A Systematic Literature Review on University Collaboration in Open Innovation: Trends, Technologies, and Frameworks

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Abstract: Open innovation is a concept of collaboration of ideas, knowledge, and resources that originates from within the organization and involves external organizations. University-industry collaboration is a factor driving innovation and competitiveness. Most research on interactions between universities and industry concentrated on the industrial side meanwhile, universities, as knowledge producers, play a vital role in creating an open innovation ecosystem that encourages realizing innovations that benefit society. Therefore, the problem raised in this research is how university collaboration can support open innovation. This research aims to identify research trends, the latest technologies, and inter-university collaboration frameworks that can support open innovation. The methodology used is Kitchenham's Systematic Literature Review (SLR) and bibliometric. SLR consists of Identification Study, Selection Studies, Quality Assessment, Data Extraction and Study Synthesis. From the SLR stages, 21 papers published between 2019 and 2023 were obtained. Synthesis and additional literature review were carried out to identify trends, technologies, and frameworks related to the topic comprehensively. In terms of trend, based on the application bibliometric, it was found that there was an increase in the number of publications and the top list of open innovation journals. University collaboration in open innovation more frequently takes place in the UK, and the industries mostly involved are small-medium enterprises. Quantitative research methodology and data analyses, comprising of hypothesis test, regression test, and descriptive statistics, are mostly preferred. Meanwhile, descriptive data analysis is the most common means of qualitative data analysis. Numerous suggestions on topics for future research were also identified. In addition, data analysis using machine learning survival data is identified as a novelty among data analysis methods. Technology transfer and the use of digital platforms may support open innovation processes, and the use of blockchain technology may promote digital platforms development. Seven domains form the framework for university collaboration in open innovation, namely Social Behavior, People, Process, Organization, Environment, Technology, and Performance. The findings of trends, technologies, and frameworks in this research may serve as a foundation for research on similar topics, and the identified framework domains could serve as framework components that might be used by universities to collaborate with partners in implementing open innovation processes. The research have contributes to knowledge management theoretically and practically. Theoretically, open innovation can expand the knowledge base by supporting the concept that knowledge and expertise can be found outside organizational boundaries. Practically, it can enrich knowledge management practices by emphasizing the importance of utilizing digital platform technology in supporting knowledge management sourced from external knowledge and collaboration services in the open innovation process.

Keywords: University collaboration, Open innovation, Trends, Technology, Framework

1. Introduction

Open innovation involving collaboration between universities and industry is increasing (Johnston, 2022). Such collaboration may provide great support for companies in responding to the challenges of today's highly competitive environment. Collaboration with universities can increase the industrial knowledge base through access to new knowledge, expert ideas, scientific results owned by universities, and consulting services that universities can provide (CF Băban & Băban, 2022). Universities as research partners for industry to access new technological and scientific capabilities (Gerdsri and Manotungvorapun, 2022). However, innovation problems that often occur in the innovation process in universities based on literature studies include universities needing help getting funding for research, differences in scientific disciplines that can hinder the integration of knowledge, and the downstream of research not yet optimal. One solution is to carry out university-industry collaboration. University-industry collaboration is believed to be a decisive factor that encourages innovation and competitiveness. The mechanisms through which this collaboration occurs have generated increasing interest among academics and the business sector (Vélez-Rolón, Méndez-Pinzón and Acevedo, 2020). Most

Reference this paper: Fitriasari, N.S. et al., 2024. A Systematic Literature Review on University Collaboration in Open Innovation: Trends, Technologies, and Frameworks, *The Electronic Journal of Knowledge Management,* 22(1), pp 40-58, available online at www.ejkm.com

research on the interaction between universities and industry is still concentrated on the industrial side (Bürger and Fiates, 2021), with some research gaps focused on the university side. Figure 1 shows a gap in the number of collaborative research topics on open innovation between universities and industry. The numbers were obtained by searching twice, the first using the keywords "University collaboration" AND "open innovation" and the second using the keywords "industry collaboration" and "open innovation" on three scientific databases, namely Scopus, ScienceDirect, and Emerald Insight.

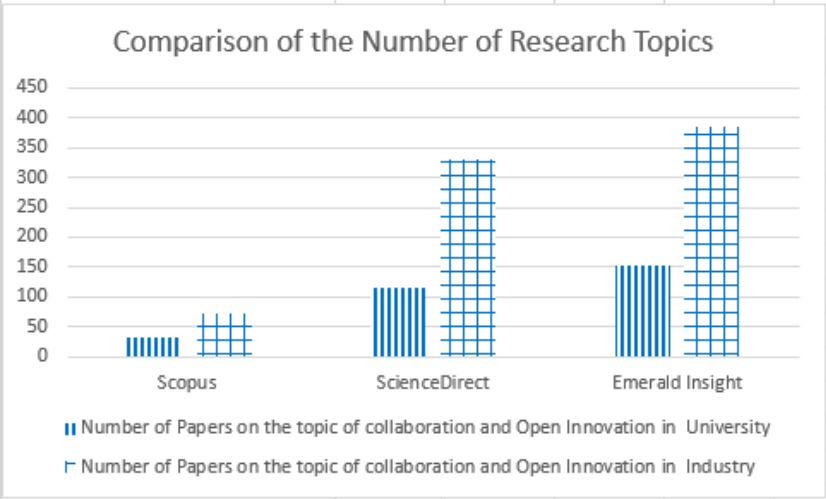

Figure 1: Comparison of the Number of Research Topic

Therefore, it is necessary to identify the latest trends in university collaborative research on open innovation to keep our knowledge and understanding of the development of open innovation updated. The objective of identifying research trends is to identify the number of publications each year, open innovation journals, countries and industries that conduct open innovation, methodology, data analysis methods, and future research in each selected literature.

Open Innovation is an innovation process that is distributed, directed, and based on the flow of knowledge across organizational and jurisdictional boundaries (Osorno-Hinojosa, Koria and Ramírez-Vázquez, 2022). It is a way to produce a product that has an added value. Using technology as a tool can support the open innovation process more effectively. Within this framework, the SLR attempts to identify what technologies are used in open innovation practices.

The success of implementing open innovation is not only based on the technology domain, but there are roles from other domains, such as people, processes, and organizations to name a few (Johnston, 2022; Arvaniti et al., 2022). This research also attempts to identify the strategic domains in developing a model or framework that may serve as a reference for organizations intending to implement open innovation.

This research was conducted using procedures of the systematic literature review (SLR) from Kitchenham et al. Then, the SLR results are synthesized to describe the trends, technologies, and frameworks. The findings could be used to assist research on the topic of university collaboration in open innovation, and the identified framework domains may serve as components that can be used by universities to collaborate with partners in implementing open innovation processes. This study's open innovation research trends are seen in 2019-2023. These findings can assist research on university collaboration in open innovation. Knowing the latest technology can provide insight into current technological developments supporting university collaboration to facilitate open innovation. The identified domains of the framework can serve as components that universities can use to collaborate with partners in implementing open innovation processes.

The research questions formulated in this study are:

RQ1. How have research trends on the topic of university collaboration to support open innovation in 2019-2023?

