

John Chrisman*, Giuseppe Calignano**

*Modes of innovation and proximity in practice:
Insights from university-small and medium sized enterprise
collaboration in biotechnology*

Keywords: university-industry collaboration, peripheral regions, cluster dynamics, innovation, proximity.

This article explores factors driving collaboration between biotechnology firms and higher education institutions, emphasizing various proximity dimensions (geographic, cognitive, social, organizational, institutional). Through interviews within Norway's Heidner Biocluster, we found geographic proximity matters more for larger, established firms collaborating with local higher education institutions, compared to smaller, internationally oriented firms. Our findings highlight differences in firms' innovation modes (doing, using, and interacting vs. science, technology and innovation) and underscore the roles of informal institutions, embeddedness, and alternative proximities beyond geography.

Modalità di innovazione e prossimità nella pratica: approfondimenti sulla collaborazione tra università e PMI nel settore biotecnologico

Parole chiave: collaborazioni università-industria, regioni periferiche, cluster, innovazione, prossimità.

Questo articolo esplora i fattori che favoriscono la collaborazione tra le PMI biotecnologiche e le istituzioni di istruzione superiore, concentrando sulle diverse dimensioni della prossimità: geografica, cognitiva, sociale, organizzativa e istituzionale. Dalle interviste condotte presso l'Heidner Biocluster in Norvegia, emerge che la prossimità geografica riveste un'importanza maggiore per le PMI più grandi e consolidate rispetto a quelle più piccole e orientate all'internazionalizzazione, quando si tratta di collaborare con le istitu-

* University of Inland Norway, School of Business and Social Sciences, P.O. Box 400, 2418 Elverum, Norway, jchrism@gmail.com.

** Università di Bologna, Dipartimento di Scienze Politiche e Sociali, Strada Maggiore 45, Bologna, Italia, giuseppe.calignano2@unibo.it.

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zioni di istruzione superiore locali. I risultati evidenziano differenze nei modelli di innovazione aziendale e sottolineano il ruolo cruciale delle istituzioni informali, del radicamento territoriale e delle altre forme di prossimità, oltre a quella geografica.

1. INTRODUCTION. – This article explores the knowledge exchange dynamics occurring between HEIs (Higher Education Institutions) and small and medium-sized enterprises (SMEs) in the biotechnology sector in the Inland County of Norway, a peripheral region. More specifically, we are interested in understanding what elements drive or, conversely, hinder these possible and fruitful collaborations. Considering the perspective of SMEs, through a spatial and relational perspective, and adopting a qualitative methodological approach and in-depth interviews, we also investigate several dimensions of proximity to better understand the ways in which local SMEs interact with academic partners at various geographic scales.

Presently, the expectation that universities contribute to the governance and innovation policy decisions at the regional level continues to grow (Benneworth & Fitjar, 2019; Fonseca & Nieth, 2021). This has been referred to as the ‘third mission’ (Gunasekara, 2006; Sánchez-Barrioluengo & Benneworth, 2019) and captures the shift that has occurred by situating universities in more of a partnership-role with regional governments. While this shift has been demonstrated in central regions, this collaboration is particularly important in peripheral regions where the role of universities can extend beyond knowledge transfer and business development (Calignano & Quarta, 2014).

We explore the role of universities in peripheral regions and detail how these roles and specific types of universities can be even more impactful in isolated and lower income regions (see Boucher *et al.*, 2003; Trippel *et al.*, 2015).

Using Boschma’s (2005) dimensions of proximity from geographical to institutional, this article takes a well-established, but not yet fully explored approach in the literature by specifically applying these forms of proximity to U-I linkages (see, e.g., D’Este *et al.*, 2013; Shi & Wang, 2023). Interviews conducted with CEOs and managers focused on the frequency and intensity of collaboration at various product life stages, barriers, and enablers, exploring various knowledge channels and the roles of cluster administrators in facilitating these linkages.

Based on these premises, this article addresses the following research question: How are different dimensions of proximity (e.g., geographic, cognitive, social, organizational, and institutional) related to collaboration choices and patterns between biotechnology-based small and medium-sized enterprises (SMEs) and local and non-local higher education institutions (HEIs)?

