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Technology and public-private partnerships: a literature review based on network analysis

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Abstract

Objective of the study: Identify the state of the art of scientific research on the topic of technology in public-private partnerships (PPP) studies.
Methodology/approach: The methodology is based on a bibliometric study (Mukherjee et al., 2022) using knowledge discovery tools (Zhang et al., 2021) and network analysis (Wang et al., 2018).
Originality/Relevance: This paper brings to light the technology theme in PPP studies using a current methodology and with the support of knowledge discovery software.
Main results: This paper presents the main authors, institutions, references, the distribution of the knowledge base in the world, and trending topics for future studies on technology in PPP studies.
Theoretical/methodological contributions: It presents the trend of studies on PPP and technology: (i) PPPs integrated with the development of countries with a focus on solving social, economic, and environmental problems; (ii) investment partnerships and financing-based projects; and (iii) efficiency and effectiveness of partnerships and their relevance to society. As a methodological contribution, it was found that the triangulation of research resources (bibliometrics-knowledge discovery-network analysis), besides being viable, enriches the data framework and facilitates analysis.
Social contributions/to management: This study presents the knowledge base on technology in PPP studies that can become a strategic asset for organizations that, among their objectives, intend to adopt the collaborative PPP strategy for their technological advancement.

Keywords: collaborative strategies, public-private partnership, technology, bibliometrics, social network analysis

Authors' notes

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Resumo

Tecnologia e parcerias público-privadas: uma revisão da literatura com base em análise de redes

Objetivo do estudo: Identificar o estado da arte da pesquisa científica sobre o tema da tecnologia em estudos de parcerias público-privadas (PPP).
Metodologia/abordagem: Metodologia alicerçada em um estudo bibliométrico (Mukherjee *et al*., 2022) utilizando ferramentas de descoberta de conhecimento (Zhang *et al*., 2021) e análise de redes (Wang e*t al*. 2018).
Originalidade/Relevância: Este trabalho traz à luz a temática da tecnologia em estudos sobre PPP utilizando uma metodologia atual e com apoio de softwares de descoberta de conhecimento.
Principais resultados: Este trabalho apresenta os principais autores, instituições, referências, a distribuição da base de conhecimento no mundo e tópicos de tendências para estudos futuros sobre tecnologia em estudos de PPP.
Contribuições teóricas/metodológicas: Apresenta a tendência de estudos sobre PPP e tecnologia: (i) PPP de forma integrada com o desenvolvimento dos países com foco na resolução de problemas sociais, econômicos e ambientais; (ii) parcerias de investimento e projetos baseados em financiamento; e (iii) eficiência e eficácia das parcerias e sua relevância para a sociedade. Como contribuição metodológica, verificou-se que a triangulação de recursos de pesquisa (bibliometria-descoberta de conhecimento-análise de redes) além de viável, enriquece o arcabouço de dados e facilita a análise.
Contribuições sociais para a gestão: Este estudo apresenta a base de conhecimento sobre a temática da tecnologia em estudos de PPP que podem se tornar um ativo estratégico para as organizações que, dentre os seus objetivos, pretendam adotar a estratégia colaborativa de PPP para seu avanço tecnológico.

Palavras-chave: estratégias colaborativas, parceria público-privada, tecnologia, bibliometria, análise de redes sociais

Resumén

Tecnología y alianzas público-privadas: una revisión de la literatura basada en el análisis de redes

Objetivo del estudio: Identificar el estado del arte de la investigación científica sobre el tema de tecnología en estudios de asociaciones público-privadas (APP).
Metodología/enfoque: Metodología basada en un estudio bibliométrico (Mukherjee et al., 2022) utilizando herramientas de descubrimiento de conocimiento (Zhang et al., 2021) y análisis de redes (Wang et al. 2018).
Originalidad/Relevancia: Este trabajo saca a la luz el tema de la tecnología en los estudios de APP utilizando una metodología actual y con el apoyo de software de descubrimiento de conocimiento.
Principales resultados: Este trabajo presenta los principales autores, instituciones, referencias, la distribución de la base de conocimiento en el mundo y temas de tendencia para futuros estudios sobre tecnología en estudios de APP.
Aportes teóricos/metodológicos: Presenta la tendencia de los estudios sobre APP y tecnología: (i) APP de manera integrada con el desarrollo de los países con un enfoque en la solución de problemas sociales, económicos y ambientales; (ii) asociaciones de inversión y proyectos

basados en financiamiento; y (iii) eficiencia y eficacia de las alianzas y su relevancia para la sociedad. Como aporte metodológico, se encontró que la triangulación de recursos de investigación (bibliometría-descubrimiento de conocimiento-análisis de redes), además de viable, enriquece el marco de datos y facilita el análisis.
Aportes sociales/a la gestión: Este estudio presenta la base de conocimiento sobre el tema de la tecnología en los estudios de APP que puede convertirse en un activo estratégico para las organizaciones que, entre sus objetivos, pretenden adoptar la estrategia de APP colaborativa para su avance tecnológico.

Palabras clave: estrategias colaborativas, asociación público-privada, tecnología, bibliometría, análisis de redes sociales

Introduction

The search for technological innovations in organizations is increasingly present. Hence, public organizations have also sought to incorporate new technologies into their processes, products, and services. One of the ways used is through collaborative strategies with non-public organizations, public-private partnerships (PPP).

In recent years, research on Public-Private Partnerships (PPPs) has gained momentum in academic research in economics, law, engineering, and administration (Wang, Xiong, Wu & Zhu, 2018). Regarding studies in administration, it is clear that PPPs are generally conceived as a phenomenon (Hodge & Greve, 2009; ibidem, 2017) or management strategy (Meyer, 2021) and investigated relative to different aspects, such as economic-financial performance, efficiency, quality, structuring of arrangements between players, regulation, administrative management, risk management and incentives, and governance. These same studies often fail to consider the possibility of generating technological advances for the organizations involved. Technological advances, understood herein in their broad sense, are not restricted to information technologies, but expand to the understanding of the Organization for Economic Cooperation and Development, OECD (2018) on technology that consists of converting resources into results, resources that can be processes, knowledge, tools, and other elements (Michaelis, 2023), not exclusively ICT.

