University-community engagement for inclusive innovation: A quadruple helix perspective

大學與社區參與共創包容性創新：四螺旋視角

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Abstract: Inclusive innovation refers to the process of developing and implementing new ideas that aim to create opportunities for improving social and economic well-being for disenfranchised members of society. This study examines how an intermediary organization, Rural Technology Action Group, affiliated with a university in India facilitates collaboration among quadruple-helix stakeholders for inclusive innovation. We utilized a multiple-case study approach to achieve our objective. We conducted twenty-eight semi-structured interviews between March 2021 and February 2022. This study enhances existing literature by proposing a conceptual framework that would facilitate universities to practice inclusive innovation. The findings of this research have important implications for various stakeholders, such as policymakers, education administrators, industry professionals, and civil society members.

Keywords: University, quadruple helix, rural industry, India, inclusive innovation.

摘要：包容性創新指的是開發和實施新想法的過程，這些想法旨在為社會上被邊緣化的成員創造改善社會和經濟福祉的機會。本研究檢視了一個與印度

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某大學相關聯的中介組織——農村技術行動小組，如何促進四螺旋利益相關方之間的合作，以實現包容性創新。我們採用了多案例研究方法來實現我們的目標。我們在 2021 年 3 月至 2022 年 2 月之間進行了二十八次半結構化訪談。本研究通過提出一個概念框架來增強現有文獻，該框架將促進大學實踐包容性創新。本研究的發現對各種利益相關者，如政策制定者、教育管理者、行業專業人士和民間社會成員具有重要的意義。

關鍵詞：大學、四螺旋、農村產業、印度、包容性創新

1. Introduction

Emerging economies are witnessing a new form of innovation labeled as inclusive innovation. It has various names that reflect various significance, including pro-poor innovation, below-the-radar innovation, grassroots innovation, and BoP (bottom-of-the-pyramid) innovation (Foster and Heeks, 2013). George *et al.* (2012) define inclusive innovation as the generation and implementation of innovative ideas that aim to improve the social and economic well-being of marginalized members of society.

Many multinational and domestic enterprises in emerging economies are defying conventional innovation methods and inventing more items with fewer resources to attract millions of low-income consumers (Prahalad and Mashelkar, 2010). Previous BoP literature concentrated on multinational companies (Pansera and Sarkar, 2016; Patnaik and Bhowmick, 2020). Patnaik and Bhowmick (2020) state that academic institutions and non-government organizations (NGOs) can actively intervene and develop technology for resource-poor communities to improve their livelihoods and have a positive social impact by acting as enablers, knowledge producers, and intermediaries.

Grobbelaar *et al.* (2017) state that universities play a crucial role in driving economic development by providing new knowledge and advanced skills. They are considered essential sources of learning and innovation for firms in developed economies and for integrating marginalized and impoverished individuals into

innovation systems in developing countries. However, Jacobs *et al.* (2019) claim that the growing commercialization of knowledge has led universities to prioritize university-industry networks over university-community networks. This shift has resulted in a neglect of the social aspects of innovation. University knowledge transfer offices should expand their focus beyond commercializing knowledge and prioritize assisting marginalized populations (Compagnucci and Spigarelli, 2020). To address societal challenges, universities should actively incorporate marginalized communities in knowledge generation (Humphrey, 2013). In this paper, we aim to explore - how an academic anchor intermediary organization coordinates quadruple helix partners for inclusive innovation- especially in science and technology (S&T) intervention in the rural cottage industry.

To achieve our objective, we study the case of Rural Technology Action Group (RuTAG), an academic intermediary organization in India. RuTAG was established in 2003–2004 by the Principal Scientific Adviser (PSA)[2] to the government of India (Saha and Ravi, 2019). RuTAG aims to empower and support technical universities and institutions in revitalizing traditional rural cottage industries through the application of S&T (Bhattacharjya *et al.*, 2019). RuTAG centres are located in seven different Indian Institute of Technology (IITs) and share common objectives and visions (Banerjee *et al.*, 2022). IITs are India's premier technical universities and play an important role in the country's innovation system (Chandra, 2008; Datta and Saad, 2011). RuTAG centres work in collaboration with regional NGOs, public research institutes, universities, and enterprises (Bhattacharjya *et al.*, 2019).

The remainder of the paper is organized as follows: the next section provides a literature review. The third section explains the research methods, while the subsequent section provides the findings. The fifth section provides a discussion, and the final section presents the conclusion and scope of further study.

2. Literature review

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[2] The Principal Scientific Adviser, often known as the PSA, serves as a chief advisor to the government of India on issues that are associated with scientific policy.

2.1 Inclusive innovation

In recent years, there has been a growing emphasis among scholars and policymakers on a new form of innovation referred to as social innovation, inclusive innovation, and frugal innovation. These approaches entail utilizing science, technology, and innovation in various ways to tackle social needs (Ely *et al.*, 2017). While many innovations tend to prioritize affordability, inclusive innovation seeks to establish a mechanism that empowers and enhances the capabilities and well-being of underrepresented populations by firms and other actors (Mortazavi *et al.*, 2021; Peerally *et al.*, 2019).

International organizations such as the OECD and the World Bank, national governments, and multinational firms are increasingly involved in inclusive innovation (Heeks *et al.*, 2014). As an example, the Indian government places high importance on achieving inclusive economic growth and devotes substantial financial resources to initiatives aimed at diminishing poverty, generating job prospects, and ensuring that essential services are accessible, particularly for the impoverished (George *et al.*, 2012).