Our empirical analysis has uncovered several findings with which we intend to contribute to theoretical and policy discussions on this topic. First, our study

confirms the importance of different dimensions of proximity in U-I interactions, although geographic proximity to the local HEIs appears to be particularly important for older and larger firms operating in the broader field of agricultural sciences i.e. the sciences concerned with the study of plants, soil and agricultural techniques. In contrast, newer and smaller firms operating in the more specialized agricultural biotechnology subsector i.e. the use of a collection of scientific techniques used to improve the production of plants and livestock (Hefferon, 2016) collaborate more often and effectively with geographically more distant partners. Despite this difference, it should be noted that many of the firms have similar goals which may overlap. However, the smaller newer ones are more technologically focused and narrow in their scope than the larger older ones. We were able to relate these findings to the socio-institutional environment in which the target Norwegian firms operate and the mode of innovation they primarily employ (e.g., Doing-Using-Interacting [DUI] vs Science-Technology-Innovation [STI]).

2. THEORETICAL BACKGROUND. – Universities are generally considered important partners for regional businesses, whose goal is to innovate to remain competitive in their respective markets (Lazzarotti *et al.*, 2025). Nowadays, knowledge-intensive activities play a key role in the economy, and innovation – which is one of the keys to maintain competitiveness – is often the result of ‘open’ methodologies (Chesbrough, 2003) and frequent exchanges between industrial and academic spheres (Zhang & Wang, 2017). This is the so-called ‘third mission’ of universities, that is, the social, economic, and cultural contribution to local and regional development through the transfer of technology and knowledge to industry (Etzkowitz & Leydesdorff, 2000; Gunasekara, 2006; Sánchez-Barrioluengo & Benneworth, 2019). Along with teaching and research, this is one of the key activities carried out by HEIs.

Universities and private industry collaborate for several reasons. Academics can benefit from publications, new ideas, and projects focused on applied research that enable them to address the problem of academic conservatism. On the other hand, industrial partners benefit from collaborations with university researchers especially in terms of quality of human capital, talent selection, monitoring of scientific progress and, perhaps most interesting for the purposes of this article, basic research and open access to new information (see Foray & Lissoni, 2010).

Although important everywhere, the role of universities is even more critical in the case of peripheral regions (Calignano & Quarta, 2014; Evers, 2019). Previous research from Boucher *et al.* (2003) have classified academic institutions in peripheral regions as either single-player or multi-player universities. While the role of the former is to encourage entrepreneurship and technology transfer, the main roles of the latter are to foster regional consortia, participate in cultural networks,

support the health care system (through the exchange of knowledge and new technological solutions), and trigger new paths of development by attracting knowledge-based extra-regional SMEs.

A further useful taxonomy was provided by Trippl *et al.* (2015), who distinguished universities according to their different contributions to regional economic and social development. Specifically, entrepreneurial university models contribute to regional development by actively commercializing the knowledge they produce through spin-offs, patents, and licensing. Regional innovation system (RIS) university models focus on systemic innovation and interactions with other RIS actors, while they do not focus exclusively on commercializing research activities, but use more diverse channels of knowledge exchange, which include research and development (R&D) cooperation, supply of skilled labor to local markets, and informal contacts. Mode 2 university models are characterized by applied, trans-disciplinary and heterogeneous research, usually related to their respective environments, and collaborative research projects with other HEIs. Finally, engaged university models focus on the specific needs of the regional areas in which they are located, and their research activities are strongly linked to local industries and society.

As mentioned above, U-I interactions occur through various knowledge exchange channels. These may include research contracts, other types of contracts (e.g., consulting, experimentation, activities), partnerships in national and international consortia, and informal contacts (Calignano & Quarta, 2014; Trippl *et al.*, 2015). These channels are decidedly influenced by the type of companies involved and the industrial sector they belong to. Similarly, the geography of U-I interactions is influenced by the type of industry and knowledge base that characterizes a particular SME (Asheim & Gertler, 2005).

An important distinction is often made between the STI and the DUI modes of innovation. As noted by Jensen *et al.* (2007), the STI mode is primarily rooted in the production and application of codified scientific and technical knowledge, whereas the DUI mode relies more on informal learning processes, practical experience, and tacit know-how.