RQ2. What are the latest technologies used in university collaboration frameworks to facilitate open innovation?

RQ3. What domains have been used by universities to create university collaboration frameworks that can support open innovation?

This paper is divided into seven sections, namely Introduction, Literature Review, Research Methodology, Result, Discussion, Conclusion and Implications, Limitations, Future Research

2. Literature Review

Literature regarding university collaboration and open innovation is the main topic used in this research, including research from (Johnston, 2022) , which found that effective collaboration between small and medium enterprises (SMEs) and universities to encourage innovation in science is ' Proximity Matrix,' namely evaluating similarities between actors through evaluating their closeness in terms of distance, network membership, knowledge base, and working practice. Research from (Ponce, Polasko and Molina, 2021)proposes a new concept for open innovation laboratories at universities based on four overlapping innovation facilities capable of changing according to product needs. Research from (Koria *et al.*, 2022) examines how intermediary organizations that encourage innovation can encourage and enable the diffusion and adaptation of local knowledge, open innovation practices, and collaboration between universities, companies, and social innovators.

One application of technology to support the open innovation service process is to build a website-based digital platform that can be accessed by university partners for collaboration or by utilizing social media/networks; this is in line with the opinion of previous research (Szromek *et al.*, 2023)stating that coordination, information and communication functions, carried out in social networks and online platforms. Digital media can be used to obtain creative ideas, innovate products and services, and maintain contact with key stakeholders (Santoro, Ferraris and Winteler, 2019). One example (Koria *et al.*, 2022)creates an innovation platform that focuses on developing new products and services and research (Johnston, 2022) regarding the Gateway to Research website, which provides information in the form of details of all publicly funded research projects in the UK.

Several studies show that the term technology transfer in open innovation refers to sharing knowledge, technology, processes, or innovative solutions between organizations, companies, research institutions, or individuals. Technology transfer to accelerate innovation and development of new products through collaboration and utilization of external and internal resources. (Băban and Băban, 2022)found that the presence of universities near an industry can provide high-quality resources for research and innovation activities as well as support for the transfer of knowledge and technology, including in the context of open innovation

Previous research has shown that the successful implementation of open innovation in organizations does not only emphasize one dimension but must pay attention to other dimensions. Leavitt's socio-technical theory views organizations as complex systems with four dimensions: people, structure, tasks, and technology, which influence each other. People include individuals and groups working within an organization. Structure refers to the formal and informal work organization, including hierarchies, workflows, procedures, and policies. Task refers to work or activities that must be carried out to achieve organizational goals. Technology includes the tools, techniques, and methods to complete tasks (Leavitt, 2013). The following research from (Kobicheva, Baranova and Tokareva, 2020) is mapped into socio-technical—task components- Research processes, and activities related to interaction mechanisms that drive the innovation process. Apart from internal interactions within its departments, the university also conducts external interactions with the business world and government through living laboratories and a network of business incubators on open innovation online platforms. Components of society - groups involved in innovation activities are universities, the business world, and the government. The university has three departments: technical, economics, and humanities. Structural component- relationships between parties are based on the concept of open innovation, characterized by exchanging knowledge and ideas and working on potential projects in the future. The technology-platform component produced in this research is a web-based digital platform called the open innovation online platform. This technology facilitates living laboratories and Network Business Incubators.

Another example is research (Johnston, 2021), which emphasizes three factors that influence the formation of relationships between universities and industry, namely Organizational Proximity, Spatial Proximity, and Technological Proximity. Organizational Proximity: The existence of ties between actors, such as previous experience working with the company or collaborating with other companies in the sector, has been identified as the most influential factor in forming UI relationships. Spatial Proximity: The physical proximity of university partners to companies has been proven to influence the formation of UI relationships positively. Technological Proximity: The relevance of the partner university's knowledge and expertise to the food sector has been identified as an essential determinant in forming UI relationships, highlighting the importance of technological proximity. Gender factors in the people dimension also influence open innovation activities, as shown by two previous studies on gender in open innovation activities. The first study is research (Weerasinghe and Dedunu,

2021)This study found that academic staff collaboration in joint research activities and human resource mobility still need to be improved in Sri Lanka. Male academic staff have a more significant role in academic participation than women. Knowledge exchange occurs in joint research and training. Institutional factors significantly moderate the university-industry relationship, and the quality of academic work is the only individual factor that significantly moderates the relationship. The second study is research which found that gender positively affects open innovation activities in institutions. The presence of women in the top management team (TMT) has been proven to increase open innovation. Female executives are essential in moderating the relationship between TMT gender diversity and open innovation. Research shows that the influence of TMT gender diversity on open innovation increases when female executives have greater power to influence and when institutional conditions support it.

3. Method

The methods used in this research are systematic literature review (SLR), kitchenham, and bibliometric. SLR is used to obtain a collection of appropriate literature to answer the research question. In contrast, bibliometric is used to answer research question 1 regarding research trends on university collaboration topics to support open innovation.

The SLR stages use the Kitchenham procedure, consisting of:

1. Identification Study. At this stage, research questions are formulated using Population, Intervention, Comparison, Outcome, and Context (PICOC).
2. Selection Studies. There are two stages of selection conducted. The first stage of selection is based on the title and abstract, while the second stage is full-text selection. Both selections are carried out based on "inclusion" and "exclusion" criteria.
3. Quality Assessment. This stage involves assessing the methodological quality and reliability of the studies that have been selected.
4. Data Extraction. Once papers are selected and evaluated, relevant data are extracted by labeling papers based on relevant topics.
5. Study Synthesis. At this stage, analysis and synthesis are carried out based on the data resulting from the previous extraction, which is then used as a foundation for the research question.

Minimizing bias and limitations in research can be addressed through methodological steps at the study selection and quality assessment stages. At the study selection stage, the process is carried out in two steps: first, title and abstract selection, which must include key terms according to the research question, namely collaboration, university, and open innovation. In the second step, full-text selection is carried out by understanding the contents of the paper to determine whether there are key terms that can answer the research question. The final stage to avoid bias is to conduct a quality assessment of each paper, where the quality of the paper is assessed based on ten criteria, including clear research objectives, significant research contributions, and appropriate research methodology. Complete details can be seen in Table 10.

3.1 Study Identification

At this stage, a research question is formulated based on Population, Intervention, Comparison, Outcome, and Context (PICOC). The PICOC table can be seen in Table 1, and the research questions are shown in Table 2.

Table 1: PICOC

Population	University collaboration, technology, open innovation
Intervention	collaboration, universities, technology, digital platforms, applications, open innovation, knowledge
Comparison	Open Innovation in Industry
Outcome	Trends, technologies, and frameworks
Context	study at university

Table 2: Formulated research questions

RQ 1	How have research trends on the topic of university collaboration to support open innovation in 2019-2024?
RQ 2	What are the latest technologies used in university collaboration frameworks to facilitate open innovation?
RQ 3	What domains have been used by universities to create university collaboration frameworks that can support open innovation?

