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The entrepreneurial university and development of large-scale research infrastructure: exploring the emerging university function of collaboration and leadership

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Abstract
This paper aimed to explore the emerging university function of collaboration and leadership in developing large-scale research infrastructure (LRI). A qualitative approach, drawing from both primary and secondary data, was employed to delve deeper into the roles and aspects of the entrepreneurial university pertinent to LRI development. The study highlighted the need for the entrepreneurial university to establish a strategic direction for collaboration and leadership in LRIs. A conceptual model was crafted that delineated the central role of the entrepreneurial university, segmenting the findings into three research elements: (1) research and education (2) collaboration, and (3) utilization and impact. Actor perspectives from both academia and industry were included. The findings emphasized that entrepreneurial universities had to engage more robustly with external actors to foster practical research applications. Universities were found to require a more synergistic role. The model proposed that entrepreneurial universities should classify actors not only by their viewpoint but also by their potential role in LRI. Key actors were identified as belonging to LRI and multi-academic environments, with some being directly involved, while others were indirectly or peripherally engaged. Directly involved actors, including numerous academic and industrial users, had a clear understanding of LRI utility and engagement, whereas indirectly involved ones were curious yet unsure about LRI interaction.

Keywords Entrepreneurial university · Large-scale research infrastructure · Academia · Industry · Collaboration · Research · Education

JEL Classification O25 · O32 · O38

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1 Introduction

Large-scale research infrastructures (LRIs) are important for advancing science across various domains, setting the stage for pioneering experiments. Among the diverse types of LRIs, the university LRI stands distinct, tethered to a nation and serving dual purposes of research and education. In contrast, there are national facilities termed "equipment of excellence," and international setups, born from the collaboration of multiple countries or organizations (Coughlan et al., 2016). Given their magnitude, actualizing LRIs demands multinational cooperation and public endorsement. Marshalling vast resources necessitates negotiations among a spectrum of actors (Autio et al., 1996). Moreover, these expansive research establishments do not function in isolation; they engage actively with their surroundings (Horlings et al., 2012). To harness the state-of-the-art technologies that LRIs house, a robust cadre of aptly skilled researchers is indispensable (Horlings et al., 2012). Consequently, any new infrastructure invariably exerts pressure on the encompassing institutional milieu (Yang et al., 2023). Despite their significance, research concerning LRIs remains limited, as underscored by Lozano et al. (2014).

Due to their prohibitive costs, LRIs often transcend national boundaries, necessitating global partnerships (Elzinga, 2012). These partnerships at LRIs typically manifest through formal inter-institutional contracts and policy blueprints (Lauto & Valentin, 2013). Delving deeper into these dynamics, Kohn Rådberg and Löfsten (2023) discerned that stakeholders like academia, industry, and policy mold the value blueprint of LRIs. In this tapestry, large industrial entities often gravitate towards academic establishments to fuel their technological ascent. Yet, the challenge often lies in forging these academic-industrial synergies.

The academic realm is currently witnessing a transformation. Universities are amplifying their roles, and entrepreneurial paradigms are gaining prominence. Although the overarching mission remains—addressing socio-economic conundrums through innovative ideation and execution—universities today play a role that's markedly different from three decades ago. This shift has led to the emergence of what Clark (1998a) termed *entrepreneurial universities*. These entities reflect profound shifts in university culture, organizational structure, and external relationships, driven by intense external pressures. The nexus between LRIs and entrepreneurial universities is crucial for propelling research, innovation, technology transfer, and regional and economic progression. Such a synergy cultivates a milieu wherein forefront research addresses significant societal issues, potentially catalyzing societal and economic advancements. The evolution of the entrepreneurial university arises from its intrinsic growth, external influences, and the augmented significance of knowledge-driven innovations. Many governments are crafting frameworks to foster more entrepreneurial universities. Consequently, this study delved into the rising role of universities in fostering collaboration and leadership within LRIs. Furthermore, there remains a research void about the entrepreneurial university's role in LRI development. Universities might need to shoulder more responsibility, intensifying ties with external stakeholders to translate research into practical applications.

Etzkowitz (2004) posited that universities have adopted economic and social development responsibilities, leading to the introduction of the term entrepreneurial university. This concept is pivotal within the triple helix model, and as per Etzkowitz (2003b) and Etzkowitz and Leydesdorff (2000), the university's third mission (preceded by education and research) is to further economic progress. This additional role necessitated transformative shifts in university organization and the endeavors they pursued (Etzkowitz, 2019). Such transformations manifested in joint research initiatives, patents, and licenses (Ardito et al.,

2019; Feldman et al., 2019; Feola et al., 2021; Fuster et al., 2019; Petruzzelli & Murgia, 2019). Confronted by significant political and economic pressures, universities expanded their roles, not only enlightening society but also engendering and disseminating knowledge pivotal for business and societal evolution.

Earlier studies regarding entrepreneurial universities can be classified as patenting and licensing of inventions, technology transfer offices, science parks and incubators, academic spin-offs, external teaching and education, academic entrepreneurship, regional growth and research-led technological innovation (Grimaldi & Grandi, 2001; Aaboen et al., 2008; Audretsch & Keilbach, 2008; Holden & Goldstein, 2010; Gordon et al., 2012; Abreu et al., 2016; Rizzo, 2015; Trequattrini et al., 2015; Johnstone & Huggins, 2016; Carlesi et al., 2017; Fernandez-Alles et al., 2018; Pugh et al., 2018; Feola et al., 2021, Salamzadeh et al., 2022). Several scholars have studied entrepreneurship within the university as well as entrepreneurship training programs (Kirby & Mullen, 1990; Laukkanen, 2000; Shane, 2004).

Several studies have been conducted regarding university-industry collaboration from various perspectives and identification of obstacles (Siegel et al., 2003; Valliani et al., 2016; Yusuf, 2008). However, despite studies regarding entrepreneurial universities over the years, the topic remains underexplored (Secundo et al., 2020). Earlier research mainly focused on the background and historical development of the facilities, science policy, or scientific performance (Hallonsten, 2013; Qiao et al., 2016). Scholars have also studied collaborations with large research teams (Bozeman & Youtie, 2017; Dias & Selan, 2023) or collaboration types and policy effects (D'Ippolito & Rüling, 2019). The universities' strategic partnerships are also not sufficient in this context because there are larger dynamics involved in working with LRIs and managing other relevant actors, which has led to a research gap. Sandberg and Alvesson (2011, p. 23) called the process of finding research gaps in the literature "gap-spotting."

Given this context, the prevailing goal is to establish innovation milieus that foster collaboration and exchange while also enhancing research and education at universities.

Considering the aforementioned background, this study sought to identify the conditions necessary for entrepreneurial universities to assume a pivotal role in LRI development. Specifically, (1) universities and academic entities must adapt and redefine their roles, moving beyond traditional confines and venturing into new research terrains to augment their research output, and (2) these universities and academic participants must emphasize cooperative initiatives and exhibit leadership in shaping the evolution of LRIs, inclusive of their constituents and underlying dynamics. This leads us to our primary research question:

How can entrepreneurial universities coordinate and develop collaboration with large-scale research infrastructure, industrial firms and academia, for added value for the economy and society?

The remaining study is organized as follows. Section 2 presents a review of the literature and Section 3 describes the data and data collection methods. Section 4 presents the empirical findings and Section 5 delineates the discussion and conclusions.

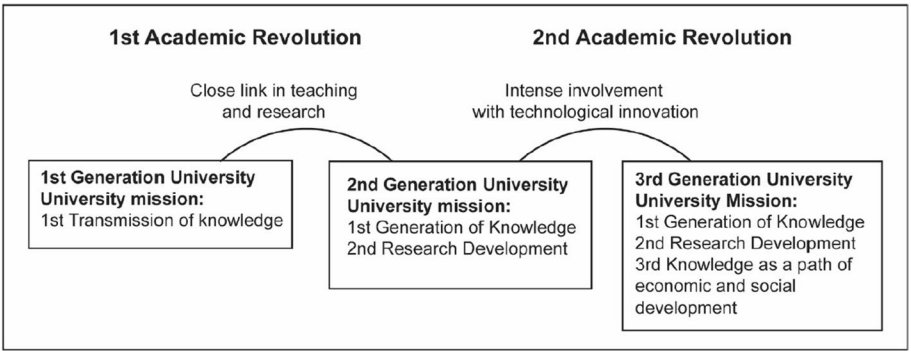

Fig. 1 The trajectory of university-classification. *Source*: Boruck Klein and Pereira (2020, p. 1). The figure is based on Etzkowitz and Leydesdorff (2000), Etzkowitz et al. (2000) and Etzkowitz (2004) classification

2 Literature review and research elements

2.1 The concept entrepreneurial university

Guerrero and Urbano (2012) described the concept of entrepreneurial university as "organizations that have improved mechanisms to contribute to regional development and increase their incomes" (p. 2). Other concepts such as innovative universities and market universities have also been used in this context (Clark, 1998a, 1998b; Slaughter and Leslie, 1997). The entrepreneurial university plays a crucial role both in producing and disseminating knowledge is a key player as a producer as well as disseminator of knowledge. Several studies have tried to explain entrepreneurial universities using a theoretical approach (Clark, 1998a, 1998b; Etzkowitz, 2004; Rothaermal et al., 2007) and the analyses are based on formal and informal (environmental) factors. They also identified the resources and capabilities (internal factors) which are crucial for this transformation process. Schulte (2004) emphasized that universities' new missions comprise social development and economic growth. Additionally, the performance of an entrepreneurial university has to be connected to research, teaching, and entrepreneurial activities. Numerous definitions exist in academic literature about what constitutes an entrepreneurial university. These definitions encompass adaptation to environmental shifts, embracing new responsibilities, fostering an entrepreneurial culture, aiding economic development, and commercializing research (Clark, 1998a, 1998b; Kirby, 2002; Etzkowitz, 2003a; Jacob et al., 2003).

The entrepreneurial university is often defined as an institution that can adeptly navigate uncertain and intricate environmental conditions (Clark, 2001). While Pelikan (1992) noted opposition from some scholars, fearing it undermines academic integrity, the crux of their concern hinges on the belief that a university's core roles are to educate students and publish research. Yet, transitioning to an entrepreneurial model does not diminish focus on these core activities. Instead, it positions them as assets, enabling universities to potentially profit from collaborations with businesses and other entities. The culture within a university, encompassing attitudes, values, and norms, also plays a significant role in this evolution (Birley, 2002; Smilor et al., 1990).

Figure 1 illustrates the three generations of various types of universities (Klein & Pereira, 2020). The second academic revolution includes intense involvement with technological innovation; this generation appears to have relevance for social and economic

development and also greater integration to society (Laredo, 2007). Etzkowitz and Leydesdorff (2000) observed that in the current era, there is an active role in transferring both human resources and technology.