Although the STI and DUI modes have clear implications for the relational dimensions of innovation – including various forms of proximity that shape and influence U-I linkages – this topic has been overlooked in the literature. Where it is addressed, it is often treated tangentially rather than being examined for its potential consequences at the industrial, academic, and especially territorial levels.

One of the few, albeit not recent, exceptions is the study by Isaksen and Karlsen (2010), which examined innovation and cooperation between firms and universities in two Norwegian regional industries: marine biotechnology in Tromsø, dominated by the STI mode, and oil and gas equipment suppliers

in Agder, characterized by the DUI mode. Their findings show that university-industry cooperation must be carefully tailored to both the university's knowledge base and the region's dominant innovation mode. Additionally, González-Pernía *et al.* (2015) were among the first to challenge the prevailing view that universities are the primary STI partners providing science- and technology-driven knowledge for innovation. Their study demonstrated that both STI and DUI partnerships play important roles in driving product and process innovations. However, the impact of these partnerships varies: product innovation benefits more from the combination of DUI and STI collaborations, while process innovation is more strongly associated with DUI partnerships alone.

Continuing this line of reasoning, the case study presented in this article considers biotechnology SMEs located in a peripheral region of Norway that have engaged in collaborations with HEIs. Although not exclusively, biotechnology is primarily a scientific field characterized by an analytical knowledge base (Asheim & Gertler, 2005). According to many scholars (Boschma *et al.*, 2014; Martin & Moodysson, 2013), companies in this type of industry exchange codified knowledge (e.g., scientific articles or reports and patents) and use an STI mode making their knowledge exchange less sensitive to geographic proximity (Jensen *et al.*, 2007). That is, biotechnology companies can potentially source the knowledge they need from more geographically distant academic institutions. However, it should be underscored that frequent interactions with local universities are equally advantageous in the case of broadly defined biotech SMEs that have their roots in agriculture, forestry or animal husbandry and tend to use more tacit knowledge and apply the DUI mode of innovation (Aslesen & Pettersen, 2017). Despite some notable exceptions (Asheim *et al.*, 2011), the possible combination of STI and DUI modes of innovation in biotechnology and its implications for U-I interactions is a topic seemingly neglected by economic geographers and regional scientists. On the contrary, we believe that focusing on this aspect can lead to interesting and original results on the relational and geographical dynamics underlying collaborations between the industrial and academic spheres. The frequency and intensity of interactions between co-located organizations, as in the case of SMEs and HEIs, appear to be particularly important in the initial stages of the product life cycle, that is, when creativity is key and less standardized activities are performed (Feldman & Kogler, 2010). However, other factors such as government incentives (e.g., tax breaks; see Mercuri & Birbeck, 2020) or specific policy actions (e.g., joint participation in research consortia or targeted funding programs; see Schulze-Krogh and Calignano (2020), can help stimulate interactions between local SMEs and co-located HEIs.

Linking this discourse to the critical issue of proximity in innovation dynamics (Boschma, 2005), geographical proximity is, however, only one of the possible

forms of proximity that can generate satisfactory collaborations (Chrisman, 2024). In this regard, it is worth noting that geographical proximity makes U-I linkages easier, faster, and cheaper (Feldman & Kogler, 2010), but it is not in itself a sufficient condition for U-I interactions to take place. In other words, geographical proximity alone may not be enough to initiate collaborations with regional academic partners, suggesting that other equally relevant dimensions of proximity may be needed. In addition, other dimensions of proximity might trigger U-I interactions between distant organizations when a SME cannot locally secure the kind of skills, competencies, and abilities (but also tools or machinery) it is looking for (Alpaydin & Fitjar, 2021). In this regard, Boschma's (2005) seminal work still supports our empirical search for an association between U-I interactions and different dimensions of proximity. In addition to geographical proximity (i.e., cooperations facilitated by spatial proximity), Boschma (2005) refers to cognitive, social, organizational, and institutional proximity, which can be considered as possible critical factors for collaborations with geographically close and extra-regional universities.

