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ARTICLE



Sustainable innovations, knowledge and the role of proximity: A systematic literature review

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Abstract

Innovations can substantially contribute to the transformation toward sustainability if they induce a positive social and/or environmental impact. Such sustainable innovations differ considerably from conventional, purely economic innovations. The main difference stems from the different knowledge bases necessary for the development of these innovations. These knowledge bases are widely dispersed across different actors from business, academia, government, and civil society. Following the innovation system approach, we look at actor constellations, linkages between actors, and knowledge flows within networks that generate sustainable innovations. For this purpose, we conduct a systematic literature review, focusing on the concept of proximity and its five dimensions (geographical, cognitive, institutional, organizational, and social proximity). The results show that all proximity dimensions, as well as the interdependencies between them, are relevant for analyzing knowledge flows leading to sustainable innovations. The interplay of the different proximity dimensions can be described via two mechanisms, one being reinforcement and the other one being either substitution or overlap. We conclude that for the occurrence of radical, systemic innovations, which have the potential of altering the prevailing socio-economic paradigm toward

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greater sustainability, a combination of low cognitive and low (micro-) institutional proximity combined with high organizational, social, or geographical proximity, appears particularly conducive.

KEYWORDS

innovation, innovation system, knowledge, proximity, sustainability

1 | INTRODUCTION

Humanity is facing the grand challenge of sustainability, as apparent in issues such as climate change, loss of biodiversity, depletion of natural resources, persisting poverty, and detrimental levels of inequality in income and wealth. A transformation toward sustainability will require far-reaching changes in our current production and consumption patterns. The normative and multidimensional nature of sustainability makes this a very demanding endeavor. Consequently, numerous authors refer to sustainability as a "wicked problem" (Rittel & Webber, 1973) that bears no easy solutions (Batie, 2008; Wehrden et al., 2017; Wiek et al., 2012).

Innovations can serve as a suitable means for tackling this wicked problem and thus can contribute to the transformation toward sustainability (Dwyer, 2013; Hall & Vredenburg, 2003; Luederitz et al., 2017; Pyka, 2017; Strambach, 2017). However, innovations do not have a positive influence on sustainability per se (Schlaile et al., 2017; Schot & Steinmueller, 2018). In a purely economic sense, innovations refer to new or improved products, processes, or approaches that have a commercial value, much in line with the approach depicted in the widespread Oslo Manual (OECD/Eurostat, 2018). In this definition, environmental or social impacts are irrelevant (Rennings, 2000). To capture the idea of innovations that also have a positive effect on the social and/or environmental dimension of sustainability, a variety of different concepts and labels have emerged, such as environmental innovations, responsible innovations, or transformative innovations, to name some (see Franceschini et al., 2016 for a non-exhaustive overview). There is quite some conceptual overlap between these notions, some are used interchangeably by some authors but not by others, and most of these notions are not being used coherently.

Despite this pluralism of definitions, there seems to be a common denominator: They all seem to differ considerably from purely economic innovations, especially regarding the underlying knowledge bases (Hojnik & Ruzzier, 2016; Horbach et al., 2013; Strambach, 2017). The relevant knowledge for sustainable innovations seems more dispersed (Ghassim, 2018). Firms seeking such innovations thus tend to collaborate more extensively with external partners (Marchi & Grandinetti, 2013). Those partners do not only come from the business world or academics but in many cases also include governmental organizations, NGOs, consumer groups, and other civil society organizations. These diverse groups of actors are involved due to their specialized knowledge in fields covering social and environmental aspects of sustainability (Carayannis & Campbell, 2010; Clark et al., 2016).

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Following the innovation system approach (Cooke, 1992; Lundvall, 1992; Nelson, 1993) in the tradition of evolutionary economics, this is no surprise, as this approach emphasizes the interaction of various agents in the creation, diffusion, and application of economically useful novelties. Knowledge flows play a particularly important role in these interactions, as the creation and exchange of knowledge are the basis for innovation (Lundvall, 2016). The relationships between the actors of an innovation system influence these knowledge flows and are therefore highly relevant for understanding the emergence of innovations. A powerful analytical framework for analyzing these relationships is the concept of proximity which is widely applied in economic geography (Capello, 2014) and whose relevance for interactive learning and innovation processes in multi-actor settings is widely acknowledged (Balland et al., 2022). The different dimensions of proximity (geographical, organizational, institutional, social, and cognitive) facilitate the creation, co-creation, and transfer of knowledge between different agents by solving the underlying coordination problem (Boschma, 2005). In contrast to the large scholarly body of work examining the role of proximity for purely economic innovations (confer Balland et al., 2022), little work has been done so far regarding innovations that imply positive social and environmental effects. As mentioned above, there are differences between these two types of innovations, stemming from different target dimensions (economic vs. economic, social and ecological) and the resulting necessary sources of knowledge. Taking these differences into account, we seek to analyze the role of the different proximity dimensions in the emergence of sustainable innovations. We expect that insights into the effects of the different proximity dimensions will contribute to the field of innovation economics and provide valuable knowledge for a wide variety of stakeholders. Companies could utilize this knowledge for their innovation and network management by selecting partners with favorable levels of proximity, thus improving the chances of success of joint innovation projects. Understanding the effects of the different proximity dimensions could furthermore be used in innovation policy to enable more effective promotion of sustainability-oriented innovation networks. Finally, civil society initiatives could use this knowledge to make strategic decisions about how to introduce best their ideas and demands into such networks, whether to collaborate with other initiatives in proximity (or at an adequate distance), or whether to involve businesses, universities, or government agencies in their initiatives.

To examine the effects of the different proximity dimensions, we conduct a systematic literature analysis, guided by the question: What is the literature saying about the role of the different proximity dimensions in knowledge processes related to sustainable innovations?

Our analysis provides insights into how different actor constellations shape knowledge processes that lead to sustainable innovations. We find that all proximity dimensions are relevant for understanding flows of knowledge in such multi-actor settings. Furthermore, there are important interdependencies between the different proximity dimensions. Those interdependencies can be described with two mechanisms, one being reinforcement and the other being either overlap or substitution. Regarding the different proximity dimensions, we find that certain combinations of high and low levels of the different dimensions seem to be more common than others. For the development of systemic, radical innovations that foster a transformation toward sustainability, a combination of low cognitive and low (micro-)institutional proximity, together with high levels of social, organizational, or geographical proximity, seems especially conducive.

The paper is organized as follows. Section 2 gives a brief overview of the relevant theoretical background. Section 3 describes the methodological approach of the systematic literature review.



The results of the analysis are presented in Section 4. Section 5 discusses, concludes, and outlines avenues for further research on the topic.

