

UNLEASHING INNOVATION IN RURAL AREAS: INSIGHTS FROM QUADRUPLE HELIX CASE STUDIES

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Abstract: Addressing complex and highly interlinked challenges facing rural areas is paramount. Innovation is key in addressing these challenges while creating economic gain and social capital to promote sustainable development. This work reviews existing rural innovation spaces, that follow the Quadruple helix innovation framework, a tried and tested knowledge economy model in the design of innovation spaces. This research identified three place-based themes across 11 worldwide case studies that can be utilised in future innovation developments: People as the Bridge, Geographic strategy, and Local Knowledge Integration. From this review authorities, businesses, universities, and the public can implement the three-theme model (using subthemes) to build successful innovation spaces for social, environmental, and economic good. This review provides the ‘how’ to support the ‘who’ of the Quadruple helix.

Keywords: Quadruple helix, Rural innovation, Place-based, Local Knowledge, People as the Bridge

Highlights

- Rural depopulation is mitigated through innovation, generating economic value and social capital.
 - Systematic review using the Quadruple Helix framework.
 - Search criteria included the N-Helix and a physical rural innovation space.
 - Identification of place-based themes: People as the Bridge, Geographic Strategy, and Local Knowledge Integration.
 - Participatory Action Research is recommended to better capture social and geographic dynamics.
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1. Introduction

Globally, rural communities face accumulating challenges driven by regional, national, and global forces beyond their control, pushing them toward decline (Rodríguez-Soler et al., 2020; van Ginkel et al., 2020). The distinctive nature of rural areas provides an opportunity for innovation to address these challenges sustainably through a place-based approach. Currently, no one-size-fits-all approach exists due to their diverse attributes (Eder & Trippel, 2019; Makkonen & Kahila, 2021). This aims is to identify the factors that facilitate rural innovation, using established frameworks and existing literature, to create a guiding model that could be applied across rural settings. This is increasingly important as rural areas are a significant pillar of national employment, prosperity, and identity (Calzada, 2019; Goetz & Han, 2020; Wiggins & Proctor, 2001). They can be considered as areas with sources of unleashed social, environmental and economic potential with a key role to play in the knowledge economy and innovation (Goetz & Han, 2020; Hemlin et al., 2008). This review explores the common themes essential to harnessing that unleashed potential.

Innovation is a central element in sustained local growth and development. The process by which we create something new or bring about change through novel means to benefit people can involve technology or concepts (Crowley & McCann, 2018 {Schütz, 2019 #231}) In considering innovation, we take our lead from the United Nations (UN) UN 2.0 innovation capacity; *‘learning to generate, test and scale up novel ideas, processes, products or services that create value. It requires supportive and inclusive environments, open minds and diverse skills’* (UN2.0, 2023). Innovation can bring great regional socio-economic benefits such as jobs, income, health benefits and systematic care (Crescenzi & Rodríguez-Pose, 2017; Martínez et al., 2023), and a space centre, or hub (henceforth referred to as a ‘space’), can be digital, physical, or social. Holding this space for innovation is an integral part of innovation (Butt et al., 2021; Merrell et al., 2022). This is the reason the authors chose to cross-analyse the experiences of real-life case-

studies developing physical innovation spaces with a rural sense of place – this differs from existing reviews, which include innovation strategies and regional specialisation (Devine-Wright, 2013; Lew & Park, 2021).

Innovation spaces have previously lent themselves to the high-density population and fast-paced nature of cities and only recently has their use in rural areas come to the forefront of rural regeneration (Crescenzi & Rodríguez-Pose, 2017; Irvine et al., 2014; Li et al., 2019). Baseline socio-economic and landscape characteristics differ significantly between rural and urban areas, therefore innovation strategies must be tailored to address diverse needs and promote sustainable equitable growth (Tomasí et al., 2022). Physical innovation spaces in rural areas must be tailored to their local context and audience to be successful, as challenges arise when people are not consulted, funding is not readily available, and infrastructure is not developed (García-Terán & Skoglund, 2019a). For this reason, innovation spaces link closely to Regional Innovation Strategies (RIS). In these strategies regions (an area, especially part of a country or the world having definable characteristics but not always fixed boundaries) are the key drivers of innovation, working towards delivering socio-economic improvements or benefits based on the characteristics of the area (Irvine et al., 2014; Tomasí et al., 2022). In this way, social equity, which puts people at the heart of innovation, is the cornerstone on which this work builds its understanding of innovation and the role of innovation spaces (Devine-Wright & Davies, 2023; Irvine et al., 2014; Li et al., 2019).

The past decade has been characterised by widespread regional innovation strategies (RIS) across the world, particularly in Europe, where regional innovation strategies are driven to promote cohesion and balance with more emphasis on less favoured regions (Irvine et al., 2014; Wigger, 2023). However, many of the strategies aimed at developing innovation emanate from policymakers in centrally-located urban sites, based on specific policy models that were created under the one-size-fits-all notion (Casale Mashiah et al., 2023; Hervás-Oliver et al., 2021). To tackle this, there has been a contribution to policy from the knowledge-based approach of smart specialisation, which focuses on what is unique and profitable (both socially and economically) in an area, and can be described as strengths-based (Fabbri, 2016; Reidolf & Graffenberger, 2019). While smart specialisation is a valuable approach, it can overlook the crucial success factor of cross-fertilisation, which is critical to innovation, meaning its application in policy can then be misaligned with optimal innovation (Esteves et al., 2021; Wigger, 2023).

To overcome the barriers of politically-driven RIS and smart specialisation, innovation spaces are acting as a tool for holistic approaches to locally-led and collaborative economic and social growth (Carayannis & Rakhmatullin, 2014; Foray, 2014; Höglund & Linton, 2018). An innovation space is held for creating collaboration between partners and generating new ideas, products and solutions (Bosworth & Salemin, 2021). Partners support one another and often share (or the 'space' provides) resources (e.g., funding), and facilities (e.g., laboratories). Innovation spaces can be part of a university, government department or a standalone business (Bosworth & Salemin, 2021; Hemlin et al., 2008). The spaces often become known as an incubator or ecosystem for innovation and transdisciplinary work (Allahar & Sookram, 2019; Martínez et al., 2023; Nicolopoulou et al., 2017). Innovation spaces have the potential to act as magnets, thus attracting businesses to settle or remain in areas that may not have otherwise been the case making them valuable for an area's economic and social success.

To ensure a space is supported, it should integrate partners from a suitable range of groups and sectors that can co-shape the direction of innovation (Schütz et al., 2019; Szarka et al., 2023). A beneficial framework to guide this is the N-helix, which ensures a variety of players' opinions and needs are met and will theoretically deliver innovation success and advantage through enhanced democracy and creativity (Carayannis et al., 2018; Hemlin et al., 2008; Lew et al., 2018). The N-helix is a model in innovation that ensures the contribution to the knowledge economy and exchange of varied stakeholders in the innovation ecosystem, by providing key distinct groups to incorporate (Carayannis & Rakhmatullin, 2014; Lew & Park, 2021; Lindberg et al., 2012)).

