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# The Evolutionary Emergence of Quintuple Helix Coalitions: A Case Study of Place-Based Sustainability Transition

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## Abstract

Complex societal, environmental, and economic challenges are affecting the post-covid-19 societies. They must increasingly rely on multi-stakeholders' and multi-domain coalitions to find innovative solutions and achieve sustainability transitions in the near future. Triple helix model featuring interactions among academia, industry, and government successfully explained collaboration in technological innovation dynamics. The models integrating a fourth helix, i.e., bringing knowledge from the civil society and a fifth helix i.e., bringing knowledge from the natural environment, emerged to understand innovations addressing complex societal and environmental problems. By adopting an evolutionary perspective and incorporating agency in the quintuple

helix, we propose a conceptual framework to shed light on how multi-domain coalitions might emerge in local productive systems engaging in sustainability transitions. Drawing on this framework, we analyze the case of a rural local system where a quintuple helix coalition emerges together with the development and adoption of sustainable agronomic practices triggering a sustainability transition process.

## Keywords

quintuple helix coalitions – quintuple helix agency – local productive systems – sustainability transition

## 1 Introduction

The contemporary environmental and social challenges, exacerbated by the Covid-19 pandemic shock and the recent outbreak of the war at the boundaries of Eastern Europe, demand transition processes supported by multi-stakeholders' collaborative innovation (Nguyen et al., 2022). At the beginning of the 21st century, the triple helix model (TH) was introduced to analyze the complex mechanisms of collaborative knowledge production and innovation among actors of the three different institutional spheres of the academy, business, and government (Etzkowitz and Leydesdorff, 2000). Since then, the model has had a great empirical diffusion, and continuous attention has been given to strengthening its foundations and analytical power (Cai and Amaral, 2021).

The increasing necessity to find innovative solutions to environmental and social challenges is pushing the interest of scholars toward quadruple and quintuple helix models, which have tried to integrate the direct contribution of the civil society and the natural environment to innovation together with triple helix actors (Carayannis and Campbell, 2010; Grundel and Dahlström, 2016). While the quadruple helix model is central to several recent studies that expanded its applications in theoretical and empirical terms (to mention a few: Miller et al., 2016; Mora et al., 2019; Bellandi et al., 2021; Nguyen et al., 2022), there is still a lack of empirical studies on quintuple helix dynamics due to the complexities of the interactions involved and the difficulty to identify the agency of the quintuple helix (Cai and Lattu, 2021; Mineiro et al., 2021; Taratori et al., 2021).

Furthermore, criticisms have been raised concerning the theoretical foundation of these enhanced constructs, three in particular. First, the civil society and the natural environment constitute, in any case, the necessary context

where the core relations between the triple helix's actors take place, and, in many cases, there is not an evident necessity to consider representatives of the civic society and the natural environment as crucial parts in innovation interactions (Cai and Etzkowitz, 2020); second, the direct contribution of the two added helices to innovation dynamics would be hard to analyze and measure (Leydesdorff, 2012); third, in case it were demonstrated a significant knowledge contribution of fourth or fifth helices, etc., the multi-process and multi-actor's interactions would be more fruitfully analyzed by decomposing the n-tuple (with n greater than 3) in sets of basic THs and looking at their internal interactions and higher order ones (e.g., Etzkowitz and Zhou, 2006; Leydesdorff and Lawton Smith, 2022).

We do not aspire with this paper to present a thorough discussion of the complex theoretical sides of these questions (Cai and Amaral, 2022). However, we try to open a possible route of empirical explorations related to the same questions, considering two specific aims. The first one is the elaboration of a framework going further on the agency dimension of quintuple helices (Mineiro et al., 2021), specifically inserting it within a local context of sustainability transition evolving toward quintuple helix dynamics and innovation partnerships. The second aim is an assessment of the interpretative potentiality of the same framework by discussing its application to an empirical case.

Such framework is rooted in the recent debate relating quintuple helix dynamics to include sustainability issues within innovation ecosystems (Grundel and Dahlström, 2016; Carayannis and Campbell, 2010; Durán-Romero et al., 2020; Park and Stek, 2022). More specifically, the study of human agency in sustainability transitions of local productive systems (LPSS) has been linked to the works of collaborative quintuple helix networks for innovation (Bellandi and De Propris, 2021). Finally, the constitution of complex innovation partnerships may be characterized by co-evolutionary dynamics, where the innovation process is also the arena for learning, adaptation, and differentiation in partners' goals and functions (Bellandi et al. 2021; Cai and Lattu 2021).

Therefore, we insert the consideration of the fifth helix at the core of the conceptual framework as a set of actors whose role in co-innovation dynamics emerge within a path of sustainability transition rather than an impact of the natural environment on agency. This has already been suggested by Gebhardt et al. (2022) in a theoretical context of twinned THs instead of quintuple helices. In our framework, such actors may have different organizational identities and cognitive approaches and become involved in co-innovation quintuple dynamics when they progressively combine explicit environmental-sensible goals and related scientific and regulative functions with day-to-day practices and needs expressed by local communities of producers and citizens.

We adopt a case study methodology to explore a local initiative based in the rural LPS of Montespertoli, Tuscany region (Italy), where quintuple helix actors have progressively emerged and started to collaborate for helping what may be seen as an impending sustainability transition.

The following section recalls the debate on the quintuple helix model and its most recent applications in the scientific literature. Next, it presents the theoretical premises constituting the background of the conceptual framework on the emergence of coalitions of quintuple helix actors and functions in LPSS facing sustainability transitions. After introducing the empirical methodology, the paper illustrates the case study drawing on the conceptual framework. The main implications and conclusions are provided at the end of the article.

## 2 The Quintuple Helix: First Conceptualizations and Recent Applications

Climate change, waste production, and energy and food supply shortage are some of the multifaceted challenges that society must face in the aftermath of the Covid-19 pandemic. They have been exacerbated by the recent outbreak of the war at the eastern boundaries of the European Union. Such wicked problems with their tragic impacts, including the opportunities related to reactions supported by technological change and social innovation, must be addressed with a multi-actors' perspective. The triple helix innovation model has successfully embodied a multi-stakeholder approach, where the interactions between universities, industries, and governments are pivotal in enhancing innovation and economic development (Etzkowitz et al., 2000). In this model, knowledge creation according to feedbacks and nonlinear dynamics, the so-called Mode 2 of Innovation, is expanded by knowledge sharing fostered in coalitions between the three types of actors and the capacity of each actor to take the role of the other (Etzkowitz and Leydesdorff, 2000).