2 | THEORETICAL BACKGROUND

2.1 | Sustainability innovations

Ever since Schumpeter put innovations high on the agenda of economics, much has been written about the emergence of technological and organizational novelties that spur economic development. In the conventional sense, innovations can be defined simply as commercialized inventions (Freeman & Soete, 2000). Hence, the profitability or added value of a new technology, product, service, or process is the decisive characteristic that qualifies a novelty as an innovation. This elucidates the importance of innovations for economic growth and explains the extensive scientific coverage of this subject.

Today, the issue of sustainability ranks high on the agenda of politicians, business leaders, and academic scholars worldwide. An issue, which is closely intertwined with economic growth. The idea, that the maxim of constant or even more growth might not be feasible on a planet with finite resources and limited regenerative capacity, came up prominently in the 1970s with several publications addressing this topic (among them Meadows et al., 1972 and Georgescu-Roegen, 1971). In the late 80s, the so-called Brundtland report (WCED, 1987) gave a widely recognized definition of sustainable development and triggered intense political coordination and action on a global scale, leading, among other things, to the United Nations Sustainable Development Goals. To date, however, there is no commonly accepted definition of sustainability or sustainable development, much less a commonly accepted operationalization or set of indicators to capture and measure sustainability, despite the progress that has been made in measurement approaches (Qasim, 2017).

We share the widespread view that it is most appropriate to understand sustainability as a normative concept with economic, social, and ecological aspects, entailing a temporal, intergenerational dimension and implying cause-and-effect relations on a global scale (Grunwald, 2007). This however implies questions about the normative directionality, legitimacy, and responsibility (Schlaile et al., 2017) and a continuous discussion within society about the actual meaning of sustainability and the resulting implications and objectives (Blättel-Mink & Kastenholz, 2005). The scientific debate on this topic is correspondingly broad (see e.g., Lin & Zheng, 2016).

But even in the absence of a commonly accepted definition (which might not be reached), the importance of sustainability is obvious and undoubted, considering the devastating consequences of persisting poverty, the costs and negative welfare effects of inequality (Atkinson, 2015), and the urging necessity to keep planet earth in a "safe operating area for humanity" (Rockström et al., 2009). In addition, and independently of potential costs associated with a loss of biodiversity (Cardinale et al., 2012), one can easily argue for the moral obligation of humanity to preserve nature and its biodiversity.

In this context, innovations that not only drive economic growth but also have positive social and/or environmental effects, have received increasing attention. Many different notions and concepts have been developed for such innovations. Rennings (2000), for example, discusses the concept of eco-innovations, being technological, organizational, social, or institutional which contribute to ecological targets and thus mainly address the environmental aspect of sustainability. There are numerous similar concepts, addressing innovations that link economic growth with a reduction of negative environmental externalities (see Barbieri et al., 2016 for an overview).



Adams et al. (2016) examine a broader concept. They discuss the concept of sustainabilityoriented innovations as an approach driven by organizations to incorporate sustainability in their products, processes, and into the underlying culture of the organizations, with the aim of creating positive social and environmental impacts, in addition to economic value. They address different levels of such innovations, from internally oriented shifts on the firm level to more radical and systemic changes building upon multi-actor collaborations and new business paradigms.

Sustainability innovations can be incremental technological improvements, such as novelties that increase resource efficiency. But more often they are associated with radical, system-wide changes (Boons et al., 2013; Schlaile et al., 2017), implying a change in the prevailing techno-economic paradigm (Dosi, 1982). Comprehensive economic concepts such as the knowledge-based sustainable bioeconomy (see e.g., Pyka & Prettner, 2018) or a sustainable circular economy (Geissdoerfer et al., 2017) frequently incorporate the idea of such transformative innovations. This is in line with a large number of authors arguing for systemic, transformative change to address sustainability (Caniglia et al., 2021).

Many authors furthermore doubt that a purely technological solution to the sustainability challenge is likely (e.g., Dwyer, 2013; Grunwald, 2007; Sterman, 2008; Steward, 2012). Considering environmental and social outcomes, many, or even the majority of new technologies, have the potential to bear positive effects. But the actual impact of a new technology depends on its usage confer the infamous rebound effect, which counteracts efficiency gains and leads to a net increase in resource consumption or pollution. The distribution of benefits and negative externalities of a new technology which occur throughout its whole life cycle, from resource extraction to disposal, can also have unintended but severe impacts on sustainability.

Numerous authors stress the importance of social innovations for sustainability (König, 2015; Rennings, 2000; Schlaile et al., 2017). But here again, there is no commonly accepted definition of the term social innovation, and some argue that social innovations are not necessarily positive for sustainability (Pol & Ville, 2009). In general, assessing the impact of an innovation on social and environmental sustainability is not a trivial task. An example is the framework proposed by E. G. Hansen et al. (2009) to assess the sustainability effects of innovations. It consists of three dimensions, which result in 27 sustainability areas in which impacts can occur and to which 71 assessment methods are assigned.

The multitude of definitions and terms for sustainable innovations is no surprise, considering the conceptual ambiguity of the underlying concept of sustainability. It is not in the scope of this paper to give a conclusive discussion of the different concepts, but to contribute to the understanding of the processes that lead to the emergence of such innovations, focusing on the commonalities of these types of innovation, and the factors that distinguish them from conventional innovations. In the rest of the paper, we will only use the term "sustainable innovations" for the sake of simplicity.

2.2 | Knowledge, proximity, and innovations

Building upon the definitions of Lundvall (1992), Nelson (1993), and Cooke (1992), we understand innovation systems as intricate networks comprising institutions, actors, and their interconnections. These elements dynamically engage in the creation, dissemination, and implementation of economically valuable novelties within specific geographical boundaries, whether at the national (Lundvall, 1992; Nelson, 1993) or regional level (Cooke, 1992). Knowledge plays a central role in these interactions. Its creation, co-creation, and transfer provide the basis for every innovation. Gregersen and Johnson (1997) even place knowledge at the center of their definition of an



innovation system. They state that the fundamental functions of such a system lie in the creation, allocation, and utilization of knowledge, whereby the utilization happens primarily through the introduction of innovations. These processes, in turn, result in desired outcomes such as economic growth.

The innovation system approach has since been used extensively to analyze issues such as competitiveness or innovative performance at different geographical levels and has exerted considerable influence on politics (Fagerberg, 2017). It was furthermore extended and adapted to focus on sectors, industries, or technologies as units of analysis instead of regions or nations, leading to concepts such as technological innovation systems and sectoral innovation systems (Weber & Truffer, 2017). In recent years, the concept was adapted to specifically address sustainable innovations (see e.g., Altenburg & Pegels, 2012 or Pyka, 2017).

