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ARE CLUSTERS AND INDUSTRIAL DISTRICTS REALLY DRIVING SUSTAINABILITY INNOVATION?

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Abstract: This study explores and conducts a critical literature review in order to answer a fundamental question in the industrial district literature: how can clusters and industrial districts (clusters/IDs) move on towards sustainability? By intersecting different yet related strands of literature, we take stock of what we know about sustainability innovation in clusters/IDs. Insights point out that the sustainability innovation process (development and diffusion) in clusters/IDs and their firms couples into mainstream cluster/IDs framework; clusters/IDs enable sustainability innovation through usual mechanisms, fostering collective change towards sustainability innovation, vis-à-vis other settings, and strengthening firm sustainability innovation and performance. Sustainability innovation in clusters/IDs requires coupling different multi-scalar institutional systems effectively, and cooperation of local organizations and policymakers for co-designing dedicated policies. Collective actions are important and firm heterogeneity needs to be considered in the clusters/IDs framework.

1. Introduction

Sustainability-oriented or environmental innovations are new ideas, behaviors, products and processes or technologies that contribute to achieving sustainability targets (e.g. Rennings, 2000: 322). At the firm level, they represent sources of competitiveness, competitive advantage and performance (e.g. Aragón-Correa & Sharma, 2003), especially for organizational resilience and long-term performance (Ortiz-de-Mandojana & Bansal, 2016). For territories, it is considered an environmental upgrading (e.g. Ponte et al., 2023), improving territory competitiveness (e.g. Barakat, Tipi and Wu, 2023; Kamath, Elola & Hermans, 2023; Ratten, 2018; Grimstad & Burgess, 2014).

Research on clusters and industrial districts¹ (clusters/IDs) transition to sustainability is growing, but it is still in its infancy (e.g. Grimstad & Burgess, 2014; Arbolino et al., 2018;

¹ For the sake of brevity, we use the terms clusters and industrial districts without distinction, albeit recognizing differences.

Hansen & Coenen, 2015; Ponte, De Marchi, Bettiol & Di Maria, 2023). Broadly, different strands of literature intersect this debate: from the cluster literature (e.g. Zen et al., 2022; Ratten, 2018), Evolutionary Economic Geography (EEG) and Regional Innovation Systems (RIS) (e.g. Kamath, Elola & Hermans, 2023; Steinböck & Trippel, 2023; Trippel et al., 2020; Truffer & Coenen, 2012), and from the managerial perspective exploring co-located firms in clusters at the micro-level (e.g. Díez-Vial, Belso-Martínez & Martín-de-Castro, 2023; Sunny & Shu, 2019; Martinez-del-Rio & Cespedes-Lorente, 2014). Connecting them and building upon these different yet related perspectives that address regions, clusters and cluster firms, we conduct a critical literature review in order to understand how sustainability innovation couples into clusters/IDs framework. We focus primarily on the study of sustainability in the clusters/IDs framework as a process of new knowledge development and diffusion in a spatially-bounded context that favors innovation, attempting to assess whether clusters/IDs mechanisms enable sustainability innovation. In doing so, we attempt to incorporate sustainability innovation into the mainstream framework, analyzing when, why and how sustainability innovation is activated in clusters/IDs. The study present implications to enrich scholars on the topic, fosters more effective policymaking and supports managers' decision making process on the topic. Overall, this study contributes to the clusters/IDs literature.

In doing so, we are answering important questions, such as: Are clusters really driving and enabling sustainability? If so, what are the mechanisms at play? Do clusters/IDs exert an effect on cluster firms' sustainability practices? What policymaking works for promoting sustainability innovation in clusters/IDs? Our approach prevents the fragmentation of literature, cross-fertilizing different yet related strands to move the topic of sustainability innovation in clusters/IDs forward, clarifying scholars' research on this sub-line of inquiry and thus supporting policymakers' agendas in designing new sustainability-oriented initiatives. Overall, this study contributes to clusters/IDs literature (Becattini, 1990; Belussi & Hervás, 2016) with the purpose of expanding it towards the new topic of sustainability innovation.

2. Territories for sustainability-oriented innovation: a regional perspective on collective actions

Understanding clusters and sustainability-oriented practices in territories originate from the sustainability -transition -studies (Brigde et al., 2013; McCauley & Stephens, 2012)

opening a debate on EEG (e.g. Hansen and Coenen, 2015) that has led to the explanation of how green path development occurs in regions, both empirically (e.g. Steinböck & Tripl 2023; Sotarauta et al., 2021) and theoretically (e.g. Tripl et al., 2020; Grillitsch & Hansen, 2019).

Zooming into clusters, it is said that the geographic and institutional context influences innovation and eco-innovations (e.g. Ratten, 2018). Addressing cluster collective actions as distinct from the firm-level analysis in clusters, studies are scarce and mostly based on qualitative methods (see Kamath, Elola & Hermans, 2023). In particular, as Kamath, Elola and Hermans (2023) point out, cluster literature does not offer a guide to move clusters into sustainability, nor has it developed a policy debate to support this process (Sjotun & Njos, 2019). Ratten (2018) studies the importance of eco-innovation for wine firms in the cluster of Barossa Valley for being globally competitive leaders based on environmental innovations, linking clusters and eco-innovation and showing that embeddedness and social ties facilitate a collective sustainability innovation orientation. Similarly, Grimstad and Burgess (2014) show a wine cluster in Australia involved in a greening path collective action (launched by the Lovedale Chamber of Commerce) to improve the cluster's competitive advantage. This is done by promoting, at the cluster level, a brand that reinforces the regional identity and competitive advantage by positioning the focal wine cluster as greener, diversifying into new tourism activities. These collective visions and actions, through distributed activities, develop collective and common understandings. In a similar way, Zen et al. (2022) show the individual and collective efforts to foster sustainability at the *Serra Gaucha* wine cluster in the South of Brazil. This work especially shows the complexity of the different levels of analysis (micro-, meso- and macro-level) and the different types of actors involved, suggesting that the orchestration (coupling) of all these different layers, that is, *multi-actor* and *multi-scalar institutional context*, is required for a sustainability-oriented change.