Triple helix has been largely used in empirical studies addressing technology transfer and technological innovation (see the recent review by Cai and Etzkowitz, 2020). However, the increasing demand of sustainability transitions for addressing complex societal and economic challenges (Geels, 2011; Stefani et al. 2022; Park and Stek, 2022) has pushed the formulation of quadruple and quintuple helix frameworks. They explicitly refer to civil society and the environment in the innovation process. Carayannis and Campbell (2010) introduced the concepts of quadruple and quintuple helix models. The quadruple helix broadens the triple helix interactions by including the actors of the civic society and the media and creative sectors. The quintuple helix

was proposed as a set of contextual factors directly impacting quadruple and triple helix innovation processes for sustainable development (Carayannis and Campbell, 2021). Carayannis et al. (2012) further elaborated the concept of quintuple helix models by pointing out that this represents cooperative arrangements in producing new knowledge from sources rooted in different subsystems, namely i) the education system, ii) the economic system, iii) the political system, iv) the public, and v) the natural environment.

These models highlight a further shift in knowledge production, Mode 3, whereby different modes of knowledge interaction and innovation co-exist, compete, collaborate, and co-evolve (Carayannis and Campbell, 2011) hosted in different and interrelated types of innovation partnerships (Amaral et al., 2020). In the perspective provided by Carayannis et al. (2017: 461–462) “the nonlinear innovation model of the Quintuple Helix, which combines knowledge, know-how, and the natural environment system together into one framework, can provide a step-by-step model to comprehend the quality-based management of effective development, recover a balance with nature, and allow future generations a life of plurality and diversity on earth.” Yun and Liu (2019) presented a study following such approach and explored how quadruple and quintuple helix theories can be adopted to foster social, economic, and environmental sustainability within the open innovation mechanisms characterizing the so-called Industry 4.0 (I4.0). In a recent work, Carayannis and Campbell (2021) stated that the quintuple helix strictly connects to the socioecological transition of economy and society following democratic political principles innervated by ecological sensitivity and where environmental threats are considered criticalities to be solved and opportunities to be seized since they can be drivers for the innovations of the future. Finally, Carayannis et al. (2022) explored the possibility of reaching Society 5.0 through the quintuple helix innovation ecosystem.

During the last few years, scholars have used this framework differently and given diverse and somehow disparate interpretations of the fifth helix (Cai and Lattu, 2020).

Baccarne et al. (2016) adopted the subsystems’ perspective on the quintuple helix and used it to include environmental goals in the innovation process for analyzing two urban living labs addressing urban sustainability. They maintain that incorporating the environment, i.e., the fifth helix, in innovation practices is pivotal to supporting sustainable city development. However, despite some reference to eco-entrepreneurs as the initiators of the two living labs, the quintuple helix is represented only by interactions of the two practices with the “socioecological environment” (*ibid.* 2016: 27). Grundel and Dahlström (2016) saw the environment as a crucial element in knowledge creation processes

and the transition toward a sustainable forestry-based bioeconomy in Sweden. Litardi et al. (2020) developed a case study with a quintuple helix approach, specifically addressing the role of universities in fostering sustainability in the waste sector. Durán-Romero et al. (2020) investigated the roles of universities, industries, governments, societies, and the environment in fostering eco-innovations in the context of the circular economy sector. The environment as the fifth helix lays again in the background; it is somehow encapsulated within the eco-innovation concept. Taratori et al. (2021) applied the n-helices theories to the governance of urban development projects, asserting that success can only be achieved in quintuple helix initiatives if citizens are involved and appropriately informed. In selecting their quintuple helix case study, the environment is considered in terms of sustainable development's goals. Also, in this case, the chosen initiative resembles a quadruple helix pointing to sustainability objectives.

A step forward is taken by Bellandi and De Propris (2021), suggesting that partnerships with a quintuple helix architecture could be central elements for sustainability transitions of LPSS. Indeed, in the transition context, there are unavoidable trade-offs arising between social, green, and technological objectives (Park and Stek, 2022; Gebhardt et al., 2022), which demand to be managed through proper public regulation and well-functioning institutions and collective leadership. According to Bellandi and De Propris (2021), such collective leadership should also incorporate explicitly specific human agencies related to the fifth helix functions and spheres. We intend to develop this suggestion in what follows.

Indeed, the possibility of incorporating human agency in the fifth helix is discussed and elaborated in the next section, where we elucidate the theoretical premises to develop a framework and help to give an operational and actor-based definition of the fifth helix and its emergence and functioning in LPSS along with sustainability transitions.

### 3 Theoretical Premises

The conceptual framework illustrated in Section 4 is based on some key premises rooted in regional and innovation studies related to the streams of contributions on helical models and processes referred to in the previous section.

#### 3.1 *Evolutionary Approaches*

A recent work of Cai and Lattu (2021) points out that in debates concerning the use of helix models, it is possible to identify a small group of works in which

the triple and quadruple helix models are not seen as alternative approaches but, precisely, as parts of the same evolving paths. In this perspective, the traditional collaborative dynamics between triple helix actors are enhanced by adding civil society organizations that become part of the collaborative structure. Similarly, Marques et al. (2021: 128), reasoning on the relevant stakeholders necessary to boost innovation in European regions, explain the rise of the quadruple helix as an “extension” of the triple helix model. In the same vein, Arranz et al. (2020) acknowledge that the triple helix cannot capture all the relevant collaborations arising in innovation systems, and other types of actors need to be considered. Also, Bellandi et al. (2021: 2) suggest that the evolutionary approach points “to integrate the civil society, seen as the social context of innovation dynamics and as an additional and crucial actor in innovation processes [...]. It should be emphasized that QH partnerships are not static. Their composition is shaped by the presence of old or emergent actors assuming a hybrid nature, between private and public sectors, as well as between social and business domains”. Notably, the emergent change here is triggered both by automatic mechanisms of selection and differentiation and by scanning, monitoring, and learning implemented by a set of actors pursuing an open and adapting set of common or complementary goals (Sabel, 2017).

### 3.2 *Agency*

The second key premise concerns precisely the identities of human agency in helical processes. In principle, triple helix processes feature three well-distinguished types of actors and related functions: business organizations with prevailing functions of value creations on markets, academic organizations specialized in the production of general knowledge and human capital bases for novelty, and public governments with their provisions of regulations and public goods (Etzkowitz et al., 2000; Piqué et al., 2020). Similarly, the fourth helix, with actors of the civil society and of the media and cultural sectors, provides knowledge for social and cultural enhancement of innovation (Carayannis et al., 2012). We have already recalled that helical processes bring about knowledge hybridization among the actors involved, a fundamental support for effective innovation outcomes (Cai and Etzkowitz, 2020).