Neoclassical economic theory addresses knowledge fairly mechanical, often involving a research and development sector which is creating new knowledge according to a commonplace production function like a generalized Cobb-Douglas function (confer overviews such as Aghion & Howitt, 2009). Knowledge thus flows rather freely and can be considered (with some exceptions) as a global public good (Stiglitz, 1999). In contrast, the innovation system approach emphasizes the existence of path dependencies in knowledge creation (Dosi, 1982), characterizing knowledge as being cumulative (Foray, 2004), being sticky (Hippel, 1994), and requiring a certain degree of absorptive capacity to be assimilated and applied (Cohen & Levinthal, 1990). Hence, the transfer of knowledge between two firms, or more generally between two agents, is associated with transaction costs, requiring some form of resource or mechanism to coordinate the exchange.

Because sustainable innovations include social and ecological goals, the knowledge relevant to them is more complex and more dispersed than in the case of conventional innovations (Urmetzer et al., 2018; van Geenhuizen & Ye, 2014). Sustainable innovations require knowledge about environmental impact measurement, relevant regulations, industry standards, and certificates. They furthermore require knowledge of the needs and demands of customers, interest groups, and political decision-makers, as well as knowledge of social impact assessments and the potential externalities of products and processes that may occur throughout their life cycles. Compared to purely market-driven innovations, the broader spectrum of potential stakeholders with potentially contradicting demands makes the development of such innovations much more challenging for companies (Hall & Vredenburg, 2003).

The networks that generate sustainable innovations include a wide variety of actors from business, academia, government, and civil society (Healy & Morgan, 2012). Actors, that are hardly involved in the creation of purely economic innovations, such as NGOs, consumer groups, environmental groups, and alike, now become important due to their specific expertise. In addition, consumers and users are gaining importance as active contributors in innovation processes (Hippel, 2006) and more generally in transition processes induced by innovations (Wilke et al., 2021). This raises questions about the interaction of such diverse actors in the development of innovations.

To better understand the flows of knowledge in such actor constellations, we use the concept of proximity, which originates from economic geography, where it is used in the context of various themes such as regional development, innovation research, or inter-organizational cooperation (Crescenzi et al., 2016; Knoben & Oerlemans, 2006). The underlying idea is, that different proximity dimensions (geographical, organizational, social, institutional, and cognitive) are conducive for knowledge exchange and innovations, whereas too much proximity might have detrimental effects (Boschma, 2005). Geographical proximity refers to the spatial distance between two agents in absolute (linear distance) or relative terms (travel time), which facilitates the exchange of knowledge through direct face-to-face contact (Ponds et al., 2007). Organizational proximity refers

to formal links between two agents and thus concerns hierarchical structures and power relations that enable the control of opportunistic behavior (Mattes, 2012). Social proximity follows a similar working mechanism but concerns personnel relations such as friendship or kinship involving trust (T. Hansen, 2015). Institutional proximity refers to the contextual framework in which the exchange between two actors unfolds. This includes elements like law, regulation, and standards. Additionally, institutional proximity extends to the internal characteristics of the actors, encompassing aspects such as organizational form, incentive structures, and corporate culture. Cognitive proximity is closely related to absorptive capacity, referring to shared cognitive concepts and the similarities between two actors in perceiving and understanding the surrounding world (Wuyts et al., 2005). The concept of proximity can be applied to investigating networks on the firm level but also to conduct studies with regions as units of analysis (Moreno & Miguélez, 2012).

3 | METHODOLOGY

To investigate proximity in innovation networks and its influence on the flows of knowledge leading to sustainable innovations, we present a systematic literature review. Our methodology for the review draws on the procedures proposed by Tranfield et al. (2003) and Palmatier et al. (2018). Figure 1 gives an overview of the literature selection process. The initial selection of papers was done through two searches, one in the database Web of Science and the other in the database Scopus. In both databases, we used broad search terms consisting of the words "proximity," "sustainab*," "innovat*," and "knowledge," with the last two words combined as two disjunctive options in conjunction with the first two words¹. The two searches yielded a high number of publications. After merging the two sets of results and deleting duplicates, 585 publications remained. The next step was to read the abstracts of these publications to decide whether to include them in the systematic review. The selection was based on the following inclusion criteria: (1) The publication must address the issue of sustainable innovations; (2) the publication must deal with the emergence of such innovations based on knowledge processes; and (3) the publication must analyze the proximity between the actors involved or use proximity as a framework for analyzing the relationships of the actors involved.

This means that publications examining other economic processes that aim at increasing sustainability and involving multiple actors were excluded, such as publications on proximity in supply chains, on spatial characteristics of flows of goods, materials, or energy, on the siting of facilities or business premises, on proximity regarding (non-innovation related) customer relationships such as distribution issues, or on the use of proximity as a concept for planning the topology of urban infrastructure with the aim of increasing sustainability. Publications that analyze spatial patterns of diffusion of sustainable innovations, such as the spreading of green energy technologies, were also not included, as we are interested in the emergence of innovations rather than their subsequent large-scale adoption. Furthermore, publications investigating the formation of networks were excluded if they did not address the flows of knowledge within these networks.

A large number of publications (514) were excluded based on the analysis of their abstracts. Further 10 papers were excluded due to their language, with most of these papers being written in French. The reason that there are so many publications in French on this topic can most likely be attributed to the French school of proximity, which provided several important early contributions to this strand of the innovation debate, such as Kirat and Lung (1999) or Torre and Gilly (2000). In the next step of our review, the full texts of the remaining publications were read, leading to the exclusion of another 41 publications, based on the above-mentioned inclusion criteria. Based on





FIGURE 1 Literature selection process.

the remaining 20 publications, citation snowballing (backward and forwards) was done to identify further relevant publications, leading to the inclusion of four additional papers. As the number of relevant papers found with this method was rather high compared to the set of papers found with the initial systematic search in the databases, we tested amendments to the search string used in the databases. That, however, led to no adjustments as the inclusion of further words did not bear better results but dramatically increased the number of irrelevant publications. Hence the final selection of 24 publications forms the basis for the systematic literature review, the results of which are described in the next section.

4 | RESULTS

4.1 | Description of data

All papers included in the analysis were published in peer-reviewed journals. Figure 2 depicts the years of publication of these articles. Most papers have been published in recent years (\sim 70 %





FIGURE 2 Year of publication of papers in the final selection.

since 2018), indicating that scholars have only recently begun putting more focus on this field of research, leading us to expect that more papers will follow in the coming years.