The concept of entrepreneurial university is therefore complex and contains varying research values, research cultures, academic traditions, and decision-making levels (Guerrero et al., 2016a, 2016b; Klofsten et al., 2019; Feola et al., 2021). Several studies have been conducted regarding the transformation of the universities' in European regions to support for innovation, development of spin-off firms, knowledge transfer offices, entrepreneurial orientation, and science parks and incubators (Feola et al., 2021; Fernandez-Alles et al., 2018; Grimaldi & Grandi, 2001; Holden & Goldstein, 2010). There is also an ongoing debate on how universities in the world are transforming to entrepreneurial, innovative, and digital universities (Al-Atabi & DeBoer, 2014; Klofsten et al., 2019). Several scholars underline that universities are increasingly involved in activities beyond research and teaching (Ardito et al., 2019; Rinaldi et al., 2018; Trencher et al., 2014).

Guerrero et al. (2016a, 2016b) stated that universities have become more open-oriented towards society and industry, performing activities beyond just research and education, such as knowledge dissemination, social innovation, advisory services, and technological innovation. In certain instances, they received support from the government. As a result, universities have increased their entrepreneurial activities, with many concentrating on technology transfer (Etzkowitz, 2003a; Rothaermel et al., 2007). The model of the "entrepreneurial university" was recognized as a significant driver for innovation and self-development and seen as a fitting reaction to thriving in turbulent and unpredictable markets (Hannon, 2013). Löfsten (2010) noted that local authorities had also been instrumental in aiding universities in actively supporting the development of local economies. Löfsten et al. (2020) discovered that science park management could foster successful relationships with universities and their students/alumni. Cadorin et al. (2021) mentioned that universities were the primary talent sources, that regional and national governments held a pivotal role in enhancing collaboration between universities and firms, and that science park management should encourage ties with local universities.

The entrepreneurial university model offers a comprehensive view of a university's activities and its scholars' roles. In response to public budget cuts, many universities have shifted towards entrepreneurial approaches that generate income (De Zilwa, 2005). While this move serves societal needs and promotes entrepreneurial mindsets among students, Provasi et al. (2012) cautioned against overly emphasizing income generation. Such a focus can divert researchers towards external incomes and intellectual property pursuits, potentially undermining the university's social mission. Nevertheless, external collaborations generally bring value to universities.

2.2 Entrepreneurial universities and academic entrepreneurship

Several studies have been conducted on academic entrepreneurship (Klofsten & Jones-Evans, 2000), entrepreneurial university (Breznitz & Feldman, 2012; Guerrero et al., 2016a, 2016b; Etzkowitz et al., 2019), innovation ecosystems (Brem & Radziwon, 2017) and on the reasons why academics are involved in industry activities (Perkmann et al., 2021). Academic spin-offs, stemming from academic origins, exemplify one facet of the entrepreneurial university and serve as a conduit for technology transfer (Lindelöf & Löfsten, 2005). Academic spin-offs are mainly recognized for the firms' contribution to a country's economy in their endeavor towards technological performance and economic

development (Carlesi et al., 2017; Di Gregorio & Shane, 2003; Rizzo, 2015; Trequattrini et al., 2015). In this context, a growing interest has been noted in a special group of firms, namely new technology-based firms (Löfsten & Lindelöf, 2002; Shane & Stuart, 2002; Clarysse, 2004; Lindelöf & Löfsten, 2004; Löfsten & Lindelöf, 2005; Bengoa et al., 2021). Some of these firms have been founded by academics from the universities with the possibility to exploit technological advances.

The literature on academic entrepreneurship primarily emphasizes research commercialization. While academic positions tend to be the main focus, Valka et al. (2020) noted a lesser concentration on intrapreneurial activities conducted by non-academic personnel within universities. *Intrapreneurship* implies entrepreneurial activities that take place within established organizations (Abreu & Grinevich, 2013; Audretsch et al., 2021; Klofsten et al., 2021). Abreu et al. (2016) differentiated academic entrepreneurship's commercial emphasis from intrapreneurship's broader scope, which includes innovations in services, technologies, strategies, and competitive stances (Antoncic and Hirsch, 2001, p. 498). Academic firms often arise from university policies supporting technology transfer, underscoring researcher academic activities (Feola et al., 2021). These support mechanisms vary (Fini et al., 2011), with entrepreneurship education gaining traction in many institutions, urging students towards entrepreneurial mindsets (Ranga et al., 2003; Clark, 2004; Guerrero & Urbano, 2012; Barba-Sánchez & Atienza-Sahuquillo, 2018; Turner & Gianodis, 2018).

Studies in regional economic development have found that universities are impatient to take position as "entrepreneurial." In this context, engaging in the third mission activities such as spin-offs, spin-outs, and technology or knowledge transfer is pertinent (Gordon et al., 2012; Johnstone & Higgins, 2016; Larty et al., 2016). However, an entrepreneurial university can be any university that contributes to entrepreneurial thinking and institutional and entrepreneurship capital (Audretsch & Keilbach, 2008) because an entrepreneurial university has a broader role than merely to generate technology transfer, i.e. patents, licenses, start-ups and spin-outs.

2.3 Entrepreneurial universities and LRIs—research elements

The role of universities, mainly for economic development is a relevant topic for scholars and policymakers (Feola et al., 2021). Mian (2011) stated that entrepreneurial universities are recognized as key actors of competitiveness, economic growth, and wealth (Feola et al., 2021). Etzkowitz and Leydesdorff (2000) and Etzkowitz (2019) underlined that universities in general have become increasingly international. In recent decades, universities have transitioned from mere centers of research and education to mediators of ideas and research applications. This shift has spurred discussions on managing study programs, incubators, science parks, technology transfer, and the role of universities in collaborating with industrial research.

De Silva (2016) claimed that employees in the higher education sector, such as universities, have the scope for involvement in several types of entrepreneurial activities related to research, teaching, and firm creation. Montiel-Campos (2018, p. 400) stated that collaboration with industry will contribute to "making universities more entrepreneurial," and Wood (2011) surmised that, if universities act as mediators or catalysts for entrepreneurial activities, they will become more than a teaching and researching organization. The literature shows that entrepreneurial universities with high levels of dynamic capabilities find

strategic alternatives to leverage their strengths to adjust for a different educational environment (Teece, 2018).

The academic literature is consistent in terms of how universities have transformed from a "simple" knowledge diffusion organization to an entrepreneurial commercialization mechanism of science (Etzkowitz, 2000; Chen & Lin, 2017). Consequently, a strong connection between these universities and innovation exists, along with the entrepreneurial or knowledge ecosystem. Siegel and Wright (2015) and Fuster et al. (2019) stated that the entrepreneurial university has the opportunity to promote academic success through entrepreneurship and create an energetic entrepreneurial ecosystem. Caraynnis et al. (2016) noted that the context in which the entrepreneurial university fits is crucial as it acts as a multiplier in the development of an entrepreneurial ecosystem (Feola et al., 2021). The concept entrepreneurial university is related to the triple helix model of teaching, research, and extension. This model posits that innovation serves as the bridge connecting universities, governments, and businesses, a paradigm shift first identified by Etzkowitz (1983).

The growing significance of sciences and research across sectors necessitates a shift from traditional to entrepreneurial universities. This transition demands innovative academic leadership for developing LRIs that creates value for both universities and society. However, all involved actors face challenges in communication and coordination concerning research topics and problems to investigate.

Addressing grand challenges demands collaboration among societal actors like universities, industry, and government, and multidisciplinary efforts within universities. A pivotal step is establishing and nurturing advanced LRIs. Successful LRI operations hinge on deep collaboration among various stakeholders, with universities taking the lead. The dynamic partnership between entrepreneurial universities and LRIs boosts innovation, economic growth, and scientific progress. Table 1 identifies three core research elements examining this relationship and LRIs development.

In essence, entrepreneurial universities and LRIs share a reciprocal bond that augments collaborative research, stimulates technological advancement, and fosters entrepreneurship. This bond not only magnetizes talent and propels regional economic progress, but also guarantees the longevity and sustainability of both establishments. Through this partnership, academia benefits from enriched learning and research experiences, driven by industry needs, facilitating a seamless flow of knowledge between the academic realm and the business world. With the tools, knowledge, and facilities afforded by LRIs, entrepreneurial universities are poised to fast-track their innovation endeavors, address industrial demands, and cultivate an ecosystem brimming with entrepreneurship and commercialization.

3 Empirical research

3.1 Research methodology—qualitative study

This study adopted a qualitative research approach, utilizing a case study methodology. The objective was to deeply understand how entrepreneurial universities coordinated and developed collaborations with large-scale research infrastructures, industrial firms, and academia to add value to the economy and society (Dyer & Wilkins, 1991; Eisenhardt, 1989; Ridder, 2017; Siggelkow, 2007; Silverman, 2013; Yin, 2018). Case studies proved instrumental in theory development, gap identification, and in offering guidelines for future research (Siggelkow, 2007; Yin, 2018). Taking an abductive approach (Dubois &

Table 1 Three research elements

(1) *Research and education*
Entrepreneurial universities, recognized for groundbreaking research and education, benefit from LRIs as cutting-edge technological platforms. Such infrastructure aids these universities in their research goals, speeding up the knowledge transfer from the academic world to industry. LRIs serve as magnets for gifted researchers, students, and industry specialists. Entrepreneurial universities, with this infrastructure, allure and nurture exceptional talent, offering an unparalleled research milieu
References: Barba-Sánchez and Atienza-Sahuquillo (2018), Cadorin et al. (2021), De Silva (2016), Pelikan (1992), Horlings et al. (2012), Provasi et al. (2012), Rothaermel et al.(2007), Schulte (2004), Teece (2018), Turner and Gianiodis (2018)
(2) *Collaboration*
LRIs foster collaborative research between entrepreneurial universities and external stakeholders. These institutions assemble experts from academia, industry, and government to tackle interdisciplinary challenges, with universities often leading. Embedding such an infrastructure in entrepreneurial universities paves the way for cross-discipline cooperation, knowledge sharing, and collective projects. This collaborative model amplifies the practicality of research results. With the symbiotic growth of LRIs and entrepreneurial universities, an innovative ecosystem emerges, enabling rich collaboration and entrepreneurial exploration
References: Ankrah and AL-Tabbaa (2015), Ardito et al. (2019), Autio et al. (1996), Coughlan et al. (2016), D'Ippolito and Rüling (2019), Etzkowitz (2003b), Etzkowitz and Leydesdorff (2000), Guerrero et al. (2016a, 2016b), MacEachren (2006), Perkmann et al. (2021), Petruzzelli and Murgia (2019), Rajalo and Vadi (2017), Rinaldi et al. (2018), Schissel (2006), Rybrink and Köningsgruber (2018), Trencher et al. (2014), Zuijdam et al. (2011)
(3) *Utilization and impact*
A hallmark of entrepreneurial universities is their commitment to entrepreneurship and tech commercialization. LRIs are instrumental in this pursuit, facilitating activities from proof-of-concept tests to product development. They provide essential tools, machinery, and know-how, turning research insights into practical solutions and viable businesses. Attracting investment, LRIs buttress startup and spin-off growth, leading to job opportunities. Together, the prowess and resources of entrepreneurial universities and LRIs invigorate regional innovation systems, catalyze industry hubs, and boost economic growth by converting research into real-world impact
References: Audretsch and Keilbach (2008), Bozeman and Youtie (2017), Dasgupta and David (1994), Feldman et al. (2019), Feola et al. (2021), Fuster et al. (2019), Di Gregorio and Shane (2003), Kohn Rådberg and Löfsten (2023), Montiel-Campos (2018), Pinheiro et al. (2015), Rizzo (2015)

Gadde, 2002), a robust link to theory was established during the design of the data collection and subsequently when drawing insights from the collected data during analysis. Moreover, for a nuanced understanding, the study drew from both primary and secondary data sources (Eisenhardt, 1989) and was conducted in real-time (Miles & Huberman, 1994) during the initial stages of the organizational development around the large-scale research infrastructure.