This idea of collective efforts resembles that of *system-level agency* (see Steinböck & Tripl, 2023; Isaksen et al., 2019; Jolly et al., 2020; Sotarauta et al., 2021), understood as a collective activity to adapt, through a collective vision, an innovation system (and its networks, institutions, etc.). This shift is usually conducted by different firms and non-firm actors (*multi-actor* perspective), in this case for greening paths (e.g. Sotarauta et al., 2021). For instance, civil society, along with trust-based regional collaborations, remains

crucial to understand greening of the mature metallurgical and chemical industry in Southern Norway (see Kyllingstad & Rypestøl, 2018). Similarly, civil society is said to be very important in the case of Prosecco transition to sustainable environmental practices (see Ponte et al., 2023).

Addressing greening paths from an RIS perspective, as Trippel et al. (2020) point out, the green regional industrial path development process is a framework from a modification of the regional asset base through different types of agency performed by multiple actors at various spatial scales. We contend that addressing clusters/IDs sustainability, the process is quite similar to that discussed for the RIS approach, constituting a reference point that can be useful.

Researching this *multi-actor* approach, Sjøtun and Njos (2019) discuss how to achieve green reorientation of clusters and how policy can support this, tackling a major gap in the literature, identifying two ‘routes’ to the reorientation of clusters – a ‘neutral’ and a ‘normative’ route – and arguing that policy is very important for sustainability purposes. The “neutral” is said to be ‘organizationally dominated’, implying that the organizational dimension has been the most influential, with an absence of active collective policies to reorient the cluster to greener domains. The ‘normative route’, however, is based on a deliberated and active top-down policy. In any case, the combination of both, where organizations and policymakers co-design and cooperate in a bottom-up approach, can be much richer for stimulating a greener reorientation.

Evidence from clusters/IDs adopting collective actions is well noted. For instance, the cluster of *S.Croce sull’Arno* in Tuscany is the largest tannery cluster in Italy, providing 35% of the country’s production of tanned leather and 98% of the country’s production of sole leather. Due to pressure from the local authorities, local communities and the influence of the customers they serve (e.g. Gucci, Armani, etc.), the local cluster has developed, in around 30 years, *collective actions* to adopt green innovations such as the *Aquarno* wastewater treatment plant (a public-private consortium consisting of a majority of private companies and the body which manages the S. Croce sull’Arno water treatment plant) and the *Ecoespanso* plant (sludge recovery plant), focused on recovering the sludge of the *Aquarno* wastewater treatment plant that flows through a specific pipeline (Daddi, Nucci, Iraldo, 2017). Similarly, as shown in wine clusters, these collective initiatives are

embedded in the territory, that is, they represent a collective effort shared by most of co-located firms as part of legitimacy and embeddedness. As Ratten (2018:325) points out, quoting interviews from local businessman in the Barossa Valley (a wine making district in Australia), respondents enhance the sense of belonging and community and the collective gains:

We need each other, it is a community here. All businesses are linked. We compete but we are friends. It is a small community. (Participant 5)

Eco-innovation as you say is becoming more popular for marketing our Barossa Valley wine overseas. (Participant 9)

In the same line of thought, Grimstad and Burgess (2014:565), for a tourism cluster, point out (from interviews) the importance of collective visions:

You know of course, we get it (environmental knowledge and motivation) from each other. But more and more now people are talking about it, at any social events [...]. Everyone is fundamentally motivated to do the right thing, by the environment, because we want our places look good and also to leave the place better than we found it (Joan Accommodation Provider).

As observed, and following Russo (2003), there is a *social* element that drives and influences institutional conformity and shares collective visions of local industries, facilitating to adopt environmental practices, as their efforts are improving the local image and can foster gains for all the community, thus constituting a local competitive advantage.

This convergence of collocated firms, however, also presents signals of heterogeneity, especially among the core and the periphery, from a network perspective. In fact, as Ponte et al. (2023) evidence, cluster heterogeneity also applies for environmental upgrading, understood as showing different sustainability practices in the same territory (Prosecco and Valpolicella districts) such as embracing certification, back to tradition, technological innovation (e.g. using precision viticulture, ecological materials for packaging, etc.) and even local politics (e.g. banning the use of glyphosate by local communities). Local firms, therefore, not only choose one single approach but many ways to pursue greener practices that will be subsequently disseminated in the territory.

For the case of the Basque pulp and paper bio-cluster, Kamath et al. (2023) empirically evidence that agency matters for cluster green restructuring: technological-

entrepreneurship (product and process innovation), institutional-entrepreneurship (institutions adaptation) and place-leadership (aligning visions). Kamath et al. (2023) show that firms and the cluster organization are the most important actors, pointing out that different greening paths might occur in a cluster, along its different stages of evolution for sustainability, and not necessarily only one.