The papers in our review discuss the occurrence of sustainable innovations in different industries and socio-economic contexts, covering agriculture, food industry, construction sector, minerals industry, cleantech sector, energy production, environmental technologies for waste recycling and water treatment, as well as niches such as biofuel production and low-carbon technologies. There are also papers on innovations that aim at tackling sustainability challenges systematically with composites of innovative private and public goods and institutional innovations. In all papers, the innovations are the results of multiple actors collaborating in the creation and exchange of knowledge. These innovation networks are situated in high- and middle-income countries around the world (North America, Europe, and China), covering rural areas as well as specialized firm clusters. The broad thematic coverage of the reviewed papers appears very heterogeneous, but we believe this is not a disadvantage for our analysis, as all papers address innovations that have similar characteristics, namely to provide a social or an environmental benefit or both in addition to creating an economic benefit.

Table 1 provides an overview of the analyzed papers, giving details about the methodological approaches of the articles, the types of innovations addressed, and the proximity dimensions included. We can see a methodological pluralism, with most papers being of an empirical nature. A number of the econometric articles (Aldieri et al., 2019, 2020; Ardito et al., 2019; Sun & Han, 2022) use patent data for analyzing the occurrence of innovations, which is a widespread approach that, however, might suffer some limitations, as not all innovations are patented or even patentable, like for instance non-technical process innovations (Crescenzi et al., 2016; Mazzanti, 2018). This seems to be particularly relevant for sustainable innovations, as they often have systemic and non-technological characteristics. The involvement of actors with primarily non-profit interests, like civil society organizations, academia, or state institutions, further reduces the likelihood that an innovation is sought to be protected via patents (Heringa et al., 2014). The other econometric papers in the final selection use survey data (Ghassim, 2018), interviews (T. Hansen,

1			
Publication	Type of paper	Type of innovation	Proximity dimensions
Addy and Dube (2018)	Case study approach	Social innovations	Geographical, cognitive, institutional, organizational, social
Aldieri et al. (2019)	Econometric analysis (patent data)	Environmental innovations	Technological (cognitive)
Aldieri et al. (2020)	Econometric analysis (patent data)	Environmental innovations	Technological (cognitive)
Ardito et al. (2019)	Econometric analysis (patent data)	Green innovations	Geographical, technological (cognitive)
Bloise (2020)	Qualitative empirical analysis (interviews)	Ecological process innovations	Geographical
Coenen et al. (2010)	Conceptual paper	Innovations for sustainability transitions	Geographical, cognitive, institutional, organizational, social
Delgadillo et al. (2021)	Conceptual paper	Innovations for sustainable product-service systems	Geographical, organizational
Dubois (2019)	Case study approach	Social and organizational innovations	Geographical, cognitive, institutional, organizational, social
Ghassim (2018)	Quantitative empirical analysis (survey data)	Eco-efficient process and product innovations, social sustainability practices	Organizational, institutional proximity (formal and Informal), Cognitive (science-related and engineering-related)
T. Hansen (2014)	Qualitative empirical analysis (interviews)	Sustainable product innovations	Geographical, cognitive, institutional, organizational, social
T. Hansen (2015)	Econometric analysis (interviews)	Sustainable product innovations	Geographical, cognitive, institutional, organizational, social
T. Hansen and Coenen (2015)	Literature review	Innovations for sustainability transitions	Geographical, cognitive, institutional, organizational, social
Ievoli et al. (2019)	Case study approach	Innovations for sustainable rural development	Cognitive, institutional, organizational, social
			(Continues)

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	Proximity dimensions	Geographical, cognitive	Geographical, cognitive, institutional, organizational, social	Geographical, cognitive, institutional, organizational, social	Geographical, cognitive	Geographical, cognitive, institutional, organizational, social	Geographical, cognitive, institutional, organizational, social	Geographical, institutional	Geographical, technological (cognitive), institutional	Geographical, cognitive, institutional, organizational, social	Geographical, cognitive, institutional, organizational, social	Geographical, cognitive, institutional, organizational, social
	Type of innovation	Innovations for sustainability	Innovations for sustainability transitions	Sustainable technological innovations	Green innovations	Innovations for sustainability transitions	Non-technological innovations for sustainability	Green innovations	Green innovations	Innovations for sustainability transitions	Biowaste-to-resource innovations	Innovations for industrial sustainability
	Type of paper	Econometric analysis (R&D project database)	Econometric analysis (questionnaire, Google Maps, databases)	Literature review	Network analysis	Conceptual paper	Quantitative empirical analysis (survey data)	Network analysis	Econometric analysis (patent data)	Agent-based modeling	Case study approach	Conceptual paper
TABLE 1 (Continued)	Publication	Janssen and Abbasiharofteh (2022)	Lopolito et al. (2022)	Omobhude and Chen (2019)	Qiang et al. (2021)	Raven et al. (2012)	Royo-Vela and Mazandarani (2022)	Shi et al. (2022)	Sun and Han (2022)	Tani et al. (2021)	Velenturf (2016)	Velenturf and Jensen (2016)



2015), other datasets like project databases (Janssen & Abbasiharofteh, 2022), or a mixture thereof (Lopolito et al., 2022) for their analyses.

Several papers in our review follow caste study approaches (Addy & Dube, 2018; Dubois, 2019; Ievoli et al., 2019; Velenturf, 2016). Two are based on network analyses (Qiang et al., 2021; Shi et al., 2022) and four papers apply other qualitative and quantitative empirical approaches (Bloise, 2020; Ghassim, 2018; T. Hansen, 2014; Royo-Vela & Mazandarani, 2022). Our final selection of papers also includes two literature reviews. T. Hansen and Coenen (2015) review the literature about geographical aspects of sustainability transitions, addressing the occurrence of innovations but also other processes. They draw on works from the proximity literature to hint at possible refinements of current approaches and suggest further avenues for research. The other literature review by Omobhude and Chen (2019) focuses on technological developments and knowledge spillovers. They review the literature on proximity, focusing on definitions of proximity and methods measuring it, and apply their findings to the development of sustainable technologies.