Thus, one may question how administration studies have dealt with technology in studies on PPPs. In this sense, it is also questioned who the main authors are, what are the reference relationship networks, the journals, the countries, and networks of institutions related to PPP and technology research. In short, this paper aims to answer the following question:

How **have scientific productions in administration contributed to developing the technology theme in PPP studies?**

To answer the research question, a bibliometric study was conducted (Mukherjee, Lim, Kumar & Donthu, 2022) using knowledge discovery tools (Zhang, Zhang, Li, Liu, Yang & Liu, 2021) and network analysis (Wang *et al*. 2018) to present: (i) the co-citation network in the field of the studied theme, (ii) the co-citation network of references, (iii) the network of related journals, (iv) the evolution of topics with the keywords, (v) the co-authorship network of publications, and (vi) also the bibliometric detailing of the most cited articles and even thematic groups of topics for future research.

The theoretical framework on PPP was established seeking to highlight PPPs through world-class authors on the topic (Hodge & Greve, 2009; ibidem, 2017) in the Brazilian context (Brito & Silveira, 2014; Meyer, 2021) and concerning a review of previous literature (Wang *et al.*, 2018) to direct the findings to fill the gap in this research. As for technology and its advancement, we sought to highlight the understanding of international organizations such as the OECD (OECD, 2018), the Organization of American States (OAS, 2023), and the International Telecommunication Union (ITU, 2023), as they present an understanding, contextualized in the considerations of the World Economic Forum (WEF, 2024), which highlights its importance nowadays.

Within this framework, shedding light on the state of the art of research on technology in the context of PPPs becomes vital for science and management practice since knowledge is a strategic asset for organizations (Gomes, Lavina, Silva, Gruber, & Marcelino, 2019). In the same sense, it contributes information to shift the topic of PPPs to clear space, further away from the lack of knowledge of this collaborative strategy, one of the main aspects that lead managers to opt for other strategies (Meyer, 2021).

Regarding the theoretical contribution, this study can guide future research and actions in the field of study, as Zhang *et al.* (2021) reinforce the objective of reviews, that is, research on technology in PPP and also as a way of deepening the literature review by Wang *et al.* (2018) on PPP on the specific topic of technology.

Furthermore, the World Economic Forum (WEF, 2024) identifies frontier technologies among the components of the four forces that will influence the paths of politics and the economy in the next 10 years. Therefore, how these can be achieved (technological advancement strategies) is increasingly important to study in the current context. In this respect, there is a need to study technology as a component of this collaborative strategy between the public and private sectors, which is the PPP.

By expanding knowledge about technology in the context of PPPs, this paper also aims to understand the extent to which PPPs have been able to contribute to the technological advancement of the public sector since this was one of the critical motivations at the time of their conception (Hodge & Greve, 2009).

Theoretical Framework

Before looking for elements that can shed light on technology in PPPs studies through a bibliometric review, a brief presentation of the theoretical constructs involved in the present work is required: (i) public-private partnerships, using the international understanding of the topic and having as main references Meyer (2021), Wang *et al.* (2018), and Hodge and Greve (2009, 2017); and (ii) technological advancement associated with the concept of innovation and based on the understanding of the Organization for Economic Cooperation and Development (OECD, 2018), the International Telecommunication Union (ITU, 2023), and the Organization of American States (OAS, 2023), which will be better described in the following items.

Public-Private Partnerships

Public-private partnerships (PPP) emerge as a strategy in public administration to enable private investment in public works in situations of fiscal constraints and also to ensure efficiency in the provision of public services with the vision of a project cycle inherent to the private sector, however, without renouncing the regulation and supervision of the services performed (Brito & Silveira, 2014).

As an alternative to traditional contracts, adopting a PPP allows the public administration to share responsibilities with the private sector to meet the needs of society (Meyer, 2021). This sharing can alleviate budgetary pressure in the short term and efficiently meet society's needs (Brito & Silveira, 2014).

Initially, PPPs, conceived as *a private finance initiative* (PFI) by the English government in the 1980s (Brito & Silveira, 2014), promised several benefits. According to Hodges and Greve (2009), PFI emerged as a way to circumvent the formal debt of the public sector, intensify private financing to guarantee infrastructure without the need for public sector financing, reduce pressure on the public budget, deliver better *Value for Money (VfM);* perform better accountability; guarantee punctuality in the project's deadline and budget; and a greater degree of innovation. However, Brito and Silveira (2014) point out that the main reason for adopting a PPP should be its efficiency, and not only for the early resolution of infrastructure problems in exchange for long-term public debt or social pressure since in the long term the

public administration will have to pay for what was advanced to it, be it private financing or the execution of a project.

PPPs can bring benefits if designed and implemented carefully and organized. Still, they are not risk-free. According to Wang, Xiong, Wu, and Zhu (2018), PPP, as complex and long-lasting cooperation, can generate more risks than traditional contracts since this complexity, depending on the PPP arrangement, can create risks at the "project, market, and country level" (Wang *et al.*, 2018, p.304), which is why the public and private sectors must share their risks and benefits to achieve their mutual objectives.

Thus, different economic contexts may present different justifications for adopting a public-private partnership. In developed countries, the main reasons for adopting PPPs are focused on relieving fiscal pressure, efficiency (Hodge, & Greve, 2009), and political environment (Wang, Xiong, Wu & Zhu, 2018). Nevertheless, in developing countries, its adoption occurs due to "higher-level government's pressure, peer pressure, and government's broad treatment of PPP" (Wang, Xiong, Wu, & Zhu, 2018, p.307).

There is no international standard for PPPs, so the definition of what a PPP is and what it should be like varies, as each country is sovereign in regulating the details of this type of collaborative strategy. Due to the legal particularities of each country, PPPs can vary from strict contracts established under legal regulations to less bureaucratic relationships between the public and private sectors (Hodge and Greve, 2009). Hodge and Greve (2009), for example, group the types of PPP into five families: (1) institutional cooperation for joint production; (2) long-term infrastructure contracts; (3) public policy networks; (4) civil society and development; and (5) economic development of urban renewal.

The concept of PPP adopted in this paper is related to the understanding of Wang, Xiong, Wu, & Zhu (2018), which assumes PPP is a complex and long-lasting cooperation between the public and private sectors to provide infrastructure and public service in which the public and private sectors must share their risks and benefits to achieve their mutual objectives.