We use 'N' to demonstrate the different number of groups (e.g., 3/4/5), and the four groups of a Quadruple helix including Community, Business, Academia and Authority (Carayannis EG, 2009; Carayannis et al., 2018). The Quadruple helix builds on the earlier Triple helix, with the addition of

'community' as an invaluable part of the innovation process. Community has multiple interpretations but we refer to community as the inclusion of civil society (including citizens and users) in innovation and knowledge production and transfer (Carayannis EG, 2009; Carayannis & Rakhmatullin, 2014; Kolehmainen et al., 2016; Nordberg et al., 2020). The helix is continuing to expand beyond this with Penta and Quint-helix models, incorporating media and culture, to help understand the complexity of modern innovation (da Costa Mineiro et al., 2023; Lew & Park, 2021). Science-led/driven innovation places more emphasis on academic expertise and guidance, but the doing, using, and interacting modes of the Quadruple helix provide a different approach (Carayannis EG, 2009). The Quadruple helix allows for the incorporation of an iterative feedback loop in its very foundations and, therefore presents a vital model when starting innovation spaces (Butt et al., 2021; Carayannis et al., 2018; Schütz et al., 2019). Appropriate use of the Quadruple helix ensures collaborative innovation that is non-linear, allowing feedback and challenging academia as the (lone) source of knowledge.

The Quadruple-helix model can be advantageous in rural areas, where the fourth helix of community and society becomes key to success, given the sparser population and the existence of a strong local identity (Devine-Wright, 2013; Höglund & Linton, 2018; Nordberg et al., 2020). Societies across the world are transforming as economic and social opportunities move towards urban areas (Ali, 2022; Tomasi et al., 2022). Due to this socio-economic disadvantage, more rural regions can face depopulation and degradation (Li et al., 2019; Wiggins & Proctor, 2001). In a study investigating why some rural areas face decline and others do not, Li *et al.* (2019), found that collaboration within and between local actor groups is essential, pointing out that resilience could be built via economic and social capital (Li et al., 2019). Innovation spaces utilising frameworks like the Quadruple helix offer solutions to this challenge and pathways to build resilience.

Rural areas have great opportunities for innovation from renewables to agriculture and tourism making them unique sites (Calzada, 2019; Nordberg et al., 2020; Reidolf & Graffenberger, 2019; Schmidt et al., 2022). In some areas, this is recognised and supported, such as in Europe by funds like the European Regional Development Fund, Horizon Europe, LEADER scheme and European Agricultural Fund for Rural Development (Foray, 2014; Nordberg et al., 2020). The rationale for such funding links closely to place-based theory (Dotti et al., 2024; Hervás-Oliver et al., 2021). Place-based theory advocates successful projects that should be tailored to the landscape socially, environmentally, economically, and culturally (Carayannis & Rakhmatullin, 2014). The diverse landscapes of rural areas vary between and within countries providing a unique opportunity that can be harnessed through the structured funding and support an innovation space can bring.

A case has been made so far for addressing socio-economic challenges in rural areas through innovation spaces, ensuring they are designed for the place in which they operate. There has yet to be an amalgamation of this valuable work on the Quadruple helix in rural areas. To explore this further and draw learning from across the world, this thematic literature review ties together shared elements and experiences of successful rural innovation spaces. The key audience for this work is community groups, businesses, academia, authorities and policymakers concerned about their region and looking to create socio-economic opportunities. The findings should support stakeholders in creating successful collaborative rural innovation spaces.

2. Methods

2.1 Scope

A literature review is a valuable tool to assess the status of a topic from a wealth of data, provide a summary of findings, and identify gaps in the knowledge accumulated within agreed parameters, which may be replicated (Kraus et al., 2020; Page et al., 2021). Collating information through a literature review is appropriate and necessary as we lack a comprehensive understanding of the facilitating factors or rural innovation spaces. This study adopts a systematic literature review approach as outlined by the PRISMA structure, followed by thematic analysis utilising the process of Braun and Clarke 2006 to identify common themes in rural innovation spaces (Page et al., 2021). This combination of thematic methods in

a systematic literature review, which aims to amalgamate the concepts from the literature, is outlined by Kraus et al (2020) as an appropriate domain review approach. By amalgamating key literature findings and comparing their observations, it aims to guide stakeholders across the quadruple helix in establishing a rural innovation space. This review is conducted with transparency and an awareness of the variety of methods and approaches used in the case studies. The themes are then presented as a model for consideration that any organisation can apply, regardless of scale or region, when setting up an innovation space.

2.2 Databases and Search Strategy

Google Scholar, Web of Science, and Wiley were chosen as prominent citation databases with broad subject coverage making them suitable for thematic analysis. Results for "'Quadruple helix' OR 'Quintuple helix' AND 'Innovat*' AND 'Centre' OR 'Hub' AND 'Economy' AND 'Rural' AND 'Case study'" over the past 10 years (2013–2023). Wiley; 2,179 (41 reference works). For Google Scholar, the same search returned 8,780. Web of Science 830.

All databases were reviewed up to the first 100 results based on relevance. Relevant texts beyond a hundred dwindled, and many more bio-helix-based papers appeared. Wiley particularly included biomedical helix studies which reduced the number of relevant studies from this search engine (these journals were not removed as medical hubs were considered as rural innovation in this study), whereas Google obtained relevant but sometimes not-peer-reviewed works. To ensure a comprehensive study, the reference lists of selected texts were checked for any additional important case studies from the same hub or centre, and multiple hub studies were compared selecting those that best delivered the following criteria.

2.3 Selection criteria

1. A detailed case study focusing on one or more innovation spaces.
2. The innovation space must be in a rural or discuss a rural region.
3. At least three of the N-helix groups must be discussed.
4. One-off interventions and living labs were not included as they lacked longevity of intervention and development for the region.
5. Did not select more than one study per innovation space or region – this would have been possible for specific innovation spaces or EU sites but would have created a bias.
6. Only included work published in peer-reviewed journals (the authors acknowledge informative dissertations on this topic).
7. Case studies were not to be speculative on how it could be done (for example, by harnessing regional policy) but focused on things that *had* happened and *had* or *were* being done – this is valuable, real-world innovation.

2.4 Screening Process

This can be viewed in the PRISMA diagram Figure 1:

- Abstracts of 300 were reviewed
- 92 warranted further investigation (abstract and title being reflective of goal and scope)
- 36 studies were selected for review based on the criteria above
- 12 studies were suitable, 1 of which had overlap in the innovation space with another piece.
- Result 11 case studies.

The overlap occurred with Österbotten, which was the focus of a paper incorporated in a study of four different countries rural innovation spaces. It was felt that this multi-country study was more relevant to include due to its focus, variety and alignment with this piece of work; excluding this would have been a problematic omission of data (Kolehmainen et al., 2016; Nordberg et al., 2020). From these papers 7 additional studies were sought with 3 requiring full paper review and only one being suitable.

Of those case studies reviewed, only 7 were explicitly rural and 4 were rural-urban regions where rurality was discussed in detail. The innovation spaces were selected, and other literature was considered to ensure the most appropriate paper/space per country was selected (studies were not duplicated on a site or country). These innovation spaces and the research pieces on them were studied to identify key factors that delivered success for these operations.