We furthermore cover four conceptual papers in our literature review. Coenen et al. (2010) review the literature on strategic niche management, which refers to governance approaches for so-called niches, which are specific (and often protected) spaces, in which sustainability innovations are tested. Coenen et al. (2010) merge the findings of this strand of literature with insights from the proximity literature, resulting in a refined analytical framework to investigate niches and their dynamics, which they then apply to a case study. The second conceptual article is by Delgadillo et al. (2021). Based on a literature review and two exploratory case studies, they propose a framework for analyzing sustainable product-service systems (integrated combinations of products and services offered by the same firm) as drivers for territorial sustainability transitions. Delgadillo et al. (2021) emphasize the role of geographical and organizational proximity in analyzing the implications of that approach. The third conceptual paper is by Raven et al. (2012), presenting a multi-level perspective (MLP) with a spatial scale. MLP is a framework used for analyzing dynamics in socio-technical systems, including innovation processes, for sustainability transitions. Raven et al. (2012) use proximity dimensions for expanding an MLP, which they apply to an empirical example, thus showing the additional analytical value of the expanded MLP. In the last conceptual paper in our review, Velenturf and Jensen (2016) discuss the industrial symbiosis approach, which focuses on material flows between firms and aims to achieve sustainability by avoiding waste and creating resource efficiency based on innovations and network development. They suggest combining industrial symbiosis thinking with economic geography's insights on proximity to further the understanding of such innovative industrial networks.

Tani et al. (2021) present an agent-based model for analyzing evolution dynamics in the development of niches for sustainability transitions. They compare the development of such innovation niches based on geographical proximity with niches that focus on relational proximity (cognitive, organizational, social, and institutional proximity). The different approaches of the papers we cover in our review illustrate the complexity of the issue at hand. The comparison of these different approaches and their findings enables a multi-layered investigation of the interplay between knowledge, proximity, and sustainable innovations.

Looking at the concept of proximity, we can see that more than half of the papers in our review address all five proximity dimensions. Seven papers address a combination of two or more proximity dimensions, while three papers deal with only one dimension each, namely geographical proximity in one case (Bloise, 2020) and technological proximity in two cases (Aldieri et al., 2019, 2020). Technological and cognitive proximity can be understood as synonyms in the context of our

study, as they both refer to the skills, expertise, and knowledge that underly a firm's operations and that form the ground for exchanging knowledge with other actors to develop innovations.

4.2 | Geographical proximity

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The basic idea, that location plays a crucial role in economic processes dates back to Marshall (1890) and the following works on industrial districts (compare Capello, 2014). Marshall's work can thus be seen as a starting point for a variety of considerations on the relationship between physical closeness and the economic performance of regions. Examples include the discussions on knowledge spillovers or the work on cluster effects. It is therefore not surprising that so much has been written after Marshall on the role of spatial proximity and its relevance for the occurrence of innovations.

For sustainability innovations, the findings regarding the role of geographical proximity are mixed. Shi et al. (2022) and Sun and Han (2022) find positive and significant effects of geographical proximity on cooperative networks that bear green innovations. Ardito et al. (2019), who investigate the role of family-owned firms in inter-firm networks for R&D collaborations leading to green innovations, come to a similar conclusion, stating that a large geographic distance between the firms reduces the innovation value within such networks. The physical closeness between collaborating partners enhances communication and interaction and thus increases the efficiency of the exchange. Delgadillo et al. (2021) see geographical proximity as a vital catalyzer for interactive learning because spatial closeness allows for easier face-to-face contact. The direct interaction of two actors who are in the same place also facilitates the exchange of tacit knowledge. T. Hansen (2014) finds that firms in the cleantech sector looking for partners for collaborative innovations seek these partners in close proximity when it comes to knowledge sharing or access to complementary technologies. Bloise (2020) also finds a positive influence of geographical proximity on the emergence of sustainable innovations but states that being spatially close is not a prerequisite for a functioning exchange of knowledge.

Velenturf (2016) argues in the same direction, stating that geographical proximity is not as necessarily inherent in collaborations as expected, as there are numerous examples of knowledge exchange across large distances. In their agent-based model, Tani et al. (2021) find that niches that develop along relational ties (cognitive, social, institutional, and organizational proximity) outperform niches that are only focusing on close geographical proximity. An explanation is the existence of a limited number of agents with very specialized knowledge, who can significantly contribute to elaborating innovations that address the highly complex, wicked problem of sustainability. Those agents are rare and geographically dispersed, leading to actor constellations with low geographical proximity. This argument is also reflected by Janssen and Abbasiharofteh (2022): World-class top innovators are needed in a joint effort to find solutions to the grand challenge of sustainability. To sum up, geographical proximity can substantially facilitate knowledge exchange for sustainable innovations, but it seems to be no condition-sine-qua-non and may even hamper the innovative capacity if it leads to the exclusion of distant actors with relevant knowledge.

The reviewed papers furthermore show that it is advantageous to analyze geographical proximity in connection with the other dimensions of proximity. T. Hansen (2014), for example, sees the positive influence of geographical proximity on social proximity as a reason, why firms want to collaborate with physically close partners, especially if these partners are research institutes (low institutional proximity) or the knowledge bases are very dissimilar (low cognitive proximity). Dubois (2019) argues in a similar vein, stating that cognitive proximity becomes more impor-



tant in the absence of geographical proximity. The interdependencies of the different proximity dimensions are illustrated in detail in Section 4.7. But before that, we want to look at the other dimensions one by one.

4.3 | Cognitive proximity

Knowledge is cumulative, meaning that an agent needs a certain stock of knowledge as a starting point to be able to acquire an additional piece of knowledge. Without a cognitive base, additional information cannot be processed meaningfully and thus cannot be applied purposefully and hence does not become new knowledge. Cognitive proximity refers to the relation between two or more agents who exchange or (co-)create new knowledge. For them to communicate successfully and to understand and interpret the information exchanged, they need a common cognitive basis, such as a shared vocabulary and a common basic understanding. The need for cognitive overlap between two agents increases with the complexity and subject-specificity of the knowledge they want to exchange. However, if their knowledge bases are almost identical, there is not much to be learned from each other. Thus, there seems to be an optimal cognitive distance (or proximity) between two agents that allows for an optimal level of mutual learning, indicating an inverted U-shaped relation between cognitive distance and innovative performance (Nooteboom et al., 2007; Wuyts et al., 2005).

Aldieri et al. (2019) use technological vectors based on companies' industrial domains to map cognitive (technological) proximity. They found an inhibiting effect of close cognitive proximity, as knowledge spillovers between different industrial sectors appear to be much more conducive to environmental innovations. Ardito et al. (2019) arrived at a similar result. They describe a positive influence of family-owned firms on green innovation networks, which however is significantly reduced if the companies are technologically close to each other. T. Hansen (2014) describes similar findings, illustrating that cleantech firms seeking new knowledge or technologies for collaborative innovations search for partners with low to medium cognitive proximity. The reasons are complementarities between (sector-specific) knowledge bases and different strategies for addressing problems.