3.2 Research setting—MAX IV, ESS and other establishments

LRIs such as MAX IV and European Spallation Source (ESS) in Lund, Sweden, are considered crucial for advancing science and addressing social challenges. These LRIs are central to research, innovation, and education and play a key role in promoting and disseminating knowledge and technology. MAX IV and the ESS, among the most high-tech research facilities, are expected to be Europe's new center for multi-disciplinary materials research. MAX IV, inaugurated—while still in the process of completion—in 2016, is the world's most powerful synchrotron radiation infrastructure and its accelerators produce

high-quality x-rays. ESS is a research facility based on the world's most powerful neutron source. It receives funding from 13 countries and is expected to host 2,000–3,000 researchers annually. The ESS is one of the largest science and technology infrastructure projects ever built. For small countries like Sweden, the connection between extensive LRIs, universities, government and the business community is of importance, and it becomes even more pertinent as it gains greater clarity and increasing demands. Past investments should have been directed more towards the challenges that existed in society, and future investments must similarly prioritize addressing current societal challenges.

Both these institutions are recognized as among the most sophisticated research facilities in their respective domains. The MAX IV is reminiscent of its predecessors, the MAX labs in Lund, which were affiliated with Lund University. The inaugural MAX-lab was founded in 1986 and has since undergone numerous developments and enhancements. One notable focus was integrating it with an environment comprising engaged industrial firms. Upon its completion, the MAX IV laboratory anticipates hosting over 2,000 researchers annually from diverse fields such as material science, structural biology, chemistry, and nanotechnology. Similarly, the ESS is projected to rank among the grandest science and technology infrastructure projects currently under construction.[1]

Both MAX IV and ESS have synergistic goals, aspiring to emerge as significant nodes in Europe's LRI network, in addition to bolstering the research landscape in Lund and the broader Swedish region. These establishments are driven by a vision to produce knowledge pivotal for addressing societal challenges and fostering business advancements.

Significant efforts have been invested in the preparation for establishing these LRIs, engaging the triple helix actors—academia, industry, and policy—primarily at regional and national levels. Moreover, an international dimension comes into play, especially for ESS, which has garnered international funding. During the initial phase, marked by funding challenges, the Swedish Research Council assumed the pivotal role of orchestrating the initiative. Collaboration was sought from academia, industry, and government stakeholders, while additional support flowed in from key entities such as Sweden's Innovation Agency, Region Skåne, Big Science Sweden, and RISE (Research Institutes of Sweden). These organizations have maintained close involvement in the process.

In addition to their primary focus, the Ministry of Trade and Industry and the Ministry of Education have emphasized the importance of establishing infrastructure to harness the potential impact and utilization of the two LRIs. Given Sweden's lack of prior experience in owning or hosting such extensive global research facilities, a distinct approach has been adopted, drawing inspiration from entities like CERN and its evolution. The conception of an ecosystem surrounding these facilities, fostering collaboration among institutes, academia, research centers, and enterprises of all sizes, marks a significant departure in Sweden's history. However, Sweden boasts a strong tradition of investing in research and higher education, and its reputation as one of the world's leading innovative nations according to the Global Innovation Index underscores its credentials. Nonetheless, the establishment and management of LRIs like ESS and MAX IV, coupled with high expectations of returns, present novel challenges.

[1] https://www.lund.se/en/brunnshog/about/project-phases/max-iv-and-ess/

3.3 Data collection

The study involves both primary and secondary data collection. Secondary data research offers flexibility and can be executed through various procedural and evaluative steps (Doolan & Froelicher, 2009). However, there is limited literature defining a specific process (Johnston, 2014). A complication of using secondary data is the need for researchers to evaluate the data (Clarke & Cossette, 2000). Our study's secondary data consisted of published reports from diverse stakeholders and agencies, supplemented by documentation from conferences and meetings organized by governmental and industrial bodies, relevant to the specific case. Table 2 delineates the report types encompassed in the data collection. The secondary data were scrutinized by the two researchers and subsequently informed the design of the interview procedure for primary data collection, aimed at identifying pertinent aspects and actors.

The primary data were collected through semi-structured in-depth interviews (Fontana & Frey, 2000; Kvale, 1996), with key elite informants (Aguinies & Solarino, 2019) possessing a comprehensive understanding of LRIs akin to MAX IV and ESS. Semi-structured interviews permit flexibility, enabling the inclusion of follow-up questions to elicit more profound and detailed responses beyond those covered in the interview guide. Given the elite nature of the informants, several follow-up queries were posed. To ensure meticulous record-keeping, one researcher posed the questions while the other took notes. They collaboratively posed additional follow-up questions to prompt further insights from the respondents (Creswell & Creswell, 2017). Nonetheless, because these interviews offer less rigid structure compared to fully structured interviews, the data collection and analysis process becomes somewhat intricate. The interviewees were chosen from academia and industry viewpoints, identified through various associations, collaborative networks, universities, and organizations affiliated with MAX IV and ESS. All participants were elite informants, boasting extensive knowledge and experience (Aguinis & Solarino, 2019) related to LRIs and the diverse roles of different actors. They were drawn from regional and national research contexts, firm-level settings, and engineering organizations. Each interviewee was required to possess an in-depth understanding of both academic and industrial mechanisms as well as operations concerning LRIs. Table 3 outlines the actors and the perspectives they represent. The "category" signifies the current role of the actor, and their specific "position." The "major perspectives" denote the interviewee's knowledgeable and experienced domains that informed their reasoning.

A comprehensive case study protocol was formulated, outlining the inquiries and delineating the procedural aspects pertinent to the participants' domains. Thirteen detailed semi-structured interviews were conducted, employing either in-person meetings or virtual sessions on platforms like Zoom or Teams. Each interview spanned 70 to 90 min, adhering to the semi-structured interview guide (refer to Appendix, Table 9). This guide was crafted to address the significance of research facilities in industry and business, as well as the pertinent environmental context. It encompassed diverse perspectives from academia, industry, and policy domains. All interviewees were afforded anonymity, and all interactions were meticulously recorded and transcribed. Simultaneously, notes were taken during interviews, subsequently integrated into the transcribed records during analysis. The interviews were conducted by two researchers, and, as per Yin's guidelines (2018), all data were meticulously archived in a dedicated case study database.

Table 2 Reports included in the data collection

Type of published reports	N of reports	Year	Focus
National and regional governments	6	2010–2018	Regional development, competence
National research funding agencies	4	2018–2021	Research utilization in academia and industry
Industry agencies	4	2020–2021	Research utilization in industry and competitiveness
Universities and institutes	3	2017–2019	Research utilization in academia and industry
International organizations (EU, OECD, NSF)	6	2016–2021	Research utilization and regional development

Table 3 Actors and perspectives included by the interviewees

N	Category	Position	Major perspectives
9	Academia	Researcher and Director	Academic research and Infrastructure
11	Academia	Director	Academic research and Industry
13	Academia	Director	Academic research and Industry
12	Academia	Researcher and Director	Academic research and Infrastructure
7	Academia	Director	Academic research and Infrastructure
8	Industry	CEO	Industry and Infrastructure
11	Industry	Senior manager	Industry and Academic research
1	Industry	Senior manager	Industry and Academic research
5	Industry	Industrial association	Industry and Academic research
4	Industry	Industrial association	Industry and Infrastructure
2	Policy	Manager regional development	Academic research and Utilization
3	Policy	Manager regional development	Academic research and Industry
6	Policy	Research funding agency	Academic research and Infrastructure

3.4 Data analysis

The primary data were subjected to multifaceted analysis, underpinned by an abductive methodology (Dubois & Gadde, 2014). The collaborative analysis was undertaken by both researchers, aiming to establish a comprehensive portrayal of the empirical landscape (Langley, 1999; Nag & Gioia, 2012). The analytical process encompassed primary and secondary coding stages. Commencing with structural coding, data segments were clustered into meaningful categories, tagged with pertinent terms, and correlated with the various perspectives represented by the interviewees, as detailed in Table 3. This framework then served as the foundation for the ensuing coding phase.

For instances involving open-ended responses, characteristic of semi-structured interviews, wherein participants offer extensive and intricate insights, a descriptive coding method was adopted. This entailed encapsulating the core essence of the interviewees' expressions (Belotto, 2018; Campbell et al., 2013). These codes were subsequently amalgamated into dimensions germane to the research question (Braun & Clarke, 2006). These dimensions were subsequently refined, and through revisiting the literature and juxtaposing findings, three dimensions emerged: research, collaboration, and utilization/impact, explored from both academic and industrial vantage points.

In Table 4, we furnish a synthesized summary derived from the literature analysis, structured according to academic and industrial standpoints, encompassing *research and education, collaboration,* and *utilization/impact aspects*. The ensuing findings section elaborates further on each dimension.