Foster and Heeks (2013) claim that previous studies (Altenburg, 2009; Cozzens and Sutz, 2012; Utz and Dahlman, 2007) on inclusive innovation have identified four aspects of inclusivity. These aspects include: 1. Ensuring that innovations are relevant to the needs of the poor. 2. Engaging the impoverished in the innovation process. 3. Ensuring that the poor can adopt and benefit from the innovations. 4. Ensuring that the innovations positively impact the livelihoods of the poor. To achieve inclusiveness, Schillo and Robinson (2017) suggest looking beyond high-tech sectors to labor-intensive and labor-extensive sectors. Inclusive innovation core objectives go beyond immediate economic growth; thus, it seems unproductive to merely view commercialization of new products or processes as innovation.

Despite growing interest in inclusive innovation among researchers (Heeks *et al.*, 2014; Mortazavi *et al.*, 2021; Schillo and Robinson, 2017). More research should be conducted to determine how to develop appropriate policies and

interventions to promote inclusive innovation. Future research should focus on the types of organizations that launch inclusive innovation, as well as how these organizations effectively implement and integrate their efforts.

2.2 University and inclusive innovation

There is limited evidence to support the notion that universities have consistently been involved with society (Grobbelaar *et al.*, 2017). Benneworth (2013) states that despite increasing pressure on universities to engage with industries and society outside of academia, universities retain their exclusive nature. Universities have shown a greater inclination towards establishing their international academic connections, rather than actively interacting with disadvantaged local populations.

The university undermines the participation of individuals who represent social and cultural norms of communities in knowledge generation for social benefit (Sandy and Holland, 2006). Jacobs *et al.* (2019) state that the existing literature thoroughly discusses the mechanisms involved in the transfer of knowledge from universities to external stakeholders that possess the necessary intellectual, managerial, and financial resources to effectively employ this knowledge. Nevertheless, there remains a dearth of comprehensive understanding regarding the exchange of knowledge in communities that have limited resources. Ngoc (2017) claims that it is still uncommon for inclusive innovation practices to occur in the university sector. Universities and public research institutions, which are formal institutes, have limited involvement with low-income markets and have been excluded from inclusive regional innovation systems (Yao *et al.*, 2018).

Benneworth (2013) states that universities face certain difficulties in engaging with marginalized communities: First, socially excluded communities may not be ready to communicate with universities and frame their requirements. Second, while there are many successful spin-off enterprises, there are no inspirational community engagement examples. It's unclear what would be an iconic engagement project that would attract policymakers. Finally, people might not have the knowledge, connections, or social capital to interact with universities.

Humphrey (2013) claims that the promotion and reward systems rarely recognize community involvement, which devalues the activity and the engagers involved, puts obstacles in the way of staff members who are dedicated to community engagement and weakens support from the academic community. In their study, Grobbelaar *et al.* (2017) highlighted the significance of creating and nurturing an intermediary platform. This platform plays a crucial role in fostering sustained involvement with projects and facilitating the practical implementation of research outcomes, ultimately benefiting marginalized populations.

2.3 Quadruple helix innovation system

The innovation system is a complex network of actors and institutions that play a crucial role in the development, diffusion, and utilization of new products and processes (Bergek *et al.*, 2008). In the field of innovation studies, the triple helix and quadruple helix models are commonly utilized conceptual frameworks. These models have been extensively applied in empirical investigations, despite appearing to be competing concepts (Cai and Lattu, 2022). The main concept underlying the triple helix model posits that the need for fostering innovation and development in a knowledge-driven economy lies in the collaborative efforts among industry, government, and academia (Etzkowitz and Leydesdorff, 2000).

Despite its increasing popularity since its proposal, the triple helix model has faced criticism primarily due to its insensitivity to contextual environments (Cai, 2014) and its failure to fully consider new and complicated factors that come up when societies transform (Reich-Graefe, 2016). The quadruple helix paradigm, which includes civil society as a fourth helix, better explains formal and informal mechanisms that enable social innovation (Nordberg *et al.*, 2020). Kolehmainen *et al.* (2016) believe that the lack of knowledge-intensive institutions hinders the growth of knowledge-based industries in remote, rural, and underdeveloped areas. Community organizations and civil society can affect several aspects, making the quadruple helix a useful framework.

Even though there is no consensus on what constitutes the fourth helix, most researchers consider the fourth helix to be civil society, the consumer, and the end-

user (Höglund and Linton, 2018). Arnkil *et al.* (2010) constructed four different quadruple helix models: the triple helix + users model, the firm-centred living model, the public sector-centred living lab model, and the citizen-centred quadruple helix model. Hasche *et al.* (2019) note that many researchers have made significant contributions to the study of the quadruple helix from the perspectives of knowledge transfer (Colapinto and Porlezza, 2012), stakeholder theory (McAdam *et al.*, 2018), regional innovation management (Kriz *et al.*, 2018), system approach (Nordberg, 2015) and a mode 3 model (Carayannis *et al.*, 2018). However, more research is required to comprehend the relationship between actors, how products are developed, and how actors are involved. University technology transfer studies with quadruple helix stakeholders are scarce (Marques *et al.*, 2021). The process of technology transfer involves the movement of established technologies, including tools, facts, skills, and routines, from providers to recipients (Sánchez Preciado *et al.*, 2016).

2.4 Intermediary role in a quadruple helix innovation system

Saad (2004) states that the helix model could potentially face challenges when crucial actors involved in the collaboration lack the necessary capacity and authority to effectively execute their respective roles. The importance of intermediary organizations in facilitating triple helix collaboration has been mentioned in the literature (Betz *et al.*, 2016; Johnson, 2009; Letaba, 2019).