Ghassim (2018), by contrast, who distinguishes between engineering-related and sciencerelated cognitive proximity, finds a positive influence on collaborative efforts in the minerals industry, leading to increased process and product innovations. Higher shares of personnel with a university degree or degree from a technical school allow firms to acquire knowledge from external sources such as research institutes, specialized firms, or NGOs more easily. Lopolito et al. (2022) also see cognitive proximity as an important driver for knowledge-based networking. Janssen and Abbasiharofteh (2022) find that the actors in R&D projects dealing with sustainability issues have a relatively high level of cognitive proximity compared to R&D projects in other subject areas.

An explanation for these seemingly contradictory results might be found in the abovementioned inverted U-shaped relation between cognitive distance and innovations (though this shape is not uncontested, see e.g., Heringa et al., 2014). The obvious difficulty with a curve of this shape is to determine the turning point for a given exchange between two actors. Especially since other proximity dimensions might also affect the level of optimal cognitive distance. Dubois (2019) finds that in actor constellations with low geographical proximity, cognitive proximity seems more relevant. In particular, shared ideas about the importance of sustainable innovations, the common goal so to speak, seem to be important in establishing knowledge exchange and col340

laboration across large distances. A similar finding is presented by Ievoli et al. (2019), who state that in long-distance collaborations, in which actors rely on the use of modern information and communication technology (ICT), cognitive proximity seems to be more important. More generally, cognitive proximity in the sense of shared expectations about the sustainability impacts of the intended innovations seems to play an important role in the collaboration of different actors (Coenen et al., 2010).

4.4 | Institutional proximity

Institutional proximity refers to commonalities and differences regarding the institutional framework in which the actors cooperate, as well as to the institutional characteristics of the actors themselves. Laws, rules, regulations, social norms, habits, routines, traditions, and so on set the frame when two economic agents collaborate. The internal institutional logic of the actors, their incentive structures, organizational forms, codes of conduct, corporate culture, and values equally influence the collaboration. It makes a difference whether two firms of similar size from the same industry work together, or whether a multinational company, a university, and a civil society organization collaborate, even more, if those partners come from different countries with different languages and different legislations. As the institutional framework is dependent on locality, there is a link between institutional and geographical proximity, but of course, no congruence, as two spatially close agents can be separated by national borders, or be situated in adjacent yet different regions with legal or cultural peculiarities.

Lopolito et al. (2022) see institutional proximity as an important driver in networks for sustainable innovations, however with varying importance in different phases of a collaboration. Dubois (2019) also describes the changing relevance of institutional proximity. With repeated interactions, the actors increasingly rely on institutional proximity in the form of a "tacitly agreed code of conduct." Ghassim (2018) distinguishes between formal and informal institutional proximity, with the first being rules and laws and the second being norms and values. He finds that formal institutional proximity is conducive to sustainable process and product innovations, while informal institutional proximity positively affects social innovations. T. Hansen (2014) describes varying levels of institutional proximity when it comes to access to complementary technology and the acquisition of new knowledge. On the one hand, institutional proximity seems to be a way of compensating for a lack of cognitive proximity. On the other hand, collaborations between firms and partners from other institutional realms such as academia, state institutions, or NGOS seem to be particularly conducive to innovations, apparently due to complementary knowledge bases, working routines, and incentive structures.

4.5 | Organizational proximity

Organizational proximity describes to what extent the collaboration between two actors is formalized in an organizational arrangement. This can range from a very low level of proximity in the form of ad-hoc collaborations with no formal ties to very high proximity levels with the existence of a formal hierarchy, for example, when two departments of the same cooperation or two firms belonging to the same parent company collaborate. In between are other forms of formal settings such as loosely coupled networks based on cooperation agreements or consortia of independent entities working together on a funded project. This proximity dimension is thus about control



and power, and the corresponding ability to steer economic activity and prevent opportunistic behavior.

Delgadillo et al. (2021) see organizational proximity as being essential for the relationship between cooperating actors, as the sharing of strategies and organizational structures significantly improves coordination between them. Dubois (2019) finds that with repeated interactions, partners tend to establish modes of more formalized cooperation, thus increasing organizational proximity. This seems to simplify routine-based forms of cooperation which also work in the absence of other forms of proximity. Ghassim (2018) finds a positive relationship between organizational proximity and social innovations in collaborations among distant actors. T. Hansen (2014) finds that organizational proximity is usually low in partnerships that aim at bringing together complementary technologies or serve the purpose of exchanging new knowledge, as it seems unlikely that the desired technology or knowledge can be found at an affiliated company. Therefore, these collaborations regularly involve research institutes and other partners, with whom informal relations are more common. Ievoli et al. (2019) see a strong connection between the use of ICT in the collaboration of geographically distant actors and the creation of new network structures, thus leading to an increase in organizational proximity. ICT allows the establishment of mechanisms and agreements to coordinate the remote control of economic activities and flows of knowledge, thus reducing uncertainty and facilitating the development of innovations.

4.6 | Social proximity

The idea behind social proximity is derived from the argument that almost all economic activity is embedded in social relations (Granovetter, 1985). Social proximity is expressed through social ties on the micro level such as kinship, friendship, or mutual sympathy. It is based on prior experiences and involves trust. It thus facilitates the exchange of knowledge as it reduces the uncertainty about the motives of other agents, diminishing the risk of opportunism. Social proximity can provide informal mechanisms based on personal contacts, which can be even more efficient than formal rules for collaborating as they involve lower transaction costs.

Coenen et al. (2010) support this view, as they emphasize the importance of trust between the actors in innovation networks occupied with radically new technologies. Lopolito et al. (2022) also see social proximity as a driver of niche networking. For Dubois (2019), social proximity is especially important in the absence of formalized modes of cooperation, and in cases with low institutional proximity. T. Hansen (2014) finds that firms seeking partners to acquire new knowledge and technologies often desire a high level of social proximity. The reason seems to be that high social proximity helps to overcome difficulties arising out of low cognitive proximity. Cooperation between two partners who share a small common knowledge base requires more resources. It takes more time and effort to understand each other and misunderstandings are more likely to occur. Furthermore, the competencies and expertise of one partner might not be fully verifiable by the other. Trust helps to mitigate these problems. The same seems to be the case for low geographical proximity. Knowledge exchange is facilitated by social proximity in situations, in which partners have difficulties meeting regularly due to high costs or lack of time caused by long travel distances. Conversely, geographical proximity can help build trust by facilitating regular face-to-face exchange (Delgadillo et al., 2021).

Apart from prior experience in collaborating, Velenturf (2016) describes another source of trust relevant to sustainable innovations, namely shared beliefs about the necessity of a transformation toward sustainability. This rather "cognitive-based" form of trust is very similar to the finding

described by Dubois (2019) about the relevance of a shared objective (see 4.3 cognitive proximity). As for the other proximity dimensions, it seems appropriate to analyze the role of social proximity in combination with the other proximity dimensions, which we will do in the next section.