Table 4 Summary of the structure of the analysis

	Research and Education	Collaboration	Utilization/Impact
Academia	World class lab and surrounding services that attract top research groups (national and international) Enable strong trans-disciplinary research International doctoral programs	Collaborations with other labs as CERN and top-class institutes to drive excellence Advance academic and industrial collaborations	Venture creation related to university research and to other venture hubs Services to ease industry access and utilization of results
Industry	Access to various research areas and international Universities, institutes, and intermediaries Participate in academic research as well as basic industrial research	Research collaborations and data sharing collaborations Networks, openness, accessibility, presence, international	Venture collaboration. R&D collaborations with small companies Start-ups related to research as a stepping-stone to develop own research capability

4 Empirical findings

4.1 Establishing and developing MAX IV and ESS

LRIs are commonly governed and managed by universities or academic research constellations, primarily due to their orientation towards fundamental research rather than applied science. This characteristic accounts for the heightened interest exhibited by universities and academia in these facilities. Respondents concurred with prior research, asserting, "That the universities should have a leading role is pretty self-evident, but everything must be connected" (interv. 6). Nonetheless, realizing optimal utilization alongside openness presents challenges. Achieving a vibrant amalgamation of diverse actors to facilitate trans-disciplinary utilization and outcomes, while accommodating researchers from institutions beyond the immediate vicinity of the facility, remains intricate.

In the context of ESS and MAX IV, Lund University shoulders the financial responsibility for MAX IV, conferring it with a more pronounced role than other Swedish universities. ESS follows a distinct trajectory, being a relatively new and substantial endeavor in progress. Notably, Lund University has strategically integrated both MAX IV and ESS into its framework, positioning itself as the solitary Swedish university to do so.

4.2 The university's role in enhancing research and education related to LRIs

In addition to accommodating numerous top international academic research groups from diverse disciplines at the LRIs, a concerted effort is also placed on fostering robust industrial engagement. Citations in Table 5 exemplify the growing demand for enhanced collaboration and stronger ties between academic and industrial research, particularly in the realm of basic research. Presently, research-driven industries exhibit a heightened interest and willingness to participate in fundamental research, albeit with distinct articulations compared to academic research. The nuances of being closely aligned with academic research are not always clear, leading to a need for innovative collaborative settings around LRIs where academia and industry can engage in mutual learning.

The dynamics have evolved beyond academic researchers solely framing questions and interpreting results for industry. Instead, industrial researchers are increasingly raising intriguing questions that contribute to the evolution of academic research. This necessitates the cultivation of novel modes of collaboration that reshape research practices and utilization of outcomes. The university's role remains pivotal across these initiatives, with education being a prime responsibility that must be upheld. Disseminating awareness about the potential of MAX IV and ESS across diverse projects falls within the purview of the actors in the system. Education is conducted at a high level, intertwining various research endeavors with conventional coursework. Customized packaging of education is paramount to effectively cater to varying needs.

4.3 The university's role in driving collaborations

Collaborations are unanimously regarded as crucial, indispensable, and beneficial by all stakeholders. Both academic and industrial viewpoints call for enhanced and more sophisticated collaborative efforts. As evidenced by the quotes in Table 6, novel collaboration models are essential to fulfill a range of needs and demands associated with the

Table 5 Academia and industry: research and education

	Research and education
Academia	It's about establishing this ecosystem with academic presence at the right level, to understand the importance of materials research to development. Lund University will establish Nano lab and both the Chemistry and Physics departments are interested in getting out there. (Interv. 7) I hope several universities in Sweden, to begin with, will get more joint working and positioning, so we can take more leadership and invite interesting foreign universities and research groups. There does not have to be this competition between higher education institutions. Rather, it is about what Swedish higher education institutions can together offer. (Interv. 10) ESS has an international position and will really become a European facility. Many countries have more, and stronger, research groups than Sweden. Sweden needs to strengthen neutron-based research. (Interv. 9) Lund has created links with strongly outward-looking activities. There is a great ambition to spread knowledge about how to use these facilities, even to be a driving force in the development of doctoral courses and other courses, and even ideas about how to use the facilities for advanced research in new areas. (Interv. 13) EMBL—the European Molecular Biology Lab is large and prestigious. Their head office is located in Heidelberg but they have "outstations", or sites, in Grenoble, Hamburg and other places. For me, it is a given that they will also establish a branch in Lund. (Interv. 12)

Table 5 (continued)

	Research and education
Industry	There are more companies today then 20 years ago that have the interest and competence of doing research with academia. Those companies can be a good door-opener for other companies, large or smaller. (Interv. 2) Having been working as a researcher in the academic setting and now in industry related to the academic environment, I can clearly see that there are great possibilities for cross-fertilization between how industry conduct research and academia. Here PhD students and post-docs may play a central role, which puts emphasis on early setting up international doctoral programs around the facilities. Treesearch and other initiatives are driving this. (Interv. 4) In the dialogues with industrial partners, there have been discussions to varying degrees about involvement in research linked to ESS & Max IV. To use Chalmers' researchers as a gateway, seems to be the best way to open up the facilities for at least part of the industry. (Interv. 8) Linked to ESS, there is an "executive advisory board" that among other things focus on how and in what way the business community can be involved in research and how to raise interest in the facility and what is relevant. Those who are here see it from a strategic perspective, ie those at Board and CEO level. (Interv. 11)

utilization of ESS and MAX IV. Universities are actively exploring innovative collaboration approaches. For instance, Chalmers' collaborative infrastructure is highlighted as a dynamic example of academia-industry partnership evolving based on industry needs and academic research focus areas.

However, realizing the vision of increased economic development resulting from ESS and MAX IV's establishment necessitates novel collaborative structures that encompass diverse forms to accommodate various actors and their distinct requirements. The analysis underscores the significance of openness and dynamism, both in the collaborative environment and the collaborations themselves, to attract international actors from different domains and facilitate flexible engagement.

Industrial collaborations emerge as a focal point, where academia's stronger participation is emphasized. Doctoral students and industrial PhD programs are positioned as

Table 6 Academia and industry: respondents' views on collaboration

	Collaboration
Academia	Universities needs to create new and different networks and collaborations with industry on regional levels on ideas about joint research and how to manage such. A better understanding about the opportunities for industry and how to collaborate is needed. Lund and Uppsala are more advanced here in specific areas. Chalmers and KTH is starting. I hope KI and SLU do the same. (Interv.9)
	Chalmers has a project to work on the interests of both academic research and business. Chalmers has its strategic "Areas of Advance" in multiple areas, which support collaboration in both education and research. So far, it is mostly the Area of advance of materials that has provided seminars and "workshops" to establish interest and focus. (Interv. 12)
	The institutes have an important role to play, however we do not traditionally think about their role in Sweden. Here we need to bring the central institutes into the environment, and those who are most respected internationally. (Interv. 10)
	There is a strong need for a well-functioning ecosystem around MAX IV and ESS, but it really must be built from the ground up. What does it take to create a good ecosystem where you have to find a common culture? How should this ecosystem relate to other ecosystems? How should it work? How should the actors operate within this? It is important including several university environments, and innovation environments in here. It is absolutely crucial for the successes, that one is not limited to Lund or even Sweden. (Interv. 13)

Table 6 (continued)

	Collaboration
Industry	It's not easy for companies to find forms of cooperation. That results in inaccessible technology and inaccessible environments. Developing the idea of accessible partnerships and collaboration then becomes very important. (Interv. 8) It is then important to have "one foot in both camps", ie in the university and industry. There is still a little unhealthy respect between these two environments, where the university does not want to deal with product development. In general, ecosystems are becoming more and more complex, and in the case of ESS and MAX IV, something absolutely fantastic has been done regarding the level of ambition on the materials side. Industrial PhD programs and doctoral programs are important here. (Interv. 1) Sweden is known for having an innovation system that is attractive. We also have a culture of collaboration, and the ability to bring together different competencies and we are not as hierarchical as in many other places. It is an important aspect that drives the development not only of facilities but what is done generally. (Interv. 4)

pivotal bridges and catalysts for collaborations and knowledge exchange. Effective leadership is required to construct environments that stimulate and encourage collaborations, driving the evolution of a comprehensive ecosystem of collaborative stakeholders.

The university's role is akin to an open and impartial entity with access, knowledge, and networks that can be extended to industrial counterparts. Notably, research-intensive global industrial players often establish collaborations with universities across the world. The data indicates that universities cultivating greater collaboration with peers are more adept at fostering attraction and networks. Universities must comprehend the mechanisms to construct open and dynamic environments that harness research, education, and international collaborative practices, involving multiple actors and universities.

4.4 The university's role in developing impact and entrepreneurial environments

Amid a heightened emphasis on impact and diversified approaches to disseminate and transform knowledge for societal benefit, universities are extending their influence beyond student production, research publications, and conventional Technology Transfer Offices

(TTOs), encompassing patents, science parks, and venture hubs. Collaborative spaces have emerged in close proximity to universities and LRIs to facilitate the active engagement of stakeholders and foster collaborative initiatives. However, the mere presence of infrastructure is not enough; proactive involvement and collaborative drive are essential components in realizing impactful and entrepreneurial environments.

Insights from interviews with individuals well-versed in both academic and industrial research underscore the heightened role that universities need to assume in establishing innovative and entrepreneurial ecosystems. Such ecosystems demand an expanded level of engagement from universities, transcending previous boundaries and incorporating other venture-oriented entities. Proficiency in establishing arenas for entrepreneurial and innovative undertakings emerges as a driving force in collaboratively nurturing environments conducive to innovation and entrepreneurship rooted in basic research.

An innovative and entrepreneurial milieu surrounding a basic research-oriented LRI varies significantly from the conventional university landscape. Importantly, the participation of multiple universities from diverse regions is a critical aspect. In addition to universities, entities like Science Village and various research institutes play pivotal roles, necessitating the active engagement of numerous stakeholders in various capacities.

In Sweden, numerous science parks facilitate interactions between universities and businesses, shedding light on a university's stance on commercialization. Table 7 illustrates the perspectives of both academia and industry respondents on utilization and impact.

5 Discussion and conclusions

5.1 A conceptual model

Traditionally, innovation was perceived to be primarily driven by industry. However, a contemporary perspective asserts that universities, leveraging their extensive networks, are emerging as key drivers of innovation, steering their research towards tangible products and services. This study centered around the dynamics between universities, industry, and LRIs like MAX IV and ESS. The historical context of industry-university collaboration has been well-established (Ankrah & AL-Tabbaa, 2015). Collaboratively, policymakers and universities endeavor to fulfill the universities' third mission by engaging in patenting, establishing technology transfer offices, science parks, and incubators (Perkmann et al., 2013). The interaction between universities, government, and industry forms a critical axis for fulfilling this mission, enabling the application and commercialization of research through industry partnerships.

Rybnicek and Königsgruber (2018) highlighted that success factors for industry–university collaboration are resources, structure, willingness to change, communication, commitment, trust, culture, objectives, knowledge and technology transfer, environment, contracts and intellectual property rights, and geographical distance. Technology transfer and knowledge dissemination between academia and industry will have an effect on innovation because these collaborations combine heterogeneous knowledge (Rajalo & Vadi, 2017). Governments have an important role in supporting university-industry collaboration where the aim is to implement innovation policies (Etzkowitz et al., 2000; Park & Leyesdorff, 2010; Perkmann et al., 2013). Pinheiro et al. (2015) stated that universities also have a key role in achieving economic growth.