Cognitive proximity occurs when two collaborating organizations share similar skills and expertise, facilitating knowledge exchange whereas social proximity refers to friendships, kinship, common knowledge, and previous positive collaborations that strengthen trust and lead to fruitful interactions between the two spheres of reference. Institutional proximity is indirectly related to geographical proximity, as it corresponds to formal (laws and rules) and informal institutions (cultural norms and habits) that influence the outcomes of interactions and the way collaborating organizations interact. Finally, organizational proximity in Boschma's (2005) taxonomy is related to the hierarchical coordination of economic activities between establishments belonging to the same parent company (i.e., multinational SMEs, mergers, acquisitions, etc.) that allows SMEs to successfully manage complementary pieces of knowledge. In this article we interpret this type of proximity differently by looking at shared shareholdings on the same boards of scientific and industrial associations or cluster management as an expression of organizational proximity. Although predictable, it is worth clarifying at this point that all these forms of proximity, which can trigger successful U-I interactions, can be an obstacle to possible successful collaborations between the two spheres when they are lacking.

Economic geographers and regional scientists have shown a great interest in the topic of proximity in regional development (Calignano & De Siena, 2018; Roth & Mattes, 2023; Torre & Wallet, 2014) and a relatively high number of studies has similarly applied this key approach to the study of U-I interactions. Among others, D'Este *et al.* (2013) found that geographical proximity is important in shaping collaborations between regional SMEs and HEIs in the United Kingdom, but that

this effect is weakened when SMEs are in dense technology clusters. In this case, SMEs can ignore distance and collaborate frequently and effectively with more distant academic partners. Crescenzi *et al.* (2017) focused on co-patenting in the Italian context and found that geographic proximity can be a substitute for a lack of institutional proximity, while the reputation of both academic and industrial inventors is a key element in collaboration models. Nilsen and Lauvås (2018) found that social proximity and high levels of organizational proximity can overcome the lack of geographical proximity in the Nordic periphery. Moreover, Calignano and Quarta (2014) examined the geographical distance of industrial partners who signed research contracts with a peripheral university in southern Italy and found that the frequency and value of such contracts varied significantly by the type of client i.e., that public clients are geographically concentrated in the regions concerned, while private clients are more geographically dispersed. Chrisman (2024) recently highlighted those structural, softer' factors – such as age, size, and trust – can help SMEs compensate for deficiencies in innovativeness and human capital, thereby fostering more frequent and intense collaborations with local HEIs. Previous studies have shown that the degree of satisfaction in U-I interactions varies significantly (Calignano & Jøsendal, 2018; Schulze-Krogh & Calignano, 2020). All the factors illustrated in this section (proximity dimensions, type of companies and universities involved, modes of innovation, etc.) can contribute to success or hinder the positive outcomes of collaborations between academic institutions and private companies.

3. METHODOLOGY. – Through seven qualitative interviews, this paper evaluates Boschma's (2005) proximity dimensions as they apply to higher education institutions (HEIs) and small and medium-sized enterprises (SMEs) in peripheral regions. It also investigates the drivers of collaboration between SMEs and HEIs in the biotechnology sector, aiming to better understand the key enablers and barriers SMEs face in partnering with both local and non-local HEIs. We drew on Boschma's (2005) conceptualization of proximity, alongside Jensen *et al.*'s (2007) and Asheim and Gertler's (2005) work on DUI (Doing-Using-Interacting) and STI (Science-Technology-Innovation) modes of innovation, to inform our interview guide, case selection, and coding framework. Deductive content analysis was used to test these concepts against the interview data.

Our analytical framework followed the five-step deductive content analysis method outlined by Sheydayi and Dadashpoor (2023), which involved selecting the type and theoretical orientation of the data, defining research objectives, describing data analysis and interpretation procedures, and outlining how results were applied (Sheydayi & Dadashpoor, 2023, p. 9). Boschma's (2005) proximity dimensions directly informed our interview guide. For example, to address

geographical proximity, we asked: “Did you instantly look towards Oslo or Bergen or Berlin, or did you try to stay local?” To explore social proximity, we included questions about informal or personal connections that had led to collaboration. Organizational proximity was examined through questions about existing networks, alliances, and structures. For DUI and STI modes, we relied on the work of Jensen *et al.* (2007) and Asheim and Gertler (2005), asking firms about their R&D processes, trust-building, knowledge alignment, the timing of collaboration in the product development cycle, and examples of interactive learning. During coding, we focused on references to collaborative projects, trust, and social ties, mapping them onto Boschma’s proximity dimensions.