However, actors can present “amphibious” features (Powell and Sandholtz, 2012) even before entering knowledge hybridization processes within helical coalitions, features that may help those same processes. For example, many “social economy” organizations carry market-oriented activities together with social or environmental impact functions (OECD, 2022; Park and Stek, 2022). The nature of university spin-off is to cultivate a bridging identity between academic research and market value (Leydesdorff and Meyer, 2006), sometimes

with a concern of social or environmental impacts. Benefit corporations (see Treedom referred to below) are commercial companies joining market goals with statutory goals regarding social or environmental objectives. Generally, in the recent decades, market and government failures have opened windows for organizations moving and possibly cooperating within “hybrid domains” (Aoyama and Parthasarathy, 2018).

Such amphibious features may be the outcome of past helical processes, but even if they are not, when entering a new helical partnership, the amphibious actors quite naturally contribute to bridging, brokering, and hybridizing functions within the partnership, together with other organizations with more defined identities and functions. It is important to consider this possibility within the evolutionary emergence of complex (quintuple helix) partnerships.

### 3.3 *LPSS*

The third key premise concerns the class of phenomena we target in applying quintuple helix innovation models. Let us recall that triple helix models suggest that helical dynamics emerge and develop more easily in contexts where they find the support of factors of innovation “systemness”, which are accumulated by history and agency in specific “areas” (Leydesdorff 2021: 118–119). Innovation “systemness” stands for contextual conditions by which a set of organizations or individuals localized in an “area” and taking different types of knowledge and resources find it relatively easy to constitute innovation networks among them and address possible positive returns to the strengthening of the same conditions in the area. The areas may be identified along different dimensions (territorial/sectoral) and at different scales: consider, for example, regional, national, transnational, sectoral, and technological innovation systems (Asheim et al., 2011). As a basic unit of analysis, we refer to areas defined at a local (i.e., regional or subregional) level hosting innovation “systemness” together with more general place-based factors propelling local development paths.

According to a long tradition of regional and industrial studies, areas of accumulation of history and agency for innovation and local development are identified as LPSS (Garofoli, 2002), such as industrial districts, dynamic cities, and rural systems, featuring evolving productive specializations rooted in the sociocultural and institutional relations of the place (Becattini et al., 2003). Factors of “systemness” are identified by a nexus of interests and cognitive approaches connecting the people of the place and pivoting on the local productive, sociocultural, and institutional heritage. These factors support auto-reproductive circles of innovation and development when they are oriented by shared values of trust and visions of a common future where



individual and collective well-being increases, thanks to local productive work and entrepreneurial investments (Becattini, 2015). The aforementioned nexus provides the basis for delineating a consensus space and shared strategies for helical partnerships (Champenois and Etzkowitz, 2018; Bellandi et al., 2021), intersecting with the potential action of place-leaderships and multi-level governance (Sotarauta and Beer, 2017).

### 3.4 *Place-Based Sustainability Transitions*

The last key premise is directly connected to the previous one and concerns our focus on LPSS involved in sustainability transitions. Sustainability transitions point to conditions where an “innovation gap” combines with wicked/disruptive environmental sustainability problems and implies a more general processes of radical/systemic innovation and structural change than just a new product or a new technology (Geels, 2011; Stefani et al., 2022). Originally, the concept of sustainability transitions was applied to sociotechnical systems developing around a new technology or productive sector, without explicit spatial qualifications; quite soon, however, spatial qualifications have been made explicit, referring to multi-scalar and cross-territorial spaces that host and are impacted by such processes (Truffer and Coenen, 2012).

Indeed, opportunities and barriers to circles of innovation and development in LPSS facing environmental challenges can be studied in relation to sustainability transitions intersecting new local development paths (Belliandi and De Propris, 2021). Indeed, an LPS's local nexus may also include the impact of experiences of direct contact with natural resources and environmental contexts, including the active involvement of civic and ecosystem actors in related processes of knowledge sharing. This is the place-based support of “sustainability transitions” (De Propris and Bailey, 2021).

Specifically, in sustainability transitions intersecting LPSS, the multi-level structure of the transition (landscape, sociotechnical regime, niche emergence, niche experiments, niche selection, and regime transformation) is seen in its multi-territorial dimension. Niches for potentially radical/systemic innovations, i.e., contexts partially sheltered from the direct competition of dominant/regime solutions, may develop within some LPSS throughout the accumulation of learning on experiments and applications (Cooke and Leydesdorff, 2006). Some niche solutions may become strong enough to expand beyond the local protected context, i.e., they succeed in overcoming barriers and selective mechanisms in the larger institutional and competitive landscape hosting the dominant solutions of the regime. Thus, they scale up throughout their docking in an increasing number of other local systems (De Propris and Bailey, 2021).

Considering agency, we believe that sustainability transitions are “necessarily about interactions between technology, policy/power/politics, economics/business/markets, and culture/discourse/public opinion” (Geels, 2011: 25). Therefore, they demand multi-level initiatives and helical processes of innovation (Carayannis et al., 2012; Park and Stek, 2022). In our perspective, place-based sustainability transitions are a meaningful context for the emergence and functioning of quintuple helical coalitions, which must be understood in a multi-territorial perspective pivoting on change in LPSS.

## 4 Conceptual Framework

The above-mentioned theoretical premises set the stage to develop a conceptual framework, giving interpretive clues on the emergence of quintuple helix coalitions in LPSS engaging in sustainability transitions. Figure 1 below summarizes a full-fledged set of quintuple helix actors and processes unfolding in an LPS. This is considered a context of innovation systemness presenting closeness to the needs and resources of natural environments, facing the breakout of some disruptive environmental, social, and economic challenges. Figure 1 constitutes the potential final point in the emergence of quintuple helix coalitions and dynamics in LPSS. The following elucidates each component included in the framework.