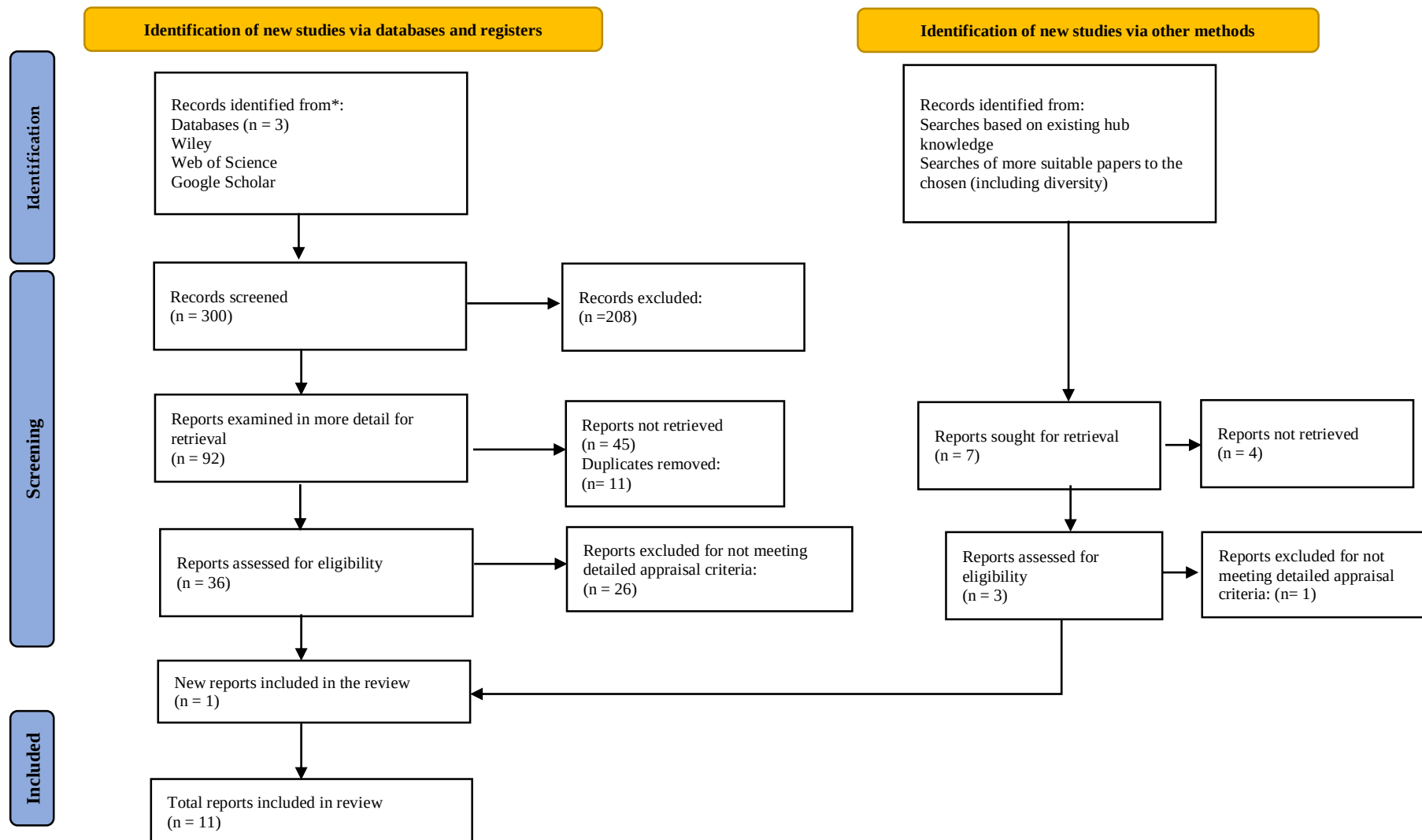


Fig 1. PRISMA Flowchart on the screening and assessment process adapted from Page et al., 2021

2.5 Thematic analysis

Thematic analysis (TA) was conducted in accordance with Braun and Clarke (2006); this method, although not specifically designed for literature reviews, is valued for identifying recurring concepts across the texts. Ensuring the case studies provided enough depth and breadth of narrative text information meant nuanced themes could be developed that met the requirement of Big Q qualitative data upholding qualitative research values (Braun & Clarke, 2023). Big Q allows for theme generation within a non-positivist framework (e.g., frequency of references to 'X') that recognises and empowers the subjective nature of the researcher, and when used in a literature review, accepts and values the approach and context of the original studies reviewed (Braun & Clarke, 2023).

The works were approached from an interpretivist perspective, reasoned inductively (data was initially read and coded manually) and abductively (place-based theory revealed itself as highly relevant so this was mapped back onto the data), a reflexive approach to TA (Braun & Clarke, 2019). Items that were coded only related directly to the case study in question, centring around the methods, results and discussion as well as general statements (regarding rural innovation) that were not corroborated directly in the findings of the paper.

NVivo software was used to group themes after a 'manual review' of stages 1–3 highlighting relevant points and coding (Braun & Clarke, 2006). Once the researcher had understood, determined, and divided the important coded aspects of the works they could subsequently then review using NVivo oversight tools (mapping and exploring) and complete the remaining 4–6 stages (iteratively and with the subsequent impact of place-based theory).

3. Results

The following 11 case studies and their respective geographic region and countries as presented in Table 1 were selected based on meeting the above criteria. This resulted in the production of three themes: **People as the Bridge**, **Geographic strategy**, and **Local Knowledge Integration**, every theme being supported in all 11 case studies. All themes can be described as supportive of place-based innovation, with each theme having three contributing subthemes and 3–4 characteristics associated with their discussion as outlined in Table 2. These are then described and explored in detail with quotations from the papers.

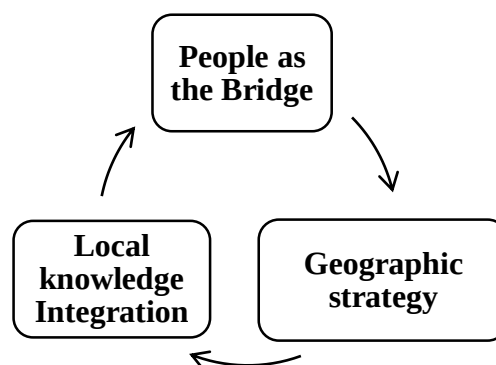


Fig 2. The core themes identified and their interactions with one another. Source: own elaboration

3.1 People as the Bridge

People as the Bridge is an overarching theme that discusses the need *for* and importance *of* people in building trust, maintaining partnerships, sharing knowledge, and fostering an overall productive collaboration that leads to successful innovation. It is a broad social theme that helps us understand the role that actors and their interactions play in the success of rural innovation and provides explanations as to why this may be the case. It is comprised of the subthemes 'Intermediaries in the ecosystem of knowledge', 'All actors as the 'fourth helix'', and 'Mutual Trust and Respect'.