Finally, from a regional policy perspective, Grillitsch and Hansen (2019) elaborate on providing a rationale for identifying place-based policy implications for growing green industries in different types of regions, exploring the pathways for greening the economy in different regional contexts and how such green pathways can be promoted through policy. For instance, in the case of peripheral regions, it seems that path upgrading, in the sense of increasing knowledge intensity in the industry and attracting higher-value added activities for new sustainability-oriented activities, is the most suitable path development possible. This would be focused on developing a shared green vision among multiple actor groups; establishing and promoting green policy rationales and providing direction for that. Similarly, Trippel et al. (2020) elaborate a framework that explicates how regional preconditions in the form of pre-existing industrial structures, organizational support structures, institutional set-ups, and natural assets are transformed into various types of green path development through agentic processes of asset modification. Green paths are those known, such as path renewal, creation, importation, and diversification. In this perspective, agency matters and the multi-scalar institutional contexts also influence regional green development, along with place- and path-dependency. Greening paths can be achieved by system-level agency undertaken by different actors but can eventually end up in “maintaining agency” securing the persistence of existing structures (e.g. Sotorauta et al., 2021; Trippel et al., 2020; Steinböck & Trippel, 2023), that is, cognitive inertia and lock-in (e.g. Glasmeier, 1991).

3. Firms in clusters/districts: sustainability-oriented innovation at the micro-level

3.1 Marshallian framework: an overview

According to mainstream literature, clusters and industrial districts present features that promote knowledge circulation and spillovers among co-located firms. These geographical settings circulate knowledge and information faster than other non-agglomerated settings. There are intense and repetitive inter-firm and personal

interactions. Most of the industry value chain or the supply chain is encountered in the same geographical settings, therefore, interactions are the usual business. Moreover, there is a social dimension characterized by social norms, trust, and personal ties. These social ties, usually fueled by personal ties, constitute a reinforcing mechanism that also supports the inter-firm interactions and reduces transaction costs. Accessing know-how, know-who or other types of tacit knowledge is easier for local firms, vis-à-vis firms non-co-located in clusters. Local firms also share a sense of belonging that reduces opportunistic behaviors. Overall, *embeddedness* promotes knowledge circulation and recombination (à la Kogut and Zander, 1992) among local networks that foster innovation (e.g., Becattini, 1990; Piore & Sabel, 1984; Porter, 1990; Poudier & St. John 1996; McEvily & Zaheer, 1999; Belussi & Hervas-Oliver, 2016).

Local networks, based on a combination of competition and cooperation, are a very important vehicle of knowledge diffusion and dissemination. These networks are usually orchestrated by leading firms that disseminate technology and knowledge along production and innovation activities and also perform technology gatekeeping activities (e.g. Lorenzoni & Lipparini, 1999; Hervas-Oliver, 2021). Local firms need legitimacy to access the tacit knowledge that circulates along these networks (Scott, 1992: 16). This tacit knowledge is based upon trust, reciprocity, and socially accepted norms that reduce opportunistic actions (Becattini, 1990; Saxenian, 1994; Bellandi, 1996).

Social ties, embeddedness, and legitimacy reinforce the strong collective identities that are supported by accepted institutions, producing *institutional isomorphism* (DiMaggio & Powell, 1982). Thus, collocated firms present similar paradigms and understandings about technologies, markets, business practices, or social norms, forging a *who we are* or “shared understanding of the basic industrial, technological, social and institutional features of a cluster” in the sense of Staber and Sautter (2011: 1350). The idea *institutional isomorphism* (DiMaggio & Powell, 1982) is typically encountered in industrial districts and clusters (see Poudier & St. John, 1996; Morrisson & Rabelloti, 2005; Zucchella, 2006; Tan, Shao, & Li, 2013; Molina & Martínez, 2009), albeit using different constructs such as collective identity (Staber, 2009).

This *imitation* is also possible because monitoring competitors, especially local ones, is easier for co-located firms. Thus, co-located firms also present more competitive pressure, as most direct competitors are co-located (Porter, 1990; Saxenian, 1994; Pouders & St. John, 1996). Co-located competitors monitor each other, search for legitimacy and also converge through imitation. As Bell and Zaheer (2007) point out, institutional-level ties are valuable in knowledge transmission *only* when such ties are geographically proximate.

3.2 Does sustainability innovation couple into the Marshallian framework?

3.2.1 The firm level: heterogeneity in clusters/IDs

[Table 1 here]

How is the micro level addressed when researching sustainability innovation in clusters/IDs? As observed, the traditional drivers of environmental responsiveness offered by Bansal and Roth (2000), that is, competitiveness, legitimation, and ecological responsibility, are combined with innovation frameworks from innovation management (i.e. product and process innovation, collaborations, firm capabilities, R&D, etc., e.g. Díez-Vial, Belso-Martínez and Martín-de-Castro, 2023). As Grimstad and Burgess (2014) have evidenced, firms' attitude towards sustainability (e.g. responsibility, credibility, strategy, etc.) and firms' attitudes towards innovation are very important to understand sustainability-oriented practices in cluster firms. In any case, the Marshallian framework (e.g. networking and cooperation, network closure, etc.) mechanisms do support sustainability innovation. For instance, Díez-Vial et al. (2023) research on product- and process-based eco-innovations, using primarily drivers such as collaborations with suppliers and supporting organizations, while Martínez-del-Río and Céspedes-Lorente (2014) measure the (dependent) sustainability variable as *utilization of natural environmental arguments in marketing; conducting environmental quality audits regularly*, etc. Then, for the independent variables, *networking embeddedness* or *collaboration with local supporting organizations* stand out.