### 4.1 *Quintuple Helix Actors and Functions*

The first component concerns agency and its functions within quintuple helix processes. Generally, what follows has been recalled in the section above in reference to what suggested by Bellandi et al. (2021) and Bellandi and De Propris (2021). We propose to make explicit the human agency in the fifth helix. This also helps empirical analysis. Therefore, we consider the natural environment as a context impacted and impacting on the actions of triple/quadruple helix coalitions and as a set of actors, such as organizations operating green activism initiatives, territorial infrastructures, natural resources/waste/disasters management, agencies specialized on ecosystem services, promoting circularity in productive *filieres* and, more generally, the intermediation between the objectives of the environment and those of the society (Gebhardt et al., 2022). These agents can have environmental protection as their main goal (e.g., the well-known NGO Green Peace) or as an object of their daily operations (e.g., benefit corporation, such as Treedom s.r.l. <https://www.treedom.net/it/>). In principle, they differ from the fourth helix’s actors, as they do not incorporate needs and

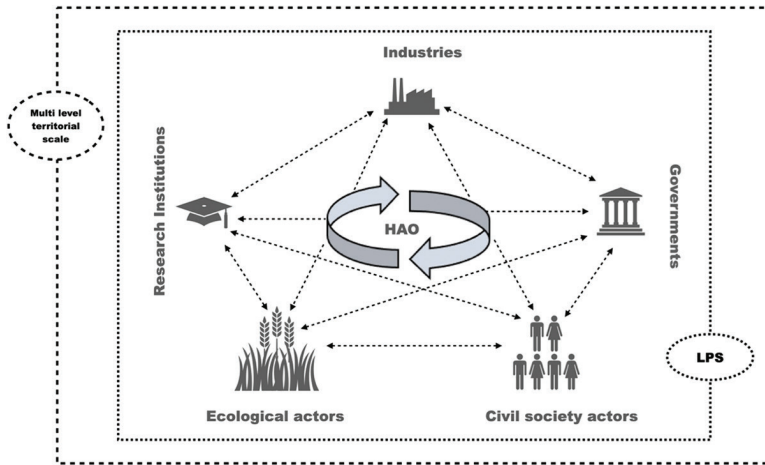


FIGURE 1 A full-fledged set of quintuple helix actors and relations in LPS  
 SOURCE: AUTHORS' ELABORATION

functions spurred from the civil society but directly from the natural environment. Notably, the social and environmental dimensions of the fourth and fifth helix, respectively, can incorporate different, either convergent or divergent, demands and objectives. In this sense, to disentangle the different natures of fourth and fifth helixes organizations and actors, we suggest looking at their goals and functions rather than focusing on their juridical forms. In Figure 1, the fifth helix is identified with ecological actors while the actors associated to the other four helices are those usually indicated by the literature of recalled in a Section above.

4.2 *Actors Relations, Emergence of Hybrid Autonomous Organizations and Quintuple Helix Coalitions*

The dotted arrows of Figure 1 illustrate the complex and reciprocal web of relations between actors that, in principle, bring different types of knowledge and resources to innovation projects, such as novelty production, market value creation, regulation, users' and citizens' participation, and environmental sustainability. The light gray round arrows suggest the inner functioning of the hybridization process, where the basic logic of the triple helix model also applies to more complex quintuple helix partnerships, with each type of actor possibly exchanging with the other types and partially entering the role of others in circular interactions of knowledge hybridization. Following Champenois and Etzkowitz (2018), we argue that in this context, boundary-spanning functions

are activated within some institutional spheres (public, business, academic, or what else) exploiting factors and shared experiences of contact with natural resources, problems, and opportunities. Such functions help create a consensus space among different types of actors. The coalescence of meetings and discussions on sustainability strategies within this consensus space supports the more-or-less formal structuration of “Hybrid Autonomous Organizations” (HAOS) (*ibid.* 2018: 29). These latter can reinforce the hybridization process, promote entrepreneurial discovery of innovation gaps, multi-level brokering, mediation, and negotiation activities, and, together with these, favor the emergence of helical coalitions on shared strategies for innovation and development. These shared strategies also provide feedback to the common local nexus of interests and cognitive approaches and feedforward to implementation phases thanks to learning processes.

Furthermore, as previously mentioned, the hybridization can also be strengthened by the amphibious features potentially embodied by helical actors. In principle, they present different organizational natures and carry different functions. However, amphibious features are an increasingly frequent phenomenon in contemporary worlds of production and innovation (Aoyama and Parthasarathy, 2018), which, entering helical coalitions, develop within related processes of knowledge hybridization, together with further processes of specialization and differentiation.

Since we adopt an evolutionary perspective, we posit that a local community can progressively incorporate quadruple and quintuple helical goals, actors and functions. We recall here that “evolutionary” refers both to processes whereby unintended social outcomes emerge from a context of selection and variation of competing individual strategies and to collective learning and social experiments on disruptive challenges, which progressively enhance and integrate networking capabilities and agency. A qualification of this evolutionary scenario is that, at the beginning, the helical process can be based on the presence of actors with more than a single identity. For example, within coalitions that have the appearance of a triple helix, the local governance and place-based leadership may also directly represent the experiences of the civic society, the business actors may also include some with direct contact with natural resources and environment, and the research actors may also play boundary-spanning functions. Therefore, under the appearance of a triple helix, an emergent quintuple helix process may be supported by actors who exploit their amphibious features from the beginning. If the path has some initial success, the quintuple helix processes may include, in the following phases of strengthening and expansion, actors incorporating new amphibious

features and actors bringing more differentiated helical identities. In a sense, this evolutionary perspective on the quintuple helix may be considered as an extension of what Ranga and Etzkowitz (2013: 246) suggested for the triple helix models, when they argued about the possibility of “substitution,” with actors of one helix helping to fill the gaps emerging when actors of another helix are weak.

### 4.3 *Multi-Level and Multi-Territorial Processes*

The last component of our conceptual framework concerns the multi-level/multi-territorial structuration of sustainability transitions (dotted external lines in Figure 1). We point out two qualifications. The first relates to the context of LPSs presenting different types and levels of internal complexity and external connectedness, particularly with respect to features of innovation systemness (Isaksen and Trippel, 2017). The qualification elaborates on contributions, such as Binz et al. (2014) and Cai et al. (2019), on multi/cross-territorial relations in sustainability transitions and innovation systems. Indeed, a certain LPS in a certain period is not necessarily self-contained with respect to the local presence of different types of quintuple helix actors, relations, and processes. Not only localized actors may have relations with nonlocal actors, but it is also possible that a certain type of actor or function appears weak at the local level, and the local circle of helical processes (triple, quadruple, or quintuple) finds completeness thanks to cross-local or upper-level actors and relations.