4.7 | Interdependencies of the proximity dimensions

To better understand the knowledge processes in sustainable innovation networks, it is helpful to take a closer look at the interdependencies of the different proximity dimensions. In principle, all dimensions are relevant for analyzing the occurrence of sustainable innovations (Velenturf & Jensen, 2016). And all dimensions can have a positive effect on knowledge exchange and the emergence of sustainable innovations (Addy & Dube, 2018), just as they do for conventional innovations, although they might depict rather low levels for very new, disruptive technologies, compared to well-established ones (Raven et al., 2012). Nonetheless, the question arises, whether a high level in all dimensions at the same time is desirable (or even feasible) when forming networks for sustainable innovations, considering that too much proximity might hamper innovative performance (Boschma, 2005). As Ievoli et al. (2019) put it, the success of such networks is likely to depend on a balanced level of proximity in all dimensions, with none being too strong nor too weak. Tani et al. (2021) come to a very similar conclusion with their agent-based model (as presented above): Networks taking into account multiple dimensions of proximity outperform networks concentrating solely on geographical proximity.

In our review, we found mainly two mechanisms regarding the interdependency of the different proximity dimensions. The first one is reinforcement: High proximity in one dimension can lead to an increased level of proximity in another dimension. The second mechanism is a dyadic effect of either overlap or substitution: A high level of proximity in one dimension can gap the distance in another dimension.

Addy and Dube (2018) find several reinforcement effects in their case study, which work over different time horizons. In the short run, geographical proximity can enable cognitive proximity, as a close, direct face-to-face interaction facilitates knowledge exchange (including the exchange of tacit knowledge) for creating a common understanding. In the medium term, formal organizational structures are likely to positively influence cognitive proximity and social proximity, as they foster continuous exchange and provide shared resources. In the long run, organizational proximity can furthermore reinforce institutional proximity in the form of shared codes of conduct, norms, and values. Royo-Vela and Mazandarani (2022), looking at the relationships between the non-spatial proximity dimensions, also find that institutional proximity and social proximity are affected by organizational proximity, as well as vice versa. However, they find no relationship between organizational and cognitive proximity. They furthermore find that social proximity as well as institutional proximity are both affected by cognitive proximity, and vice versa. Between institutional and social proximity, they find no relationship. They find the strongest link between institutional and organizational proximity and state that the social dimension has the weakest measurable effect on other dimensions. Dubois (2019) sees that social and cognitive proximity can lead to organizational and institutional proximity, as collaborations based primarily on trust and mutual understanding become more formalized and based on agreed procedures. Several authors (Delgadillo et al., 2021; Dubois, 2019; Lopolito et al., 2022) refer to the argument, that geographical proximity favors the building of trust and hence enables social proximity.

The second effect, the overlap or substitution of different proximity dimensions, is comprehensively described by T. Hansen (2015), although he limits his analysis to spatial versus



non-spatial proximity dimensions and does not relate the different non-spatial dimensions to each other. T. Hansen (2015) finds a substitution effect between social and geographical proximity, as firms collaborate more easily with unknown partners that are spatially close but prefer the presence of established social ties when partners are far away. Furthermore, he finds overlap between geographical and institutional proximity resulting from the fact that many institutions are place-bound, which supports the notion that long-distance collaborations mainly struggle with institutional differences. For cognitive and geographical proximity, he also finds a substitution effect: Partners being spatially close to each other often have different, complementary knowledge bases. The same result was found by Dubois (2019) and Ievoli et al. (2019), who see an increased relevance of cognitive proximity in long-distance collaborations, as a low frequency of personal meetings or the replacement of face-to-face contacts by ICT increases the need to have shared understandings. For organizational and geographical proximity, T. Hansen (2015) finds a strong substitution effect, which is also reported by Ghassim (2018): Formalized networks can significantly facilitate knowledge exchange with partners that are far away. The working mechanism seems to be similar to that of social proximity. This view is supported by Velenturf (2016) who finds that social and organizational proximity can work as substitutes, however, with some limitations as trust and formal arrangements are to some extent complementary and cannot fully replace each other.

5 | DISCUSSION AND CONCLUSIONS

Firms increasingly focus on external knowledge when developing sustainable innovations (Aldieri et al., 2019). This knowledge can often be found with non-profit partners such as research institutes, state agencies, or civil society organizations, which leads to innovation networks with different actor constellations, compared to conventional, purely economic innovations. To better understand the knowledge flows in such sustainability-oriented innovation networks, we conducted a systematic literature review focusing on the concept of proximity with its five dimensions. The review shows that each dimension in itself is valuable for understanding the linkages between the actors in innovation networks. However, looking at the interdependencies of the dimensions allows further insights into the working mechanisms at hand. We found two effects in the literature. One is the reinforcement effect: Certain proximity dimensions can enable other dimensions. The second effect is substitution or overlap: Certain proximity dimensions can replace other dimensions, whereas other dimensions show a high degree of overlap.

We found that geographic proximity is highly conducive to sustainable innovations, as it allows for frequent face-to-face contact and the exchange of tacit knowledge, which is especially relevant for actor constellations with low (initial) levels of trust, in the absence of formal ties, and for collaborations with low cognitive proximity. However, geographical proximity is no prerequisite and might limit the innovative performance of a network if distant partners with relevant knowledge are excluded.

Cognitive proximity is the only proximity dimension that appears to be a prerequisite for knowledge exchange to work properly. Without a certain level of absorptive capacity and mutual understanding, it is highly unlikely that two partners will fruitfully exchange knowledge or prolifically create new joint knowledge. However, too much cognitive proximity leaves little space for genuine new knowledge combinations. Regarding the social and environmental aspects of sustainability, comparably low levels of cognitive proximity seem promising, combining the specific sustainability knowledge of research and civil society partners with the economic,

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market-oriented knowledge of firms. Partner constellations with low levels of cognitive proximity, however, seem to require higher levels in other proximity dimensions for cooperation to be effective.

This leads to institutional proximity. A common institutional framework in the form of rules, regulations, and social norms that apply to all partners, can significantly facilitate cooperation. The same holds for the internal institutional settings of the involved partners. Collaboration between two universities is facilitated by the similarity of the incentives and constraints faced by both partners. But, regarding the argument above, that sustainability-oriented innovation networks have a higher innovative potential if they include partners from different institutional spheres (business, academia, state, and civil society), a low level of internal institutional proximity seems more promising. This leads us to conclude that splitting up the institutional proximity dimension into a micro level and a macro level is a fruitful approach for better analyzing the institutional setting of such innovation networks. The macro level would refer to legislation and culture of a specific locality (which is linked to geographical proximity), and the micro level would refer to the internal organizational logic of the involved agents.