A cluster effect or positive relationship is evidenced between collocation in clusters and performing firm eco-innovations (Díez-Vial et al., 2023; Martínez-del-Río & Céspedes-

Lorente, 2014). Put differently, the spatial context positively influences firm green innovation. In addition, we also observe *asymmetric gains* and heterogenous strategies. This means that the cluster effect impacts on a firm's eco-innovation performance depending on different firms' innovation capabilities and their specific types and intensities of innovation activities (collaborations, R&D, etc.). For instance, Martínez-del-Río and Céspedes-Lorente (2014) show that rivalry pressure and competitor monitoring, interaction with collective actors (industry associations), and network embeddedness positively link cluster firms to sustainability orientations, signaling the important strength of the high closure network in clusters, disseminating eco-innovations. Eco-innovations are diffused within clusters but not all firms gain the same. In the same line of thought, Díez-Vial et al. (2023) explore how green innovation impacts on a firm's performance in the Spanish footwear industry, along with the moderation exerted by geographic concentrations on that relationship. This is done by using a sample that contains different cluster densities in geographic settings that depict agglomeration (size of clusters) (e.g. Shaver & Flyer, 2000). The study evidences that green innovation has a curvilinear relationship with firm sustainable performance, an inverted U-shape, that suggests that green innovation is less profitable above a certain threshold. The study shows that there is a cluster effect on green product innovations, meaning that the higher the agglomeration density, the higher the probability of adopting eco-innovations. Therefore, we can assert that being located in a cluster improves the relationship between green product innovation and firm performance, and the effect varies across different cluster strengths, albeit the cluster effect on process eco-innovations is less important. All in all, firm-level in clusters matters and heterogeneity is also important.

Belso et al. (2024) empirically evidence that clusters do exert a relevant role on green innovation. A central insight evidenced in that study is that not all clusters influence green innovation equally but this will depend on their specific institutional quality, especially their informal institutions, in this case the *right thing to be done* (going green). The national regulatory system, that is, formal institutions in the country where the cluster is located (depicting regulations, mandates, etc.) *per se* is not significant except when the informal institutional context of the cluster plays a role of diffusion amplifying its effect: when national institutions in a country are green-oriented, then clusters leverage that effect on firms' green innovation depending on their (informal) institutional quality. Put differently, the cluster effect *per se* is not enough: the national level needs to be

considered and the quality of the institutional setting of the cluster appropriate, showing the importance of *coupling* different multi-scalar institutional systems for greening paths, as highlighted in regional literature (see Tripl et al., 2020).

Similarly, Martínez-Pérez, García-Villaverde, and Elche (2015) empirically evidence that knowledge exploration strategy is a key driving force through which firms located in cultural tourism clusters can take advantage of the potential of bridging capital in order to develop eco-innovations. Put differently, exploration strategies (*à la March*) to access technology- and cluster-distant knowledge positively impact the development of eco-innovations. This study evidences that for radical innovation to occur, local knowledge is not enough for eco-innovations. Those firms that can combine local and external-to-the-cluster knowledge are better equipped for developing eco-innovations. This approach avoids the problem of redundant information and the block-in of bonding capital that exists in clusters, that is, too much dependence on cluster-based knowledge might drive cognitive inertia and diminishing returns (see Molina & Martínez, 2009) or over-embeddedness (Uzzi, 1997). In addition, Martínez-Pérez et al. (2015) recommend firms located in cultural tourism clusters not only focus on building local relationships but complement them with external relationships for developing knowledge exploration strategies that can yield better eco-innovation results.

3.2.2. Sustainability innovation: diffusion and limitations

From the studies that have linked clusters to sustainability innovation, it is said that clusters spill over sustainability practices (e.g. reducing energy and water consumption, recycling materials, etc.) among collocated firms. Factors such as *embeddedness* and *interactions* with the local system contribute to developing sustainability-oriented practices, activities, and innovations (Russo, 2003; Galdeano-Gomez et al., 2008; Cainelli et al., 2012; Martínez-del-Río & Céspedes-Lorente, 2014). As clusters foster the circulation of knowledge more rapidly than in other settings, especially among local networks that promote *embeddedness and legitimization*, clusters support the circulation and learning mechanism for accessing new environmental or sustainability-oriented knowledge. Cainelli et al. (2012) suggest that cluster firms are more efficient at producing eco-innovations because of the learning-by-doing in the cluster, imitation, and cost reduction due to the existence of the Marshallian effects (labor pool, suppliers, and knowledge).

The above-mentioned externalities or spill-overs typically encountered in clusters facilitate the diffusion of green practices and eco-innovations by different means, such as imitation, subcontracting, and exchanging knowledge, cooperation, labor mobility, legitimacy or just to responding to competitive pressure from local rivals that are intensively monitored (e.g. Cainelli et al., 2012; Bridge et al., 2013; Martinez-del-Rio & Cespedes-Loriente, 2014; Hansen & Coenen, 2015). In particular, the institutional context (formal and informal regulations, norms, and cognitive aspects) in clusters drives sustainability-oriented practices and eco-innovations (e.g. Ratten, 2018; De Marchi & Di Maria, 2019; Ponte et al., 2023). Therefore, the *cluster effect* facilitates individual and collective generation/adoption of green innovations, vis-à-vis other settings not agglomerated.