The next stage, to find relevant papers, is carried out through a Boolean string search in five scientific databases: Scopus, ScienceDirect, Emerald, ProQuest, and Sage. This database was selected based on its extensive coverage of the literature on the research topic of open innovation and the ease of accessing literature relevant to the research questions. The selection of keywords is based on key concepts in the research question, such as university collaboration, open innovation, technology or digital platforms or applications, models or frameworks, and knowledge. The keywords 'model' or 'framework' are used to facilitate the identification of the domains involved in establishing the framework. The Boolean String format can be seen in Table 3 below.

Table 3: Boolean search string

Scientific Databases	Boolean Search String
Scopus	*TITLE-ABS-KEY ("university collaboration" AND "open innovation" OR (model OR framework) AND (technology OR "digital platforms" OR applications) OR knowledge)*
ScienceDirect	Title, abstract, or author-specified keywords: TITLE-ABS-KEY ("university collaboration" AND "open innovation" OR (model OR framework) AND (technology OR "digital platforms" OR applications) AND knowledge
Emerald	*TITLE-ABS-KEY ("university collaboration" AND "open innovation" AND (model OR framework) AND (technology OR "digital platforms" OR applications) AND knowledge)*
ProQuest	*("university collaboration" AND "open innovation" AND (model OR framework) AND (technology OR "digital platforms" OR applications) AND knowledge)*
Sage	*("university collaboration" AND "open innovation" AND (model OR framework) AND (technology OR "digital platforms" OR applications) AND knowledge)*

The inclusion and exclusion criteria at this stage can be seen in Table 4 below.

Table 4: Inclusion and exclusion criteria at the initiation stage

Stages	***Inclusion*** **Criteria**	***Exclusion*** **Criteria**
Initiation Stage	• In accordance with the searched keyword • Written in English • Published in 2019-2023 • Article • Selecting journals that suit the topic to filter databases resulting in thousands of papers.	• Written in languages other than English • Publication year beyond 2019-2023

Based on an initial search using a Boolean search string in five databases, 466 articles were obtained with the following details: Scopus 52 articles, ScienceDirect 222 articles, Sage Journal 8 articles, ProQuest 107 articles, and Emerald 77 articles.

3.2 Study Selection

At this stage, two stages of selection were carried out. The first stage of selection was based on the title and abstract, while the second stage was full-text selection. The inclusion and exclusion criteria for these two stages are shown in Table 5. The first stage and the second stage resulted in 193 articles and 21 articles respectively.

Table 5: Table of study selection criteria

Stages	***Inclusion*** **Criteria**	***Exclusion*** **Criteria**
Stage 1 (Selection of Title and abstract)	• Containing the term "collaboration" • Containing the terms related to university stakeholders, such as "government", • "industry", and "society"	• Other than open innovation

Stages	*Inclusion* Criteria	*Exclusion* Criteria
	• Containing the term "open innovation"	
Stage 2 (Full-Text Selection)	• Containing open innovation-related processes • There is collaboration between universities and stakeholders • There is the use of technology • *Open access papers*	• Not containing open innovation-related processes • There is no collaboration between the university and stakeholders • Papers whose full text cannot be accessed • Paper Review

3.3 Quality Assessment

At this stage, a quality assessment was carried out for the 21 articles obtained in the previous stage. Article quality assessment can be seen in Table 6

Table 6: Quality assessment

Check the list	Question Checklist
C1	Does the paper explain the research objectives clearly?
C2	Does the paper include a literature review, background, and research context?
C3	Does the paper show a different contribution from previous research?
C4	Does the paper show the proposed architecture or methodology used?
C5	Does the paper present the university collaboration?
C6	Does the paper use technology as a collaboration medium?
C7	Does the paper describe the concept of open innovation clearly?
C8	Does the paper describe the domain of a digital platform-based PT collaboration framework that can support open innovation?
C9	Does the paper have research results and conclusions relevant to the research problems?
C10	Does the paper recommend future work?

For each checklist, a five-point scale is given, namely 0 (very poor), 0.25 (poor), 0.5 (fair), 0.75 (good) and 1 (excellent). The maximum value for each article will be 10 points. Selected articles are those that get 6 points and above.

3.4 Data Extraction

Data extraction was carried out to identify the main contributions of the selected studies. The results are presented in the Results section later in this paper.

3.5 Synthesis

At this stage, analysis and synthesis were carried out based on the data from previous extraction. An additional literature review was carried out to answer the research question comprehensively. Synthesis results can be seen in Subsection 4.

4. Results

This section presents the results of the analysis of the systematic literature review in three sub-sections, namely research trends, use of technology in promoting open innovation, and framework domains for higher education collaboration.

4.1 Research Trends

This subsection displays research trends identified in 21 published papers selected based on SLR discussing about university collaboration in the context of open innovation. The papers were then analyzed using descriptive statistics to reveal research trends based on the distribution of papers by year, journal, country, industry, research methodology, and quantitative and qualitative data analysis methods. The distribution of publications by year can be seen in Figure 2. It can be seen that five publications are in 2020, 2022, and 2023 each, with three publications in 2019 and 2023.

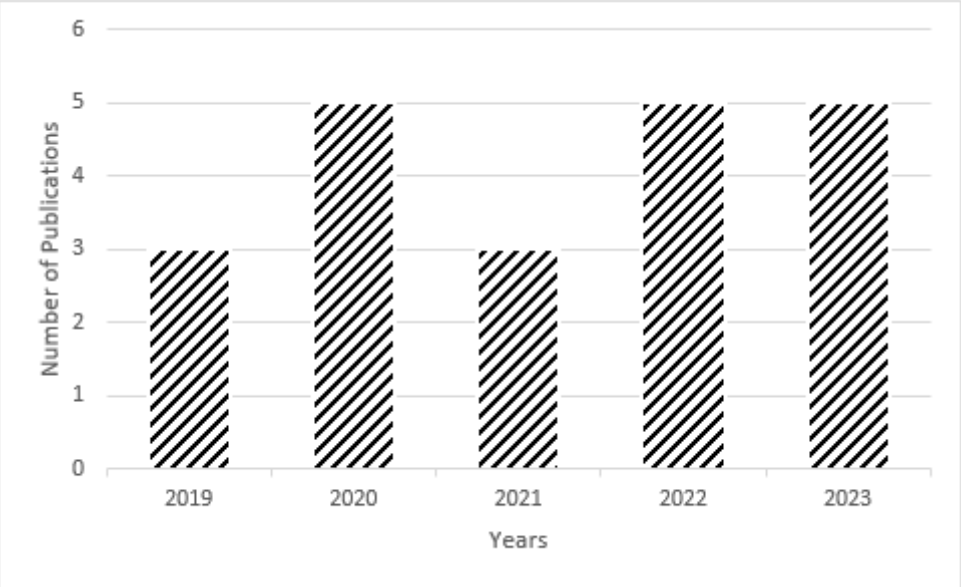

Figure 2: Distribution of Publications by Year

Most papers on the topic of university collaboration in open innovation were in the Journal of Open Innovation: Technology, Market, and Complexity reaching 19%, followed by the European Journal of Innovation Management and Mathematics with 14%. Next is the Journal of Technology Transfer at 10%, while the rest are 5% each. The detailed distributions of the journals can be seen in Table 7.