Innovation intermediates are defined and referred to by a wide range of terms in the literature. Innovation intermediaries are also known as matchmakers, boundary organizations, bricoleurs, open innovation incubators, technology brokers, and knowledge agents (Betz *et al.*, 2016). Howells (2006) states that an innovation intermediary is any entity or group that mediates or facilitates any step of the innovation process between several stakeholders. MacGregor *et al.* (2010) proposed that the intermediary actor, which includes government and university technology transfer offices or university spin-off firms, can play a crucial role in quadruple helix arrangements. These actors can navigate across different sectors to overcome existing gaps in practice and foster collaboration. Vallance *et al.*

(2020) argue that the establishment of the quadruple helix as a local innovation system is not an inherent occurrence, but rather requires deliberate initiatives from various actors and supported by intermediary vehicles. There is a lack of studies that clearly explain the distinction between the intermediaries coordinating resources from academia, industry, government, and civil society and those actors belonging to the fourth helix (Björk, 2014). The existing knowledge gap highlighted within the literature presents an opportunity to examine how an academic intermediary organization can facilitate quadruple helix partnerships for inclusive innovation.

3.   Research design and methods

3.1   Context of the study

In developing economies in Asia, including India, the importance of cottage industries is widely acknowledged (Chadha, 1992). Individual and family laborers form the majority of cottage industries and are distinguished by low capital investment and traditional tools and equipment (Islam, 1992). Pulamte and Abrol (2003) argue that the cottage industry is crucial to India's burgeoning rural economy. However, the S&T policy pays little attention to this sector. Low productivity, underdevelopment, and low wages are commonplace in cottage industries. The technology-push approach to upgrading traditional rural industries, as Abrol (2004) explained, has failed to connect well with the local markets and resources accessible to the rural poor. The technology development process fails to recognize end-user participation in the innovation system and technology transfer as interactive activities. India's S&T policy does not adequately address the cottage industries, which operate in the informal sector[3], despite the important role they play in boosting the rural economy (Bhattacharjya *et al.*, 2019). Technology upgradation is the most crucial challenge among cottage industries in India and developing economies if they are to survive in the highly competitive

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[3] The informal sector, commonly referred to as the informal economy or informal employment, encompasses economic activity and jobs that lack government regulation or protection.

global market.

The PSA to the Government of India established RuATG to empower and support technical universities and institutions in revitalizing the rural economy through the application of S&T. The RuTAG centre is anchored by the Indian Institute of Technology (IIT) and is run under IIT's administrative control. RuTAG centres are located at seven different IITs, including IIT Madras, IIT Guwahati, IIT Kharagpur, IIT Delhi, IIT Roorkee, IIT Bombay, and IIT Kanpur. Each center is responsible for covering a specific region or state. For instance, RuTAG-NE IIT Guwahati operates in eight states in the northeast region of India. These states include Assam, Arunachal Pradesh, Sikkim, Tripura, Meghalaya, Manipur, Mizoram, and Nagaland. While RuTAG IIT Madras operates in the southern states of India, namely Tamil Nadu, Kerala, Karnataka, Andhra Pradesh, and Telangana. Even though RuTAG centres have a common set of objectives and visions, they collaborate with different actors in their respective regions and operate under different IITs.

3.2 Case study

A qualitative case study approach was selected to examine how university intermediaries facilitate quadruple helix partnerships for inclusive innovation, especially for S&T intervention in rural cottage industries. The unit of analysis is university intermediaries' activities and their roles. Case studies can lead to novel discoveries that can enhance and advance existing theoretical understanding (Eisenhardt and Graebner, 2007). A multi-case study approach is selected as it allows for evidence to be gathered from multiple contexts and references (Darke *et al.*,1998). To compare and contrast the events, activities, and processes, a cross-case study is useful (Yin, 2014).

Conducting multiple case studies can be quite costly and time-consuming (Gustafsson, 2017). For this study, we selected two out of seven RuTAG centres in India: RuTAG IIT Madras in the south, which is affiliated with IIT Madras, and RuTAG-NE IIT Guwahati in the northeast, which is affiliated with IIT Guwahati as shown in Table 1. The rationale for these choices is briefly explained: To start,

Table 1

Summary description of cases

Intermediary Center details	RuTAG IIT Madras	RuTAG-NE IIT Guwahati
University, in which selected cases are attached.	IIT Madras (est.1959)	IIT Guwahati (est.1994)
Year of the establishment (est.)	2004	2005
Assigned region	South India	North East India
Characteristics of the region	India's southern states provide a distinct growth paradigm and are now the country's economic engine. The region is attracting global IT (services) and automobile (manufacturing) enterprises.	Underdeveloped agrarian and industrial sectors characterize the northeast region (NER) economy. The region's landlocked position hinders economic and industrial growth.

Source: Raj and Shruthi (2019); Subrahmanya (2017); Sachdeva (2000); Bhowmik and Viswanathan, (2021).

a random sample might not be the best strategy when the goal is to obtain a deep understanding of a particular problem or phenomenon (Flyvbjerg, 2006). Second, to find essential and variable features of a phenomenon as perceived by various stakeholders in various circumstances, we employ a maximum variation purposive sampling technique (Suri, 2011). Patton (2002) states that this sampling method yields two distinct outcomes: (1) comprehensive and precise descriptions of each case, which are valuable for documenting their characteristics; and (2) significant common patterns that surpass individual cases and gain their significance that emerged out of diversity.