The seven SMEs selected for interviews were chosen based on differences in age, size, economic scope, sector, and the extent to which they exhibited DUI or STI innovation modes within the NCE Heidner Biocluster. Including both older, larger firms and newer, smaller ones allowed for comparison of differing approaches to innovation and collaboration. All participants were in or near Hamar, Norway, worked in the biotechnology sector, and had direct experience collaborating with local HEIs through research or business projects.

All interviewees represented SMEs that are members of the Hamar-based NCE Heidner Biocluster. This cluster, Norway’s only national cluster focused on sustainable food production and the green bioeconomy, comprises over 50 members ranging from micro-enterprises to large corporations, along with national research institutions and university colleges. Collectively, these members employ over 15,000 people and generate a combined turnover exceeding NOK 66 billion (NCE Heidner Biocluster, 2020).

Our selection of representative SMEs was based on a two-part survey conducted among cluster members in 2022 and 2023. This survey collected data on employee educational backgrounds, firm age, economic characteristics, product development stages, and existing collaborations within the cluster (Chrisman, 2024). These results helped us identify suitable SMEs for qualitative interviews. Semi-structured interviews, each lasting approximately one hour, were conducted using an interview guide informed by the proximity and university–industry linkage literature, particularly Boschma (2005), Tripli *et al.* (2015), and Calignano and Quarta (2014).

Questions addressed collaboration across various product development stages, engagement in research, experiences with cluster management, and organizational structure. Interviews were conducted in person, and informed written consent was obtained from all participants in accordance with ethical guidelines from the Norwegian Centre for Research Data (NSD) and the General Data Protection Regulation (GDPR), particularly with respect to data storage, anonymization, and use. Transcripts were deductively coded based on Boschma’s (2005) proximity

framework and related concepts from Trippi *et al.* (2015) and Calignano and Quarta (2014). Themes were developed iteratively and validated through repeated consultation with the interview data.

Although the study is based on a small sample of seven SMEs, the careful case selection, and their representative positions within the cluster, combined with survey data and in-depth interviews, provided a robust empirical basis for this exploratory, qualitative research.



Fig. 1 - Map of the Inland region of Norway. © OpenStreetMap contributors

4. CASE STUDY DESCRIPTION AND RESULTS. – A central theme emerging from the analysis was differences in age, sector, and size of SMEs and their distinct DUI vs STI approaches. SMEs were categorized into two groups (Cash & Snider, 2014), validated using secondary sources. The first group includes larger, older SMEs (1, 7, 6, 3), established before 2002. These SMEs are deeply embedded in the agricultural sciences sector with strong local ties, ongoing relationships with regional universities, and collaborations with local SMEs. The second group consists of smaller, newer SMEs (2, 4, 5), founded post-2002, focused on agricultural biotechnology but less regionally embedded, often partnering internationally.

Tab. 1 - Demarcation of groups based on small and medium-sized enterprise characteristics

<i>Type of SMEs</i>	<i>Larger, Older, Established, Embedded SMEs</i>	<i>Smaller, Younger, Startups</i>
Sector	Agriculture sciences	Agricultural Biotechnology
Collaboration with universities	Mainly local	Mainly national and international
Innovation mode	Combination of DUI and STI	STI
Importance of geographical proximity	Yes	No
Importance of other forms of proximity	Cognitive; Social; Institutional; Organizational	Cognitive; Institutional
Collaboration phase	Early	Early
Enablers (collaborations w/local universities)	Participation in cluster activities; political activities; social events; embeddedness in local environment	Benefiting from activities carried out in local business incubator
Barriers (collaborations w/local universities)	Lack matching expertise; Necessity to improve outreach, engagement, public-private partnerships	Lack matching of expertise; Necessity to improve outreach, engagement, public-private partnerships, lacking social ties and affinities with local established values and ways of doing things; different mentalities, lack of initiatives, less dynamic regional environment
Enablers (collaborations w/non-local universities)	Expertise, equipment, laboratories, internal funds which are not available regionally; possibility to apply for external funds (e.g., creation of EU consortia); culture of collaboration; perceived prestige of non-local universities	Expertise, equipment, laboratories, internal funds which are not available regionally; possibility to apply for external funds (e.g., creation of EU consortia); culture of collaboration; perceived prestige of non-local universities