Table 7: Distribution of Publications by journal

Journal Name	Number of Publications
European Journal of Innovation Management	3
Mathematics	3
Science, Technology & Society	1
Industry and Innovation	1
EuroMed Journal of Business	1
International Journal of Innovation Science	1
The International Journal of Electrical Engineering & Education	1
Journal of Open Innovation: Technology, Markets, and Complexity	4
Technological Forecasting and Social Change	1
Asia Pacific Management Review	1
Sustainability	1
The Journal of Technology Transfer	2
Dimension Empresarial	1

The country with the most collaboration between industry and universities in open innovation is the UK at 23%, followed by 14% by Romania and Italy, 9% by America with the remaining 5% each. The number of publications of the countries is displayed in Figure 3.

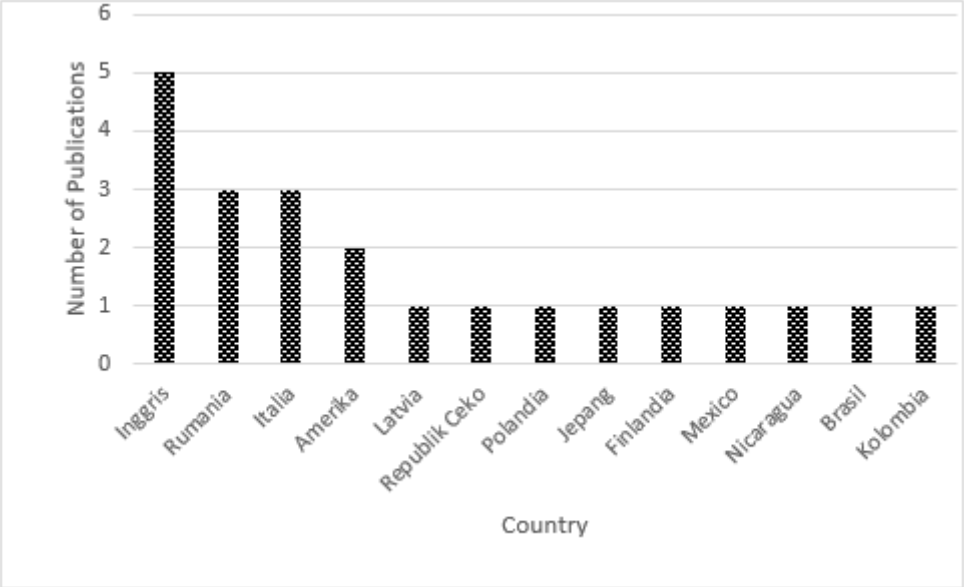

Figure 3: Distribution of Publications by Country Carrying Out Open Innovation

Meanwhile, a more detailed description of the role of industries in open innovation with universities can be seen in Figure 4. Small medium enterprises rank the highest, namely 26%, followed by startups, jewellery, automotive, electronics, and technology sectors each at 11 %, and the remaining 5% each in the food manufacturing industry, construction industry, tourism industry, and Sanitation Company.

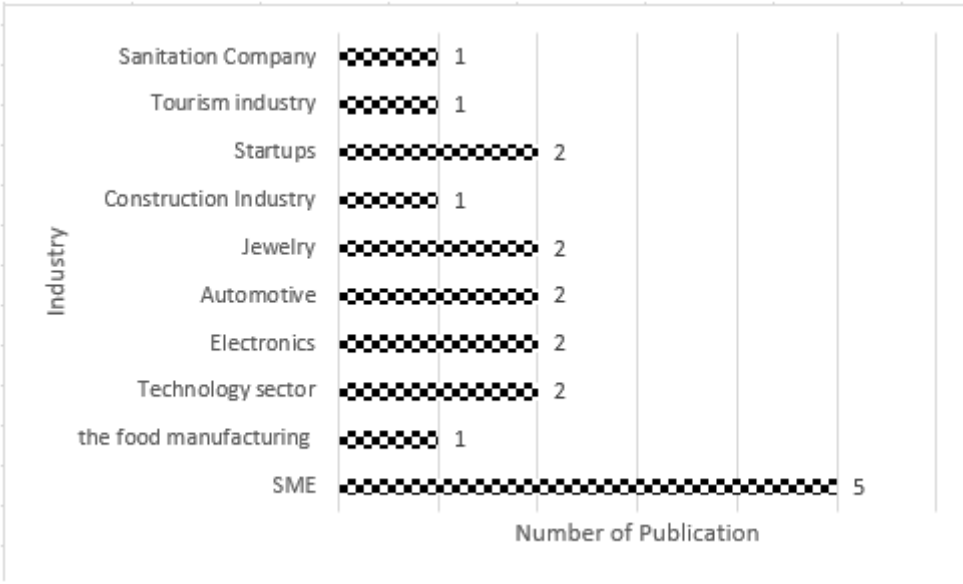

Figure 4: Distribution of Publications by industry collaborating with the University

Quantitative research methodology is the most common research approach in attempts to investigate the type of collaborative research for open innovation, taking 66%. This is followed by a qualitative approach at 24%, with the lowest the mix method, namely 10% (as seen in Figure 5).

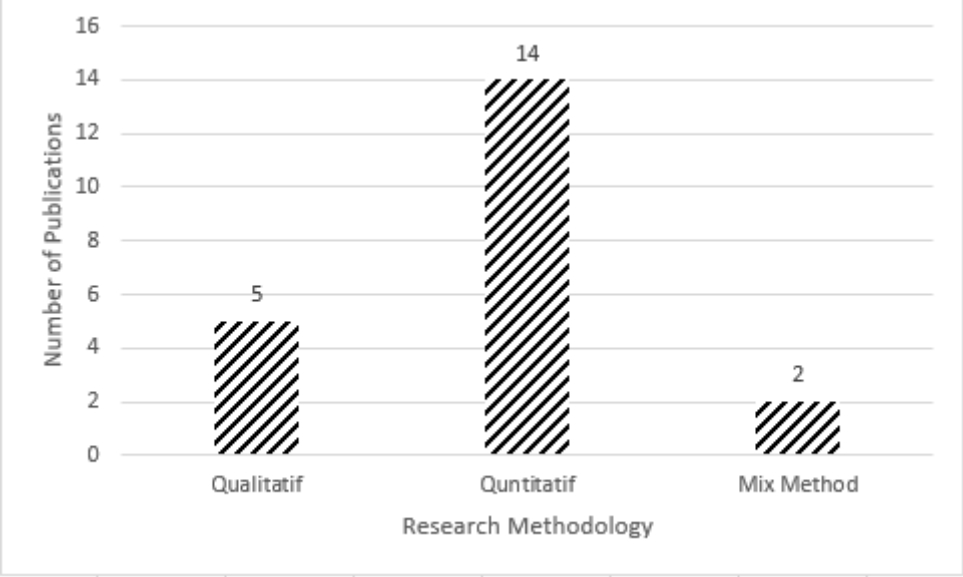

Figure 5: Distribution of Publications Based on Research Methodology

There are also differences in how data are analysed. In quantitative research, the Hypothesis Test is most commonly employed at 27%, followed by Regression Test at 15%, Descriptive Statistics at 12%, Artificial Neural Networks (ANN) at 9%, and Confirmatory Factor Analysis (CFA) and Correlation Test each at 6%. Adaptive Neuro-fuzzy Inference Systems, Data Envelopment Analysis (DEA), chi-square, Fisher's Exact Test, Fuzzy Logic, Generalized Method of Moments (GMM), Malmquist Productivity Index, and Social Network Analysis (SNA) are all 3% each. The data analysis methods used in quantitative research can be seen in Figure 6 below.