Tab 1. Studies included in this review. Source: own elaboration

Space and Country	Level	Year of paper	Title and Author of paper
Japan – Niigata Prefecture	Rural – Regional	2023	Regional Innovation Led by the Fourth Helix: a Case of Sake Development (Yoda & Kuwashima, 2023).
India – RuTAG	Rural – Regional Project (hub country wide)	2023	Co-creating community-led frugal innovation: An adapted Quadruple Helix? (Bhattacharjya et al., 2023).
China – Concealed identity – 12 rural bases	Rural – Country wide	2023	Role of Networks of Rural Innovation in Advancing the Sustainable Development Goals: A Quadruple Helix Case Study (Irungu et al., 2023).
Indonesia – BengKoang Creative Hub	Rural – Local	2021	The Cross-Sector Collaboration for Development Policy of Rural Creative Economy: The Case of Bengkoang Creative Hub (Rosyadi et al., 2021).
Italy – Hub Innovazione Trentino (HIT)	Rural – Regional	2018	Gravitating Towards the Quadruple Helix: International Connections for the Enhancement of a Regional Innovation System in Northeast Italy (Lew et al., 2018).
Sweden – Robotdalen	Rural/urban – Regional	2018	Smart Specialization in Regional Innovation Systems: A Quadruple Helix Perspective (Höglund & Linton, 2018)
Portugal – Ageing Coimbra	Rural/urban – Regional	2018	The Quadruple Helix-Based Innovation Model of Reference Sites for Active and Healthy Ageing in Europe: The Ageing@Coimbra Case Study (Malva et al., 2018)
Australia – Tasmania (creation of hub)	Rural/urban – Regional	2017	Readying a region: temporally exploring the development of an Australian regional quadruple helix (Kriz et al., 2018).
Canada – Logging Quebec	Rural project – Rural/urban Region	2016	Challenges in technology transfer: an actor perspective in a quadruple helix environment (Van Horne & Dutot, 2017).
Finland – KETEK	Rural Regional	2015	Enabling Regional Growth in Peripheral Non-University Regions—The Impact of a Quadruple Helix Intermediate Organisation (Nordberg, 2015).
European Hubs – Scotland, Hungary, Finland and Sweden	Rural Regional Projects – across the Continent	2015	Quadruple Helix, Innovation and the Knowledge-Based Development: Lessons from Remote, Rural and Less-Favoured Regions (Kolehmainen et al., 2016).

Tab 2. Rural innovation in line with the Quadruple Rural helix. Source: own elaboration

Themes	Subthemes	Characteristics
People as the Bridge	Intermediaries in the ecosystem of knowledge	Enhanced via International and national networks
		Researchers and students as intermediaries
		Local charity local organisations provide links to communities
		Chained bridge (multiple partners)
	All actors as the fourth helix	Small population as a resource
		Strong local leaders and key nodes
		Multiple roles in the community
	Mutual Trust and Respect	Equality/diversity of voices
		Underlying collaboration
		Threat of undermining trust and respect
Geographic Strategy	Utilising natural assets for specialisation	Flexibility to one another's needs
		Physical and chemical properties of the area
		Attraction of the Landscape
	Local solutions to spatial inequality and justice	Specialism or generalisation
		Environmental justice
		Social benefits such as education and health improvements
	Challenges and solutions of disparate nature of rural populations	Economic benefits, work and income to the region
		Mobile units to reach communities
		Online resources
Local Integration	Knowledge	Placements in-situ
		Remote study for education
		Linking to cultural/local practice
	Incorporating traditional and cultural practice	Traditional industries focus
		Shared local identifiers/identity use
		Social norm incorporation
	Harnessing local knowledge	Valuing lived experience and co-creation
		Recognising academia is not the sole holder of knowledge
		Formal agreements and mechanism
	Place-based governance platform and decision-making	Shared local goals
		The innovation space as 'neutral'
		Policy and local authority support/guidance

Intermediaries in the ecosystem of knowledge

This subtheme explores the roles of intermediaries and networks that are enhancing the success and speed of innovation. Intermediaries help bridge the gap between international and regional partners to overcome local knowledge or skill limitations, as demonstrated by varying scale approaches like HIT in Italy and BCH in Indonesia. The KETEK case study selection of appropriate partners is highlighted; ***'The strategy in the selection of partners can be interpreted as a sensitivity to what the industry of the region is in need of at the time... Moreover, this competence is primarily searched for in the nearby region'***. Intermediaries, including charities, NGOs, and government officials, connected businesses, academia, and communities, fostering trust and accessibility while balancing social objectives, as seen in RuTAG's use of an NGO to build partnerships within its broader scheme. ***'It is evident from our analysis that the presence of an intermediary helps in bridging the void between academia and local people, which is a crucial part of the innovation process. RuTAG has dedicated manpower who regularly visit and interact with the local people. Besides, RuTAG organizes stakeholder interactions in remote villages.'*** In this example: there are two intermediaries the NGO that supports RuTAG in reaching communities and RuTAG itself, which were essential.

It appears that multiple intermediaries can create a valuable interconnected bridge and ecosystem of knowledge. For example, Ageing@Coimbra benefits from its multitude of ***'institutional partners that promote the social inclusion and participation of seniors in meaningful social activities and lifelong learning'***. This wide and complex health innovation project would not be effective in raising awareness of and tackling health issues, without its many intermediary bridges into the rural communities, in turn connecting them back to work that may be occurring in urban areas. Robotdalen found great power in the bridged ecosystem of three local sites: By combining the three counties to form the Robotdalen region, the counties can each gain more than when acting alone because the different regions have large synergy effects when combined together. Most innovation spaces reviewed tended to operate in an 'ecosystem' fashion with a web of partner groups (rather than as a hub-and-spoke or linear model).

Directly bridging the academic gap as intermediaries, students emerged as a prominent 'resource' fostering collaboration and successfully embedding PhDs and graduates in businesses and research institutes across locations such as Robotdalen, Trentino, Rural China AU, Debrecen, and Ageing Coimbra. Such intermediaries can increase international/regional links that foster innovation: ***'The university is also internationally connected via research, mobility, and exchange programs. This is an important element that allows local scientists and researchers to work with regional firms on R&D and innovation. The Trentino region is well connected with other regions regarding the mobility of its graduates.'*** However, in Quebec, PhD students were embedded in businesses, but success was limited due to the timeframe and goal clashes of business and academia. If the local Quadruple helix can collectively support intermediaries and promote viable connections, then perhaps innovation can be retained through the students and researchers as intermediaries.

All actors are the fourth helix

The subtheme "all helix actors are the fourth helix" highlights how, in rural areas, individuals often wear "many hats" due to limited players and closer communities, bridging Quadruple helix (QH) groups but causing blurred roles. For example, in Niigata's sake industry, intermediaries like the Brewers Association and research centres are seen as the "community" fourth helix, though they also fulfil business and academic roles; ***'in this study, we will...consider intermediary organisations and interest groups as the fourth helices, specifically, the following three: (a) the Niigata Crop Research Center', (b) the Niigata Prefectural Sake Research Institute, and (c) the Niigata Sake Brewers Association'***.