Despite the fact that the cluster context facilitates networking and the diffusion of eco-innovation and sustainability-oriented practices, as explained, cluster mechanisms also include *over-embeddedness* (e.g. Uzzi, 1997; Poudier & St. John, 1996), and the problems of over-searching in the focal cluster, and *cognitive inertia* (e.g. Glasmeier, 1991) which might impede radical changes and the adoption of rather exploratory approaches to innovate *à la March*.

Martínez-del-Rio, Pérez-Luño, and Bojica (2023) evidence that, in clusters, the dark side of managers' social capital could undermine benefits due to existing network closure, that is, a high degree of network closure limits managers' willingness to depart from the common practice and activate innovative work practices in their organizations.

As Hervas-Oliver et al. (2019) point out, in IDs local managers imitate other local managers, creating a generalized and accepted way of thinking. In this way, Poudier and St. John (1996:1207) posit that:

“Mental models based primarily on local competitors will be biased toward those competitors; at the same time they will direct attention away from outside competitors. Consequently, as local competitors increasingly dominate the perceptions of managers in the hot spot, competitors outside of the industry will be subject to less rigorous scrutiny...”

Cognitive inertia and even unwillingness to change due to the preservation of (old and unsustainable) local value systems are also observed. Steinböck and Tripll (2023) show how powerful firm incumbents from the fossil-based plastics industry, universities, and

support organisations (intermediaries) work against a reconfiguration of the innovation system, thereby conserving the status quo and impeding full change in bioplastics in Lower Austria. As it is evidenced (p. 741):

Bioplastics challenge the economic positions and business models of old path actors. Incumbents protect their vested interests through various forms of maintenance agency. Together with partners from academia and industry associations (see also section 4.3), they have formed an alliance oriented towards conserving the status quo. This alliance has considerable political power, resulting in the slow implementation and continuous postponing of environmental legislation, and a lax execution of regulations.

4. Integration and discussion of literature

This study's literature review presents different important ideas.

Do clusters drive sustainability innovation?

The answer is yes, they do. The knowledge creation and diffusion mechanisms, including imitation, sustained upon embeddedness and legitimization, move knowledge faster than in other (non-agglomerated) settings. In addition, the sense of belonging, the local identity and the institutional isomorphism drive firms to adopt what others do in the territory, as managers' mental models converge and competition monitoring is pervasive in these contexts. Co-location in clusters is positively related to produce and diffuse environmental innovations and practices, that is, a cluster effect exists, fostering spillovers of eco-innovations through the different cluster mechanisms (knowledge circulation, imitation, embeddedness, networking, legitimacy, competitors monitoring, etc.). I call this *positive isomorphism* (see Hervas-Oliver et al., 2019). Therefore, clusters/IDs really drive sustainability. Cluster firms show more collaborations related to environmental innovations than non-co-located firms, in no small part because interactions and collaboration in agglomerated settings are higher than in other non-agglomerated ones (see Martinez-del-Rio & Cespedes-Lorente, 2014).

Complex adaptation and system-level change: collective efforts

Complementing the interaction between a cluster effect and cluster firms, collective actions, addressing cluster change in sustainability-encompassing multi-actor initiatives, are also important and they can either incept collective-based sustainability-oriented

changes (Daddi, Nucci, & Iraldo, 2017; Ratten, 2018; Ponte et al., 2023) or just inspire specific actors (e.g. firms) to change.

Overall, sustainability-oriented change in clusters, as Kamath et al. (2023) shows, is a *complex* and *adaptive* process in nature, in the sense of Martin and Sunley (2011), that is, non-deterministic and with multiple possible trajectories and outcomes, i.e. greening-paths. In this vein, clusters can be influenced by the type of greening path occurring in their region and they can achieve different types along its evolution (e.g. green path modernization, path creation, etc.). The multi-scalar institutional context and the different policy domains in regions influence cluster green development. As Zen et al. (2022) show, this transition presents different stakeholders' objectives and is shaped by micro-, meso- and macro-level influences. Moreover, other useful constructs, such as agency, path, and place dependency, influence green path development in regions and clusters (Trippel et al., 2020; Kamath et al., 2023). Collective actors, such as cluster organizations, local chambers of commerce, or innovation and technology transfer institutes, are important, along with firm strategies and commitments towards sustainability (Kamath et al., 2023), as they drive the way, support firms, and legitimate change. These collective actors and collective actions observed in sustainability innovation (e.g. Daddi et al., 2017) resemble other initiatives for Industry 4.0 in districts, such as the ones evidenced in Hervas-Oliver et al. (2019) and Hervas-Oliver (2021), where local actors co-designed Industry 4.0 initiatives with policymakers. Similarly, sustainability-oriented change in clusters can be driven by leading firms are usually the ones that drive change (Zen et al., 2022), as corroborated in literature (e.g. Munari et al., 2012).