Table 7 Academia and industry: respondents' views on utilization/Impact

	Utilization/impact
Academia	Regarding the technology park function in Science Village Lund University wants to have decisive influence and play a pivotal role. But both facilities and Science Village will have to have a national and international perspective. This means that several universities must participate. In addition, there are other actors, such as Big Science Sweden, industry and, of course, also the relevant research institutes and facilities to be taken into account. (Interv.1) There are real estate companies that run research and innovation parks internationally and that own both processes, but also engage in collaboration with others, for example as a partner with the "Cambridge Innovation Centre", which allows Science Village to enter completely different networks within the ecosystem right from the start. In Sweden, we have the technology parks that drive that kind of process between the university and companies and who are also used to understanding the university's lack of interest in commercialization. (Interv. 10) Big Science Sweden could take both an up-stream and down-stream perspective to see the possibilities for the development of, for example, materials technology. In this case, it is an advantage for the universities to be behind Big Science Sweden, as it is important for the international and industrial attractiveness to MAX IV and ESS. (Interv. 6)

Table 7 (continued)

	Utilization/impact
Industry	As a specialist technology company we work with long-term technology research projects and have people who "rotate in" at in various research programs at Chalmers, CERN and so on. This helps to build the long-term network. It is extremely important with these environments for both universities, and companies. (Interv. 8) Science Village want to have a profile as the entrepreneurial academic, or the academic entrepreneur. Then it becomes important to involve the industrial community already from start, as there are several of these actors that actually know what then need and want in terms of services, support, activities, networks etc. as several of them have been involved in international research in other countries. (Interv. 11) Science Village already has a dialogue with national and foreign companies and institutes that are considering establishing a presence in Sweden due to MAX IV and ESS. It is important to continue to collaborate with other international environments. Science Village really wants to be active so that this becomes a super-region in the world of research. (Interv. 4) The basic idea is not to build new science parks, but mainly to use what already exists. Science Village need to build the entrepreneurial network with science parks and incubators. A network that comprises existing structures. (Interv. 2)

Several theoretical models and approaches have been presented in the literature regarding entrepreneurial universities (Clark, 1998a, 1998b; Sporn, 2001; Etzkowitz, 2004; Kirby, 2006; Guerrero et al., 2006; Salamzadeh et al., 2011; Sooreh et al., 2011; Guerrero et al., 2016a, 2016b; Rinaldi, 2018; Etzkowitz, 2019; Klofsten et al, 2019; Boruck Klein, 2020; Feola et al., 2021). Several empirical studies have also been conducted, however, these studies mainly analyzed the environmental factors that determine the entrepreneurial university cycle at the time. Guerrero et al. (2006) used institutional theory to structure factors as formal or informal, where the formal is determined by the government of the university and the informal factors contain university attitudes towards entrepreneurship and

reward systems. The model also includes the educational perspective, new firms started by students, and the conditions for the development of entrepreneurship. Salamzadeh et al. (2011) claimed that the "outputs" in their model are entrepreneurial human resources, research regarding market needs, innovations, and entrepreneurial networks which form the third mission of an entrepreneurial university.

Besides focusing on utilization levels within the labs for a diverse range of users, there is a concurrent imperative to foster an open, dynamic environment around the labs, conducive to various related activities and the emergence of novel ideas. The establishment and management of these labs, coupled with venture hubs, intermediary entities, and their surrounding ecosystem, align with the essence of the entrepreneurial university concept, offering a framework to address the leadership requisites for developing such environments around LRIs. Companies commonly seek a gateway to swiftly address pressing issues, often through a mediator who can offer assistance. In Sweden, science parks and incubators play a pivotal role in mediating interactions between universities and companies, shedding light on the universities' commitment to commercialization. Indeed, stringent mandates ensure universities' physical presence and integration, fostering robust collaboration within these facilities.

LRIs normally typically possess both national and international orientations, acting as collaborative platforms among academia, industry, and research institutes. Such facilities predominantly facilitate collaboration in conjunction with public knowledge institutions, yielding benefits for a multitude of stakeholders. Nevertheless, governing LRIs poses a complex set of challenges. One foundational assumption of LRIs is their role as intermediary infrastructures, bridging gaps between universities and industry within an entrepreneurial milieu. The European Strategy Forum on Research Infrastructures (ESFRI, 2018) emphasizes the significance of various stakeholders in developing the relations between LRIs and industry. These stakeholders must focus on operational performance, scientific excellence, and service quality, which are essential for attracting users and ensuring the long-term sustainability of the facilities.

Given the diverse perspectives of multiple actors and their varying roles within the ecosystem surrounding MAX IV and ESS, a systematic categorization of these actors becomes necessary. Identifying the key actors in university-LRI collaboration from empirical data entailed a methodical analysis of the collected information, involving coding and categorization. Within the coded data, entities frequently mentioned, holding prominent roles, or exerting considerable influence in university-LRI collaborations were identified. Apart from classifying actors into stakeholders, another significant categorization emerged from our analysis: that of focal actors, directly engaged, versus peripheral actors, indirectly or tangentially involved in the collaborative efforts.

Through the analysis conducted in this study, we have discerned the significance of engaging actors from diverse layers within academia and industry, as delineated in Table 8 below. *Focal actors*, constituting those with pronounced interests and substantial influence in the advancement of LRIs and the creation of a vibrant environment around these facilities, emerge as pivotal. In this context, establishing a multifaceted academic environment emerges as crucial. *Directly involved actors* are the numerous academic and industrial users possessing an immediate necessity and comprehension of how to effectively utilize the facilities and partake in a dynamic adjacent setting, if present.

Indirectly and peripherally involved actors encompass those who exhibit curiosity but might not fully grasp the manner and extent of their interaction with LRIs or the surrounding milieu. The diverse actors and dimensions contributing to the development of the environment encompassing LRIs are expounded in greater detail in Table 8.

Table 8 The various actors and dimensions of collaboration

	Focal—leading role in collaboration	Directly involved	Indirectly and peripheral interests for involvement
Academic	A mix of national and international universities with strong research, collaboration and network in relevant areas to collaborately manage aspects of the milieu	Universities and Institutes with knowledge, skills and network that can take advantage and contribute to the milieu	Research groups from various academic environments that are interested in conducting research and collaborating
Industry	Industrial and related actors that contribute strongly to the environment with its presence	Industrial actors and intermediaries that are active in the knowledge area and want to conduct research as well as collaborate with existing and new partners	Industrial actors and intermediary actors that want to understand more about the environment and how to engage more
Policy, inter-mediators and other actors	In terms of understanding how to attract, retain directly and indirectly involved current and new actors		

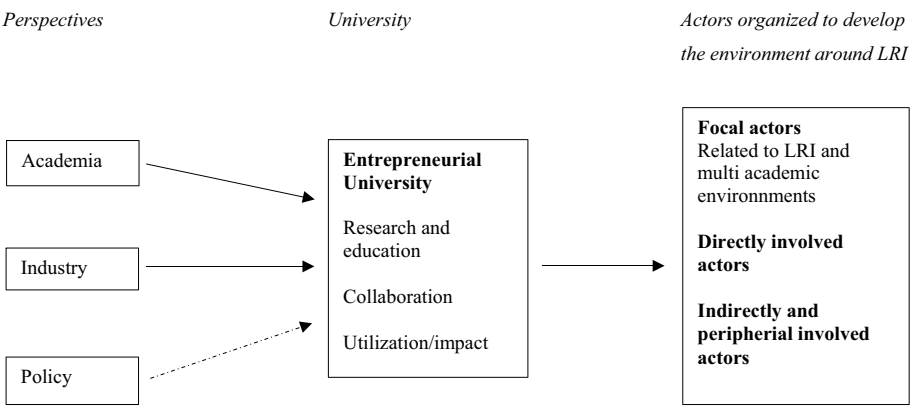

Fig. 2 Conceptual model

In accordance with Table 8, actors that exhibit direct involvement encompass universities and institutes endowed with knowledge and networks, along with active industrial actors and intermediaries in the knowledge domain. Nonetheless, universities typically tend to emphasize long-term research, while firms are inclined towards short-term product development. As the significance of science and research in various sectors of the economy and society continues to grow, progressive universities will encounter novel demands in establishing LRIs, necessitating a distinct form of academic leadership compared to the past (Etzkowitz & Leyersdorff, 2000).

The internal dimensions within a university, concerning the formulation and management of processes that foster the entrepreneurial university concept, can be aligned with intrapreneurship. Intrapreneurship holds the potential to confer a competitive edge to firms and other organizations (Urbano et al., 2013). In essence, intrapreneurship refers to both formal and informal activities within a university, culminating in the implementation of innovative ideas and behaviors. Within organizations, employees can generate knowledge rooted in innovation, which is pivotal for entrepreneurship and concurrently bolsters organizational performance (Alpkan et al., 2010).

In this context, the entrepreneurial university assumes a pivotal role in advancing LRIs, establishing international connections, nurturing social and business environments, and fostering economic development. LRIs typically possess both national and international orientations, founded upon collaborations between academia and industry researchers, as well as researchers associated with research institutes. Such facilities are predominantly accessed through partnerships with public knowledge institutions, thereby conferring advantages to multiple stakeholders. Figure 2 elucidates the conceptual model formulated in this study, outlining the central role assumed by the entrepreneurial university. Drawing from the perspectives of academia, industry, and to some extent, policy, this model delineates three distinct research elements: (1) *research and education* (2) *collaboration and* (3) *utilization and impact.* These elements, expounded in the literature Sect. 2.3 and elaborated upon in the empirical Sect. 4, underscore the development of a vibrant environment around LRIs. The organization of actors into mixed groups, categorized based on their roles as focal, directly involved, or peripherally interested entities in the knowledge and research developed, contributes to the establishment of this dynamic milieu.

Collaborative innovation is significantly influenced by the proximity characterizing the involved stakeholders and actors. Enhancing the awareness of different stakeholders regarding the existing potential for cooperation is essential, particularly where business and industry align with research-oriented facilities. However, achieving this heightened awareness stands as a crucial requirement. To embrace the leadership role required by an entrepreneurial university, acting as a multiplier, parallels the perspective advocated by Carayannis et al. (2016) concerning the initiation of new businesses, but extends to collaborative endeavors. A more profound comprehension of how to integrate diverse perspectives, which hold particular importance in managing LRIs over time amidst challenges and in attracting stakeholders to foster an encompassing ecosystem, becomes essential. Understanding the roles and needs of various actors across different levels of involvement is imperative. These findings serve as exemplars in managing intricate collaborations within complex environments (Clark, 1998a, 1998b, 2001), particularly pertinent for entrepreneurial universities operating in open settings (Guerrero et al., 2016a, 2016b).