RuTAG IIT Madras is located in south India which is one of the most developed regions of India. The pro-industrial government sets regional policies and promotes university-academia-government collaborations (Subrahmanya, 2017). RuTAG-NE IIT Guwahati is located in northeast India, which remains underdeveloped and isolated from mainland India. Mishra and Upadhya (2019) state that most states in the region have a long-term fiscal reliance on the central government and have paid limited attention to their economic and fiscal viability. The central government created the Ministry of Development of the North Eastern

Region (MDoNER) to oversee socio-economic development in the northeastern region.

Despite being located in different regions, RuTAG IIT Madras and RuTAG-NE IIT Guwahati are the oldest RuTAG centres and have made a significant social and economic impact in their respective regions. IIT Madras has undertaken numerous projects aimed at improving livelihoods, reducing drudgery, and enhancing productivity in rural areas of southern India (Seetharaman, 2019). RuTAG-NE IIT Guwahati has implemented numerous S&T intervention initiatives in the northeastern states (Banerjee *et al.*, 2022).

3.3 Data collection

Desk reviews were conducted to analyze and interpret existing secondary data, such as policy documents, research articles, books, and academic reports, to gain a better understanding of particular phenomena before conducting more in-depth research. We use an interpretative approach to the case study, where the researcher aims to gain a deep understanding of the particular phenomenon from the participants' perspectives through interviews. Primary data were collected through 28 semi-structured interviews conducted online and over the phone between March 2021 and February 2022 (see Table 2). The interviews were conducted in Hindi and English and lasted 30 to 60 minutes.

3.4 Coding and analysis

During the coding stage, which precedes analysis, many categories are often used to manage large quantities of text. First, we classify data into categories (Miles and Huberman, 1994) based on the quadruple helix structure of government, industry, universities, and civil society. We studied transcripts to comprehend the actors' activities and resources. The analysis of the collected data was done using MAXQDA software.

The data analysis was conducted using the grounded theory approach recommended by Gioia *et al.* (2013). The analysis consisted of two main stages: first, the development of a data structure, and then the exploration of the

Table 2

Interview distributions

Respondent type	Occupation/Rank	Role
Academia	1 Professor from Mechanical Engineering IIT	RuTAG co-ordinator, Project PI
	1 Professor from the School of Design IIT	Project PI, Advisory committee member
	1 Professor from Humanities and Social Science IIT	Advisory committee member
	1 Associate Professor from Mechanical Engineering (regional university)	Project PI
	1 Professor from Mechanical Engineering IIT	Project PI
	1 Professor from Chemical Engineering IIT	RuTAG co-ordinator, Project PI
	1 staff from IIT	Involved in a project to scale up the technology
	1 Professor from Mechanical Engineering (regional engineering college)	Project PI
RuTAG Officials	7 including Project Advisor and Project staff	General RuTAG activities including field visits and prototype development
Government	1 Manager of a financial corporation	Involved in collaboration project
	1 Ex-Director of marketing corporation	Involved in collaboration project
	1 Senior Scientist	Monitor all RuTAG centers and strategic planning
Industry	3 Founders of micro-enterprises	Collaborate in product development
NGOs/ Civil society	4 Founders of NGO	Involved in the RuTAG project
	1 CEO of a non-profit research organization	As advisory committee members
	1 Chairman Alumni Association	As advisory committee members
	1 Program director of a non-profit organization	Involved in the RuTAG project

Source: Authors' own.

connections between the theoretical dimensions that arose from this structure. We

began by establishing an initial open data coding to construct the data structure, prioritizing the main research objective: how academic intermediary organizations coordinate quadruple helix partners for inclusive innovation and ensuring the accuracy of first-order (informant-centric) terms. We utilized axial coding, following the approach outlined by Strauss and Corbin (1988), to identify and analyze the similarities and differences in our data. This process enabled us to reduce the codes to a more manageable number. For example, we combined "system of regular interaction," "Informal connection and building network," and "workshop with NGOs and other stakeholders" into one first-order concept called "a platform for regular interaction between formal and informal actors." After narrowing down the set of first-order concepts, we proceeded to second-order analysis to identify the abstract themes that were emerging from these concepts. The procedure provided us with a comprehensive list of second-order themes, which we later merged into an aggregate dimension as depicted in the data structure in Figure 1.

4. Findings

This section explained how RuTAG centres coordinated with quadruple helix actors for inclusive innovation.

4.1   Foster collaboration and inclusivity

Developing a collaborative and inclusive network is crucial for fostering inclusive innovation, particularly in situations where there is a significant knowledge disparity between universities and marginalized rural communities. Here, RuTAG serves as a platform to facilitate interaction between actors in the formal sector, including universities and public research institutions, and informal sectors, such as rural artisans working in cottage industries. RuTAG services are free and NGOs find it easy to engage and approach RuTAG. Some of the participants stated