Firm-level matters in clusters

There is an abundant debate in literature about environmental management and green practices linked to firm innovation (Aragon-Correa, 1998; Albort-Morant et al., 2016). It seems that innovative capabilities are also linked to environmental innovation (e.g. De Marchi, 2012; Karna et al., 2015), as well as collaborations for developing sustainability-oriented practices (e.g. De Marchi et al., 2022). In our clusters/IDs realm, literature exploring cluster firms has also included these firm-level managerial constructs, building upon them (e.g. Martinez-del-Rio & Cespedes-Lorente, 2014), under the premise that a firm innovation capability is positively related to environmental innovations and sustainability-oriented practices. Put differently, beyond the cluster spatial lens, it is

evidenced that firms' attitude towards sustainability (e.g. responsibility, credibility, strategy, etc.) matters. Therefore, we can use this knowledge to elaborate our place-based phenomenon, cross-fertilizing perspective to improve our framework: firms' attitude towards sustainability (e.g. responsibility, credibility, strategy, etc.), not only in the cluster context (meso-level), as evidenced in the managerial approach intersecting clusters/IDs (e.g. Martinez-del-Rio & Cespedes-Lorente, 2014). In addition, local firms and their specific innovation capabilities and strategies are said to be key actors in understanding system-level change in clusters (see Grashof, 2021; Hervas-Oliver et al., 2023). In this chain of thought, focusing on cluster firms becomes necessary, especially attempting to understand the influence of the local context on firms' innovation (vis-à-vis non-co-located firms), as well analyzing how firms' capabilities utilize more or less the advantages and opportunities of the territory for (green) innovation, that is, heterogeneity, asymmetric gains, and strategies to access to local resources, as in the mainstream literature (e.g. Hervas-Oliver et al., 2018a; Lorenzoni & Lipparini, 1999).

Inertia and lock-in pervasive

Despite the usual cluster mechanisms of spillover, it is also necessary to consider some limitations to change and adopt green practices and innovations, such as searching knowledge only in the focal cluster of adscription, a fact that might impede radical eco-innovations that require the emergence of exploration strategies (e.g. Martinez-Pérez et al., 2015). These stylized facts in mainstream literature are supported by ample evidence, accounting for *cognitive inertia* (e.g. Glasmeier, 1991) or *over-embeddedness* (Uzzi, 1997). In this chain of thought, for the case of the bioplastic cluster in Lower Austria, Steinböck and Trippel (2023) evidence how resistive incumbents from the fossil-based plastics industry, academia, and support organizations preserve historically grown system configurations that favor the old unsustainable industry and create barriers to the consolidation of the bioplastics path. This adverse effect responds to pre-existing industrial structures (Hansen & Coenen, 2015), and regional innovation system structures provide enabling or constraining conditions for green regional path development (Trippel et al., 2020).

These elements that influence sustainability innovation in clusters, using the mainstream framework, are listed in Table 2. Table 2 shows some of the most important factors in understanding greening paths in clusters.

[Table 2 here]

5. Conclusions

This study attempts to incorporate sustainability innovation into the mainstream framework, analyzing when, why and how sustainability innovation is activated in clusters/IDs. Thus, this study's scope focuses on understanding *how* clusters/IDs and their firms enable sustainability innovation, attempting to couple this new topic into the clusters/IDs framework. In doing so, we are answering important questions, such as: Are clusters really driving and enabling sustainability innovation? If so, what are the mechanisms at play? Do clusters/IDs exert an effect on cluster firms' sustainability practices? What policymaking works for promoting sustainability innovation in clusters/IDs?

Findings from literature review and analysis indicate that sustainability innovation, despite using new constructs for capturing this specific process (e.g. eco-innovation designs, utilization of natural environmental arguments in marketing; conducting environmental quality audits regularly; natural environmental training, etc.), couples into the clusters/IDs framework. Put differently, the usual mechanisms (collaboration, rivalry, networks, cooperation, bridging, network closure, etc.), does work for activating sustainability-oriented innovation and change, as in other types of innovation (e.g. Industry 4.0, product innovation, etc.). Our analysis shows how the established framework operates with sustainability innovation.

The review of literature and its analysis bring important answers to the phenomenon, as follows. First, is there a cluster effect on sustainability innovation? Yes, studies show how clusters/IDs exert a positive effect on firm sustainability (Cainelli et al., 2012; Sunny & Shu, 2019; Díez-Vial et al., 2023; Belso et al., 2024). Sustainability generation and its diffusion within clusters/IDs is facilitated by mainstream mechanisms highlighted in literature, especially accounting for the effect on (sustainability) innovation of spillover mechanisms (Marshallian externalities): rivalry and competitive monitoring, imitation; embeddedness and legitimization; (positive), institutional isomorphism; networking; and others (spinoffs, labor mobility, etc.), confirming previous literature (e.g. Audretsch & Feldman, 1996; Becattini, 1990; Bellandi, 1996; Oerlemans, Meeus, & Boekema, 2001).

Second, addressing sustainability innovation, is there firm heterogeneity in clusters/IDs? Yes, intra-cluster heterogeneity (different types of firms and green strategies (Ponte et al., 2023) – responsibility, credibility, ethics, Corporate Social Responsibility, etc. – is evidenced. Each firm gains differently (asymmetric gains) in clusters/IDs (e.g. Díez-Vial et al., 2023; Martínez-del-Río & Cespedes-Lorente, 2014); the relationship between green innovation and performance is inverted U-shaped (Díez-Vial et al., 2023, in line with the double externalities problem); there are different types of eco-innovations and each firm pursues them differently (Ponte et al., 2023). As regards firm heterogeneity, that is, the fact that regional changes are driven by firm capabilities (Zhang & Rigby, 2022), our conclusions align with the idea that regional or cluster-level recombination and accumulation of capabilities, in this particular case for sustainability, are driven primarily by specific regional actors, such as leading firms triggering the process. This connects our discourse to the *agents of change* sub-line of inquiry, where specific regional actors drive changes (e.g. Hervás-Oliver et al., 2023; Zhang & Rigby 2022). Put differently, firm (innovation) capabilities matter for understanding clusters, even thinking of the power of some firms in the system-level agency, especially leading firms. This also confirms basic mechanisms about firm heterogeneity and asymmetric gains in clusters/IDs literature (e.g. McEvily & Zaheer, 1999; McCann & Folta, 2011; Hervás-Oliver et al., 2018a) and can even transform territories (Hervás-Oliver et al., 2023; Grashof, 2021).