The second qualification elaborates on a side of the multi-level model of Geels (2011) on sustainability transitions, i.e., that niches for radical/systemic innovations usually meet barriers to expansion related to traditional regulatory, funding, and sociotechnical regimes. We argue that those barriers can be faced with the help of multi-level and multi-territorial brokering functions played or supported by the HAO, pulling the engagement of actors who: (a) move at regional, national, and international levels; (b) suggest adaptations of the local shared strategies; and (c) favor their penetration in the mainstream regulatory, funding, and sociotechnical regimes.

Contradictory effects, due to clashes between the local nexus and the different subcultures taken by the extra-local specialized actors, cannot be excluded. Meanwhile, evolutionary positive effects might emerge with the local anchoring of the external actors when played as an opportunity to enhance the openness of the local community and the completeness of quintuple helix processes at the local level. In the long run, positive cross-fertilization effects may qualify and strengthen the same local nexus and identity.

## 5 Method and Data

To explore how a quintuple helix coalitions can emerge in an LPS engaging in a sustainability transition, a case study method (Yin, 2003) is applied on the conceptual framework developed in the previous section. The case study method is usually adopted where there are too many variables of interest concerning the amount and variety of quantitative data available. Indeed, this qualitative method relies on multiple sources of evidence, searched for, collected, and interpreted circularly with the development of theories and models (Frankfort-Nachmias and Nachmias, 1996). In selecting the case, we have followed a theoretical sampling principle, which recommends choosing a key representative phenomenon of the object under study (Eisenhardt and Graebner, 2007). Therefore, our case purposefully concerns a LPS facing contemporary competitive and sustainability threats, which pushed toward a transition process involving actors bringing identities and competencies of the fourth and fifth helix types. Specifically, we analyze a local initiative, the local productive chain of bread from ancient wheat in the rural system of Montespertoli, in the Tuscany region (Italy).

Data have been collected from different sources, such as websites (of the Association, Rural Seed network, related initiatives), minutes of the annual assemblies of the Association, newspaper articles, and two rounds of semi-structured interviews carried out with key actors of the bread chain (producer, miller, baker, researcher, former municipality council member) in 2016–2018 and 2023. All interviews lasted around 40 minutes and were duly transcribed. In the first round, four key actors were selected considering all stages of the supply chain: from growing the wheat and milling the grain to the product. Additionally, we identified and interviewed two key informants from research institutes, and other public bodies who contributed to developing the chain. The interview protocol aimed at exploring the unfolding of collaborations and collective action within the bread chain and assessing the strategic views of the actors through a participatory SWOT analysis.<sup>1</sup> Thus, any mention of helix-like partnerships and dynamics was spontaneously made by the interviewees. The second round of interviews was performed in 2023 with three key informants (agronomist, president of the Association, miller) to grasp possible changes and challenges caused by the pandemic and more focused insights on helix partnerships development. The interviews were performed in Italian; some extracts from such interviews were translated into English and used in the next Sections to give evidence to some key passages in the case's narrative. Additionally, immersive ethnographic research (Cragg and Cook, 2007; Angrosino, 2007) from 2016 to 2021 was carried out by one of the authors.<sup>2</sup>

## 6 Case Study: Ancient Wheat Varieties in Montespertoli, Retro-Innovation within a Sustainability Transition

### 6.1 *Empirical Context*

The case study concerns an agronomic innovation in local food chains where the innovation management process takes place at different levels to deal with institutional barriers and enlarge the knowledge base. The core is a locally based initiative in the rural system of Montespertoli, which has been unfolding around the creation of a short food supply chain, involving a local mill, a baker, and a few local farmers at the beginning,<sup>3</sup> to create and capture the value of differentiated wheat products (flour, bread, and pasta). The specific basis for the differentiation of wheat products was the re-introduction of the cultivation of ancient (or local) wheat varieties. Ancient wheat varieties, of which “conservation” varieties are the legalized or formal version, maintain the original nutritional traits of wheat, strong adaptability to the environment in which they were developed, and lower or no need for chemical fertilizers and herbicides. These desirable properties come at the cost of lower yields, poorer technological properties, and the lack of standardized recipes for their cultivation and processing. The innovation has a systemic nature since novelties and adaptations concern the cultivation, milling, and breadmaking processes, all pointing to a sustainability transition (Stefani et al., 2022). It is a considerable form of sustainable retro-innovation defined as “the purposeful revival of historic practices, ideas and/or technologies” (Zagata et al., 2020: 640). Retro innovations play an important role in transitions toward sustainable agricultural systems in response to the current industrial agricultural paradigm (Zagata et al., 2020). Thus, farmers behave as ecological actors by embracing the systemic changes induced by the re-introduction of ancient varieties. Additionally, the nearby University of Florence and the municipality of Montespertoli have been involved in an informal coalition from the start.

The rural system of Montespertoli presents local productive and cultural heritages, civic attitudes, and environmental experiences, plausibly the basis of a local nexus of interests and cognitive approaches. The small town of Montespertoli was renowned for breadmaking up to the 1950s. The agricultural activities surrounding the town were considered the granary of Florence, and several mills were present along the Virginio River at the base of the hill hosting the town. Wheat, together with promiscuous olive groves and vineyards, were among the typical *croci* of the share-cropping (“*mezzadria*”) system of governance of farms, which characterized the Tuscan agriculture till the first half of 20th century (Gualandi and Gualandi, 2016; Stefani et al., 2017). With the modernization of agriculture, farms mainly specialized in wine-making, as

Montespertoli is part of the Chianti area (a protected denomination of origin of a type of wine). Local wheat production gradually declined, and all mills shut down, except one which moved to the center of the town. An attempt to resume a quality bread chain in Montespertoli was promoted by the remaining miller in 2004 as part of the Tuscan Region program on short food supply chain (“*filiara corta*”), which provided financial support for selling food produced within 70 km of the retail outlet. The chain was based on modern wheat varieties cultivated, milled, and baked in the village. However, the initiative ended after a few years because the bread did not “have sufficient unique features to go beyond a couple of bakeries and few selling points” (Gualandi and Gualandi, 2016: 31).

## 6.2 *Actors*

The miller started to look for alternatives after the scarce success of the Montespertoli wheat chain project, until the meeting with prof. S. B., a geneticist from the Department of Agricultural Sciences of the University of Florence (henceforth UNIFI), in 2008. Florence is not far from Montespertoli. S. B. suggested to replace the cultivation of modern wheat varieties with ancient varieties to differentiate and qualify Montespertoli bread with their higher nutritional quality, taste, and environmental performances. According to the miller, meeting with the researcher was a turning point:

We did some tests, very skeptical. But we saw immediately that these grains are remarkably different [from the ordinary ones], even at the level of digestibility ...