RuTAG centres can connect at ground level and are able to provide solutions to people who are unreachable. (Government # 1)
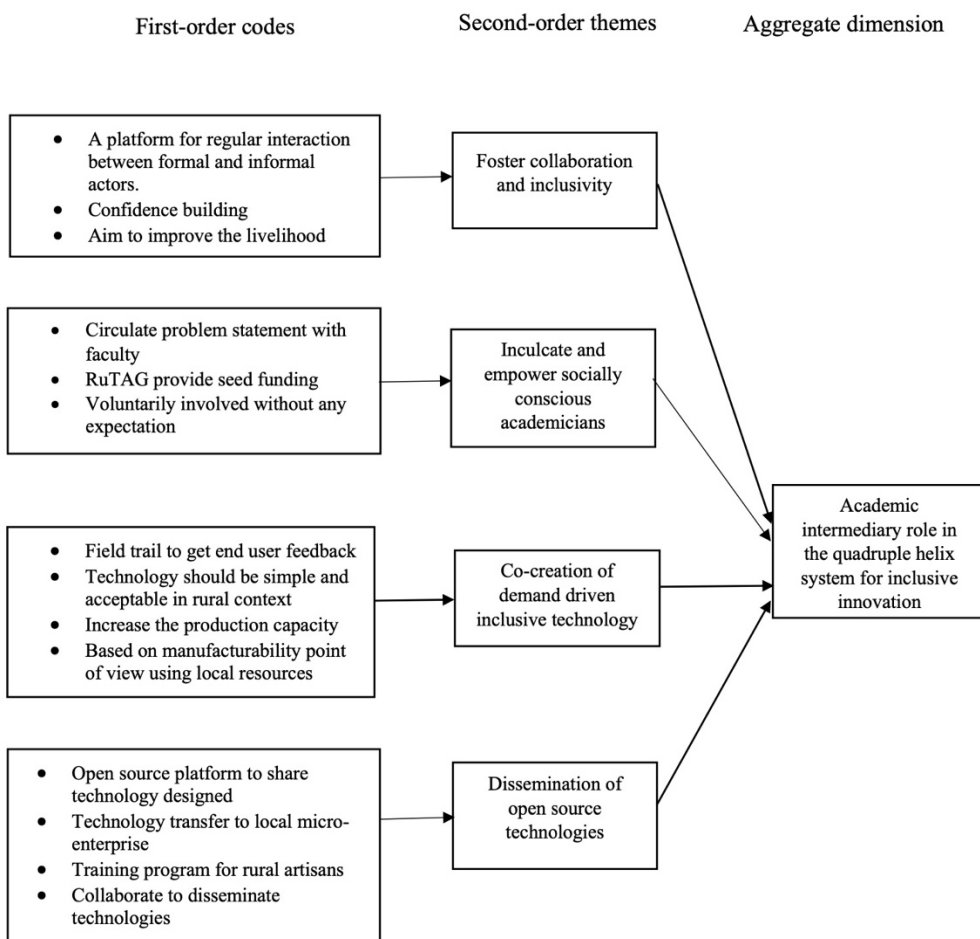
Figure 1
Data structure

There are a lot of problems that the artist is facing. To get a solution, we approach research institutions, but the problem with that is we cannot directly approach very big organizations because we won't be recognized by them because we are very small in comparison with them at the organizational and intellectual level. So, we approach RuTAG with the problems identified in the rural sector. They call us directly for a discussion. (NGOs # 1)

RuTAG centers have been putting their efforts into building confidence with

regional stakeholders so that even an illiterate villager could come to IIT and discuss their problem. We found that both RuTAG-NE IIT Guwahati and RuTAG IIT Madras over the years have established a strong regional network with different quadruple helix actors. Civil society and NGOs play a crucial role in connecting RuTAG technical staff with rural artisans, who are the end users. RuTAG centres regularly conduct need identification workshops in collaboration with local NGOs. The objectives and expected outcomes of the events are communicated to the NGOs before the workshops. It was found that rural artisans may struggle to prioritize and quantify a problem. The RuTAG advisory committee, consisting of individuals from diverse backgrounds such as NGOs, IIT faculty, and industry consultants, plays a crucial role in shortlisting the problem statement. The selection of problem statements is primarily based on their significance in improving the livelihood of rural artisans. The RuTAG centers initiative demonstrates a consistent willingness to engage in collaborative efforts with other organizations, effectively utilizing common resources.

Socially excluded communities may struggle to communicate with universities and frame their needs as they lack the necessary skills, opportunities, and social capital (Benneworth, 2013). Based on our findings we proposed that:

Proposition 1. The presence of academic intermediaries is more likely to develop synergy and regional networks with quadruple-helix actors, facilitating universities to practice inclusive innovation, such as conducting periodic need identification workshops in collaboration with NGOs.

4.2   Inculcate and empower socially conscious academicians

Members of the academic community, participate in different RuTAG activities. The RuTAG centre coordinator (Professor in charge) communicates problem statements that require S&T intervention with IIT professors who have the relevant expertise and skills. Some Professors commented-

They are naturally inclined towards this kind of rural activity. I like interacting with farmers and NGOs, but the majority of faculty don't like it. (Academia # 1)

There is more mental satisfaction and seeing people become better financially. (Academia # 2)

We found that the involvement of IIT faculty members in RuTAG activities is entirely voluntary, and faculty members are motivated by a desire to help marginalized rural artisans. RuTAG provides seed funding to these faculty members to develop prototypes. Faculty and students from regional engineering institutions and polytechnics were also encouraged to participate in RuTAG activities.

We also found that RuTAG IIT Madras has started conducting proposal writing workshops with the Pan Alumni Leadership Series (PALS)[4] and sharing problem statements with regional engineering colleges and polytechnics. If the proposal submitted by these colleges and polytechnics is found promising, the project is funded. We also learned that PALS works closely with the management teams of these colleges so that faculty working on RuTAG projects get support from their institution. In the case of RuTAG-NE IIT Guwahati, collaboration with regional colleges and universities was not very successful. When a motivated faculty member switches to another institute, it is difficult to find a person with similar motivation in the same institute or university. Humphrey (2013) noted that there is a lack of recognition for community engagement in promotion or reward systems, which can be discouraging for staff who are dedicated to community engagement. Hence, we proposed the following proposition.