Despite the expectations and popularity that Public-Private Partnership strategies have in the political sphere relative to the opportunities for delivering greater Value for Money – VfM (Meyer, 2021; Hodge & Greve, 2009), public value (Bovaird, 2004) and also the significant increase in academic studies in the last 10 years on PPP (Wang, Xiong, Wu, & Zhu, 2018), it is argued that there is a need to investigate further the PPP strategy with regard to its relationship with the possibility of generating technological innovation.

One of the least discussed benefits for public administration in the literature dealing with PPP is the acquisition of know-how (Meyer, 2021) and more advanced technologies

(Hodge & Greve, 2009) through the collaborative relationship with the private partner. Within the scope of this paper, this benefit is relevant.

Another essential aspect to be considered is the call by Wang, Xiong, Wu, and Zhu (2018) for studies that seek ways to evaluate the value of a PPP, the possibility of PPP being constituted as a network, and its performance being measured according to the performance of the network. Hence, it is also worth highlighting that these networks can contribute to generating innovations; therefore, seeking the status of research on PPP technology is the first step in elucidating these issues.

Technologies and their advancement in Public Administration

The massive use and dependence on information and communication technologies (ICT) by organizations have grown over the last 20 years, sometimes to the point of absorbing the meanings of broader terms such as the term "technology," which encompasses processes, education, tools, and other aspects (Michaelis, 2023), not exclusively ICT. Therefore, it is necessary to restore the heterogeneity and breadth of the term technology so that it is possible to discuss the importance of its advancement and usefulness for public administration.

The dependence on the use of information technologies by organizations was evident during the period of health restrictions and social distancing caused by actions to combat the COVID-19 pandemic, with remote work, remote citizen service, emergency remote education, and other actions. These new developments in the face of the emergency reinforced the need for organizations (public and private) to be supported by an organizational, technological matrix composed of technological artifacts (technology) and trained human resources (knowledge) to maintain their operations in adverse situations or to generate efficiency gains with the use of technology (Weill & Ross, 2020).

Although the term technology encompasses information technology and has its value as a technological artifact, it is not the only existing technology; other types of technologies are also helpful to organizations and are not exclusively related to information technologies. According to the Michaelis Portuguese language dictionary, technology can be related to processes, education, tools, and others (Michaelis, 2023), not exclusively to ICT. The OECD (2018), in turn, defines technology "*as the state of knowledge about how to convert resources into results*" (OECD, 2018, p.117).

Considering the understanding of the OECD (2018), in which "*the novelty or improved characteristics of an innovation is generally due to the use of new or modified technology,"* the

occurrence of significant technological advancement or the implementation of new technology in a given organization can be considered an innovation.

Technological solutions and innovations have emerged to support both business and public administration management activities. Incorporating information and communication technologies into the public sector gives rise to terms such as e-Gov and electronic government (OAS, 2023).

Another point to be considered to justify the importance of technology, especially in the public sector, refers to the scenario of international tensions (ITU, 2023) and public insecurity that, at times, forces the State to improve its way of developing products and services, as well as rethink its structure to serve citizens better, making public activity increasingly innovative, transparent, and efficient (Faleiros Júnior, 2023).

This continuous improvement of the public sector in the current economic and social model occurs because the state apparatus needs to meet society's demands to provide services and infrastructure necessary for the lives of citizens. However, excessive control resulting from misinterpreting public administration principles, bureaucratic dysfunctions, and aversion to business risks can often strengthen the "bureaucratic mindset" (Meyer, 2021), bringing obstacles, slowness, and inefficiency to internal processes.

One alternative is forming partnerships between the public and private sectors (PPP), as they can expand the range of strategies that the public sector can adopt in fulfilling its responsibilities towards citizens (Meyer, 2021; Thamer & Lazzarini, 2015), as well as inserting private players as members of the public governance structure of some locations (Meyer, 2021).

Methodological Procedures

This work is based on a bibliometric study (Mukherjee *et al*., 2022) using knowledge discovery tools (Zhang *et al*., 2021) and network analysis (Wang et *al.,* 2022). 2018). The design of this exploratory research was based on the bibliometric method through data collection from journals in the Web of Science and Scopus databases. This was chosen due to its representativeness in the research theme. Quevedo-Silva, Santos, Brandão & Vils (2016) describe the bibliometric study as a quantitative approach used not only to become aware of a particular subject but also to survey trends or new themes that can be identified.

In this study, a bibliometric review with network analysis was adopted on the topic of technology in Public-Private Partnerships, following the steps used in the bibliometric study by Zhang *et al*. (2021), considering the practical and theoretical contributions of the study by

Mukherjee *et al.* (2022) and complementing the review by Wang *et al.* (2018) on an under-discussed topic, technology in PPP studies.

The evolution of methodologies for conducting bibliometric studies, as well as the availability of various digital tools, such as Gephi, Cite Space, and R-studio, make it possible to perform more in-depth quantitative research, which can present: (a) the status of contributions of the main authors, (b) most cited references, and (c) the most popular journals related to the topic under study, and a correlation can also be made between these analysis variables. Concerning public-private partnerships, the dimension of the contributions of authors and journals on the theme can be highlighted, which, in turn, will contribute to the overview of the status of this research.

In their bibliometric review, Zhang *et al.* (2021) highlights that dependence on economic development and technology is a significant factor in the research distribution for countries and institutions. When focusing on the theme of public-private partnerships in technology, there may be a similar occurrence in which the dependence on technology and the availability of economic resources in a developed country may be decisive in the concentration of research that contributes to the field and the theme.

Another aspect highlighted by the authors is the importance of identifying collaborations between countries and institutions, as this collaboration can contribute to the general development of the scientific research level on the topic (Ebadi & Schiffauerova, 2015). Thus, the relative contribution and cooperation of countries and institutions on the topic of public-private partnerships in technology can be identified. Identifying the current status of research development and evolution is made possible through the analysis of the keywords of the productions, making it possible to conduct a temporal analysis of the evolution of topics within the portfolio of scientific publications (Zhang *et al.*, 2021).

Krishen *et al.* (2021) conducted a network-based bibliometric study that consisted of identifying connections between publications, where bibliometric information from the research was used to construct the evolutionary path of keyword terms, establish a citation network, co-citation and co-authorship networks, which were analyzed using social network analysis (SNA) tools. Also, using the social network analysis methodology, Zhang et al. (2021) established a step-by-step process for obtaining results from their research data, which was adapted as shown in Figure 1.