Besides S. B., other scholars<sup>4</sup> joined the initiative at the very start or a bit later. A member of the Municipal Council, P. D., was an agronomist and was involved in the meetings quite soon.

Thus, a consensus space involving what can be considered possible helical actors started to develop despite the initial skepticism, thanks to researcher’s preliminary and tentative boundary-spanning action. Prof. S. B. played as a locally embedded researcher and sustainability activist and as a broker of scientific and technological knowledge developed in nearby research structures of the university. As the agronomist of the bread chain<sup>5</sup> put it:

There was a co-occurrence of elements there: there was G. P. who belongs to a family of millers, he met S. B. [a geneticist at UNIFI] at a meeting, and he was told: “If you want to make a really quality product, you have to put the stone mill back in operation and regrow the old varieties”. He started working. The same was for a baker, friend of him. As well, few farmers in



the area started sowing the old varieties. Then, the concomitance was that in the territory of Montespertoli there is Montepaldi [experimental farm of UNIFI] that had the old varieties, without using them. In those years, 4–5 years ago, there was as town council member [of the municipality of Montespertoli] P. D., also an agronomist, and she helped.

The miller involved a backer in a meeting with S. B., and as remembered by the backer:

The one who made the change: the meeting with S. B., the good fortune of an hour of lesson. [...] Lucky to have an hour of someone explaining something passionately to make you understand that things are possible

The miller and the baker accepted the challenge of an entrepreneurial discovery action based on an emerging innovation gap. On their turn, they persuaded a few farmers, already clients of the mill, to try cultivating ancient wheat varieties. Producing the ancient wheat varieties started, and local bakeries began to produce bread from them despite the technical difficulties.

The town council member, in touch with the coalition, gained the support of the local administration, as remembered by the miller:

The town council member, [...], immediately believed in this project and introduced it in the school canteens of Montespertoli: here both bread and pasta that children eat [are made from] ancient grains.

To introduce bread from ancient wheat varieties in local school canteens, the local municipality devised procurement rules as specific as possible to the local product, highlighting the connection with the civil society.

Therefore, civic society has been integrated into the project as the nutritional qualities and the sustainability of the bread were deemed a direct opportunity for the local community. Table 1 summarizes the role of the different helical actors, highlighting those that we can consider amphibious and those external but related to the Montespertoli chain.

### 6.3 *Emergence of HAOS and Quintuple Helix Coalitions*

Indeed, what we see at the beginning of the local helical processes is a triple helix carrying quintuple helix identities. After some years (from 2008), the actors must provide a stronger structuration to their initiative. A central role in linking the different actors (university, local municipality, and chain actors) was assumed by the Association of Ancient Grains of Montespertoli (*Associazione Grani Antichi Montespertoli*, henceforth the Association) founded in 2014. The

TABLE 1 Quintuple helix actors in the Montespertoli bread chain

Actors	Description
Research institutions	The University of Florence (plant geneticist*, plant pathologist, food technologist, economist), <i>ETS</i> (Tuscan Seed Body)*
Producers (Industries)	Miller, backers, Farmers*, Agronomist*
Public bodies (Government)	Municipality of Montespertoli, <i>Tuscan Region</i> , <i>CREA</i> (acting as inspecting body for seed legislation), local schools*
Civil society actors	<i>GAS</i> (ethical purchasing groups), local schools* (as pupils and parents), <i>ETS</i> *
Ecological actors	Farmers* (acting in direct touch with natural environment as object of their daily operation), Geneticist* and Agronomist* (for their fondness on agrobiodiversity conservation), <i>RSR</i> (Rural Seed Network)

Note: external actors in italics, \* signal amphibious actors.

SOURCE: AUTHORS' ELABORATION

town council member was a founder and a strong promoter and is now president of the Association.

The act of constitution of the Association clearly stated the following:

“born with the purpose of recreating a virtuous chain, missed in past years, among farmers, millers, bakers, pasta makers and consumers, with all activities performed paying maximum respect to Nature,” *another goal being* “to promote innovation within the chain, experiencing new solutions also in agreement and in collaboration with the university.”

We suggest that this Association presents features of a Hybrid Autonomous Organization. In 2021, the Association changed its name into “Food Community of the ancient grains of Montespertoli”,<sup>6</sup> exploiting the national law on biodiversity 194/2015, which provided some funds for initiatives aimed at raising awareness among the population, supporting agricultural and food production, and promoting behaviors protecting agrobiodiversity. The transformation allowed to strengthen links also with civil society as stated by the current (2023) President of the Association:

there were some positive developments [...] we linked consumers to us and [...] they proved to be much more active than some farmers members.

This was the most interesting thing for me: now consumers actively participate, they are inside the board and go to all the participatory guarantee visits.<sup>7</sup> Something we have never been able to do before

The law specifically foresees this interaction of farmers, chain actors (including consumers), universities, and local administrations within the communities. Indeed, the idea of a Food Community helped relaunching the initiative after the stop imposed by the pandemic.

A specific role within the Association was entrusted to the agronomist with experiences in bread chains and organic agriculture in other Italian rural systems. Although she has never held official positions within the Association, she has always played a role in recognizing the gaps between farmer practices and the scientific methodologies proposed by the university. She contributed to intensify the relations between producers and researchers:

I've had quite a role to intensify [the relationship with the university], to say that we have working minds, we have open minded people, researchers interested and willing to make links to our reality

#### 6.4 *Multi-Level Processes*

Like the case of the re-introduction of wheat for breadmaking in the Netherland described by Wiskerke (2003), the Montespertoli initiative should be considered a niche constrained by the prevalent sociotechnical regime centered on conventional agriculture. Meanwhile, the low yield of ancient varieties posed a threat to the economic sustainability of the chain, while the national and EU seed legislation were a barrier to the cultivation of these varieties (see the Appendix).

As for the threat to the economic sustainability of the chain, a sort of administered price scheme was initially set up with the support of the miller.

This created a protected environment to experiment new wheat varieties, as acknowledged by the President of the Community:

Being sure of the purchase, the farmers started doing something they had never done. [...] then they enjoyed the idea to be able to produce and reproduce their own seeds and making a different product, which you knew where it ended up.