Organizational and social proximity are both conducive to knowledge exchange and sustainable innovations, especially in actor constellations with low institutional, cognitive, or geographical proximity. Both dimensions can furthermore substitute each other to a certain extent, and both can lead to higher levels of cognitive proximity.

Summing up, the networks developing sustainable innovations can be characterized by various combinations of differently pronounced proximity dimensions. A very high level in all proximity dimensions seems unlikely (and not very favorable for sustainable solutions), as does a very low level in all dimensions. Going back to the understanding of sustainable innovations as systemwide, radical changes that have to be more than merely incremental technological novelties, the following combination of proximity dimensions seems plausible: Low cognitive proximity and low micro-institutional proximity, as actors from different institutional spheres (business, academia, state, civil society) are involved, having highly diverse knowledge sets; in combination with either high social, high organizational or high geographical (linked to high macro-institutional) proximity, providing effective mechanisms for mitigating the problems arising out of low cognitive and low micro-institutional proximity.

A simple example illustrates this argument: A network consisting of a university, a firm, an environmental organization, and a government agency, each having its sector-specific, specialized knowledge base, could be a promising starting point for developing sustainable innovations if they (A) have a binding organizational arrangement, such as a consortium agreement (organizational proximity); or (B) have a high level of trust to each other due to prior experiences working together or due to personal ties (social proximity); or (C) are spatially close to each other, e.g., are all situated in the same municipality. Of course, a combination would be imaginable as well: E.g. two have worked together before, two are spatially close and all partners together have signed a memorandum of understanding for cooperating.

The results of our study suggest a number of policy implications. First, it appears important to acknowledge the relevance of diverse actor constellations in shaping knowledge processes. Policies could incentivize the inclusion of various stakeholders, including those from different sectors, disciplines, and backgrounds, to promote a richer exchange of ideas and perspectives. This could be done in the frame of funding schemes for research and development projects. Such funding instruments could require the inclusion of actors from specific groups, which appears especially relevant for including civil society actors and governmental agencies. However, such approaches must be balanced with the funding models for purely curiosity-driven basic research. Another



approach could be a proactive regulatory framework and incentivization strategy to encourage more active involvement of governmental actors in sustainability-oriented innovation networks.

Second, innovation policy should address coordination challenges by considering the various dimensions of proximity and their interdependencies by elaborating strategies for enhancing specific proximity dimensions where needed or leveraging existing strengths in other dimensions. Corresponding instruments could be used to help actors with low cognitive and low (micro-)institutional proximity to successfully establish networks. It appears plausible that such instruments should primarily target social and organizational proximity, as the geographical circumstances of established actors are more difficult to change. This could also enrich regional clustering activities by providing access to remote agents who possess valuable knowledge.

Following our literature review, the next step would be the attempt to validate our findings. For this purpose, a comprehensive analysis of a large number of sustainable innovations and the networks behind them would be promising. An empirical, quantitative study of the different proximity dimensions in these networks could provide further insights into whether the abovementioned combinations of proximity levels are indeed prevalent. Such a study could involve different industries and regions to provide a comprehensive understanding of sustainable innovation networks. One challenge presumably is the identification of such networks. As mentioned above, patent data or data on co-publications might not be the best proxies for sustainable innovations. Another approach could be to utilize databases for research and development projects, such as data on the European Framework Programs (CORDIS). After identifying relevant innovation networks, data collection could be done based on surveys and questionnaires.

However before conducing a qualitative analysis, it seems appropriate to aim for further conceptual clarification of two proximity dimensions. The first one is institutional proximity which should be separated into two distinct sub-dimensions, one being micro-institutional proximity and the other one being macro-institutional proximity.

The second proximity dimension that seems to need further conceptual research, is cognitive proximity. The findings for this dimension are mixed, presumably due to the reverted U-shaped relation between cognitive proximity and innovation. It would be interesting to go into more detail and examine cognitive proximity in relation to different types of knowledge. As there is a multi-tude of knowledge typologies, the initial step would be to choose an appropriate one. Since the innovations we are scrutinizing all refer to sustainability, a suitable choice seems to be the tripartite of systems knowledge, transformative knowledge, and normative knowledge, which is widely recognized as being important for a transformation toward sustainability (Abson et al., 2014; Urmetzer et al., 2018; Wehrden et al., 2017; Wiek et al., 2012).

In-depth case studies on these two proximity dimensions and their differentiation into subdimensions potentially provide rich insights into the nuances of institutional proximity and cognitive proximity and how they influence sustainable innovation networks. This could be done by examining real-world examples of sustainable innovations to understand how these two dimensions manifest in practice.

Another avenue for further research could be the comparative analysis across different thematic fields and regions. It would be interesting to explore whether the relationships between the proximity dimensions hold consistently across different sectors and regions. A comparative analysis could reveal whether certain proximity configurations are more prevalent or effective in specific contexts. This could lead to valuable insights for policymakers and practitioners aiming to foster sustainable innovations in diverse settings.

The systematic literature review we presented here, has its limitations. As with every systematic review, there is always the risk of omitting a relevant paper, which we tried to counteract by using

very broad search terms in two databases with wide coverage, by applying variations in the search terms, and by conducting thorough citation snowballing (checking for relevant references, which of course is limited by relying on the set of cited articles). These steps also helped to minimize potential biases in the search terms.

The methodical pluralisms of the papers we analyzed is another point, which we see as an advantage as it offers different studies of proximity from a variety of different angles. However, inherent to comparing such a multiplicity of approaches is the challenge of having different definitions, operationalizations, and measurement approaches, and hence a certain degree of conceptual fuzziness and slight variations in the exact meanings of the underlying concepts. This variability in definitions and operationalizations should be associated with challenges in generalizing the findings of the study. However, we believe that the commonalities of the different papers outweigh the slight variations in the used definitions, thus allowing for comparison and thus the derivation of general findings. The above-mentioned avenues for future research address these issues by examining whether it is possible to cluster the prevalent variations into subgroups based on specific criteria.

Nonetheless, we believe our study contributes to the field of innovation economics and provides helpful insights for practitioners, such as firms searching for suitable cooperation partners, policymakers drafting programs for promoting sustainable innovations, or civil society initiatives seeking strategies to advance their causes.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

Not applicable.

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ENDNOTE

¹The exact search queries were TITLE-ABS-KEY(proximity AND sustainab* AND (innovat* OR knowledge)) for Scopus and TS = (proximity AND sustainab* AND (innovat* OR knowledge)) for Web of Science

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