Social network analysis allows identifying several connections to be analyzed (Zhang *et al.*, 2021), such as (i) the co-citation network in the field of the studied topic, (ii) the co-citation network of references, (iii) the network of related journals, (iv) the evolution of topics

with keywords, (v) the co-authorship network of publications, and (vi) also the bibliometric detailing of the most cited articles, all explored in this paper.

Wang *et al.* (2018), in turn, conducting a bibliometric study on Public-Private Partnerships in public administration, identified in the literature: (i) the evolution of publications over time, (ii) the leading countries, (iii) the prominent journals, (iv) citations by author, (v) the main theories used to study PPP, and (vi) the main topics formed by the keywords represented through social networks.

This study conducted a bibliometric review based on network analysis; however, the search theme focused on public-private partnerships without area restrictions. Thus, using Boolean operators OR and AND, the search string was formed as follows: Public AND Private AND Partnership for title and Technolog* for abstracts. The data collected from the Web of Science and Scopus databases was analyzed using the CiteSpace network analysis tool, with the steps shown in Table 1.

The search occurred on August 16, 2024, without any time restriction, initially selecting 9,432 documents within the theme. In this initial selection, several leading authors in the field, such as Graeme Hodge and Carsten Greve, were listed in the database. After applying the criterion for analyzing only open articles and review articles, a total of 219 papers were obtained, as per the steps in Figure 1.

Table 1

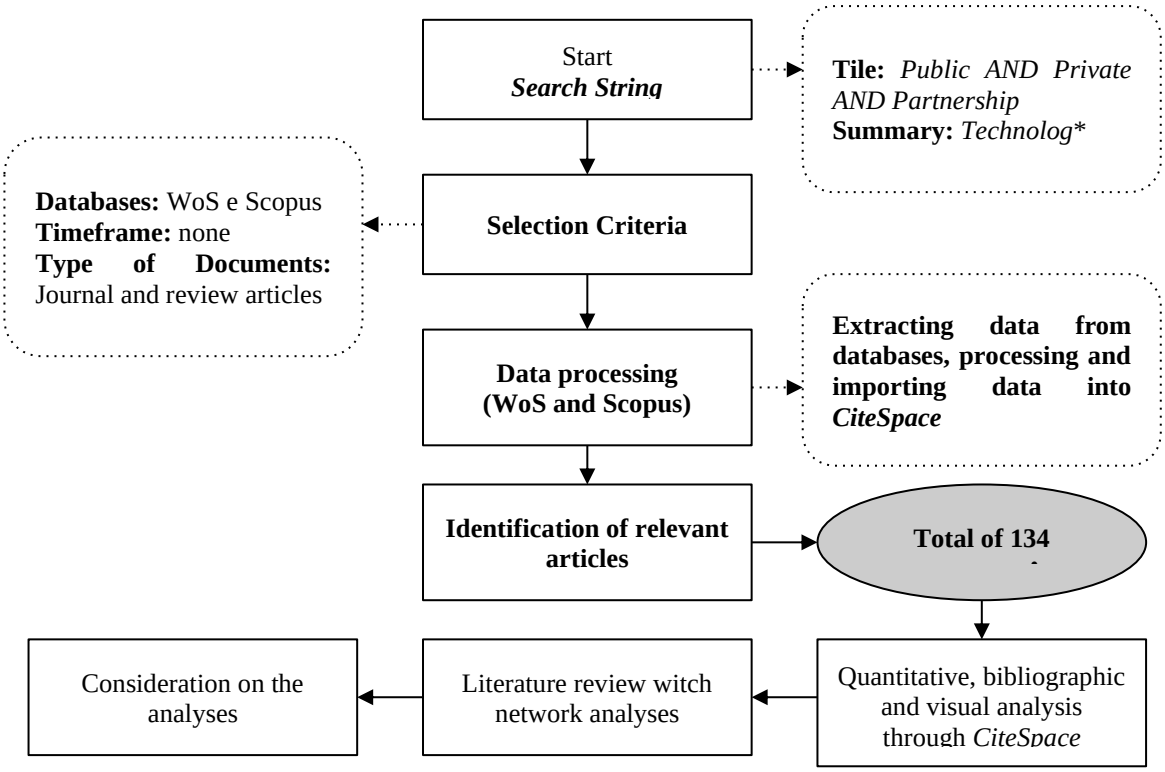
Steps for composing the research portfolio to be analyzed

Criterion	Conditions	Web of Science	Scopus
Title	Search string (for title *Public AND Private AND Partnership)*	3607	5825
Document type	Article and Review Article	2516	3882
Access	Open	1004	1366
Abstract	Refinement (string for abstract refinement *Technolog* *)	95	124
Area restriction	None	95	124
Duplicates	Deleted duplicates	0	85
Total papers selected		**134**	

Note. Source: authors, 2023

Figure 1

Bibliometric review work framework



Note. Source: adapted from Zhang *et al.* (2021).

With the universe of scientific productions, a refinement was used through the abstracts, including those with the term "technolog*" in their abstracts, leaving a total of 134 articles for the bibliometric analysis portfolio, after which it was possible to continue with the steps described in Figure 1.

This number does not make the work unfeasible, as it expresses the reality of publications in the databases applying the inclusion and exclusion criteria explained in this paper. Thus, the procedures for converting Scopus data from "CSV" to "TXT" file format were conducted, and then the data from both databases was imported into CiteSpace.

The CiteSpace software used in the study is based on Java architecture and is specific for research on bibliometric research data (Chen, Ibekwe-SanJuan & Hou, 2010). In this software, references are imported, and analyses are performed that make it possible to identify the most significant number of publications per author, co-authorship networks, co-citation, and relationships between keywords, besides enabling the representation of networks formed by interactions between those involved in a given field of research (Chen, 2006). After the analysis, it was possible to present the following results.