Third, is sustainability innovation driven by a multi-actor and multi-scalar institutional and system-level change process? Yes, the multi-actor and multi-institutional scalar perspective conjointly sustains system-level change in clusters/IDs (e.g. leading firms – global and local – and collective actors – cluster organizations, research and transfer institutes, trade associations, etc.). In addition, this approach also shows the importance of collective initiatives (e.g. branding a territory as sustainable) in clusters/IDs for greening paths (e.g. Zen et al., 2022; Kamath et al., 2023; Daddi, Nucci & Iraldo, 2017; Ratten, 2018). This system-level change in territories is characterized by collective and distributed activities and path development types (path renewal, diversification, importation and creation²), along with sound policymaking (Trippel et al., 2020; Steinböck & Trippel et al., 2023). Facilitating system-level change requires the coupling of multi-scalar institutional systems (Belso et al., 2024). These *collective actions* to change are

² Trippel et al. (2020)

also reported in previous mainstream literature (e.g. Hervás-Oliver, 2021) along with the competition and cooperation logic in IDs (e.g. Becattini, 1990).

Fourth, is the cluster/ID knowledge enough for radical green innovations? As expected, it is usually for incremental innovations. For (sustainability-oriented) radical innovation, exploratory strategies and technology-distant knowledge is required (Martínez-Perez et al., 2015), confirming mainstream mechanisms for understanding radical innovation (Hervas-Oliver et al., 2018b; Glasmeier, 1991).

Fifth, does lock-in and inertia (“maintenance-agency”) apply for green innovation? Yes, industrial pre-conditions, multi-actor, and multi-scalar conditions, along with path- and place-dependency might impede sustainability change (e.g. Steinböck & Tripl, 2023; Jolly et al., 2020), as in mainstream literature signaling lock-in, over-embeddedness (e.g. Glasmeier, 1991; St John & Poudier, 1996; Martínez-del-Río, Li, & Guthrie, 2021).

All in all, this study contributes to enrich the clusters/IDs framework by focusing on environmental sustainability innovation. By studying different strands of literature, we position our conversation in understanding *how* clusters/IDs enable sustainability innovation, unfolding key drivers for sustainability innovation. In addition, we enhance the importance of clusters/IDs heterogeneity and the necessity to study at the micro-level firm innovation capabilities. This is very important for understanding the inception of micro-level (e.g. Grashof, 2021) and firm-led innovations that subsequently might foster change in a given territory (see Hervás-Oliver et al., 2023). It is important to notice that the firm-level sustainability literature from managerial and innovation studies (e.g. Ortiz-de-Mandojana & Bansal, 2016; Aragón-Correa & Sharma, 2003; De Marchi, 2012) shows a longer tradition of studying the topic, albeit place-blinded. Scholars in the clusters/IDs literature can borrow concepts and support the understanding of a very relevant actor in clusters, i.e. firms, for exploring sustainability innovation.

The results from this study contribute to improve and accelerate the study of the topic by academics and support policymakers’ agenda in designing new sustainability-oriented initiatives. Scholars can use the knowledge to articulate research strategies aimed at finding evidence of different sub-lines of inquiry within the topic of sustainability

innovation in clusters/IDs. Then, for policymakers, it is important to understand that similar to other changes, such as Industry 4.0, sustainability requires collective actions led by local actors, cooperation and a shared vision (see Hervas-Oliver, 2021). Similarly, the *positive* isomorphism, that is, the rapid imitation and search for legitimization that occurs in clusters/IDs, is a powerful mechanism for encouraging local firms move towards eco-innovations (see Hervas-Oliver et al., 2019). Finally, policymakers also need to orchestrate or facilitate the coupling of different multi-scalar institutions placing firm heterogeneity firmly on the agenda.

As for future studies, we need to increase research in sustainability in clusters/IDs by investigating positive (successful) and negative (failure) collective (system-level) actions; introducing the concept of cluster life cycle in the study of sustainability or researching cases when leading firms act as a springboard for cluster sustainability, among many others, constitute fruitful ideas.

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Table 2: Main elements in the mechanisms for supporting sustainability innovation in clusters/IDs

<p><u>SPILLOVER MECHANISMS</u></p> <ul style="list-style-type: none"> -Rivalry and competitive monitoring is easy, driving (positive) institutional isomorphism, that is, imitation -Embeddedness and legitimization -Networking -Collective actions by supporting organizations -Competition and cooperation -Others (labor mobility, etc.) <p><u>MULTI-ACTOR AND MULTI-INSTITUTIONAL PERSPECTIVE</u></p> <ul style="list-style-type: none"> -Leading firms (global and local ones) -Collective actors (cluster organizations, research and transfer institutes, trade associations, etc.) -Collective and distributed activities -Path development types (path renewal, diversification, importation and creation³) -Policymaking -Multi-institutional scales and system-level agency (vs <i>maintenance</i> agency) <p><u>LIMITATIONS:</u></p> <ul style="list-style-type: none"> -Pre-existing industrial structures -Place-dependency -Path-dependency -Cognitive inertia -Over-embeddedness and dependence on the cluster knowledge sources (especially for radical innovations) -Lack of leading firms or relevant actors that lead and diffuse. -Intra-cluster heterogeneity (different types of firms and green strategies –responsibility, credibility, ethics, Corporate Social Responsibility, etc.-)
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Source: own, from literature review.

