediation working at a time to advance the generalisation process, others are characterised by a combination of objects which supports the importance of treating intermediation as a process and not as a type of actor (Steyaert et al., 2017; Kivimaa et al., 2019). Indeed, this suggests that generalisation processes operate through the interaction between (at least) two "levels" of interaction. The clear example of this is in the case of the TSOs whereby innovations are generalising simultaneously through pointed projects, but also through advocacy work to change the institutions of research and rules about how associations can receive funding to conduct research. This parallel intermediation seems to be the mechanism through which networks can be expanded beyond the first ring of users. Thus, our results support Wigboldus et al. (2016) rejection of the term scale. In line with Kivimaa et al. (2019), we argue that when we look at generalisation, we must learn to be able to see the multiplicity of actions by different actors across networks that are feeding into each other as constituting intermediation. Our relational and material approach offers a way to do this.

During generalisation, intermediation activities are thus carried out both upstream and downstream of actor network formation and at several levels of organisation. Looking at intermediation as a confluence of these processes during different phases of generalisation complements the idea that there are four ideal-type pathways for generalisation (Sengers et al., 2021). We suggest that these activities are the micro-pinning necessary for any generalisation process to unfold. Building from the notion of micro-level intermediation in order to effect meso-level generalisation, we propose that generalisation as an intermediated process occurs: 1) with regards to the insertion of innovations into pre-existing institutional contexts; 2) by reconfiguring the network of actors involved, and 3) by reformulating the initial objectives of the innovation. This reformulation of objectives can be understood as taking place at the intersection of the situations of emergence, development or convergence of innovations and the future state of the network that the actors envision for their collective work. Put differently, generalisation connects spaces of anticipation and/or legitimation of the visions/values, knowledge, infrastructures and rules of a socio-technical innovation (cf. Janssen et al., 2023). Intermediation in these networks constructs the boundaries within which it is possible to produce turning points in transformative trajectories.

6 Conclusions

This article set out to better conceptualise and operationalise how system innovations generalise in the face of unanticipated challenges so to create transformative change in food systems. We found that the literature has not yet been able to specify how the pathways and mechanisms of generalisation take shape, particularly because there has been too much focus on the human actors of intermediation, often forgetting the roles of non-human actors. By introducing a relational and object-oriented approach to recognising turning points in transformative trajectories as the result of situated intermediation, we offer both a new conceptual framework and new avenues for research into the meso-level mechanisms of generalisation. Our conceptual framework allows us to identify a sequence of challenges and how objects of intermediation can solve them. Evaluation and valorisation of these very objects could be a helpful way to think about generalisation and the directionality failures that have been highlighted in the current literature. As a future direction, we propose research that could build on our meso-level understanding of generalisation and explore how this might be usefully combined with the generic policy pathways for enabling convergence on wicked problem-solution constellations introduced by Wanzenböck et al. (2020). Such reflections should push the innovation studies community to better articulate the interdependencies among different trajectories at the heart and on the edges of socio-technical regimes. Future empirical research might seek to test which forms of intermediation might be best suited for specific transformation challenges.

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Annex 1: Publications of original data

Source	Case studies	Methodologies
Matt, M., Robinson, D. K., Joly, P. B., Van Dis, R., & Colinet, L. (2023). ASIRPAReal-Time in the making or how to empower researchers to steer research towards desired societal goals. Research Evaluation, 32(2), 412-425. https://asirpa.hub.inrae.fr/60-cas-etudies	60 case studies of agricultural innovations (plant, livestock, food, environment, agronomy, biodiversity…) generated by a single French public research organization.	Standardized innovation case studies based on semi structured interviews with diverse stakeholders involved in the various steps of an impact pathway ; and secondary sources (websites, official documents, archival material, and publications) to cross-check the information
Loconto, Allison, Poisot, Ann-Sophie and Pilar Santacoloma. 2016. *Innovative Markets for Sustainable Agriculture : How innovations in market institutions encourage sustainable agriculture in developing countries*. Rome: FAO. Loconto, Allison, Jimenez, Alejandra and Emilie Vandecandelaere. 2018. *Constructing markets for agroecology – An analysis of diverse options for marketing products from agroecology*. Rome: FAO. Loconto, Allison et al. 2020. *Enabling sustainable food systems: Innovators' handbook*. Rome: FAO and INRAE. https://doi.org/10.4060/ca9917en	27 case studies of multi-actor initiatives that have created alternative markets for sustainably produced food in 25 countries (including France).	Standardised case templates completed by the innovators about the institutional innovation histories. Secondary sources (websites, official documents, expert validation, newspaper articles and NGO publications) to triangulate the data. Semi-structured interviews (90), an online discussion group comprising 86 members who identified challenges and solutions, and field visits of the case study sites, comprising observations, informal interviews and collective analysis. 221 stacked, structured questionnaires completed with producers, intermediaries and consumers in 12 initiatives. Three researcher-practitioner writing workshops and two validation workshops including over 100 participants.
Lhoste, Evelyne Françoise and Loup Sardin. «Unveiling Research Intermediations in Citizen Science.» Citizen Science: Theory and Practice 9.1 (2024): 1	35 case studies of funded TSO's projects in France	We collected the empirical material between 2019 and 2022, as part of a formative evaluation of an experimental grant to participatory research. Standardized case studies based on semi structured interviews with grant winner organisations, participatory observation in organisations and steering committee of the grant, focus groups as part of the impact pathway process, and secondary sources (e.g., websites, official documents, grant applications) to cross-check the information.

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