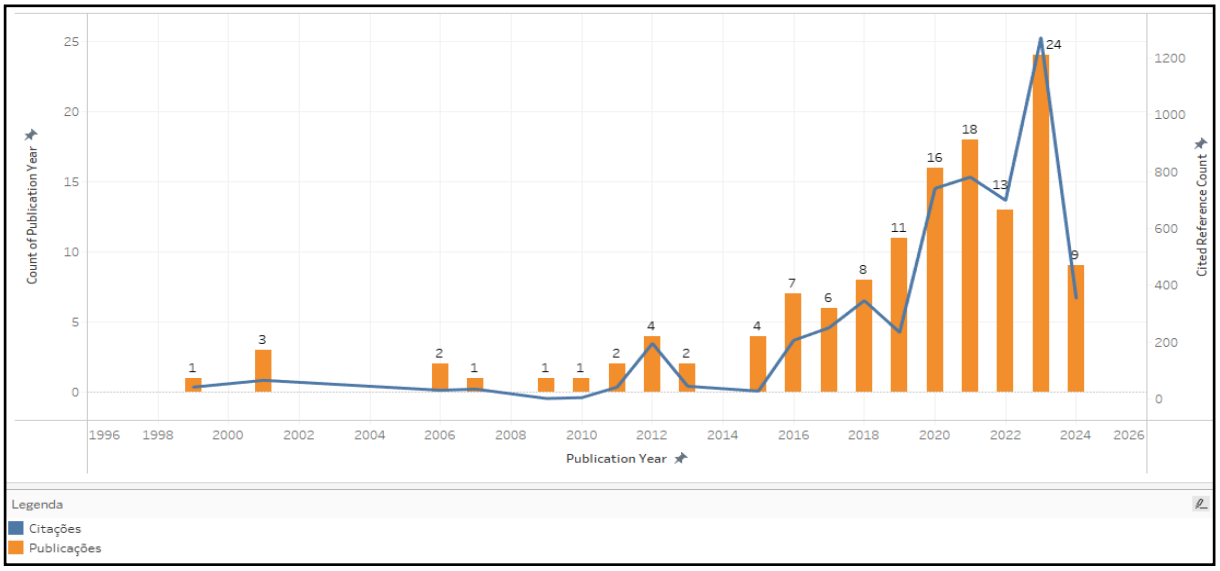
Results

Development of PPP research within technology

Initially, to identify the status of research development on public-private partnerships in technology, the publications were grouped by year of publication where it was possible to verify that the first article within the analysis parameters of this work was published in 1999, a time when collaborative PPP strategies were becoming more popular in the world through actions in the United Kingdom (Hodge & Greve, 2009). Also, there was a scalar growth until 2023, when 24 publications were obtained; Figure 2 shows this growth.

Figure 2

Number of publications per year on PPP in the context of technology



Note. Source: research data

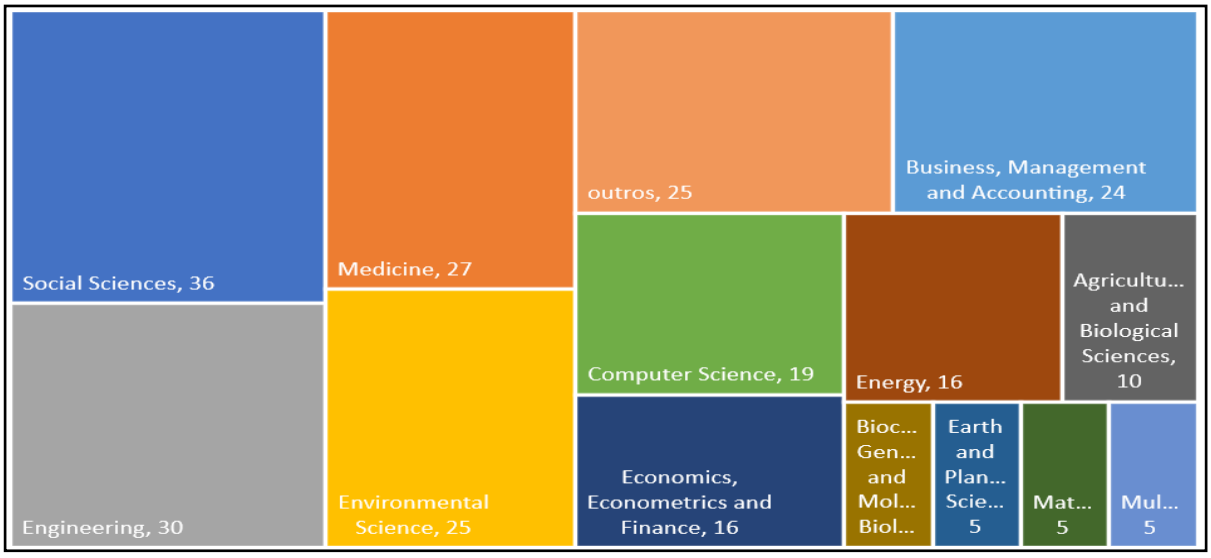
This growth demonstrates that public-private partnerships concerning technology are on the rise, indicating an estimate of continuity in the coming years. It highlights the importance academia has given to the theme in recent years. Another aspect of equal relevance is that the number of citations of the works in the portfolio also follows the trend of the number of productions, showing the interest that academia has given to the topic and may be an indication of low research saturation, that is, a broad and interesting field to be explored, despite its decrease in 2022.

Still concerning the status of research development of public-private partnerships in technology, it is worth emphasizing the research areas in which the portfolio articles are

inserted. In total, 47 areas related to the topic were identified; however, the 10 main areas represent the most significant portion of the total number of articles, as shown in Figure 3.

Figure 3

Highlighted publication areas of the analysis portfolio



Note. Source: research data

As can be seen in Figure 3, the five areas of study that most research public-private partnerships in technology are: Social Sciences, with 36 articles; Engineering, with 30 articles; Medicine, with 27 articles; Environmental Sciences, with 25 articles; and Business, Management, and Accounting, with 24 articles.

The areas of Computer Science, Economics, and Energy follow shortly after, with, respectively, 19, 16, and 16 articles each, delimiting the main areas of the research field where the theme has been addressed. It is worth noting that it was observed that some articles had more than one area assigned in their reference; thus, occasionally, the same article could be in two or more areas simultaneously. Also, the areas presented in the Scopus database were used for standardization purposes.