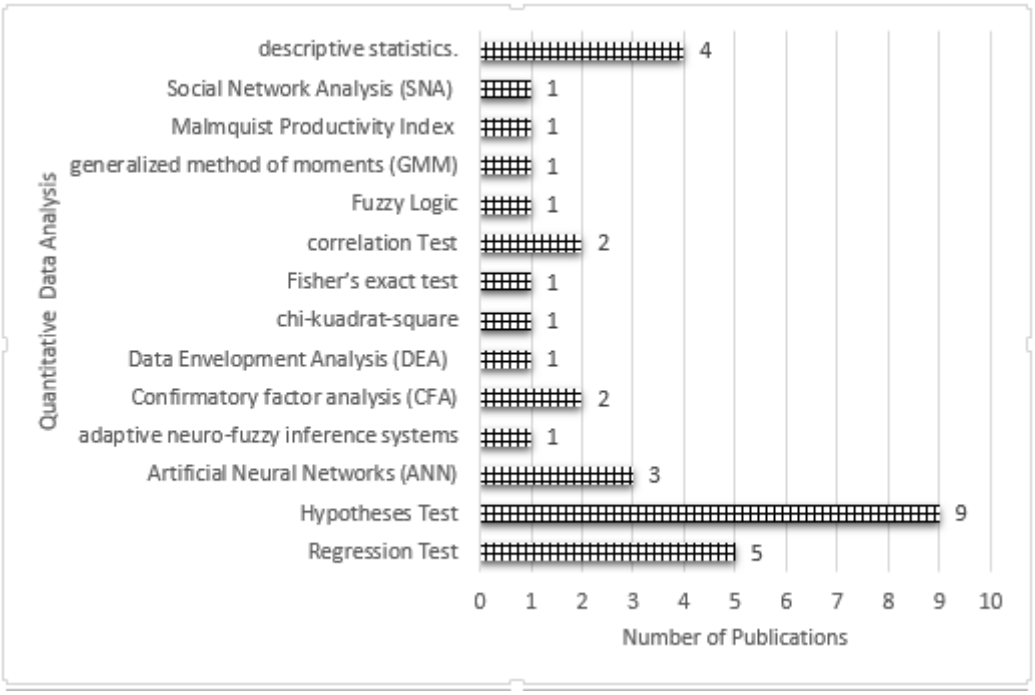

Figure 6: Distribution of Publications based on Quantitative Data Analysis

Whereas, qualitative data analysis mostly uses descriptive data analysis, as much as 40%, followed by narrative content analysis, multiple correspondence analysis (MCA), and content analysis method at 20% each (displayed in Figure 7).

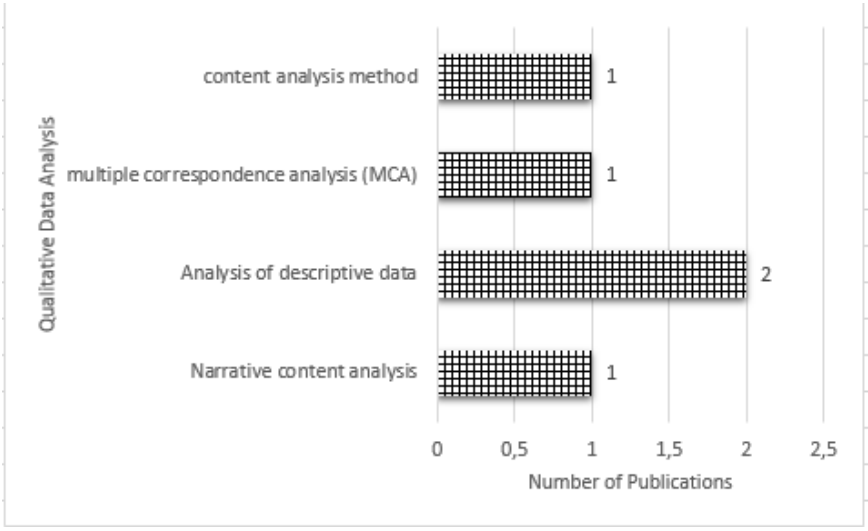

Figure 7: Distribution of Data Analysis Methods in Qualitative Research

Table 8 below depicts future research topics suggested by researchers of the selected papers.

Table 8: Future research topics

Suggested Future Research	Reference
Using similar methodology in different sectors and country contexts, to provide confirmatory evidence supporting the generalizability of the findings	(Johnston, 2021)
Conducting model validation, exploratory investigations with larger sample size surveys, and addressing nonlinearities between antecedent variables	(Călin, Băban and Rangone, 2022)
Validating the proposed variables through confirmatory and exploratory factor analysis	(Băban, Băban and Mitran, 2023)
Exploring the determining factors from the perspective of academics involved in the collaboration with industry to develop a methodology for implementing open environmental policies and procedures for innovation between industry and universities.	(Baban, Baban and Rangone, 2021b)
Presenting the impact of SMEs on universities by examining the extent to which these collaborations can support academic activity	(Johnston, 2022)
Taking the influences of other actors of innovation, for example, the quadruple/quintuple helix model, into account in promoting open innovation	(CF Băban & Băban, 2022)
Implementing an Open Innovation Patent (OIP) and an investigation is conducted into how to produce this type of patent	(Comai, 2020)
explains the role of universities as agents of innovation and entrepreneurship to support the economy	(Huggins, Prokop and Thompson, 2020)
Analyzing indicators for improving open innovation communities (OICs)	(Vélez-Rolón, Méndez-Pinzón and Acevedo, 2020)

4.2 Use of Technology to Facilitate Open Innovation

The use of university collaboration technology in open innovation is displayed in Table 9.

Table 9: Technology in open innovation

Technology	Information	References
Technology Transfer	Resource exchange process	(CF Băban & Băban, 2022;) .
Platform/website/ application	Digital-based platform	(Santoro et al., 2019) ; (Johnston, 2022)

There are different meanings when using "technology" in open innovation. The first understanding refers to technology transfer, which refers to transferring knowledge, skills, or technology from one partner to another. The partners include universities, industry, research organizations, and government. The second definition is an application used to help facilitate open innovation activities such as Knowledge Flow, Knowledge transfer, Knowledge management, Selection, Negotiations, Evaluation, and Commercialization. The application is, of course, website-based so that partners can access it.

4.3 Domain Framework for Higher Education Collaboration on Open Innovation

The domain grouping is based on a framework that is generally used to analyze the factors that influence the implementation of information system in an organization. The framework in question is PPT (People, Process, and Technology) and TOE (Technology, Organization, and Environment). However, in accordance with the conducted SLR, there are additional domains of Social Behavior and Performance. These domains are shown in Table 10 below.