Proposition 2. The presence of an academic intermediary is more likely to encourage and support socially conscious and motivated academicians to engage with quadruple helix actors, such as by providing seed funding to develop prototypes.

4.3   Co-creation of demand-driven inclusive technology

Numerous challenges arise in developing inclusive technology for

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[4] PALS is an IIT alumni voluntary association that mentors regional engineering colleges, particularly in south India, to improve engineering education. PALS is a virtual entity register at IIT Madras Alumni Charitable Trust (MACT).

marginalized rural communities. The technologies should be able to work effectively in areas where existing modern and advanced technologies may not be appropriate. Incorporating end users in the product development process and considering their feedback increases the chances of technological adoption. As one of the professors commented

Two students who came for this internship also happened to be the most appropriate students from a social background point of view because this paddy thresher is expected to be for those farmers who have only two acres or four acres. So, they did the first design with us, with faculty members from mechanical engineering. And then they discussed it with the farmers who had the problem. After modification, they went back home so they could get feedback from their parents, relatives, and the community. So even in the technical design stage itself, they got a lot of feedback. (Academia # 3)

The project is carried out by RuTAG officials and students, who are supervised by an IIT professor. Faculty from regional engineering colleges also participate in prototype development. The primary objective of the RuTAG center is to enhance production capacity by either mechanizing or semi-mechanizing existing technologies or by developing novel technological solutions. The technology should be simple and affordable for use in rural areas.

Officials from RuTAG collaborate with micro-enterprises or local fabricators to develop prototypes. During these collaborative efforts, there is an informal transfer of knowledge that aims to enhance product design and improve efficiency. Importance is placed on the utilization of locally sourced raw materials in the development of products. After the development of a prototype, NGOs facilitate RuTAG officials to conduct field trials involving rural artisans.

Both RuTAG-NE IIT Guwahati and RuTAG IIT Madras succeed at facilitating the co-creation of demand-driven technology by actively engaging with various stakeholders in their respective regions. It is worth noting that given the power constraints and low voltage in the region, RuTAG-NE IIT Guwahati tends to focus on portable and manually propelled technologies, either by hand, by legs, or simultaneously. RuTAG IIT Madras has created more power-driven

technologies, some of which permit data transmission over WiFi, LAN, and IoT.

Universities should actively incorporate marginalized communities in knowledge generation (Humphrey, 2013). Based on our findings we proposed that

Proposition 3. The presence of academic anchor intermediaries is more likely to facilitate the co-creation of inclusive technology by engaging different quadruple helix actors, such as marginalized rural artisans in different stages of product development.

4.4   Dissemination of open source technology

To enhance the diffusion of technology in traditional cottage industries operating in the informal sector. RuTAG technologies are not patented, and simple mechanisms are kept to transfer technology to local micro-enterprises so that the technologies can be developed where demand arises. As one of the participants commented.

RuTAG does not earn any loyalty or profit, and it has not patented these technologies. (Academia # 4)

Despite being attached to academic institutions with limited funding, RuTAG centers are actively exploring various approaches to support the dissemination of technology. We found that RuTAG-NE IIT Guwahati follows a conventional method of training and handholding micro-enterprises. Budding entrepreneurs are provided with advance payments to build their confidence. When NGOs or government organizations inquired about their technology, they outsourced it to the fabricator but were involved in setting the price and quality. While RuTAG IIT Madras preferred outsourcing the technology design and manual through an IT platform where 2D and 3D designs with the bill of materials will be uploaded and can be accessed by end users as well as fabricators (https://rutag.iitm.ac.in/Crossfyre/). The fabricators can make further improvements by incorporating their designs.

To disseminate technologies to the underserved rural artisans, some state and central government agencies collaborate with the RuTAG centre. RuTAG technologies are listed on government websites so that relevant agencies can

contact   RuTAG   centres
(https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1845121).

The successful projects that we have mostly involved local government stakeholders. For example, we have disseminated our technology in Kerala in collaboration with Khadi and the Village Industries Board, and with the help of the Tamil Nadu government agency, we have implemented a common facility center for the weaving community. (Academia # 3)

In 2017, MDoNER[5] started the Science & Technological Intervention project in the northeast to improve the livelihood of the vulnerable population, especially the farmers and artisans. The agency has selected six RuTAG-NE IIT Guwahati technologies and implemented them across northeastern states. (RuTAG official # 1)

According to the participants, successful projects undertaken by RuTAG IIT Madras have involved local and state government agencies. In RuTAG-NE Guwahati's case, successful projects involved central government agencies and limited collaboration with the regional government. RuTAG centres, and NGOs can access corporate social responsibility[6] (CSR) funds. Large corporations have the potential to play an essential role in rural development without relying solely on government funds and agencies. CSR funds are critical to establishing a common facility center (CFC) and implementing RuTAG technology in rural areas. RuTAG centres and NGOs conduct training programs to enable rural artisans to adopt technologies. We found that in the northeast region, few NGOs were involved in S&T intervention. RuTAG-NE IIT Guwahati helps NGOs find government initiatives and agencies to propose and fund technological implementations.

To assist marginalized people, the university knowledge transfer office should look beyond commercializing knowledge (Amry *et al.*, 2021;

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[5] The Ministry of Development of North Eastern Region (MDoNER) is accountable for planning, executing, and monitoring development schemes and projects in the North Eastern Region.

[6] Corporate Social Responsibility (CSR) is a corporate approach where companies acknowledge and take responsibility for the effects of their activities on different stakeholders, including society as a whole.