Relative contribution and network relationships of authors

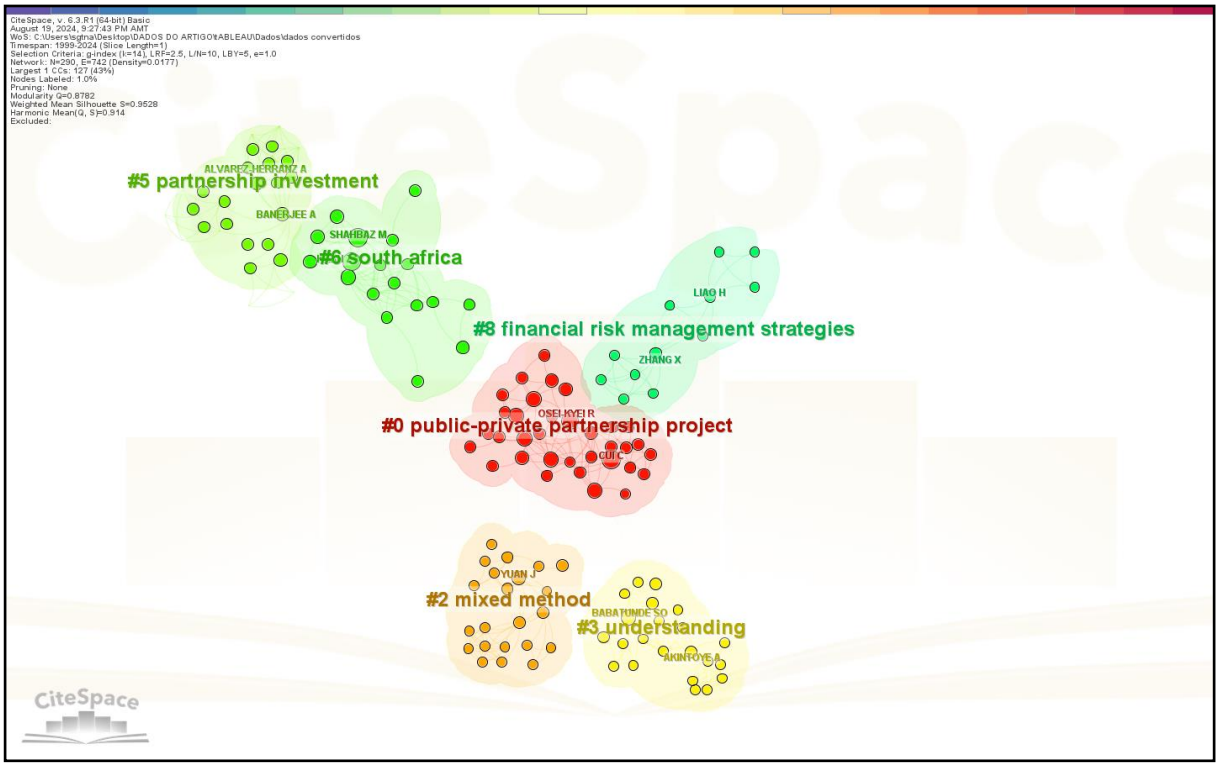
Author co-citation networks

The co-citation network can express the interrelationship between authors. Nevertheless, to deepen the relative contribution of the most representative authors in the network, the co-citations were clustered by themes developed based on the titles of the works through three Latent algorithms: Semantic Indexing (LSI), log-likelihood ratio (LLR) and

mutual information (MI), thus enabling the identification of lines of research of the most representative authors. Figure 4 expresses the topic-clustered co-citation network.

Figure 4

Topic-clustered co-citation of titles in CiteSpace



Note. Source: research data

The largest cluster (id 0) has 34 members and a silhouette value of 0.948. This cluster was called a "public-private partnership project" through the LSI and LLR algorithm and "bibliometric analysis" by MI. The most relevant author of the "id 0" cluster was Zhou (2022), with the work *Impacts of government credit on government performance of Public-Private partnership project in China*: *A WSR system theory perspective*.

The second largest cluster (id 2) has 23 members and a silhouette value of 0.941 and was labeled as "mixed method" by the LLR algorithm, "public and private partnership" by the LSI, and "Saudi Arabia" by the MI. The most relevant author of cluster "id 2" was Alonazi (2017), with the work *Exploring shared risks through public-private partnerships in public health programs: a mixed method*.

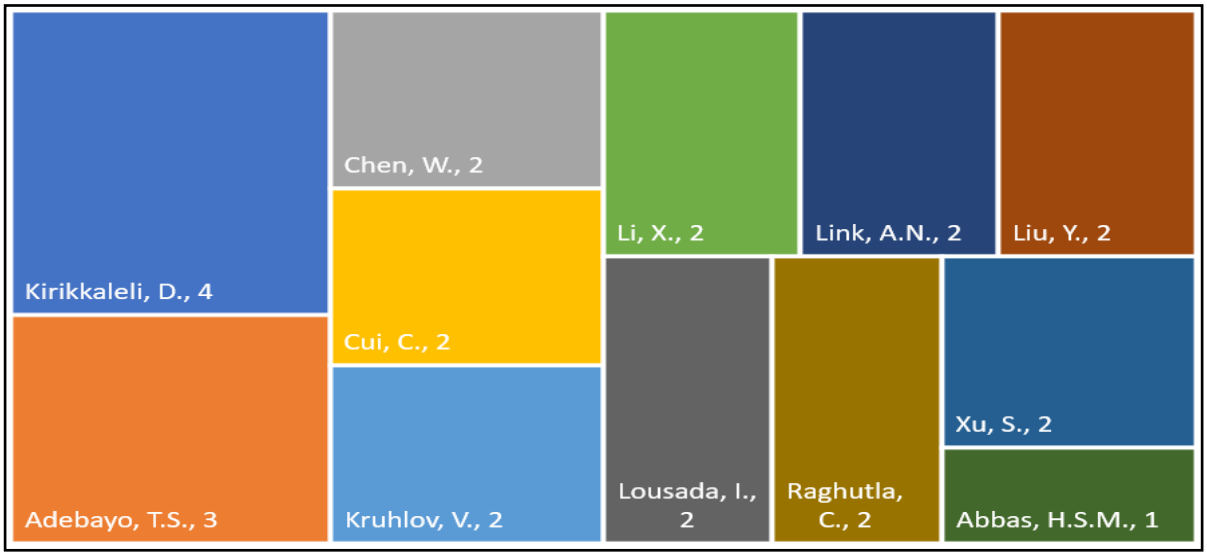
Another way to identify the authors' contribution is through the number of papers each has and, subsequently, verify the representativeness of their papers for the database under analysis. The first activity consists of a simple count of each author's works. In contrast, the

second activity is based on a comparison with the other papers in the study portfolio. Figure 5 represents the number of papers per author.