Similarly, innovation is often propelled by strong local leaders – like the BCH village leader in Indonesia or the enthusiastic motivators in Osterbotten – who hold key roles in their communities. But when innovation depends too heavily on a single influential person, the system becomes vulnerable. In Osterblotten, the qualities of such leaders as nodes are discussed; ***'It could be argued that this is a matter of leadership which calls for personal level enthusiasm and the ability to motivate and energise***

representatives of different quadruple helix actor groups. At different stages of the development process, different people or actor groups may be in charge of the process...’ These valuable individuals were discussed, *‘In creating shared vision and planning, and especially carrying out concrete common measures, people that have a connecting role in local and regional networks have an important role’*

In Robotdalen and Trentino, studies focused primarily on senior representatives while excluding NGOs and grassroots voices. However, this approach risks concentrating innovation within a small and powerful group. In Robotdalen the government was considered as a member of the community rather than in their primary role *‘The fourth dimension is often described as the end user, customer or community.... The analysis of our study also reveals that the government helix can buy and use products and services and thus act as a customer’*. While such leaders are critical and this approach is understandable, equitable representation across all QH groups is essential to ensure diverse voices and avoid perpetuating reliance on a narrow pool of influential actors.

Mutual Trust and Respect

Overall, mutual trust and respect were discussed positively as something the spaces and intermediaries had, with mutual trust being believed by the authors to be established. To create harmony the innovation space itself needed to be viewed as neutral or at least not swaying to one QH actor’s needs over the other; *‘there was discontent about the fact that KETEK was often perceived as an educational unit, a further separation was consequently needed to enable closer cooperation with firms’*. Once they could trust the innovation space would work for them, then it was used to great success. In Tasmania, China, Japan, KETEK and Robotdalen, boards or partnerships were created that held respect as experts. The Tasmanian study focused on securing the association’s trust and respect of those in power, which in turn garnered respect by the association for the researchers. *‘The researcher was also introduced to an influential TC sphere member whose power bases proved critical for trust development in later phases.... several introductions were facilitated by the connection ... creating avenues for the researcher to demonstrate expert power to a wider audience, initially contacted a TC helix IA to confirm the researcher’s credibility based on previous interactions.’* This allowed them to gain trust through association, even though they did not yet have the established credibility that a rural innovation space usually provides. However, developing this credibility may be a challenge.

Formal mechanisms were frequently mentioned as a means of ensuring trust and understanding. However, in RUTAG an agreement was secured from manufacturers not to lodge intellectual property rights on the elements of innovation – this meant that they could all benefit and achieve their social objectives which was credited to; *‘Mutual trust between academia and local-level stakeholders plays a significant role because the technology transfer process does not follow any formal agreement, such as IPR (intellectual property rights).’* The role of intermediary is not easy and even an agreement cannot ensure the success of an innovation space if mutual trust and respect are not involved. *‘The government is facing apprehension from two worlds, as (1) it can be difficult to convince academics of the value to work with industry; and (2) industry has demonstrated little receptor capacities to new ideas and technologies from academics and little uptake.’* Here, innovation is hindered by a lack of trust and respect for one another’s creations and inputs between the academic and business spheres. This occurred because there was a lack of trust between both partners and therefore innovation was stifled. This subtheme suggests that innovation requires the right players with the right attitude, who appreciate each other’s roles and perspectives, or they may not be suited for leading the partnership.

3.2 Geographic strategy

This study is centred around rural regions having already recognised how they differ from urban areas in terms of innovation. The geographic nature of rurality is unique to an area and assumed to be known to those looking to establish an innovation space, however, a deeper understanding of this and how to utilise such an opportunity must be explored to deliver successful rural innovation spaces. Strategic rural

development through a Geographic strategy relies on the other themes to be successfully executed e.g., alongside local knowledge of the geography.

3.2.1 Utilising natural assets for specialisation

For Geographic strategy, it was highlighted that utilising abundant natural assets, from physical properties to visual appeal, gives rural areas a unique advantage over urban centres, attracting industry and marketing regional specialities. ***'Rurality, for example, is the very basis for the competitiveness of smart food system development in South Ostrobothnia, Finland.'***

Tourism and agriculture featured heavily as specialisations for the areas, using natural assets directly. ***'For instance, the agritourism initiative of the program is rooted in ornamental chrysanthemum flowers; the program maximizes the advantages of the world-class scientific research centre for chrysanthemums at AU.'*** Innovative tourism in rural China, as culture and natural assets connect people and encourage pride and respect for the region.

The above quotes also lead to a discussion of regional specialism or generalism, with most spaces leaning towards an agricultural or tourist specialisation (or both). Both strategies are effective, with rural innovation often leveraging natural asset-based specialism. However, generalism in the case of Trentino has been found to increase resilience: ***'One of our interviewees explained that the economic policy of the region was to encourage many diverse firms rather than focusing on creating a single industrial cluster: "The province has always tried not to focus its economy on a few sectors. And this has helped us, especially during the crisis, which has impacted some sectors... Our economic policy was always diversified and not sectorial. But the disadvantage is that, when there is an economic boom, the gains are smaller."***

Specialism based on natural assets needs to be decided collaboratively so that all partners of the Quadruple helix can form a shared goal. The specialism is not only shaped by the region but also by the people. Benkoang creative hub based its entire economy and founding innovation around a localised crop; perhaps a less focused specialism combined with traditional practice and other cultural practices could have benefited the product(s) developed. In other words, the judicious use of an area's assets can help solve socio-economic problems.

3.2.2 Local solutions to spatial inequality and justice

Rural innovation spaces not only create ecosystems of jobs and activity but also target social challenges, aligning with local needs to ensure broader success and equity. Innovation spaces in general are expected to draw people to a 'space', creating jobs and a hive of activity often referred to as an ecosystem, which can have wider social benefits. An area's assets can solve problems that threaten a region and be a source of innovation opportunities, such as in Indonesia where product desirability was causing issues for the region's businesses. ***'BCH seeks to develop a creative economy by using a local fruit known as Bengkoang or Jicama plant, which is the main agricultural product of their village.... BCH was founded because of the youth's concern about Jicama farmers' fate who often failed to harvest since their jicama fruit's shape was not round enough and was not suitable for sale in the market.'*** This project led to book discussions and entrepreneurship training supported by local social charities, including the Banyumas Literacy for Welfare Program (LIUKMAS), inspired by the environment and crops resulting in social benefits with wide-ranging implications.

Social opportunity and wellbeing (SDG 3) can be the sole focus of the innovation space, through improved health and working conditions, as in the case of RUTAG; ***'It is worth emphasizing that the objective behind the collaborations is not large-scale commercialization outside the communities but rather to help raise the well-being of the community itself.'*** This is similar to Ageing@Coimbria where regional issues and disparities in health were the driving force for collaboration.

Rural innovation often integrates environmental justice (SDG 16) with social objectives, leveraging geographic assets as seen in the China case study; ***'The program's initiative of poverty alleviation through***

ecological revitalization helps villages to practice the concept of 'lucid waters and lush mountains', which seeks to foster poverty alleviation in tandem with environmental protection and green development. The program works with county governments to promote organic agricultural practices, which have proven sustainability benefits, including improved soil quality, enhanced biodiversity, and reduced pollution.'