Tab. 1 - Continued

<i>Type of SMEs</i>	<i>Larger, Older, Established, Embedded SMEs</i>	<i>Smaller, Younger, Startups</i>
Barriers (collaborations w/non-local universities)	Cultural differences (e.g., different languages, routines, etc.); Locally oriented projects and lack of international scopes; Lacking international networks; lack of trust	Small sized projects leading to lack of interest from nationally or internationally renowned universities; Too costly collaborations for startup companies with lacking financial resources; lack of trust
Financial incentives	No	No
Degree of satisfaction (collaborations w/ local universities)	Medium-High	Medium-Low
Degree of satisfaction (collaborations w/ non-local universities)	Medium-High	Medium-High

4.1 Innovation Modes and Geographical Proximity. – As shown in Table I, larger, older SMEs preferred collaboration with local universities, particularly Inland University of Applied Sciences (HINN). A participant from SME 1 noted: “The know-how and competence here in HINN is very high.” Similarly, SME 3 stated the local university’s quality has “increased, absolutely.” Older SMEs frequently established long-term local projects and only pursued international universities when specific expertise was unavailable locally. Conversely, newer SMEs faced challenges in establishing local collaborations, opting instead for national or international university partnerships. Older SMEs utilize combined DUI and STI innovation modes, emphasizing cooperation and interactive learning with local partners, aiming to enhance regional SMEs, attract local talent, and improve local value chains. Interviewees highlighted the importance of tacit knowledge exchanges, noting that proximity enables interactions and recruitment, including student involvement in SMEs’ research. SMEs emphasized the significance of local universities in addressing technical problems and providing practical support such as technical advice and research collaboration. Although biotechnology typically emphasizes analytical knowledge, our study indicates significant tacit knowledge use and DUI modes among SMEs in agricultural biotechnology. This interaction extends beyond suppliers and customers to local higher education institutions (HEIs). Newer SMEs primarily employ the STI mode, emphasizing R&D capacity, commercialization, and enhanced mobility between universities and SMEs. Geographical proximity was valued more by larger, older SMEs, who

prioritized regional partnerships, emphasizing local product quality and industry sustainability. Conversely, newer SMEs placed less importance on proximity, highlighting expertise and exposure from national or international partnerships as more critical.

4.2 Other dimensions of proximity: cognitive, social, institutional, and organizational. – Both SME groups valued cognitive and institutional proximity, yet older SMEs emphasized social and organizational proximity, regularly participating in local cluster activities and governance. Local Biocluster involvement significantly enabled their university collaborations. Newer SMEs identified the local business incubator, co-located with the university, as an important facilitator for collaboration. However, both groups identified barriers such as the lack of matching expertise locally. Older SMEs stressed the need for improved university outreach and efficient partnerships. Newer SMEs noted difficulties due to less dynamic local environments, indicating a frequent necessity to seek expertise nationally or internationally.

4.3 Key barriers and enablers of collaboration. – Older SMEs identified equipment, expertise, funding, and the necessity of international collaboration for EU grants as primary enablers for collaborating with non-local universities. Smaller SMEs also cited the importance of diverse departments, international networks, and perceived prestige. However, cultural differences, language barriers, and locally oriented projects were barriers for older SMEs. For newer SMEs, barriers included limited funding, initial collaboration costs, and trust deficits. Local university collaboration satisfaction was medium-high among older SMEs, highlighting trust, shared culture, and quality work. Similar satisfaction was reported for non-local universities. Newer SMEs reported medium-low satisfaction locally, citing project initiation and pacing challenges, though they appreciated the cost-effectiveness. Their satisfaction with non-local universities was medium-high due to stronger collaboration cultures.

5. DISCUSSION OF THE MAIN RESULTS AND CONCLUDING REMARKS. – Focusing on biotechnology allowed us to provide some clear and hopefully interesting results from empirical, theoretical and policy perspectives. Our article confirms how geographic proximity *per se* – although important for some specific firms – “is neither a necessary nor a sufficient condition for learning to take place” (Boschma, 2005, p. 62). As emphasized by our interviewees, other forms of proximity (e.g., cognitive, social, institutional, organizational) are essential complements in the case of co-located partners or vital alternatives for generating fruitful knowledge exchange in the case of collaborations with more distant, non-local

academic institutions (on this topic, see also, D'Este *et al.*, 2013; Shi & Wang, 2023). Although this result could not seem particularly original at first glance since already observed in many other empirical analyses (Fitjar & Rodríguez-Pose, 2011; Hansen & Coenen, 2015; Nilsen & Lauvås, 2018; Wilke & Pyka, 2024), the factors underlying it (e.g., combination of innovation modes in the biotechnology sector leading to unusual or less frequently observed knowledge exchange dynamics in U-I interactions) could represent important elements of novelty that we will try to delineate and discuss more accurately below.