Compagnucci and Spigarelli, 2020). Therefore, we proposed:

Proposition 4: The presence of academic anchor intermediaries is more likely to serve as a key driver to engage quadruple helix actors to effectively disseminate technology to empower marginalized communities, such as by sharing technology design with local fabricators without any charges.

5. Discussion

Our analysis finds that universities (IIT Madras and IIT Guwahati), which serve as the anchors for the RuTAG centers, form the first helix. The university received seed funding to carry out RuTAG activities from the PSA and various government agencies also provide financial support. In this context, the government forms the second helix. We have found that problem statements can originate from two different approaches either a top-down (from the government) or a bottom-up (NGOs/ end users). NGOs serve as a bridge between RuTAG officials and end users. This collaboration allows NGOs and society to become the third helix in the process. The prototypes were developed through a collaboration with a micro-enterprise. In some cases, larger corporations provide CSR funds, which then makes the industry the fourth helix.

In addition, we have proposed a conceptual framework based on the findings of this study, which is illustrated in Figure 2. The figure effectively showcases the important factors and relationships that arise from this study. We proposed that academic anchor intermediaries: (1) Foster collaboration and inclusivity: This allows universities to not only establish trust and connections with regional stakeholders but also understand the needs of marginalized rural communities. (2) Inculcate and empower socially conscious academicians: This enables universities to involve academic staff with diverse knowledge and expertise in creating products that can enhance the productivity and well-being of marginalized rural communities. (3) Facilitate co-creation of demand-driven inclusive technology: This enables universities to involve underprivileged and marginalized communities in the process of innovation, ultimately enhancing the accessibility and acceptance of these innovations. (4) Facilitate dissemination of open source
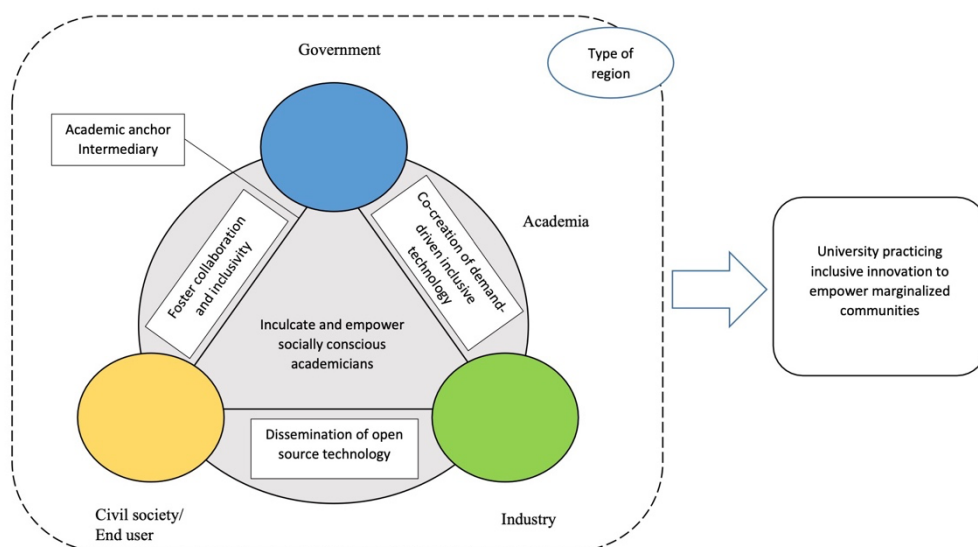
Figure 2

Proposed a conceptual framework

technology: This allows universities to distribute technology design to local enterprises and expand the reach of technologies to underserved rural communities. The academic anchor intermediary plays a crucial role in fostering university engagement with the quadruple helix actors and promoting inclusive innovation to empower marginalized rural communities.

The study also discovers that the type of region affects the collaboration patterns between intermediary organizations and quadruple helix actors. At the organizational level, RuTAG IIT Madras collaborates mainly with regional governments or related agencies, while RuTAG-NE IIT Guwahati collaborates mainly with central government agencies. RuTAG IIT Madras prefers to outsource its technology using an IT platform where fabricators or micro-enterprises can access its design and manual. In contrast, RuTAG-NE IIT Guwahati uses traditional training methods and controls technology quality. Further, RuTAG IIT Madras can take advantage of the IIT Madras alumni network to engage with regional engineering colleges and polytechnics, which IIT Guwahati lacks as a

young technical university. We also find that not all NGOs have experience with S&T implementation. However, it is possible to equip these NGOs with the requisite training to enable their participation in RuTAG activities, as done by RuTAG-NE IIT Guwahati. At the planning level, both RuTAG centres share their objectives and expected outcomes with NGOs before conducting regional workshops, and the problem statements are selected through an advisory committee. At the technology level, RuTAG technologies are not patented, and both centres aim to develop simple and affordable technology with specific importance to utilizing local resources. However, RuTAG-NE IIT Guwahati focuses on manually operated technologies. While RuTAG IIT Madras creates power-driven technologies.

5.1 Theoretical contribution

The present study contributes to the existing literature on inclusive innovation and quadruple helix literature. The study extends to quadruple helix literature by exploring how universities practice inclusive innovation through the lens of the quadruple helix framework. Providing a better understanding of how products are developed and actors are engaging in quadruple helix models, especially in the case of university technology transfer in rural traditional industries that operate in informal sectors.