Table 10: Domain Framework for Higher Education Collaboration in Open Innovation

No	Domain	Sub Domains	Description	References
1	Social Behaviour	Trust	Confidence or trust in the relationship between partners	(Johnston, 2022; Saeed et al., 2023; Santoro et al., 2019; Zhao, 2023; Ponce et al., 2021; Tomita, 2022; CF Băban & Băban, 2022; Campana et al., 2020)
		Communications	Communication between actors	(Johnston, 2021; Johnston, 2022; Zhao, 2023; Ponce et al., 2021; Rostoka et al., 2019; Tomita, 2022b)
		Collaboration	Each partner drives the other positively	(Johnston, 2021); (Călin, Băban and Rangone, 2022); (M. Băban et al., 2023) (Johnston, 2022) (Ponce, Polasko and Molina, 2021); (Audretsch *et al.*, 2023); (Tomita, 2022); (de Araujo *et al.*, 2020); (Campana *et al.*, 2020)
		Commitment	Commitment from top management	(Santoro *et al.*, 2019); (Vélez-Rolón, Méndez-Pinzón and Acevedo, 2020)
2	People	University	Industry collaboration partner	(Johnston, 2021); (Baban, Baban and Rangone, 2021b)(Băban and Băban, 2022); (Băban, Băban and Mitran, 2023); (Johnston, 2022); (Santoro *et al.*, 2019); (Zhao, 2023); (Han *et al.*, 2019); (Ponce, Polasko and Molina, 2021); (Rostoka, Locovs and Gaile-Sarkane, 2019); (Audretsch *et al.*, 2023); (Tomita, 2022); (Koria *et al.*, 2022); (Comai, 2020); (de Araujo *et al.*, 2020); (Huggins, Prokop and Thompson, 2020); (Vélez-Rolón, Méndez-Pinzón and Acevedo, 2020); (Campana *et al.*, 2020)
		Government	Policymakers and fund providers	(Ponce, Polasko and Molina, 2021); (Campana *et al.*, 2020)
		Industry	University collaboration partners	(Johnston, 2021); (Baban, Baban and Rangone, 2021b)(Băban and Băban, 2022); (Băban, Băban and Mitran, 2023); (Johnston, 2022); (Santoro *et al.*, 2019); (Zhao, 2023); (Han *et al.*, 2019); (Ponce, Polasko and Molina, 2021); (Rostoka, Locovs and Gaile-Sarkane, 2019); (Audretsch *et al.*, 2023); (Tomita, 2022); (Koria *et al.*, 2022); (Comai, 2020); (de Araujo *et al.*, 2020); (Huggins, Prokop and Thompson, 2020); (Vélez-Rolón, Méndez-Pinzón and Acevedo, 2020); (Campana *et al.*, 2020)

No	Domain	Sub Domains	Description	References
		Other Partners	Public/Citizen, Community, Research institutions, suppliers, customers	(Tomita, 2022); (Santoro *et al.*, 2019); (de Araujo *et al.*, 2020)
3	Process	Idea/Knowledge Flow	Internal and external knowledge flows	(Johnston, 2022); (Santoro et al., 2019; (de Araujo *et al.*, 2020); (Campana *et al.*, 2020)
		Knowledge transfer	Sharing knowledge between partners	(Băban and Băban, 2022); (Băban, Băban and Mitran, 2023); (Johnston, 2022); (Szromek *et al.*, 2023); (Vélez-Rolón, Méndez-Pinzón and Acevedo, 2020)
		Knowledge management	Knowledge management in open innovation processes	(Vélez-Rolón, Méndez-Pinzón and Acevedo, 2020)
		Selection	Selection of the right collaboration partner	(Johnston, 2021); (Johnston, 2022); (Rostoka, Locovs and Gaile-Sarkane, 2019)
		Negotiations	Business negotiation	(Tomita, 2022)
		Evaluation	Measuring organizational achievements	(Ponce, Polasko and Molina, 2021)
		Commercialization	Innovative products enter the market	(Johnston, 2021); (Johnston, 2022); (Han *et al.*, 2019); (Ponce, Polasko and Molina, 2021); (Huggins, Prokop and Thompson, 2020)
4	Organization	Culture	Collaborative culture	(Santoro *et al.*, 2019); (Koria *et al.*, 2022); (Băban and Băban, 2022); (de Araujo *et al.*, 2020)
		Strategy	Innovation strategy	(Saeed, Ali and Riaz, 2023); (Han *et al.*, 2019); (Ponce, Polasko and Molina, 2021); (Tomita, 2022); (de Araujo *et al.*, 2020)
		Motives	The aim of collaborating	(Baban, Baban and Rangone, 2021b); (Băban and Băban, 2022); (Ponce, Polasko and Molina, 2021); (Rostoka, Locovs and Gaile-Sarkane, 2019)
5	Environment	Collaboration level selection	Levels of Collaboration	(Johnston, 2021); (Baban, Baban and Rangone, 2021b)(Băban and Băban, 2022); (Băban, Băban and Mitran, 2023); (Johnston, 2022); (Santoro *et al.*, 2019); (Zhao, 2023); (Han *et al.*, 2019); (Ponce, Polasko and Molina, 2021); (Rostoka, Locovs and Gaile-Sarkane, 2019); (Audretsch *et al.*, 2023); (Tomita, 2022); (Koria *et al.*, 2022); (de Araujo *et al.*, 2020); (Huggins, Prokop and Thompson, 2020); (Campana *et al.*, 2020)
		Policy	Open innovation policy	(Baban, Baban and Rangone, 2021b); (Johnston, 2022); (Szromek *et al.*, 2023); (de Araujo *et al.*, 2020)
6	Performance	Patents/Intellectual Property Rights	One of the results of the open innovation process	(Johnston, 2021); (Zhao, 2023); (Han *et al.*, 2019); (Ponce, Polasko and Molina, 2021); (Tomita, 2022)
7	Technology	Technology Transfer	Resource exchange process	(CF Băban & Băban, 2022); (Huggins, Prokop and Thompson, 2020)
		Platform/website /application	Digital-based platform	(Santoro *et al.*, 2019); (Johnston, 2022)

5. Discussion

This research uses Kitchenham's Systematic Literature Review (SLR) to answer three research questions, each to determine research trends, technology, and domain frameworks in higher education collaboration in open innovation. This section discusses the findings of the questions, provides an additional literature review to enrich the discussion, and summarizes the results to be used for potential stakeholders who may benefit from the research findings.

5.1 RQ 1. What are the research trends on the topic of university collaboration in open innovation?

To answer the question, Kitchenham's SLR stages were employed in evaluating published papers, starting from study identification, study selection, and quality assessment, resulting in 21 selected papers. The number of papers found is not so large because, at the study selection stage, one of the criteria for the paper selection is that each must contain the term "open innovation" in their title.

From the selected papers, trend analysis was carried out based on year, journal, country, industry, research methodology, data analysis methods, and future research suggestions. The results of the trend analysis by year show that university collaboration in open innovation is still a chosen topic of research every year, as seen in Figure 1. This topic is likely to be a research trend in the foreseeable future because most research on the interaction of universities and industry still mostly perceives it from the industrial perspective (Bürger and Fiates, 2021). Thus, there is still a research gap from the perspective of universities.