In some of the earlier studies socio-economic benefits are given as national statistics, as in Trentino; ***'According to the Italian government's statistics agency (ISTAT, 2009), the number of persons employed in R&D in Trentino was, on average, 6.4 out of 1,000 inhabitants, versus the national average of 3.8 and the EU 27 average of 4.9.'*** Here they are framed as positive outcomes of the innovation spaces yet were not explicitly and qualitatively connected to social benefits for people, despite being vital for rural regions to thrive. It is widely understood that clear socio-economic benefits and programmes must be demonstrated; however, in some case studies, the connection between tackling spatial inequality, promoting justice, and fostering innovation could be made stronger.

The challenges and solutions of disparate rural populations

Rural areas offer benefits but also face challenges, including dispersed populations and digital exclusion, which must be addressed for successful innovation. Ageing@Coimbra highlights the challenge perfectly in the case of the central region of Portugal; ***'In inland areas, especially in the mountain area, low-density territories also create geographic barriers to mobility especially of frail people contributing to social isolation.'***

This subtheme highlights challenges in mobility and connectivity for innovation collaboration, with access improved through online delivery, mobile sites, and on-site internships. An example of utilising space is their location to the area(s) where they are needed by people, often covering vast regions in Portugal, Scotland, Sweden and China. Ageing@Coimbra: ***'The majority of municipalities in the Region have been equipped with health mobile units to deliver primary care and social care support to frail older people living in rural isolated areas. The added value of these services is well recognized by users and professionals, showing increase demand in terms of individual requests by the citizens and attracted interest by other municipalities.'***

Rural AU stated, ***"We designed a mobile classroom, relying on the three core Master of Business Administration (MBA) courses of marketing management, entrepreneurship management, and e-commerce, and moved the classroom to the main battlefield of rural revitalization."*** This is a quote from one of the participants. The paper then elaborates on what this brings to the region in terms of access provided to rural businesses, such as agriculture, to the online market, linking to the previous theme.

Similarly, to address the lack of a physical university for skill development, ***'Since the late 1980s, when videoconferencing came into use, communities without universities started learning centres with a video studio, counselling, meeting rooms, computer and broadband access, testing facilities, etc'.*** In Vasterbotten Sweden, the community sought education via online means including by those mentioned above. Accessing rural people who could develop innovations is key and online tools are a valuable tool and foundation on which centres like Vasterlotten Sweden and the Highlands of Scotland base their education engagement to improve collaboration and skill development, essential for innovation. ***'Correspondingly, in the Highlands and Islands (Scotland), for example, a versatile means of distance learning and other ICT-related solutions have been developed and utilised in order to overcome the long distances.'*** Access is often linked to education and skills delivery, with mobility crucial for innovation, business, and socio-economic development, helping innovation spaces address social inequalities.

3.3 Local Knowledge Integration

This is a theme that explores the role tradition, indigenous culture, and heritage play in shaping rural innovation. Rural areas not only have a geographic landscape but also a human one too. This can vary significantly across regions in which the innovation space operates. Although this adds complexity, it can

be an asset to innovation spaces. It is observed that traditional, indigenous and heritage practices can be seen most strongly in case studies outside of north-western cultures, with the retention and incorporation of traditional practices being stronger. However, when considering tradition from different angles (such as industry) it became apparent that every rural area has its own 'unique style' when it comes to local knowledge and identity, and it is essential that any innovation space incorporates this.

Subtheme: Incorporating traditional and cultural practice

Incorporating traditional knowledge and cultural practices shapes local innovation, as seen in Indonesia's BCH's use of Jicama fruit, India's RUTAG's focus on artisan pottery, and Japan's Niigata Sake, where improving sake production aligned with cultural goals and connected all players to enhance both tradition and innovation. In Trentino, the culture of generalism referenced previously believes that their approach to innovation stems from who they are as a people and who they have always been. In this context, innovation is perceived as ingrained in the culture and becomes an integral part of the community.

Fostering innovation in unfamiliar areas is challenging, but by respecting and valuing local traditions, innovation spaces can encourage wider participation and celebrate positive practices, gaining support from all Quadruple helix players, tourists, and the broader community. ***'The AU quadruple helix program emphasizes the importance of local communities in advancing cultural tourism, highlighting their significant role in ensuring that tourism activities align with local values, cultural heritage, and community aspirations. The program works with the local communities to promote cultural research, heritage trails and cultural festivals, and organize cultural collaborative initiatives between AU students and the local communities.'*** If an area has a strong connecting identifier, it should not be ignored but harnessed alongside the community's 'local knowledge' as it is in China.

In Ketek Kokkola-Jakobstad region they opted not to use ***'the long traditions in boat manufacturing'***, despite their traditional success. ***'Boat manufacturing, for example, stands out as an industry of craftsmanship, where new innovations are received with scepticism, and KETEK limits itself in many cases to merely giving practical support'***. The nature of the industry and the approach of 'mutual trust' meant that this was not initially an optimal focus for the innovation space. Innovation spaces must consider traditional industries alongside other themes, including harnessing local knowledge, as progress may be hindered if improvements are not accepted and the industry matures.

Innovation processes must also be aligned with local traditional and cultural calendars, as in Tasmania. Regarding the innovation timeframe, it was shaped by the ***'temporal place context... significant regional events acted as catalysts by connecting helix sphere members, such as through the Community-based Festival, and shaping the building of trust and regional readiness'***. Community traditions can economically and socially enhance innovation, but if rural areas fail to recognise and build on local traditions, they risk losing them and hindering innovation success.

Harnessing local knowledge

This subtheme highlights how harnessing local knowledge benefits innovation, but it must align with societal norms to be effective and widely adopted. This is the case of RUTAG where local knowledge was important otherwise their product would have been unusable to certain groups. ***'Traditional/experiential knowledge inherited by the community plays an important role in the process of technology standardization. Hence, stress is given to extract such knowledge and use it for technology standardization. RuTAG. The approach is that while developing technological capabilities in such situations, collaborative efforts help link the formal science of different domains with traditional knowledge. 'Existing indigenous knowledge may be taken as a starting point for innovation development, along with looking at how formal science helps in strengthening the existing tools or methods to improve productivity and reduce drudgery and overall business development.'***

At the Sake Research Institute, local industry knowledge was prioritised in product development, with independent research centres used in preference to the local university, which lacked the same degree of knowledge, expertise, or experience. ***'To summarise the knowledge necessary to foster innovation was***

held relatively more by the fourth helix than by the university.' Here innovation is being led by the community and hubs created by local people with the university being drawn into the process later. As above, the communities (fourth helix) often drive innovation spaces forward with their knowledge. They may be the primary beneficiary and the reason the work is being completed in the first place, and is the case in Osterblotten Sweden and BCH Indonesia. ***'As time went on, the creative youths found several ideas to process Bengkoang into processed products with higher economic value and tried to develop Linggasari village into a Bengkoang tourism village.'***

All of these contribute to the overall essential nature of local knowledge and expertise for successful innovation in rural areas. The best outcomes occur when local knowledge is included in the planning stages, with consultation more commonly used than co-creation from local communities and partners; ***'To involve end users early in the process and to be able to get feedback from users, the testbed Mistel for elderly and disabled people was developed in Västerås.'*** Robotdalen Sweden. This took place not just in Robotdalen but also in Ageing@Coimbra in Portugal and the Centre for Health Sciences in Scotland where learning came from the lived experiences of local people.