The study also proposes a conceptual framework that highlights several attributes that facilitate university engagement with quadruple helix actors for inclusive innovation. This further extended inclusive innovation scholarship which remained focused on the role of multinational corporations and public-private partnerships. In addition, the study enhances our understanding of the role of intermediary organizations in coordinating quadruple helix actors for value-creation activities, thereby contributing to the existing literature. Addressing Björk (2014) argument for a clear distinction between the intermediary that coordinates public, academic, industrial, and civil society resources and those actors that belong to the fourth helix. The study also discovers that the type of region affects the collaboration patterns between intermediary organizations and

quadruple helix actors.

5.2 Managerial implications

Inclusive innovation plays a crucial role in reducing poverty and the development of emerging economies. The study provides several managerial implications for policymakers and education administrators, especially in the context of developing economies. First, universities seldom engage with marginalized communities. The findings from this study provide insight into how establishing an academic anchor intermediary would facilitate universities to address societal needs. Second, education administrators and policymakers can encourage universities to practice inclusive innovation by introducing appropriate policy intervention and providing necessary support. This is particularly important because academic career progression mainly considers publications, patents, and conferences and does not count on community engagement, and resolving local and regional issues. Universities can introduce certain rewards such as reputational rewards to encourage faculty members and students to engage with marginalized populations. Third, the findings of our study can be used as a reference to establish a quadruple helix partnership to develop rural economies, especially in developing economies where the majority of the poor reside in rural areas. Fourth, civil society can play a proactive role by approaching regional governments and universities with the S&T needs of artisans working in rural traditional industries.

6. Conclusion and scope for further study

This paper explores how universities engage with quadruple helix actors for inclusive innovation using qualitative multiple case studies. Our study finds that an academic intermediary enables quadruple helix partnership in S&T intervention to improve the livelihood and productivity of rural artisans working in traditional cottage industries. However, our study is not without limitations; the limitations of our study provide an exciting avenue for further study. Since we only analyzed two RuTAG centers, future research can include the remaining centers to identify new collaboration patterns and practices of inclusive innovation. Furthermore,

there is a need to analyze the factors identified in the study using a quantitative approach and test the proposed conceptual framework. This study is focused on premier technical universities in one of the developing economies (India). Thus, the empirical work could be replicated in other developed or developing economies to identify and standardize the factors that facilitate universities to practice inclusive innovation.   Further, research can be done to determine whether the type of university and its reputation influence the university's potential to play a vital role in facilitating quadruple helix relationships. Further study should determine the enablers and barriers to university technology transfer in the quadruple helix ecosystem, particularly in rural areas of emerging economies. Additionally, the role of the fourth helix, or civil society, as a critical intermediary actor in quadruple helix partnership for inclusive innovation should be explored.

Appendix A. Semi-structure interview outline

Focusing on RuTAG officials and IIT Professors

1. What are RuTAG's objectives and long-term goals?

2. How RuTAG has evolved since it was started? Do we see any change in the way it operates?

3. Is RuTAG attached to any department or center in IIT?

4. How faculty in IITs are participating. Is its voluntary work (not mandatory for faculty and students)?

5. How do other organizations collaborate with RuTAG-IIT

6. What is the main role of the PSA to the government of India?

7. What kind of technology has been transferred until now? Do we see the adoption of such innovation in the region? Please share some examples.

8. Any issues that RuTAG IIT is facing and how do you think they can be overcome

Focusing on organization collaborating with RuTAG IIT

1. Brief description about your organization

2. How your organization collaborate with RuTAG IIT

3. What are RuTAG long-term goals and objectives

4. What kind of technology has been transferred? Please share some examples.

5. In what way RuTAG IIT has benefited the rural population in the region

Appendix B. Example of representative quote used for arriving first order codes

First order code	A representative quote from the interview
A platform for regular interaction between formal and informal actors	*Workshop with NGOs and other stakeholders* Need identification workshops will be conducted based on the collaborations with the NGO. So, we will set a context or theme upon which there will be deliberations with grassroots NGOs and their stakeholders and we will discuss have a brainstorming session on getting the need. The actual point of the need identification workshop would be to get the problem statements from them. (RuTAG officials # 2) *Informal connection and building network* "It is a two-way combination, as we identify the issue and contact RuTAG, we informally connect them and talk with RuTAG officials, in the past our employees have attended seminars and training organized by RuTAG. They want to disseminate the rural technology also they conduct seminars to build a network." (NGO# 2) *System of regular interaction* A system of regular interaction with the villagers through RuTAG I think, is this meeting between the NGOs, villagers, and RuTAG, this is a very good system as it helps to directly connect between end users and innovators. (NGO # 3)
Confidence	*Bride gap between stakeholders*

building	The NGOs bridge the gap, we build confidence with the NGOs and the NGOs use to build the confidence of the artisans or the villagers. They help the villagers to understand that RuTAG is there to help them to stand on their own, but won't provide any financial assistance or money. If you are convinced with that only you will get the benefit. So now most of 90-95% people we have to interact in villages understand and become very cooperative and get good support, but initially, we have this problem, " (Academia # 4)
	Connecting with people to work together
	RuTAG center has put in their effort for the last 10 years. So, these kinds of things are slow-going things we cannot overnight achieve or immediately connect with people cannot because the trust ability, personality, and working together is something different... (Government #1)
Aim to improve the livelihood	*Identify technological needs to improve livelihood*
	We try to focus on the technology issues and after coming back we do some brainstorming and find out that out of these technology issues which are 1. Important that can help people to have better livelihoods, 2. Are we capable of doing that, if not is there any possibility to collaborate with other org and resource agencies then we do that." (Academia # 4)
	The objective is to improve the livelihood
	RuTAG main objective is to improve the livelihood of the rural people (RuTAG officials # 3)

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