From an empirical perspective, our study has shown that significantly different drivers and barriers can be observed in the case of collaborations with local and non-local HEIs, and that this seems to be clearly attributable to the characteristics of the target firms and the biotechnology sub-group to which they belong (i.e., agricultural science vs. agricultural biotechnology; see Section 4 and Table 1 above for details). While larger and older firms in the local target area show a more pronounced propensity to collaborate satisfactorily with local HEIs, newer and smaller firms prefer collaborations with more distant HEIs because they cannot find locally the kind of knowledge, resources, and spirit of initiative they need.

As we will briefly revisit later, this is a particularly relevant finding in peripheral areas where only one or a few HEIs are present. Although universities and research centers may foster fruitful knowledge exchange and stimulate positive innovation dynamics (Boucher *et al.*, 2003; Calignano & Quarta, 2014; Evers, 2019), factors such as limited specialization (Benneworth & Hospers, 2007), capacity constraints, cultural misalignments or mismatched incentives (Marijan & Sen, 2022) can create obstacles or even hinder effective U-I linkages for certain types of firms in such peripheral geographical contexts. In the Norwegian region we examined, the greater importance of geographic proximity for larger, older firms is determined by their degree of embeddedness in the region in which they operate. This is a relevant finding as it clearly highlights the importance of informal institutions (e.g., trust; see Edquist, 1997). More specifically, these types of firms consider participation in cluster activities, political participation, social events, and existing social recognition in the local environment as key factors for their collaboration with local HEIs. In other words, a higher level of social and institutional engagement is likely to make collaborations between larger, older firms and local HEIs more frequent and stronger than those established by smaller, younger firms. We can speculate that bonding social capital plays a critical role in this regard (Grzegorczyk, 2019; Sormani & Rossano-Rivero, 2023), while this can similarly represent a sign of what scholars in other fields call 'insider-outsider' theory (Lindbeck & Snower, 2001), i.e., larger, older and more connected SMEs occupy a dominant position by benefitting from long-standing informal

interactions and formal collaborations with the local university. This aspect may have an influence on the regional innovation agenda, significantly affect collaborations patterns, and somehow exclude newer and smaller SMEs from the existing consolidated regional networks. The consequence is that such a relatively 'closed' environment could push them to search for the knowledge they need elsewhere (i.e., nationally or internationally).

As sketched out above, the clear distinction between older, larger firms and smaller, younger firms implies that other dimensions of proximity influence collaboration patterns with HEIs (e.g., cognitive, social, institutional, and organizational). In this regard, our article demonstrates how, despite the analytical knowledge base that primarily characterizes biotechnology (Asheim & Gertler, 2005), SMEs are different, even when they operate in the same industry, and can employ different innovation modes depending on the sub-sector in which they operate (in our case, firms in agricultural science combine DUI and STI, while firms operating in agricultural biotechnology tend to favor STI). As the literature on the topic suggests, different innovation modes may lead to different types of exchanged knowledge (tacit vs. codified), knowledge exchange dynamics, and geographical collaboration patterns (Martin & Moodysson, 2013; Plum & Hassink, 2011). What our paper critically adds to this broad strand of literature is that, conversely to what previous studies largely seem to suggest (Fitjar & Rodríguez-Pose, 2013; Parrilli & Radicic, 2020), STI is not an exclusive feature of U-I interactions, since some biotechnology firms can effectively combine it with DUI, even in case of interactions between industrial and academic spheres, particularly when they are embedded in long-lasting webs of relations and informal exchanges with local academics (on this topic, see also González-Pernía *et al.*, 2015).