Place-based Governance platform and decision-making

Place-based Governance and decision-making are key considerations to ensure the security of the partnership for the success of the innovation space. This involves partners working towards a shared goal while managing activities that could undermine. To ensure collaboration among all involved actors, including industry, academia, the community, and government, a neutral space must be formed that coordinates collaboration formally. It is often requested by the partners to continue collaborations; ***'The larger firms reported the need for smart specialization initiatives like Robotdalen to act as a cooperation platform for stakeholders in the region, and in this way provide a platform for networking with government and university representatives interested in robotics solutions.... To reach more stakeholders and increase cooperation, a new board was created for Robotdalen.'*** Robotdalen Sweden. Creating a neutral platform was crucial for success, as in KETEK, which needed to shift from being seen as an educational unit to a regional developer, with tailored decision-making structures enhancing cooperation with companies and regional actors. A formal mechanism, backed by a neutral space or government authority, is essential for innovation, with a shared vision, an independent entity, and strong support from local government or universities to avoid fragmentation. This is rarely the first step in innovation; getting started is, but as above it soon becomes necessary to grow innovation. ***'In a recent collaboration agreement (2014), the University of Debrecen and the regional Chamber of Commerce and Industry joined forces to establish a new innovation agency aiming to enhance open innovation, coordinating and mediating market demands of regional business actors.'***

BengKoang Creative Hub relied on volunteerism, but its lack of formality limited its ability to drive political change or broader incentives. It required greater political commitment and agreements at levels above the village leader level as local governance didn't allow for capitalising on innovative opportunities without this platform. As summarised by the authors; ***'This study suggests local governments allocate adequate resources to affirm creative economy institutions at the stage of strengthening organizational structures. Collaboration between local governments and creative economy institutions such as BCH is carried out to provide formal recognition to creative economy actors.'*** Here place-based roles and structures need recognition. The type of agreement depends on the setting, organisation and authority of the space.

Flexibility is essential, as rural populations, policies, and governments differ, though all parties must feel secure enough to collaborate openly. A formal strategy and agreements can be helpful if co-created and non-oppressive. Careful design, involving academia, Industry, and appropriate intermediaries, is crucial, with an independent board of QH members commonly used.

4. Discussion

The review revealed three core positive themes to be considered when applying the Quadruple helix (QH) innovation in rural areas, aligning with a place-based approach. At the beginning of the review, it became apparent to the authors that studies focusing on rural innovation discussed tailoring to the local landscape in terms of social, environmental, and economic aspects. This created the core themes People as the Bridge, Geographic strategy, and Local Knowledge Integration. These themes, when operated together, led to successful innovation projects, where they advocated for co-creation with all Quadruple helix groups, as displayed in Figure 2. As this is a place-based review, place is across all subthemes; recognising the unique nature of rural places and people (Shrivastava & Kennelly, 2013; Steiner et al., 2023; Wiggins & Proctor, 2001). Despite their differences, these spaces are all still dependent on a localised area, and its people with a place-based identity. Below we discuss some additional commonalities that can be drawn between the QH themes and used to tie the themes together in the practical application of the model below.

Students and young people are central to the themes explored as they are forward looking and act as bridges that integrate business and academia, where innovation moved forward in the Benkoang Creative Hub. Their forward-looking approach has driven localised innovation that has benefitted local businesses (Lew et al., 2018; Rosyadi et al., 2021). Local young people's participation and involvement can boost cultural collaborations, as seen in China, where they connect with the local community through education and engagement, and contribute to local policy development (Irungu et al., 2023). While young people were not the primary focus of the case studies, their participation in the rural innovation space is crucial for tackling economic challenges such as ageing populations (Cromartie, 2017; Li et al., 2019). Countries like the UK have integrated young people into innovation through initiatives like Knowledge Transfer Partnerships (KTPs). This funding is essential to building social capital, highlighted by Li et al. 2019 as a potential saving factor in rural innovation (Thomas & Paul, 2019; Wiltshier & Edwards, 2014). Schemes like KTPs could bridge the gap noted in regions like Quebec, as limited business budgets have led to the loss of young innovators post-education, stalling innovation (Van Horne & Dutot, 2017). The Quadruple helix model underscores that innovation occurs at the intersection of diverse groups, and equitably funding young people from varied backgrounds can align with broader themes of this review (Carayannis EG, 2009; Carayannis & Rakhmatullin, 2014; Hemlin et al., 2008; Lindberg et al., 2012). Therefore, financial support, such as PhD bursaries and KTPs post-graduation, are vital for ensuring continued diverse participation, allowing knowledge transfer and integration to succeed. With the ageing demographic of rural areas, the movement of young people could be both a challenge and an opportunity for rural areas (Cromartie, 2017; Li et al., 2019).

Another thread between the themes is that small businesses tend to form the landscape of innovation in rural areas, more than larger businesses. This is a notable difference with urban areas and something to be harnessed as unique to the people and created by the geography of the area where big industry may be limited by workforce (Hervás-Oliver et al., 2021; Li et al., 2019). Rural areas can be a hotbed for SME's and these in turn are a valuable part of the local innovation ecosystem, where connections link technology, people and place (Bhattacharjya et al., 2023; Carayannis et al., 2018; Hervás-Oliver et al., 2021). They can hold multiple roles in people as a bridge, being key in the intermediaries and networks subtheme and all actors and as the fourth helix are indeed a vital part of their communities (Kolehmainen et al., 2016; Nordberg, 2015; Yoda & Kuwashima, 2023). They include social enterprise (like community interest companies CIC, UK), where organisations work specifically to benefit their local communities, incorporating social innovation and addressing geographic inequalities, a platform that may be viewed positively in governance (Steiner et al., 2023). Furthermore, SMEs "unlike larger industries" often possess the Local Knowledge and Heritage of an area, which is incorporated into their work (Steiner et al., 2023). This includes the artisan pottery trade (usually sole traders) which was developed via innovation in the RUTAG project. Incorporating SMEs into regional geographic strategies appears vital for addressing the themes, particularly as they collaboratively tackle social and spatial inequalities in the region (Bhattacharjya et al., 2023).

Rural areas and their people possess local knowledge associated with the landscape, which can be both traditional (an amalgamation of locally relevant information) and indigenous (that of the original peoples' culture) (Wiggins & Proctor, 2001). The strength of this will vary by area and its history and depends on the social norms of the region in using this knowledge. Notably case studies from non-European and non-Western contexts place a greater emphasis on local, indigenous, and traditional knowledge as a central component of their innovation spaces. This may impact the region's innovation to harness the Local Knowledge Integration theme. It will also affect how people's identity and emotions are linked to innovation; this was noted in RUTAG in terms of social norms and acceptability of practices, and in Trentino for which the more isolated mountainous regions of Italy are identified with a culture of innovation (Bhattacharjya et al., 2023; Lew et al., 2018). Without acknowledging, understanding, and incorporating the region's and its people's indigenous and traditional practices, it is difficult to comprehend the social norms, attitudes, and power dynamics that are key to the success of Rural Innovation Spaces, where more indigenous and traditional knowledge remains.