The role of intermediaries emerges as pivotal in bolstering cooperation among LRIs, entrepreneurial universities, and industry. Additional stakeholder types, such as business angels, venture capital firms, and other high-tech enterprises, warrant consideration, requiring innovation, entrepreneurial acumen, and financial resources. Encouraging and coordinating the efforts of mediator firms is crucial to ensure streamlined collaboration and goal alignment.

5.2 Implications and limitations

Balancing the demands of scientifically challenging research with industrial needs presents a significant challenge. A potential avenue for achieving technology transfer lies in the co-solution phase, where scientific and industrial stakeholders collaborate to develop solutions for common problems. This approach differs somewhat from traditional technology transfer methods, where university researchers may employ patents for industrial solutions, or firms seek academic consultation when faced with challenges. Studies underscore the importance of LRIs functioning as hubs within social networks and learning environments, where diverse stakeholders can share knowledge. The growing industrial interest and emphasis on collaboration also open up new avenues for establishing academic-industrial constellations in emerging scientific domains. However, it is crucial to enhance the integration of scientific knowledge, results, and technological advancements with industry through effective scientist-industry collaborations. Notably, well-recognized limits exist regarding the collaboration of researchers and academics in addressing industrial issues.

An important domain involves the diverse modes of access to large-scale RIs. Industry may increasingly align with research facilities, while research facilities should adopt a more business-oriented perspective. Users of LRIs can be classified into two categories: (1) *Excellence-driven users* depend on scientific excellence, originality, quality, and technical and ethical feasibility of applications, facilitating collaborative research and technological development efforts with innovation as a result. The outcomes are also published in scientific journals. (2) *Market-driven users* must pay for access to research facilities, with the results contributing to market-driven development of advanced technologies that are not published in international journals.

Engaging industrial experts in the vicinity of the facilities can expand the ecosystem around MAX IV and ESS. This innovation-focused collaboration can also serve as a foundation for various other forms of collaboration. Addressing competency gaps can be

accomplished through training, mentoring, and knowledge transfer. Education can encompass first-cycle university courses, study programs, PhD candidate initiatives, and post-doc training tailored to industry needs. This approach could target specific industrial user groups, enhancing collaboration with industry partners. Additionally, involving industrial experts around the facilities can broaden the innovative ecosystem surrounding MAX IV and ESS, with this innovation-based collaboration serving as a platform for diverse collaborative activities.

From a theoretical standpoint, the potential implications span various research domains. Social network theory offers insights into the structure and dynamics of interorganizational collaborations between universities and LRIs, examining the formation, maintenance, and leverage of collaborative relationships within interconnected networks. Knowledge-based theories shed light on how collaborative endeavors facilitate knowledge creation, dissemination, and utilization, leading to heightened innovation outputs and economic growth. Theoretical implications can also explore how university-LRI collaboration shapes the dynamic interplay among the three stakeholders, resulting in the emergence of innovation ecosystems and the co-evolution of institutions. Analyzing collaboration through an institutional theory lens can reveal how organizations align with societal norms, expectations, and pressures, influenced by regulatory forces and expectations from academic and industry circles. Moreover, collaboration can be examined within the framework of technology transfer, highlighting mechanisms, processes, and channels through which knowledge and technologies flow from academia to industry.

Nonetheless, this study has certain limitations. The empirical analysis is centered on a single case. Furthermore, the internal dimension of universities remains unexplored, particularly the role of intrapreneurship as an important analytical dimension. Scholars assert that intrapreneurship generally offers numerous benefits, potentially contributing to higher performance. Intrapreneurship may prove more effective in generating successful innovations due to the additional resources available within universities, despite existing barriers. Studies have indicated that intrapreneurship can also enhance an organization's ability to innovate, adapt to external changes, and rejuvenate its operations.

5.3 Conclusions

This study yielded several notable conclusions. The transformation from conventional research and education to activities encompassing technology transfer through industry collaboration and dissemination indicates that the entrepreneurial university can play a pivotal role in cultivating an entrepreneurial environment within LRIs, thereby generating economic impact at regional and national levels. As the role of the entrepreneurial university expands within society, and its influence as a wellspring of technological innovation and economic progress intensifies, it becomes imperative for the entrepreneurial university to delineate a strategic trajectory for guiding collaboration and leadership in the context of LRIs. In this pursuit, universities must exhibit availability, productivity, and a collaborative spirit at these facilities. The proposition that universities should assume a leading role is indeed evident, contingent on fostering interconnections among all stakeholders. The entrepreneurial university leverages the nexus between industry and society to advance research and forge collaborations with LRIs, industrial enterprises, and academia, thus generating augmented value.

In conjunction with universities, entities like Science Village, diverse research institutes, and industrial firms assume pivotal roles in ensuring the seamless functioning of LRIs such as

MAX IV and ESS. This implies the involvement of numerous actors across various capacities. This study introduces a conceptual model wherein focal actors pertain to LRIs and multi-academic environments—ranging from direct to indirect and peripheral involvement. An underlying reflection is the complexity of this issue, encompassing diverse trajectories and manifold possibilities. When dealing with intricate matters and striving for innovation, universities and companies often necessitate the simplification, elucidation, and packaging of concepts to effectively engage those who should partake.

Appendix

See Table 9.

Table 9 Semi structured interview guide—open ended questions

Research facilities' relevance for the industry and business (research elements ii and iii)
Is it important?
How to work with it?
Who has this function/role?
What is the role of business/industry around MAX IV and ESS?
Which actors participate from the business community?
What is your view regarding the (entrepreneurial) milieu/environment around these research facilities?
About the environment (research elements i, ii och iii)
Structural elements: business angels, crowdfunding, venture capital, start-up academics, networking elements, entrepreneurship programmes, recruitment of talent, innovation challenges
How do you define 'outcome', entrepreneurial networks, new venture concepts, new technology-based firms, firm growth?
Do you have any examples of successful milieus that can be implemented?
What is the role of universities regarding new education programmes in relation to the two research facilities?
Do you have any examples of such new education programmes?
Who are the other relevant stakeholders for developing the research facilities?
Are these relevant stakeholders already involved? If so, how?
Which meeting places exist for discussion of the research facilities? Discussion forums? What are the type of interactions between the stakeholders?
How should a national structure that integrates academia, policy, and business be developed? What is missing?

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Declarations

Conflict of interest There is no conflict of interest to declare.

References

Aaboen, L., Lindelöf, P., & Löfsten, H. (2008). Towards incubator facilitation of technology transfer. *International Journal of Management and Enterprise Development, 5*(3), 331–355.

Abreu, M., Demirel, P., Grinevich, V., & Karatas-Özkan, M. (2016). Entrepreneurial practices in research-intensive and teaching-led universities. *Small Business Economics, 47*(3), 695–717.

Abreu, M., & Grinevich, V. (2013). The nature of academic entrepreneurship in the U.K.: Widening the focus on entrepreneurial activities. *Research Policy, 42*(2), 408–422.

Aguinis, H., & Solarino, A. (2019). Transparency and replicability in qualitative research: The case of interviews with elite informants. *Strategic Management Journal, 40*(8), 1291–1315.

Al-Atabi, M., & DeBoer, J. (2014). Teaching entrepreneurship using massive open online course (MOOC). *Technovation, 34*(4), 261–264.

Alpkan, L., Bulut, C., Gunday, G., Ulusoy, G., & Kilic, K. (2010). Organizational support for intrapreneurship and its interaction with human capital to enhance innovative performance. *Management Decision, 48*(5–6), 732–755.

Ankrah, S., & AL-Tabbaa, O. (2015). Universities- industry collaboration: A systematic review. *Scandinavian Journal of Management, 31*(3), 387–408.

Antoncic, B., & Hisrich, R. D. (2001). Intrapreneurship: Construct refinement and cross-cultural validation. *Journal of Business Venturing, 16*(5), 495–527.

Ardito, L., Ferraris, A., Petruzzelli, A. M., Bresciani, S., & Del Giudice, M. (2019). The role of universities in the knowledge management of smart city projects. *Technological Forecasting and Social Change, 142*, 312–321.

Audretsch, D., & Keilbach, M. (2008). Resolving the knowledge paradox: Knowledge-spillover entrepreneurship and economic growth. *Research Policy, 37*(10), 1697–1705.

Audretsch, D. B., Lehmann, E. E., Menter, M., & Wirsching, K. (2021). Intrapreneurship and absorptive capacities: The dynamic effect of labor mobility. *Technovation, 99*, 102129.

Autio, E., Hameri, A.-P., & Nordberg, M. (1996). A framework of motivations for industry-big science collaboration: A case study. *Journal of Engineering and Technology Management, 13*(3–4), 301–314.

Barba-Sánchez, V., & Atienza-Sahuquillo, C. (2018). Entrepreneurial intention among engineering students: The role of entrepreneurship education. *European Research on Management and Business Economics, 24*(1), 53–61.

Belotto, M. (2018). Data analysis methods for qualitative research. *The Quality Report, 23*(11), 2622–2633.

Bengoa, A., Maseda, A., Iturralde, T., & Aparicio, G. (2021). A bibliometric review of the technology transfer literature. *The Journal of Technology Transfer, 46*(5), 1514–1550.

Birley, S. (2002). Universities, academics, and spin-out companies: Lessons from the imperial. *Internnational Journal of Entrepeneurship Education, 1*(1), 133–153.