Kirikkaleli, with 4 papers, published the most on the subject during the analysis period. Prof. Dr. Dervis Kirikkaleli is affiliated with the Department of Banking and Finance, Faculty of Economics and Administrative Sciences, European University of Lefke, Northern Cyprus, Turkey. He holds a BA in Economics from the Eastern Mediterranean University (CY) and an MSc and PhD in Banking and Finance from the University of Stirling (UK). His research area is macroeconomics, environmental economics, and financial economics. He currently writes articles on the concepts of economic stability and environmental economics in emerging markets). The second author who published the most is Adebayo, with 3 papers. Prof. Dr. Tomiwa Sunday Adebayo is a Senior Instructor in the Department of Business Administration at Cyprus International University and conducts research in Environmental Economics, International Economics, Macroeconomics, and Energy Economics. The remaining authors appear in the reports with only one paper. Figure 5 represents the number of papers per author.

Figure 5

Number of papers by author highlighted by Web of Science analytics



Note. Source: research data

In the portfolio of data analyzed, there was not a large number of publications for just a few authors; what can be seen is that only two authors have more than two papers identified in the database. This indicates that no authors stand out in terms of the number of publications in the portfolio under analysis.

In this analysis, no reference authors were identified in research on PPPs within technology. It may indicate that PPPs and technologies are not themes addressed primarily by reference authors in research on public-private partnerships. Regarding reference authors such as Hodge and Greve (2009, 2017), although they sometimes address the discussion on the benefits of technological advancement provided by PPP, they do not make this discussion the foreground of their work. Thus, the term technology may not be present in the abstract, as this is an inclusion/exclusion criterion used in this review.

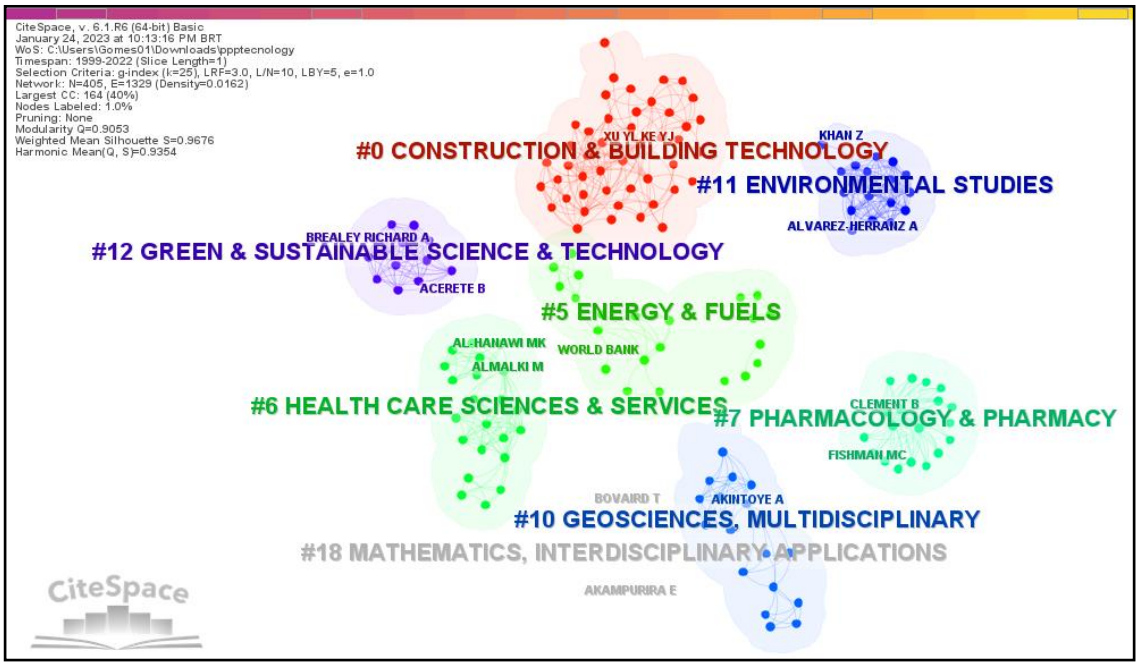
This scattering of publications may also be related to the recent interest in technology and PPP or even to the fact that studies on these topics are in their embryonic phase.

Reference co-citation networks

A reference co-citation network was created to verify the evolution of the research field and the relationship between the cited references, as shown in Figure 6. According to the network formed by the co-cited references and clustered into topics formed by their titles (Figure 6), one can see that few references in each cluster are evidenced through repeating co-citations (low density of co-citations), indicating that these few existing co-citations are the guiding principles of the themes in each cluster. In contrast, most authors are not evidenced in the network because they represent the clusters.

Figure 6

CiteSpace Co-Cited Reference Network



Note. Source: research data

Still, in Figure 6, in cluster 0, called construction and building technology, the references Xu Y. L. (2018) and Ke Y.J. (2014) are highlighted. In cluster 5, called energy and fuels, the reference Word Bank (2018) is highlighted; the other references were not labeled because, despite being visually on the network, they had a low citation count.

Besides the absolute count of citations, it is also possible to measure, using the betweenness centrality metric, in which the most critical node in the network (in this case, the reference) is responsible for most links and, consequently, the highest degree of betweenness centrality, as shown in Table 2. In this case, the betweenness centrality indicates the citation with the most significant number of connections, suggesting that it is an essential paper in the network.

Chan (2018) is at the top of references when analyzing betweenness centrality. This indicates that this reference has greater importance in the network because it mediates more co-citation links despite not being the most cited. Another reference that stands out for its degree of betweenness centrality is Al-Hanawi (2020).

Table 2

Centrality of co-cited references

Centrality	References	Cluster ID
0.11	CHAN APC, 2018	0
0.05	AL-HANAWI MK, 2020	6
0.05	AKINTOYE A, 2018	10
0.04	KE YJ, 2018	0
0.04	ALVAREZ-HERRANZ A, 2020	11

Note. Source: research data

Professor Albert Chan is Associate Director of the Research Institute for Sustainable Urban Development, Professor of Construction Engineering and Management and Professor of Construction Health and Safety, holds a Masters in Construction Management and Economics from Aston University, Birmingham and a PhD in Project Management from the University of South Australia, Australia. His research topics include construction project management. His cited work is entitled “A fuzzy model for assessing the risk exposure of procuring construction

megaprojects through public-private partnership: The case of Hong Kong-Zhuhai-Macau Bridge," which addresses risk assessment in mega PPP projects.