The low productivity was later addressed by introducing wheat varieties rising and stabilizing the crop yield, although not at the commercial variety levels (see below). Although the low profitability of ancient wheat cultivation only partly relates to low yields, the Association promoted a series of social

innovation initiatives flexible enough to adapt to an ever-changing productive context. The price, which covered cultivation costs in years with average yields, was over three times higher than the current price for conventional wheat and gave rise to an equitable distribution of value added among farmers, millers, and bakers (Sacchi et al., 2019). Then, when unexpected high yields materialized in 2019, stretching the ability of the miller to process all the wheat, a pro-quota system was introduced to guarantee all historical members of the Association a minimum quantity of wheat paid at a fixed price. The quota system was developed with the aid of a university researcher who was also a member of the Association of the Ancient Grains. Currently, an administered allocation of seeds and land areas to the cultivation of ancient varieties is still in place to prevent imbalances between the demand of wheat for baking, production, and processing capacity of the mill. Although this prevented new entrants from selling most of their wheat to the miller at the administered price, it also stimulated new solutions to maintain the innovation pace of the initiative. Some young farmers, recently enrolled in the Association, started to press for new organizational arrangements:

[young farmers/new entrants] want the farmer himself being possibly the one who sells the finished product [...] ... a first step could be the acquisition of [bread from] the bakery by farmers and then in the future that of [flour from] the mill. ... so they're moving in this direction here [G. P., miller].

At the beginning, the case was a niche constrained by the legislation, but later they could exploit the waivers provided by the same seed regulation (see the Appendix). Indeed, farmers initially resorted to informal sources of seeds, mainly reproducing the local varieties they cultivated by themselves, a practice whose legal status was uncertain, while a formal legitimation would have requested the certification of the seeds of the old wheat varieties.

Thanks to the Association of the Ancient Grains of Montespertoli, a project to transform one member of the chain into a seed company for producing seeds of legally registered “conservation” varieties was presented, with the help of UNIFI, to the Regional Government of Tuscany under the Rural Development Program. The project was eventually funded by the Tuscany region in 2017.

Now, the Food Community is the “responsible for the conservation” (a figure envisaged by the legislation, akin to the breeder of commercial varieties) of five conservation varieties: apart from Andriolo, a true local variety cultivated in Tuscany for centuries, the other varieties were created by breeders before the Green Revolution (Porfiri, 2015). Some of the conservation activities are

carried out by the Ente Toscano Sementi, a not-for-profit institution (in partnership with the Chamber of Commerce of Florence, the agricultural consortia of Florence and Siena, bank foundations and UNIFI), an example of amphibious actor external to the local system. Other conservation activities and the reproduction of seeds are under the responsibility of the farmers of the Food Community. Another external actor facilitating the innovation was a national public research organization, the CREA (Council for Agricultural Research and Analysis of the Agricultural Economy):

Then with the setting up of the seed system we also started contacts with CREA, and we found this excellent researcher [A. S., inspector of CREA] ... [F. C., Agronomist]

We have already recalled that the initiative initially coped with the low-yield productivity barrier to re-introducing ancient varieties by setting up a system of administered prices within the chain. Afterward, the chain interacted with UNIFI's researchers in the experimental testing of wheat evolutionary populations (i.e., cross-breeding of varieties), combining the sustainable characteristics of ancient varieties with higher and less variable yields. Such populations are now reproduced by farmers yearly and "evolve" by selecting the genotypes more adapted to the local context, while less performing genotypes reduce their weight in the population or disappear.

The management of the barriers posed by seed legislation was facilitated also by some actors related to networks of similar initiatives in Italy, such as Network of Rural Seeds (*Rete Semi Rurali*), a pro-environmental and pro-peasantry NGO providing agency to micro initiatives that, thanks to its international reach, has access to EU funds for participatory research on sustainable agriculture. Thus, the Montespertoli chain docked in other initiatives, being a sort of point of reference, as the miller stressed:

Montespertoli is considered one of the most important chains ... I don't know, you can say avant-garde, in short, one of the chains to look at, let's say, to keep in mind as all the supply chains took us as an example. ... Everyone goes in this direction currently but at the beginning it was not like that.

Overall, the value chains of ancient grains have grown across Italy in recent years. In 2015, the Network of Rural Seeds listed about 23 local short chains scattered across Italy (*Rete Semi Rurali*, 2015); since then, the interest in ancient grains has steadily increased.<sup>8</sup> About 50 conservation varieties have

been inscribed in the national register since its inception, mostly in recent years, although in 2018, seed production was still limited to an area of about 130 hectares<sup>9</sup> because most farmers self-reproduce their seed (Bocci, 2019).

Therefore, an evolving path is observed assuming multi-level and multi-territorial dimensions, with the engagement of not purely local actors, such as, in our case, the regional government, CREA, and the Network of Rural Seeds. Networking also helped to accumulate specific knowledge around the innovation and assumed a more explicit quintuple helix structuration.

## 7 Discussion and Conclusions

With the present work, we first pointed out a gap in the scientific literature regarding the analysis of the specific actors and dynamics of the quintuple helix model, given the complexity of the relationships between the various components of the quintuple helix structure.

Therefore, we have proposed to consider the fifth helix as a set of specialized functions and types of actors, which can emerge in an evolutionary setting and contribute to co-innovation dynamics, where some actors of a specific LPS start to explicitly incorporate environmental-sensible challenges and opportunities in their daily practices. We proposed a possible taxonomy of organizations identifiable with the quintuple helix by associating them with ecological actors directly incorporating instances of the environment and a conceptual framework, allowing in-depth exploration of how these actors and their relationships can trigger a place-based sustainability transition.

Particularly, our case study on the Montespertoli initiative is an example of how niches of agronomic innovation supporting sustainability transition may develop in specific local systems, attributed to emerging quintuple helix processes and coalitions. Also, it exemplifies how the niches' expansion can be expressed in their docking in an increasing number of other local systems. The Association (now Food Community) of the Ancient Grains of Montespertoli always refused to scale up the initiative by increasing its size. Within our conceptual framework, the risk of jeopardizing the local nexus and the consensus space built around the civic attitudes and the community's cultural heritage could be its plausible reason. Nonetheless, the Association has always been keen to help other initiatives to start elsewhere. At least two more initiatives stemmed directly from the Montespertoli initiative in Italy. One is in Montesegale, a village in the Lombardy region where two inhabitants of Montespertoli moved.<sup>10</sup> The couple convinced local farmers to start cultivating

ancient grains there, with the help of the Montespertoli agronomist. The other is Grani Antichi FVG,<sup>11</sup> an Association of farmers then transformed into a cooperative, which produces stone-milled flour and bakery products from ancient grains in the Friuli Venezia Giulia region. The founder of this initiative spent a period of his life in Montespertoli working in a bakery and then brought back to his home region the model of Montespertoli, with the help of the Association Ancient Grains.