Bozeman, B., & Youtie, J. (2017). Socio-economic impacts and public value of government-funded research: Lessons from four US National Science Foundation initiatives. *Research Policy, 46*(8), 1387–1398.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77–101.
Brem, A., & Radziwon, A. (2017). Efficient triple helix collaboration fostering local niche innovation projects—A case from Denmark. *Technological Forecasting and Social Change, 123*, 130–141.
Breznitz, S. M., & Feldman, M. P. (2012). The engaged university. *The Journal of Technology Transfer, 37*(2), 139–157.
Cadorin, E., Klofsten, M., & Löfsten, H. (2021). Science Parks, talent attraction and stakeholder involvement—An international study. *The Journal of Technology Transfer, 46*(1), 1–28.
Campbell, J. L., Quincy, C., Osserman, J., & Pedersen, O. K. (2013). Coding in-depth semistructured interviews. *Sociological Methods & Research, 42*(3), 294–320.
Carayannis, E. G., Provance, M., & Grigoroudis, E. (2016). Entrepreneurship ecosystems: An agent-based simulation approach. *The Journal of Technology Transfer, 41*(3), 631–653.
Carlesi, A., Mariani, G., & Scarfò, A. A. (2017). Academic spin-offs for the local economy growth. *Corporate Ownership & Control, 14*(2–2), 350–359.
Chen, S. H., & Lin, W. T. (2017). The dynamic role of universities in developing an emerging sector: A case study of the biotechnology sector. *Technological Forecasting and Social Change, 123*, 283–297.
Clark, B. R. (1998a). *Creating entrepreneurial universities*. Pergamin.
Clark, B. R. (1998b). The entrepreneurial university demand and response. *Tertiary Education Management, 4*(1), 5–15.
Clark, B. R. (2001). The entrepreneurial university: New foundations for collegiality, autonomy, and achievment. *Higher Education Management, 13*(2), 9–24.
Clark, B. R. (2004). Delineating the character of the entrepreneurial university. *Higher Education Policy, 17*(4), 355–370.
Clarke, S. P., & Cossette, S. (2000). Secondary analysis: Theoretical, methodological, and practical considerations. *Canadian Journal of Nursing Research, 32*(3), 109–129.
Clarysse, B., & Moray, N. (2004). A process study of entrepreneurial team formation: The case of a research-based spin-off. *Journal of Business Venturing, 19*(1), 55–79.
Coughlan, K., Hallady-Garrett, C., Rachel, K., Sousa, S., & Thompson, H. (2016). *BIS's capital investment in science projects*. London: National Audit Office.
Creswell, J. W., & Creswell, J. D. (2017). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage publications.
D'Ippolito, B., & Rüling, C.-C. (2019). Research collaboration in large scale research infrastructures. *Research Policy, 48*(5), 1282–1296.
Dasgupta, P., & David, P. A. (1994). Toward a new economics of science. *Research Policy, 23*(5), 487–521.
De Silva, M. (2016). Academic entrepreneurship and traditional academic duties: Synergy or rivalry? *Studies in Higher Education, 41*(12), 2169–2183.
De Zilwa, D. (2005). Using entrepreneurial activities as a means of survival: Investigating the processes used by Australian universities to diversify their revenue streams. *Higher Education, 50*(3), 387–411.
Di Gregorio, D., & Shane, S. (2003). Why do some universities generate more start-ups than others? *Research Policy, 32*(2), 209–227.
Dias, A., & Selan, B. (2023). How does university–industry collaboration relate to research resources and technical-scientific activities? An analysis at the laboratory level. *The Journal of Technology Transfer, 48*(1), 392–415. https://doi.org/10.1007/s10961-022-09921-5
Doolan, D. M., & Froelicher, E. S. (2009). Using an existing data set to answer new research questions: A methodological review. *Research and Theory for Nursing Practice: An International Journal, 23*, 203–215. https://doi.org/10.1891/1541-6577.23.3.203
Dubois, A., & Gadde, L.-E. (2002). Systematic combining: An abductive approach to case research. *Journal of Business Research*, *55*(7), 553–560.
Dubois, A., & Gadde, L.-E. (2014). Systematic combining—A decade later. *Journal of Business Research, 67*(6), 1277–1284.
Dyer, W. G., & Wilkins, A. L. (1991). Better stories, not better constructs, to generate better theory: A rejoinder to Eisenhardt. *Academy of Management Review, 16*(3), 613–619.
Eisenhardt, K. M. (1989). Building theories from case study research. *Academy of Management Review, 14*(4), 532–550.
Elzinga, A. (2012). Feutures of the current science policy regime: Viewed in historical perspective. *Science and Public Policy, 39*(4), 416–428.
ESFRI. (2018). Innovation-oriented cooperation of research infrastructures. European strategy forum on research infrastructures innovation working group. ESFRI Scripta Volume III.

Etzkowitz, H. (1983). Entrepreneurial scientists and entrepreneurial universities in American Academic Science. *Minerva, 21*(2/3), 198–233.
Etzkowitz, H. (2003a). Research groups as "quasi firms": The invention of the entrepreneurial university. *Research Policy, 32*(1), 109–121.
Etzkowitz, H. (2003b). Innovation in innovation: The triple helix of university–industry–government relations. *Social Science Information, 42*(3), 293–337.
Etzkowitz, H. (2004). The evolution of the entrepreneurial university. *International Journal of Technology and Globalisation, 1*(1), 64–77.
Etzkowitz, H. (2019). *The second academic revolution: Antecedents and consequences of academic entrepreneurship*. In Handbook of Universities and Regional Development.
Etzkowitz, H., Germain-Alamartine, E., Keel, J., Kumar, C., Smith, K. N., & Albats, E. (2019). Entrepreneurial university dynamics: Structured ambivalence, relative deprivation and institution-formation in the Stanford innovation system. *Technological Forecasting and Social Change, 141*(C), 159–171.
Etzkowitz, H., & Leydesdorff, L. (2000). The dynamics of innovation: From national system and "mode 2" to a triple helix of university-industry-government relations. *Research Policy, 29*(2), 109–123.
Etzkowitz, H., Webster, A., Gebhardt, C., & Cantisano Terra, B. R. (2000). The future of the university and the university of the future: Evolution of ivory tower to entrepreneurial paradigm. *Research Policy, 29*, 313–330.
Feldman, M., Siegel, D. S., & Wright, M. (2019). New developments in innovation and entrepreneurial ecosystems. *Industrial and Corporate Change, 28*(4), 817–826.
Feola, R., Parente, R., & Cucino, V. (2021). The Entrepreneurial university: How to develop the entrepreneurial orientation of academia. *Journal of the Knowledge Economy, 12*, 1787–1808. https://doi.org/10.1007/s13132-020-00675-9
Fernandez-Alles, M., Diánez-González, J. P., Rodríguez-González, T., & Villanueva-Flores, M. (2018). TTO characteristics and university entrepreneurship: A cluster analysis. *Journal of Science and Technology Policy Management, 104*(4), 861–889.
Fini, R., Grimaldi, R., Marzocchi, G. L., & Sobrero, M. (2011). Complements or substitutes? The role of universities and local context in supporting the creation of academic spin-off. *Research Policy, 40*(8), 1113–1127.
Fontana, A., & Frey, J. H. (2000). The interview: From structured questions to negotiated text. In N. K. Denzin & Y. S. Lincoln (Eds.), *Handbook of qualitative research* (2nd ed., pp. 645–672). Thousand Oaks: Sage.
Fuster, E., Padilla-Meléndez, A., Lockett, N., & del Águila-Obra, A. R. (2019). The emerging role of university spin-off companies in developing regional entrepreneurial university ecosystems: The case of Andalusia. *Technological Forecasting and Social Change, 141*, 219–231.
Gordon, I., Hamilton, E., & Jack, S. (2012). A study of a university-led entrepreneurship education programme for small business owner/managers. *Entrepreneurship & Regional Development, 24*(9–10), 767–805.
Grimaldi, R., & Grandi, A. (2001). The contribution of university business incubators to new knowledge-based ventures. *Industry and Higher Education, 15*(4), 239–250.
Guerrero, M., Kirby, D. A., & Urbano, D. (2006). *A literature review on universities: An institutional approach*. Working papers 0608, Autonomous University of Barcelona, Business Economics Department.
Guerrero, M., & Urbano, D. (2012). The development of an entrepreneurial university. *The Journal of Technology Transfer, 37*(1), 43–74.
Guerrero, M., Urbano, D., & Fayolle, A. (2016a). Entrepreneurial activity and regional competitiveness: Evidence from European entrepreneurial universities. *The Journal of Technology Transfer, 41*(1), 105–131.
Guerrero, M., Urbano, D., Fayolle, A., Klofsten, M., & Mian, S. (2016b). Entrepreneurial universities: Emerging models in the new social and economic landscape. *Small Business Economics, 47*(3), 551–563.
Hallonsten, O. (2013). Introducing facilitymetrics: A first review and analysis of commonly used measures of scientific leadership among synchotron radiation facilities worldwide. *Scientometrics, 96*, 497–513.
Hannon, D. P. (2013). Why is the entrepreneurial university important? *Journal of Innovation Management, 1*(2), 10–17.
Holden, T., & Goldstein, B. (2010). Engines of innovation: The entrepreneurial university in the twenty-first century. *New England Journal of Entrepreneurship, 14*(2), 81–83.
Horlings, E., Gurney, T., Somers, A., & van den Besselaar, P. (2012). *The societal footprint of large-scale research infrastructures. A literature review*. Rathenau Instituut.

Jacob, M., Lundqvist, M., & Hellsmark, H. (2003). Entrepreneurial transformations in the Swedish University system: The case of Chalmers University of Technology. *Research Policy, 32*(9), 1555–1569.
Johnston, M. P. (2014). Secondary data analysis: A method of which the time has come. *Qualitative and Quantitative Methods in Libraries (QQML), 3*, 619–626.
Johnstone, A., & Huggins, R. (2016). Drivers of university–industry links: The case of knowledge-intensive business service firms in rural locations. *Regional Studies, 50*(8), 1330–1345.
Kirby, D. A. (2002). *Entrepreneurship. Maidenhead*. Mcgraw-Hill.
Kirby, D. A. (2006). Creating entrepreneurial universities in the UK: Applying entrepreneurship theory to practice. *The Journal of Technology Transfer*, *31*, 599–603.
Kirby, D. A., & Mullen, D. (1990). Developing enterprising undergraduates. *Journal of European Industrial Training, 14*(2), 27–32.
Klein, S. B., & Pereira, F. C. M. (2020). Entrepreneurial university: Conceptions and evolution of theoretical models. *Revista Pensamento Contemporâneo Em Administração, 14*(4), 20–35.
Klofsten, M., Fayolle, A., Guerrero, M., Mian, S., Urbano, D., & Wright, M. (2019). The entrepreneurial university as driver for economic growth and social change-key strategic challenges. *Technological Forecasting and Social Change, 141*, 149–158.
Klofsten, M., & Jones-Evans, D. (2000). Comparing academic entrepreneurship in Europe—The case of Sweden and Ireland. *Small Business Economics, 14*(4), 299–309.
Klofsten, M., Urbano, D., & Heaton, S. (2021). Managing intrapreneurial capabilities: An overview. *Technovation, 99*, 102177.
Kohn Rådberg, K., & Löfsten, H. (2023). Developing a knowledge ecosystem for large-scale research infrastructure. *The Journal of Technology Transfer, 48*(1), 441–467. https://doi.org/10.1007/s10961-022-09945-x
Kvale, S. (1996). *InterViews: An introduction to qualitative research interviewing*. Sage.
Langley, A. (1999). Strategies from theorizing from process data. *Academy of Management Review, 24*(4), 691–710.
Laredo, P. (2007). Revisiting the third mission of universities: Toward a renewed categorization of university activities? *Higher Education Policy, 20*(4), 441–456.
Larty, J., Jack, S., & Lockett, N. (2016). Building regions: A resource-based view of a policy-led knowledge exchange network. *Regional Studies, 51*(7), 994–1007.
Laukkanen, M. (2000). Exploring alternative approaches in high-level entreprneurship education: Creating micro-mechanisms for endogenous regional growth. *Entrepreneurship and Regional Development, 12*(1), 25–47.
Lauto, G., & Valentin, F. (2013). How large-scale research facilities connect to global research. *Review of Policy Research, 30*(4), 381–408.
Lindelöf, P., & Löfsten, H. (2004). Proximity as a resource base for competitive advantage—University–industry links for technology transfer. *The Journal of Technology Transfer, Special Issue, 29*(3/4), 311–326.
Lindelöf, P., & Löfsten, H. (2005). Academic versus corporate new technology-based firms in Swedish Science Parks: An analysis of performance, business networks and financing. *International Journal of Technology Management, 31*(3/4), 334–357.
Löfsten, H. (2010). Critical incubator dimensions for small firm performance—A study of new technology-based firms localised in 16 incubators. *International Journal of Business Innovation and Research, 4*(3), 256–279.
Löfsten, H., Klofsten, M., & Cadorin, E. (2020). Science Parks and talent attraction management: University students as a strategic resource for innovation and entrepreneurship. *European Planning Studies, 28*(12), 2465–2488.
Löfsten, H., & Lindelöf, P. (2002). Science Parks and the growth of new technology-based firms—Academic-industry links, innovation and markets. *Research Policy, 31*(6), 859–876.
Löfsten, H., & Lindelöf, P. (2005). R&D networks and product innovation patterns of academic and non-academic new technology-based firms on Science Parks. *Technovation, 25*(9), 1025–1037.
Lozano, S., Rodríguez, X.-P., & Arenas, A. (2014). Atapuerca: Evolution of scientific collaboration in an emergent large-scale research infrastructure. *Scientometrics*. https://doi.org/10.1007/s11192-013-1162-x
MacEachren, A. M., Pike, W., Yu, C., Brewer, I., Gahegan, M., Weaver, S. D., & Yarnal, B. (2006). Building a geocollaboratory: Supporting human-environment regional observatory (HERO) collaborative science activities. *Computers, Environment and Urban Systems, 30*(2), 201–225.
Mian, S. (2011). University's involvement in technology business incubation: What theory and practice tell us? *International Journal of Entrepreneurship and Innovation Management, 13*(2), 113–121.
Miles, M., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook*. Sage.