Research on university collaboration in open innovation is mostly found in the Journal of Open Innovation: Technology, Market, and Complexity. Based on Scimago Journal & Country Rank data, the journal is indexed by Scopus in Q1 with an H-Index of 38 (per November 2023).

It is also found that most of the collaborations between universities and their partners (industry, government, or community) on open innovation are conducted in the UK (see Figure 3). However, it should be noted that, based on the Global Innovation Index (GII) there are 130 countries involved in innovation ranking (World Intellectual Property Organization, 2022). The five countries with the highest rankings are shown in Figure 8 below.

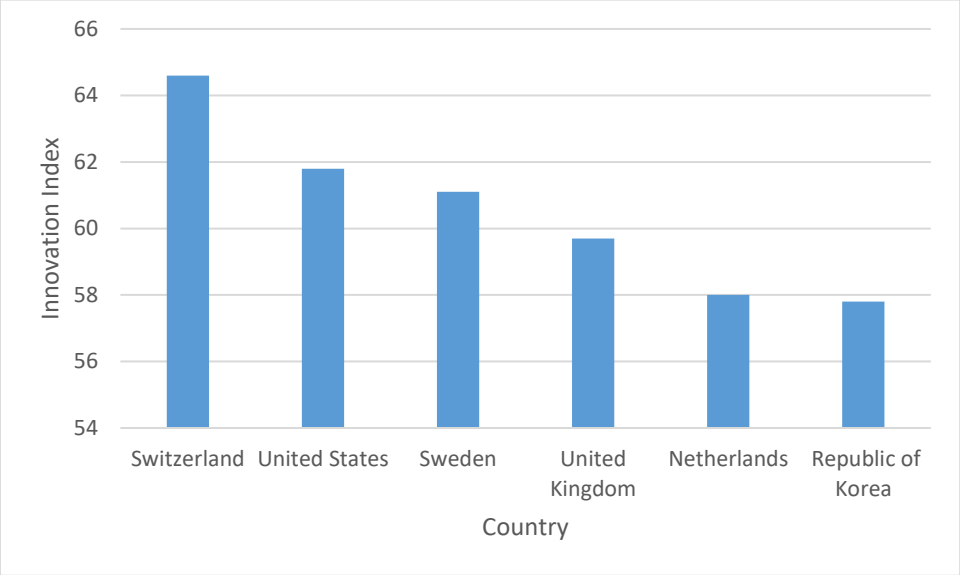

Figure 8: Innovation Index ranking by country

The score on the Innovation Index reflects how well a country innovates in various aspects of life. Some of the factors evaluated in this index include the number of patents filed, investment in research and development, industry-academic collaboration, and higher education capacity to name a few.

The industry that is most involved in university collaboration is small and medium enterprises (SMEs). One of the reasons for this is that SMEs often have limited knowledge, technology, and required resources. By carrying out open innovation, SMEs can collaborate with universities to overcome those limitations (Johnston, 2022; (Vélez-Rolón, Méndez-Pinzón and Acevedo, 2020). For example, in research (Santoro, Ferraris and Winteler, 2019) based on the results of interviews conducted with UKM, state universities are seen as practical open

innovation that complements each other for UKM. For SMEs in the ICT sector, regular meetings with university partners are needed to balance relationships and avoid delays because ICT sector products/services quickly become obsolete.

The research methodology most widely used in university collaboration in open innovation is quantitative. This is because quantitative research is considered to be more objective as it uses numerical data. The mixed research methodology is rarely used in this research, making it a novelty in future research. For example, in research (Baban, Baban and Rangone, 2021a) conducted explanatory research by combining qualitative and quantitative approaches. Qualitative has been done with a literature review to determine the conceptual framework of industry-university determinants. Quantitative has been carried out with statistical analysis and a fuzzy logic approach. Statistical analysis was carried out on the questionnaire results data, including conducting a chi-square analysis to determine whether the Italian and Romanian populations tend to rank the importance of each questionnaire item differently. A fuzzy logic approach has been used to predict the impact of five determinants of Open Innovation on the perception of universities as a source of corporate Open Innovation activities. Research (Rostoka, Locovs and Gaile-Sarkane, 2019)uses an interpretative research paradigm by combining quantitative and qualitative approaches. Quantitative has been carried out using statistics to analyze demographic and economic data, labor costs, education, level of trust in state institutions, and distribution of European Union funds. Qualitative by interviewing industry and academic experts to evaluate employee turnover rates.

This novelty can also be implemented in qualitative and quantitative data analysis, where we can use data analysis other than those shown in Figure 6, for instance, the use of machine learning. Machine learning for survival analysis concerning the topic of university collaboration in open innovation could be used to predict the determinants of open innovation collaboration or to analyze the adaptation of higher education collaboration models to open innovation.

Future research suggestions (see Table 8) can be used to direct further research on related topics. For instance, research may add the determinants of collaboration from the perspective of academics involved in open innovation (Baban, Baban and Rangone, 2021b).

5.2 RQ 2. What are the latest technologies used in university collaboration frameworks to facilitate open innovation?

The term technology obtained from SLR results has two different meanings: the first as a technology transfer and the second as a digital-based platform. Technology transfer can be defined as the process of exchanging technology, production methods, or technical expertise between partners, as happens in a collaboration between universities and industry, where universities provide high-quality resources for open innovation processes (CF Băban & Băban, 2022;) (Huggins, Prokop and Thompson, 2020). For example, in research (Han *et al.*, 2019)under the OI paradigm, there is an essential flow of external knowledge into the organization that turns into projects through collaboration with external partners, leading to the purchase and incorporation of external technologies. Research (Baban, Baban and Rangone, 2021b)The presence of universities near industry provides high-quality resources for research and innovation activities and support for knowledge and technology transfer.

Technology as a digital platform provides benefits for companies to find opportunities from obtaining big data from external parties and developing an engaging open innovation collaboration with their partner via a digital ecosystem. In this way, SMEs can utilize e-collaboration tools, social media, and big data platforms, to obtain creative ideas to innovate their products and services and to maintain collaboration with university partners (Santoro *et al.*, 2019). Another example of a digital platform is the Gateway to Research website, which provides details of all publicly funded research projects in the UK (Johnston, 2022)**.**

In addition, a new technology that can be utilized for university collaboration in open innovation is blockchain technology. Blockchain technology integrates artificial intelligence, cloud computing, and big data (Yang, 2019). This technology can be used to support the knowledge transfer process both internally and externally, especially in searching for ideas/knowledge in open innovation.

One of the critical success factors in sharing/transferring knowledge is trust (Al Hakim, Sensuse and Lestari, 2022). Trust plays a crucial role as an important facilitator in communication, which leads to good relationships, and, thus, people are more willing to engage in knowledge sharing (Azizi and Ahsan, 2023). Trust may be achieved by utilizing blockchain technology. Currently, blockchain has won much research recognition and public attention in the field of global innovation. "The Economist" compared blockchain to a “trust machine” and predicted that “the blockchain will redefine the world (Yang, 2019).

5.3 RQ 3. What domains have been used by universities to create a digital platform collaboration framework that can support open innovation?