Interestingly, biotechnology firms operating in the agricultural sciences that adopt the DUI mode in addition to STI frequently benefit from tacit knowledge and synthetic knowledge to solve specific technical problems (Asheim & Gertler, 2005) when they collaborate with HEIs. In addition to confirm what recently published studies discovered in similar contexts with regard to the importance of the engagement of regional universities and their critical role in providing services and support to local businesses (Harrington *et al.*, 2015), ours is another relevant finding in terms of theoretical contribution since customers and suppliers are generally considered the most important and frequent partners in the case of DUI mode-driven collaborations (Jensen *et al.*, 2007; conversely, on some theoretical considerations about the possibility for biotechnology firms to effectively combine DUI and STI; Asheim *et al.*, 2011).

Finally, some policy lessons can be learnt from our study. First, a single university can certainly play a key role in peripheral regions (Boucher *et al.*, 2003;

Calignano & Quarta, 2014; Evers, 2019) but apparently this happens in the case of older, well-established and industrially more traditional firms that know well the social context and institutional environment in which they operate, thus benefitting from broader networking and long-lasting interactions with local academics. Considering the knowledge bases and the innovation modes primarily employed or their combination, i.e., one of the main elements of novelty brought to light by this paper, could represent an interesting starting point for future policy ideas potentially enhancing further the effects of the current and future regional and cluster actions. More in detail, and with specific regard to problems concerning collaborations between SMEs and local HEI, policymakers and academics should take into duly consideration the fact that – in addition to social ties – newer and smaller firms report lacking matching of expertise, initiatives, and dynamic regional innovation environment among the main factors hindering quantity and quality of collaborations with the local academic institution. Although it is clearly not easy to deal with all these combined issues, the regional and local authorities, Heidner biocluster to which these firms belong, and the local university of applied sciences (HINN) itself have to consider the invocation of these young SMEs by possibly launching new or improving existing indirect (networking) policy actions comprising more engaging and effective social events engendering or strengthening ties and potentially fostering new collaborations, coordinated activities for possible participation in joint research projects and, more generally, new socio-institutional conditions fostering collaborations between local HEI and the sub-group of biotechnology firms operating in the agricultural biotechnology sector (e.g., aligning with the firms' expectations and possibly de-institutionalizing some of the existing habits, routines and practices). On the potential positive effects of indirect policy measures compared with more direct financial support in clusters and related regions, see Calignano and Fitjar (2017) and Nishimura and Okamuro (2011).

These findings can be extended to other peripheral regions, including rural and remote areas of Southern Europe. Such regions are typically characterized by lower absorptive capacity (Pinto *et al.*, 2015), fragmented and inefficient institutional frameworks (Perri, 2020) and are often constrained by the dominance of bonding social capital, which limits openness to external knowledge sources (Crescenzi *et al.*, 2013). Moreover, bonding social capital may exclude younger and less integrated firms, further restricting opportunities for these firms to access valuable networks and resources.

As our study demonstrates, newer, smaller, and more enterprising firms may successfully establish connections with distant HEIs. However, this should not be regarded as a comprehensive solution. A coordinated effort is required across all stakeholders to better align with the heterogeneous needs of firms, which variously combine STI and DUI innovation modes.

Furthermore, local authorities, regional governments, and cluster organizations play a pivotal role in shaping an enabling environment for knowledge exchange. Their actions are critical to ensure that these interactions translate into meaningful innovation dynamics capable of addressing the specific challenges of peripheral regions.

In conclusion, despite the several findings discussed above, we must acknowledge that our article is not exempt from limitations. For example, while the age, size and industry of the seven firms interviewed are like the makeup of the entire cluster, our study focuses on only a few qualitative interviews of seven firms, in addition it examines one single industry and one region and does not consider the point of view of the academic sphere on the matter or the potential generalizability of the findings. Further studies could continue to refine and evaluate the barriers and enablers, add more firms and re-interview the SMEs to confirm and validate the findings. Conducting a comparative analysis of the findings in other regional clusters, whose sector is attributed to a certain knowledge base and mode of innovation (Asheim & Gertler, 2005), like, for example, the local timber industry, could be one such analytical project. Comparing regions across diverse socio-economic, cultural, political, and even climatic contexts – particularly from the increasingly critical perspective of sustainability transitions – offers a valuable approach to uncover analogies and differences that can inform both academic research and policymaking.

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