4.1 Notably absent in the case studies

The work of Hemlin *et al* implies that multi-cultural and multi-disciplinary groups are more creative than homogenous; however, this is a notable gap in case studies (Hemlin et al., 2008). There was relative silence around diversity and inclusion as part of innovation, where some review studies regarding women and innovation spaces did appear in the search, although they did not have a clear rural focus or did not meet criteria (Lindberg et al., 2012). Some case studies were also not accessible in English, which we recognise is a barrier that needs to be addressed, likely requiring translator fees (Afrakhteh & azizi, 2020; Lindberg et al., 2012). The papers discussed the types of businesses involved and national statistics that could be used to infer gender bias, as well as the demographics they are most likely to support. However, there is little direct observation on representation within the innovation sectors, players, and projects selected for focus by innovation spaces. To avoid supposition about gender and in the absence of knowledge about the innovation impacts on diverse groups, including ethnically or neurodiverse groups of partners, place-based innovation would benefit from incorporating an understanding of this demographic landscape in future research.

Notably absent was any discussion of seasonality despite references to crop failures and of climate change as a driver of these seasonal negative impacts and despite this being long known to impact rural areas and agriculture, a prominent rural industry (Adams et al., 1998; Mahroum et al., 2007; Malhi et al., 2021). The impact of this on rural people did not consistently emerge as a theme, which may be because different countries face different seasons but climate change, which is beginning to affect all countries, is rarely featured (Malhi, 2021).

4.2 Recommendations and limitations

This study identifies "People as the Bridge" as a catalyst for innovation spaces, emphasising the need for co-creation with all Quadruple helix actors. Establishing and understanding the local identity via social norms, traditional and cultural areas before innovation and designing/planning is key. This implies a more direct incorporation of social science into innovation space. Given the critical role of people, this research recommends using Participatory Action Research (PAR) in rural innovation spaces, combined with Social Network Analysis (SNA) to identify key individuals and track their evolution (Cornish et al., 2023; Van Der Valk & Gijsbers, 2010). PAR prioritises experiential knowledge and rather it is a collaborative research approach that actively involves participants in the research process to address social issues and create positive change (Cornish et al., 2023; Kindon et al., 2007). Combining SNA and PAR could reveal risks, determine the necessary number of nodes at each PAR stage, and test the relevance of these themes as a model for rural innovation. Innovation spaces occupy a dynamic, evolving space, making PAR essential for a deeper understanding. Reviewed studies lacked a consistent methodology, though action-based research proved valuable in uncovering human relational mechanisms (Bhattacharjya et al., 2023; Kriz et al., 2018). Expanding on this by consistently applying PAR across various rural communities could provide greater insights into common innovation pathways.

Living Labs were not included in the case study review, as they are short-lived and lack a sustained impact or improvement in the rural areas they support. However, they do serve a valuable role within rural innovation (Calzada, 2019). This links importantly to integrating Local Heritage and Traditional Knowledge where Living Labs are recognised as an important methodology to use throughout the innovation journey from conceptualisation and formation to product development (Bricca et al.; García-Terán & Skoglund, 2019b; Silva et al., 2020). Regular use can form bonds and if members of the Quadruple helix fail to attend or commit, then this can be identified as a risk that needs practical mediation as in the case of Quebec (Van Horne & Dutot, 2017). Living Labs fit within the place-based approach to innovation as they solve local problems through co-creation and collaboration. Their iterative nature ensures people are consistently considered, which fits with the need to consistently ensure the three key overarching themes are maintained within the innovation process and the creation of an innovation space: People as the Bridge, Geographic strategy, and Local Knowledge Integration. A recommended foundation for rural innovation is to conduct research and map local groups, followed by utilising living Labs or workshops to understand local knowledge and reach well-informed conclusions.

Although this study attempted to include comparable spaces from across the globe it still has just under half of the studies specifically from Europe, 5 of the 11. This is due to regional development and innovation being a focus of EU policy and funding particularly through Horizon, European Regional Development Funds (ERDF), and LEADER funding schemes (Nordberg et al, 2020; Kolehmainen et al, 2016). Finding studies meeting the criteria of this paper was challenging, and rural-urban studies were a compromise. The in-depth case study approach was necessary to gather the depth of information required to review and identify nuanced themes from the data. The rural focus narrowed the pool of international and diverse studies in this area as cities still seem to hold centre stage for innovation spaces such as IHub in Kenya and Pacto Alegre in Brazil (da Costa Mineiro et al., 2023). From the search engine review, there was a bias in studies from Finland and Sweden which seemed to regularly produce exciting innovation spaces, in wide rural/urban regions. It is understood that the opportunities these areas received may not be experienced globally however, this is why approaches to funding were touched upon but did not form a theme. Nevertheless, it is worth highlighting the value of the body of work created in Finland and Sweden, in the context of rural innovation. These cases offer valuable lessons and can be promoted from a United Nations perspective to advance the SDGs. This study recognises its role in helping to decolonise the literature and includes less than 50% European studies, as it avoided selecting multiple papers from the same site. Implementing this approach aims to make the study's findings applicable to rural regions worldwide, including developing countries and those without EU or Governmental funding. However, the existing literature shows an international bias, which we believe needs to be addressed particularly in the rural areas of South America, Central America, and Africa.

The limitations of such a review primarily relate to comparability in the focus, lens and methods of the individual papers reviewed for transparency, which can be seen in Table 1. As the case studies perceive innovation spaces through varied lenses, some key similarities and differences may be overlooked in the themes. The case studies were at different levels, such as a strategic overview discussion including KETEK, or an in-depth operational analysis of a single innovation including RuTAG (Bhattacharjya et al., 2023; Nordberg, 2015). However, it must be noted that innovation spaces, countries and people (including researchers) operate differently and, therefore, will never be entirely comparable, due to the different systems in which they operate (Wiggins & Proctor, 2001). The different lenses used by the studies are partially driven by the requirement to contribute something new to the field and partly due to the author's approach to research so it was never anticipated that they would have completely comparable pieces. Additionally, the methodological approaches within the academic field of in-depth case studies will always vary, and it is apparent they have developed over time, particularly for the pre-2020 analyses where the method of codification is not given e.g., thematic or content analysis.

5. Conclusion

This in-depth thematic review examined how innovation spaces can be supported through the application of the Quadruple helix in rural areas. The learning from 11 existing case studies was amalgamated into

three themes: People as the Bridge, Geographic strategy, and Local Knowledge Integration. The findings demonstrate that place and people are universally important in rural innovation and rural areas can be a microcosm. This work advocates for the co-creation of innovation spaces utilising a diverse array of social tools and techniques and proposes that it would be beneficial to follow the co-creation of an innovation space using participatory action research (PAR). Similarly, if the Quadruple helix increases the 'surface area' of innovation, there is a need to ensure this surface area is diverse. Thus, a place-based approach to innovation is vital, and a Quintuple helix model operated using the three themes identified here, is recommended. Finally, the authors highlight the lack of studies from the rural Global South, particularly South America, and would welcome case studies from these regions. Future research would benefit from a deeper understanding of the social and geographic contexts of rural innovation which could contribute to the success and implementation of the United Nations Sustainable Development Goals.

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