We have seen that, following the collaboration between universities, producers, and local administration, the chain adapted to adverse environmental and economic conditions developing flexible institutions while maintaining a high level of consensus among the different actors. As other instances of successful sustainability initiatives, producing ancient wheat varieties requires “reconfigurations on human capital and social capital,” the substitution of some local knowledge and skills, and the “productive use of people’s capacities to work together to solve common agricultural and natural resource problems” (Pretty, 2005: 2). The process started around a triple helix logic carrying informal quintuple helix identities and met soon local communities and environmental needs. These needs were progressively subsumed by specific actors with ecosystem or bioeconomy expertise and hybrid organizations, again operating at various territorial functional levels, like the local Association of Ancient Grains, the officers of the Regional Rural Program, and the Network of Rural Seeds at the national and EU level. This multi-level development also helped engage specialized actors of the fourth and fifth helices, confirming the usefulness of explicitly considering a broad though evolving agency base.

In our view, this application to the Montespertoli initiative confirms the interpretative value of the proposed conceptual framework on the emergence of quintuple helix partnerships in LPSS facing sustainability transitions. Indeed, the main contribution of the paper lays precisely in the explicative power of a framework that connects together an evolutionary perspective and the agency dimension of quintuple helix coalitions in the context of LPSS intersecting processes of sustainability transition.

It would also be interesting to return to the tensions recalled in the introduction and in the first Section between TH and quadruple & quintuple approaches (Carayannis et al., 2021). Indeed, entering effectively onto those tensions would require further elaboration on theoretical and methodological foundations (Cai and Amaral, 2022), which are not the aim of this paper. Nonetheless, we may extract a sort of confirmation on the viability to follow a middle-ground route (Amaral et al., 2020; Cai and Lattu, 2021). Even if single effective innovation partnerships and processes need to start from some

robust underlying triangular structures (Etzkowitz and Zhou, 2006; Leydesdorff and Lawton Smith, 2022; Maruccia et al., 2020), our conceptual-guided empirical exploration contributes to an understanding that contexts in which helical structures develop interrelated, transformative, and heterarchical dynamics may host results qualitatively different from those of contexts based on purely classical TH dynamics, and possibly more in line with needs of sustainability transitions. Furthermore, it appears that those dynamics can be studied empirically.

Our study is limited by analyzing only one representative case, which diminishes the possibility of results' generalization. Therefore, while future research might apply the framework to other empirical contexts adopting multiple-case techniques, it could also expand theoretical research on agency and evolutionary processes combination within helical models and theories.

### Notes

1. A complementary analysis focused on the cooperation mechanism is referred to in Stefani et al. (2017) and in Sacchi et al. (2019).
2. The participatory observation of organization activities also involved the participation in activities like Association assemblies and chain public events, including informal discussions conducted with the miller and baker and involved agricultural scientists to explore their points of view on the unfolding of the experience.
3. Currently the initiative involves more than 40 farmers, 3 bakeries, and 2 mills.
4. One scholar of UNIFI, a food microbiologist, was also resident in the village.
5. A pro-environmental technician herself for his past experience in the organic agricultural office of the county government of the nearby province of Siena.
6. See the community web site at <https://graniantichitoscani.com/it/>.
7. A participatory guarantee system (Sacchi, 2019) was put in place to assure the compliance with the Community (former Association) Disciplinary for wheat cultivation, milling, and baking. For organic farmers the participatory guarantee is a tool to make consumers familiarize with wheat farming.
8. A simple search on Google trend shows that searches for "*grani antichi*," the Italian term for ancient grains, increased sixfold from 2015 to 2022.



9. A figure that corresponds, on average, to a total of about 230 tons of seed in turn allowing the cultivation of about 1500 hectares.
10. See: <https://www.georgescuroegen.org> (accessed 9 June 2023).
11. See: [https://www.facebook.com/GraniAntichiFVG/?locale=it\\_IT](https://www.facebook.com/GraniAntichiFVG/?locale=it_IT) (accessed 9 June 2023).

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### Appendix: The Regulatory Environment of Ancient Wheat

When the initiative on ancient grains in Montespertoli took shape, the European seed legislation was a complex and articulated institutional structure dominated by the support to conventional wheat varieties developed during the Green Revolution of the past century to enhance yields, ease mechanization, and improve the technological properties of flour.

Indeed, the EU legislation inherited and developed regulatory frames that, from the beginning of 20th century, have been applied to the seed market in several European countries to pursue productivity gains. Meanwhile, the work of breeders was oriented toward uniform and more productive varieties that have exploited the potentiality of new mechanical and chemical inputs (Winge, 2015, Wiskerke, 2003). Meanwhile, a mandatory licensing and certification system dealt with information asymmetries reducing commercial frauds, such as the marketing of seed in bad phytosanitary conditions or not corresponding to the advertised variety.

The EU seed legislation is currently based on two pillars: i) to be commercialized, wheat varieties should be recorded in a variety register and go through a certification process; ii) to be registered, a commercial variety should demonstrate specificity (being different from other varieties), uniformity, stability (maintaining essential characteristics after being reproduced several times), and agronomic value (usually this means high yields, resistance to pathogens, and good technological characteristics). Therefore, seed companies are subject to a strict regulatory regime and must apply for a license to sell seeds. Certification of seed is implemented by specialized institutions with field inspections and laboratory tests. Since each crop differs in standards of purity, germinability and phytosanitary conditions are applied according to specific norms.

The European seed market regulation's productivist approach changed in 2008 when a new type of crop variety, the so-called "conservation" variety, was acknowledged to facilitate in situ conservation of crop agrobiodiversity by cultivating local crops in the areas of origin. For these varieties, just a minimum degree of uniformity is required for identification. Indeed, a certain heterogeneity is deemed important for conserving these varieties, often at

risk of extinction. Moreover, agronomic high value is unnecessary since the conservation purpose. In any case, seed commercialization is reserved to officially registered seed companies. More recently (Decision 2014/150/UE), the EU Commission waived the commercialization of wheat evolutionary populations of varieties, attributed to the results of cross breeding between local varieties, yielding the sustainable characteristics of ancient varieties with higher and less variability. Finally, the new Organic agriculture legislation (Reg. 2018/848) has made possible the commercialization of heterogeneous organic seed material, a category that includes wheat mixtures and populations for organic agriculture.