The framework may serve as a foundation that can be used by universities to collaborate with partners in carrying out open innovation processes. The SLR on this research question came up with seven domains that form the framework. The seven domains are as follows: Social Behavior, People, Process, Organization, Environment, Technology, and Performance.

These findings group "trust", "communication", "commitment", and "collaboration" as subdomains of Social Behavior. Previous research determines Social Behavior to be consisting of trust, communication, and commitment ((Santoro *et al.*, 2019). Collaboration in the social behavior domain may refer to cooperation between individuals or groups in social interactions. Collaboration that can be carried out in open innovation includes joint research (Johnston, 2021; Ponce et al., 2021; Audretsch et al., 2023; Tomita, 2022b) and collaboration technology (Comai, 2020; M. Băban et al., 2023). One of the aims of such collaboration is to create intellectual property and achieve a competitive advantage (Campana *et al.*, 2020).

Trust is an important factor for success in collaboration, previous research found that partners are more likely to collaborate with universities they trust and have established good collaborative relationships (Johnston, 2022; Santoro et al., 2019; Zhao, 2023). Greater partner trust can increase knowledge mobility, innovation feasibility, and performance of open innovation (Tomita, 2022b; CF Băban & Băban, 2022).

The People domain consists of sub-domains of "universities", "industry", "government" and other parties (public/citizens, community, research institutions, suppliers, and customers). Each has its role in the open innovation process. The role of universities includes being a source of knowledge and experts, a provider of access to research, a facilitator of the flow of knowledge, and a developer of new products and services (M. Băban et al., 2023; Johnston, 2022; Zhao, 2023; Huggins et al., 2020). The role of industry is to transfer knowledge to universities within its operating area, where they produce innovations (Băban and Băban, 2022). The role of government is to provide funds (Ponce et al., 2021; Campana et al., 2020) and to formulate policies on open innovation that involve collaboration between partners (Szromek *et al.*, 2023).

The Process domain consists of seven subdomains, namely "idea or knowledge flow", "knowledge transfer", "knowledge management", "selection", "negotiation", "evaluation", and "commercialization". The idea or knowledge flow is the initial process where the ideas/knowledge originating from external parties combine with internal ideas/knowledge to produce innovative products or services (Johnston, 2022; de Araujo et al., 2020; Campana et al., 2020). Knowledge management is more about the process of managing internal knowledge and external knowledge. Knowledge transfer in open innovation may take the forms of publications, research collaborations, informal links and networks, consultations, or trainings (Băban and Băban, 2022). Selection is more about the process of selecting partners (Johnston, 2022). Negotiation is an interactive process in which two or more parties try to reach a mutually beneficial agreement. Evaluation is an important process for assessing the level of success of the open innovation process that has been carried out (Ponce, Polasko and Molina, 2021). While most academic research is concentrated on outputs related to the creation and commercialization of intellectual property, involving industrial partners will provide significant income for universities (Huggins, Prokop and Thompson, 2020).

The Organizational domain consists of "culture", "strategy", and "motive". A collaboration culture is very important to promote open innovation (Koria *et al.*, 2022). There are several strategies to support open innovation, including joint ownership of patents as an organizational strategy to co-innovate (Saeed, Ali and Riaz, 2023), enriching the knowledge base by integrating partner knowledge (de Araujo *et al.*, 2020). University motives for carrying out open innovation include getting access to public funding through collaborative research projects, shortening product development time, sharing risks and access to research facilities (CF Băban & Băban, 2022), gaining knowledge that is useful for teaching and learning on campus, and seeking business opportunities (Rostoka, Locovs and Gaile-Sarkane, 2019).

The Environment domain consists of two subdomains, namely collaboration level selection and policy. Selecting the appropriate level of collaboration involves determining the extent to which the university wishes to be involved in collaboration, i.e. whether at the local, national, regional, or international level. The implementation of open innovation policies must involve all stakeholders (Baban, Baban and Rangone, 2021b). From a government perspective, policymakers need to review the role of state universities in society and concentrate on establishing an ideal organizational structure at the national and regional levels involving various interested parties (Szromek *et al.*, 2023).

The Technology domain consists of two subdomains, namely “technology transfer” and “digital platforms”. An explanation of the two subdomains can be seen in Sub-chapter 4.2. The Performance domain consists of the “patent/intellectual property rights” sub-domain. University patent stocks may still be considered an important opportunity for companies (Johnston, 2021). Eventually, open innovation processes may increase intellectual property (Zhao, 2023).

6. Conclusion

The literature used in this research comes from five reputable databases, namely Scopus, ScienceDirect, Emerald, ProQuest, and Sage. Through the Kitchenham SLR method, 21 articles were obtained. The article contains the keywords university collaboration and open innovation. Based on the results of the SLR, provide an overview of the current situation regarding the topic of university collaboration research and open innovation, technology that can be utilized to encourage open innovation, and a list of domains that form the framework for university collaboration in open innovation. The research trends presented in this study include information on the number of publications each year, a list of open innovation journals, countries, and industries undertaking open innovation, methodology, data analysis methods, and future research. The number of publications about "university collaboration" and 'open innovation' has increased in 2023. Three top journals accept papers on this topic, namely the Journal of Open Innovation: Technology, Markets, and Complexity and the European Journal of Innovation Management and Mathematics. From the 21 papers found, most research case studies on collaboration between universities and open innovation took place in the UK, with university collaboration partner companies most often being small and medium enterprises (SMEs).

This research carries out classifications related to methodology and data analysis. The study found that 14 articles used quantitative methods, five used qualitative methods, and two used mixed methods. Based on quantitative data analysis, hypothesis tests are often used, and analysis descriptive data are used in qualitative data analysis. Findings obtained from research trends can be used to discover and determine research novelty. For example, mixed methods research methodology is rarely used in collaboration. Therefore, this method may be new in future research. Some future research is also presented in this research, which can be used to develop subsequent research.

Regarding the term technology, this panel obtained two meanings, namely "technology transfer" and "digital platform." Based on the literature studies that have been conducted, Blockchain technology can be applied to collaborative digital platforms because this technology can support the search for ideas or knowledge to increase the opportunity to produce patents. The research has produced seven domains of a university collaboration framework in open innovation: Social Behavior, People, Process, Organization, Environment, Technology, and Performance. Universities can use this framework to create an open innovation ecosystem. Further research development will suggest using bibliometric software such as VOSviewer, CiteSpace, or Scopus Analysis tools to obtain more visualized research results.

7. Implications, Limitations, and Future Work

This research contributes to identifying research trends that may serve as the starting points for researchers who are interested in researching the topic of university collaboration in open innovation. Universities may implement appropriate technology to support the open innovation processes. Finally, the identified domain framework can be used as a guideline for conducting collaboration between universities and their prospective partners.

The limitation of this research is that the number of papers that resulted from the SLR stage was only 21 papers. This may result in research trends to be not very general. A possible way to overcome this problem is to do additional literature reviews to identify the latest data analysis and technology. In the future, research can be extended by changing the Boolean search string and the “inclusion and exclusion” criteria, so that a large number of papers can be obtained. Validation of domains and subdomains can also be carried out in future research.

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