Table 1 Some studies in the sustainable innovation topic in clusters/IDs

Study	Setting	Main findings
Belso et al., (2024)	Three footwear clusters in Portugal, Colombia and Brazil	The cluster effect positively influences a firm’s green product innovation, and ii) informal cluster-level institutions’ effect on green product innovation is jointly and positively moderated by national institutions. Green innovation in

³ Trippel et al. (2020)

		clusters requires coupling different multi-scalar institutional systems effectively at the regional (informal) and national (formal) levels.
Kamath et al., (2023)	Basque pulp- and paper bio-cluster	Proposing a cluster-evolution framework that treats clusters and their regional innovation system as complex adaptive systems. Institutions are crucial and policymaking needs to couple a multi-scalar institutional system where collective actors, firms and regional structures need to be aligned. Place-leaders are also very important.
Steinböck and Tripl, 2023	Bioplastic cluster in Lower Austria	Powerful actors undertake strategic interventions to prevent rearrangements of innovation systems for sustainability changes. Multi-actors and multi-institutional scalar as core elements of change. Actors, institutions and policymaking need to be aligned and integrated to prevent that an old unsustainable industry might create barriers to an environmental sustainability shift. Heterogeneity of local actors is very important, as not all want change.
Díez-Vial et al., (2023)	Different clusters in the Spanish footwear industry	Green innovation has a curvilinear relationship with firm sustainable performance and that the geographical concentration of clusters has a positive reinforcing role for green product innovations: green innovations do improve performance, they have an inverted “U” shape that makes investments in green innovation less profitable above a certain threshold. While geographical concentration is stronger for green product innovations, it is less evident for process innovation.
Ponte et al., (2023)	Prosecco and Valpolicella wine clusters in Italy	Environmental sustainability in global value chains (GVCs) is analyze from a horizontal governance perspective supporting an environmental upgrading process. Institutional support, pressure from civil society groups and political dynamics at the local level are showed to be relevant. Firm heterogeneity, – through certification, going ‘back to tradition’, technological innovation and/or as an articulation of local politics – is evidenced.
Kamath et al., (2022)	Simulation through an agent-based model	Clusters in peripheral regions are difficult to change towards sustainability. Policy instruments for green-growth of clusters in peripheral regions: fines are the least effective, grants push on innovation, while financial incentives are not enough unless they bring (new entrants) advanced new knowledge.
Zen et al., (2022)	Serra Gaucha, Brazil Wine cluster	At the micro-level, the mobility and adoption of knowledge about sustainability and individual awareness will support sustainability-oriented strategies as a new source of competitive advantage. Then, at the meso-level, collective actors’ efforts towards sustainability in the cluster are using leading local firm in order to disseminate new green practices and signal change in the territory. Macro-level governmental regulations, market pressures, and others changes need to be coupled with micro- and meso-level to promote a collective-minded strategy towards sustainability: coupling multi-scalar institutional system is paramount.
De Steur et al., (2020)	Wine clusters (in Tuscany and Emilia-Romagna, Italy)	Internal drivers are more important than external ones. In particular, the ethical choice, the protection of regional products, and environmental benefits (e.g., protection of biodiversity or landscape), as well as product quality, work safety or operational efficiency were considered highly

		important, more than the external drivers (comply with governments policy or regulations, obtain subsidies or to obtain a safe environment for residents, neighbors, and community (social).
Sjotun and Njos (2019)	Three clusters: a petroleum, a marine, and a maritime cluster in Western Norway.	Two routes to re-orient clusters for environmental sustainability, – a ‘neutral’ and organizationally dominated, and a ‘normative’ route based on a deliberated and active top-down policy – The combination of both, where organizations and policymakers co-design and cooperate in a bottom-up approach can be much richer for stimulating a greener reorientation. Multi-scalar policy domains are important.
Daddi et al., (2017)	<i>Tanning cluster of S.Croce sull’Arno in Tuscany</i>	The importance of collective actions in clusters of SMEs for achieving relevant environmental benefits.
Taddeo et al., (2017)	Chemical, automotive and agri-food clusters	Industrial Symbiosis (IS) is not only a technical phenomenon; socio-relational, organizational, and cultural issues come to light in its development as well. Industrial networks and clusters have been proven to be one of the best models of local industrial development, and they can be considered also a favorable starting context for IS projects.
Martínez-Perez et al., 2015	Tourism clusters in Spain (World Heritage Cities)	Clusters matter for eco-innovation. The social capital possessed by a firm within a cultural tourism cluster - bridging capital -, facilitates the achievement of better performance in terms of eco-innovation, when social capital is driven through a knowledge exploration strategy.
Martínez-del-Río and Céspedes-Lorente (2014)	Three clusters: Cava cluster Catalonia and fresh fruit and vegetables clusters in Andalusia (Spain)	Heterogeneity of strategies in clusters and clusters are prone-to-eco-innovation settings. Cluster firms’ perceived rivalry, competition tracking capabilities, interaction with industry associations and network embeddedness influence their competitiveness and legitimation motivations for environmental responsiveness in clusters
Grimstad and Burgess (2014)	Lovelade wine tourism Cluster in Australia	Collective actions in clusters can be used to encourage eco-innovation, which can facilitate further expansion into new international markets. Sustainability in clusters needs to couple different multi-scalar institutional systems and address firms and also collective actors. Regional clusters can utilize the advantages of clustering to meet environmental goals

Source: own, from literature review