Montiel-Campos, H. (2018). University spin-offs creation in the Latin American region: An exploratory study. *Journal of Entrepreneurship in Emerging Economies, 10*(3), 386–408.
Nag, R., & Gioia, D. A. (2012). From common to uncommon knowledge: Foundations of firm-specific use of knowledge as a resource. *Academy of Management Journal, 55*, 421–457.
Park, H. W., & Leyesdorff, L. (2010). Longitudinal trends in networks of university–industry–government relations in South Korea: The role of programmatic incentives. *Research Policy, 39*(5), 640–649.
Pelikan, J. (1992). *The idea of the university: A reexamination*. Yale University Press.
Perkmann, M., Salandra, R., Tartari, V., McKelvey, M., & Hughes, A. (2021). Academic engagement: A review of the literature 2011–2019. *Research Policy, 50*(1), 104114.
Perkmann, M., Tartari, V., & McKelvey, M. (2013). Acdemic engagement and commercialisation: A review of the literature on university-industry relations. *Research Policy, 42*(2), 423–442.
Petruzzelli, A. M., & Murgia, G. (2019). University–industry collaborations and international knowledge spillovers: A joint-patent investigation. *The Journal of Technology Transfer*. https://doi.org/10.1007/s10961-019-09723-2
Pinheiro, R., Langa, P. V., & Pausits, A. (2015). One and two equals here? The third mission of higher education institutions. *European Journal of Higher Education, 5*(3), 233–249.
Provasi, G., Squazzoni, F., & Tosio, B. (2012). Did they sell their soul to the devil? Some comparative case-studies on academic entrepreneurs in the life sciences in Europe. *Higher Education, 64*(6), 805–829.
Pugh, R., Lamine, W., Jack, S., & Hamilton, E. (2018). The entrepreneurial university and the region: What role for entrepreneurship departments? *European Planning Studies, 26*(9), 1835–1855.
Qiao, L., Mu, R., & Chen, K. (2016). Scientific effects of large research infrastructures in China. *Technological Forecasting and Social Change, 112*, 102–112.
Rajalo, S., & Vadi, M. (2017). University–industry innovation collaboration: Reconceptualization. *Technovation, 62–63*, 42–54. https://doi.org/10.1016/j.technovation.2017.04.003
Ranga, L., Debackere, K., & Tunzelmann, N. (2003). Entrepreneurial universities and the dynamics of academic knowledge production: A case study of basic vs applied research in Belgium. *Scientometrics, 58*(2), 301–320.
Ridder, H. (2017). The theory contribution of case study research designs. *Business Research, 10*(2), 281–305.
Rinaldi, C., Cavicchi, A., Spigarelli, F., Lacchè, L., & Rubens, A. (2018). Universities and smart specialisation strategy. *International Journal of Sustainability in Higher Education, 19*(1), 67–84.
Rizzo, U. (2015). Why do scientists create academic spin-offs? The influence of the context. *The Journal of Technology Transfer, 40*(2), 198–226.
Rothaermel, T., Agung, S. D., & Jiang, L. (2007). University entrepreneurship: A taxonomy of the literature. *Industrial and Corporate Change, 16*(4), 691–791.
Rybnicek, R., & Königsgruber, R. (2018). What makes industry–university collaboration succeed? A systematic review of the literature. *Journal of Business Economics, 89*, 221–250. https://doi.org/10.1007/s11573-018-0916-6
Salamzadeh, A., Salamzadeh, Y., & Daraei, M. (2011). Toward a systematic framework for an entrepreneurial university: A study in Iranian context with an IPOO model. *Global Business and Management Research*, *3*(1), 30–37.
Salamzadeh, Y., Sangosanya, T. A., Salamzadeh, A., & Braga, V. (2022). Entrepreneurial universities and social capital: The moderating role of entrepreneurial intention in the Malaysian context. *The International Journal of Management Education, 20*, 1. https://doi.org/10.1016/j.ijme.2022.100609
Sandberg, J., & Alvesson, M. (2011). Ways of constructing research questions: Gap-spotting or problematization? *Organization, 18*(1), 23–44.
Schissel, D. P. (2006). The collaborative tokamak control room. *Fusion Engineering and Design, 81*(15–17), 2031–2037.
Schulte, P. (2004). The entrepreneurial university: A strategy for institutional development. *Higher Education in Europe, 29*(2), 187–191.
Secundo, G., Rippa, P., & Cerchione, R. (2020). Digital academic entrepreneurship: A structured literature review and avenue for a research agenda. *Technology Forecasting and Social Change*. https://doi.org/10.1016/j.techfore.2020.120118
Shane, S. (2004). *Academic entrepreneurship: University spinoffs and wealth creation*. Edward Elgar.
Shane, S., & Stuart, T. (2002). Organizational endowments and the performance of university start-ups. *Management Science, 48*(1), 154–170.

Siegel, D., Waldman, D., Atwater, L., & Link, A. (2003). Commercial knowledge transfers from universities to firms: Improving the effectiveness of university-industry collaboration. *Journal of High Technology Management Research, 14*(1), 111–133.
Siegel, D. S., & Wright, M. (2015). Academic entrepreneurship: Time for a rethink? *British Journal of Management, 26*(4), 582–595.
Siggelkow, N. (2007). Persuasion with case studies. *The Academy of Management Journal, 50*(1), 20–24.
Silverman, D. (2013). *Doing qualitative research A practical handbook*. Sage Publications.
Slaughter, L. S., & Leslie, L. L. (1997). *Academic capitalism: Politics, policies and the entrepreneurial university*. John Hopkins University Press.
Smilor, R. W., Gibson, D. V., & Dietrich, G. B. (1990). University soin-out companies: Technology start-ups from IT-Austin. *Journal of Business Venturing, 5*(1), 63–76.
Sooreh, L. K., Salamzadeh, A., Saffarzadeh, H., & Salamzadeh, Y. (2011). Defining and measuring entrepreneurial universities: A study in Iranian context using importance-performance analysis and Topsis technique. *Global Business and Management Research: An International Journal, 3*(2), 182–199.
Sporn, B. (2001). Building adaptive universities: Emerging organisational forms based on experiences of European and US Universities. *Tertiary Education and Management, 7*(2), 121–134.
Teece, D. J. (2018). Managing the university: Why "organized anarchy" is unacceptable in the age of massive open online courses. *Strategic Organization, 16*(1), 92–102.
Trencher, G., Yarime, M., McCormick, K. B., & Doll, C. N. H. K. (2014). Beyond the third mission: Exploring the emerging university function of co-creation for sustainability. *Science and Public Policy, 41*(2), 151–179.
Trequattrini, R., Lombardi, R., Lardo, A., & Cuozzo, B. (2015). The impact of entrepreneurial universities on regional growth: A local intellectual capital perspective. *Journal of the Knowledge Economy, 9*(1), 199–211.
Turner, T., & Gianiodis, P. (2018). Entrepreneurship unleashed: Understanding entrepreneurial education outside of the business school. *Journal of Small Business Management, 56*(1), 131–149.
Urbano, D., & Turro, A. (2013). Conditioning factors for corporate entrepreneurship: An in(ex)ternal approach. *International Entrepreneurship and Management Journal, 9*(3), 379–396.
Valka, K., Roseira, C., & Campos, P. (2020). Determinants of university employee intrapreneurial behavior: The case of Latvian universities. *Industry and Higher Education, 34*(3), 190–202.
Valliani, E., Rasmussen, E., & Grimaldi, R. (2016). How intermediary organizations facilitate university-industry technology transfer: A proximity approach. *Technology Forecasting and Social Change, 114*(C), 86–102.
Wood, M. S. (2011). A process model of academic entrepreneurship. *Business Horizons, 54*(2), 153–161.
Yang, X., Zhou, X., & Cao, C. (2023). Remaking the Chinese Academy of Sciences: Under pressure to reinvent itself, the CAS should concentrate on managing large-scale research infrastructures. *Science, 379*(66299), 240–243.
Yin, R. K. (2018). *Case study research: Design and methods*. Sage Publications.
Yusuf, S. (2008). Intermediating knowledge exchange between universities and businesses. *Research Policy, 37*(8), 1167–1174.
Zuijdam, F., Boekholt, P., Deuten, J., Meijer, I., & Vermeulen, N. (2011). The role and added value of large-scale research facilities. Final report, Technopolis Group.