Prof. Dr Mohammed Al-Hanawi is an Associate Professor of Health Economics and Financing at King Abdulaziz University (Saudi Arabia) and Head of the Department of Health Services and Hospital Administration, holds a Bachelor's degree in Finance and Economics, a Master's degree in Business Administration from King Fahd University of Petroleum and Minerals, a Master's degree in Health Policy and Management from the University of Surrey and a PhD in Health Economics and Financing from the United Kingdom and his research topics are Health Economics, Health Behavior, Health Inequality, Health Policy, Economic Evaluations. His cited work is entitled "Barriers to the implementation of public-private partnerships in the healthcare sector in the Kingdom of Saudi Arabia," which deals with identifying potential barriers to implementing PPPs in the Saudi health sector.

The main intermediary citations focus on discussing risks and barriers to the implementation and success of PPPs in the health area and in megaprojects.

Journal co-citation networks.

The journal co-citation network reveals the distribution of the knowledge base within journals. Therefore, one can see that the distribution of the knowledge base highlights the 5 leading journals in the knowledge base on public-private partnerships in technology, as shown in Table 3.

i. *International Journal of Project Management* (IJPM - Online ISSN: 1873-4634 Print ISSN: 0263-7863),
ii. *J Clean Prod* (Journal of Cleaner Production - Print ISSN: 0959-6526 Online ISSN: 1879-1786),
iii. *Sustainability - Basel (eISSN:2071-1050),*
iv. *International Journal of Project Management* (IJPM - Online ISSN: 1873-4634 Print ISSN: 0263-7863),
v. *Int J Constr Eng M (International Journal of Construction Engineering and Management - Print ISSN: 1562-3599 Online ISSN: 2331-2327)*

Table 3

Co-cited journal count

Frequency	Highest citation year	Journal
19	2018	*International Journal of Project Management* (IJPM)
15	2020	Journal of Cleaner Production (JCP)
12	2020	Sustainability-Basel (S-B)
11	2018	International Journal of Project Management (IJPM)
10	2018	Journal Of Construction Engineering and Management (IJCEM)

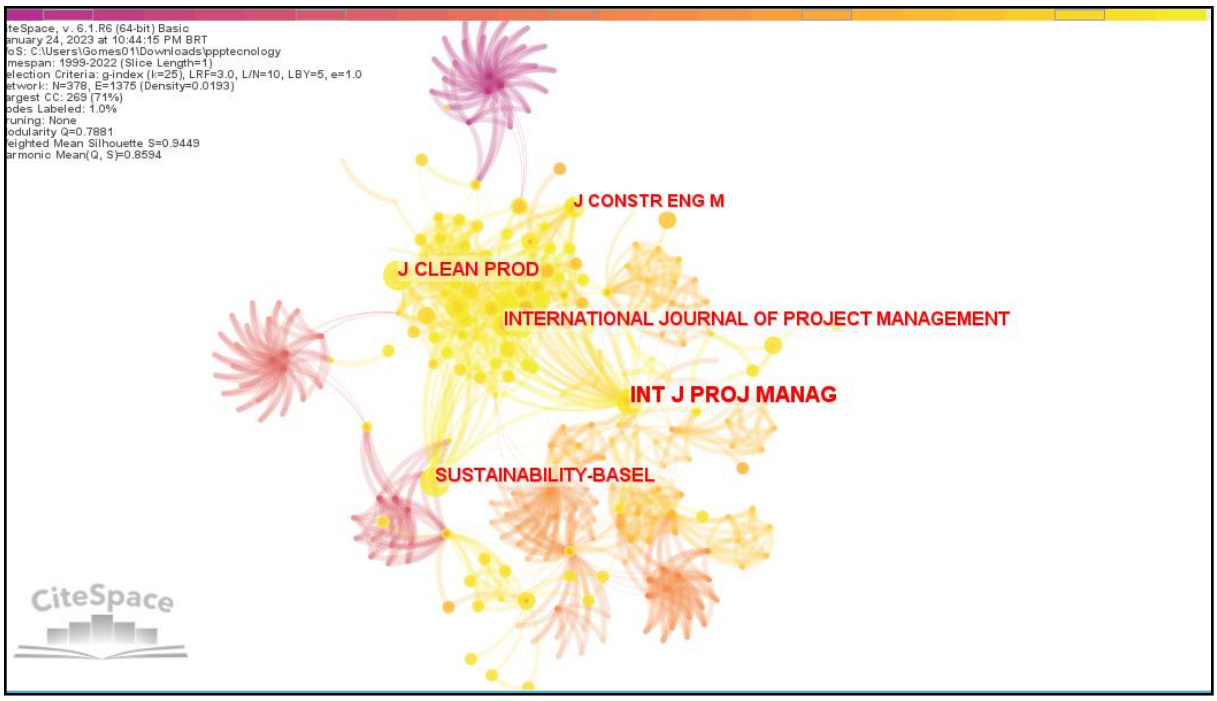
Note. Source: research data

The International Journal of Project Management appears twice in the list of top 5 journals. For this study, the sum of the two appearances is considered, totaling 30 co-citations, and it is still the journal with the most co-citations in the period.

The distribution of the knowledge base through the co-citation of journals can be identified in Figure 7 through the clustering of nodes (which represent the journals) and the links and their colors (representing co-citation). In the journal co-citation network, Figure 7, the greater the number of co-citations, the greater the number of lines that start from the main node. This feature of the network representation enables it to visually identify the distribution of the knowledge base among the journals under analysis. The colors represent the journal co-citation clusters, meaning the groups constructed from the relationship between the journals.

Figure 7

Co-cited journal network visualization through CiteSpace



Note. Source: research data

One can see that there is little variety of colors, leading to the conclusion that there is slight variation in the distribution of the knowledge base of public-private partnerships in technology since there is an intense concentration of links in yellow, red, and orange, with only 3 main concentrations in evidence followed by other sparse and not very significant nodes. This concentration of studies in a few journals can be explained through the collaborative relationship between institutions and countries, which will be addressed in the next item.

Relationship of the collaboration network of different institutions and countries

Every time there is a publication where several authors produce together, a network is formed. In this case, the authors are represented by individuals from different institutions or countries. With this network, it is possible to identify which countries are ahead in the theme of this study (PPP and technology), as well as which institutions have greater relevance to their collaboration network. It is important to emphasize that the links between authors are not static; there may be a certain mobility over time, and this study captures the relationships when the data was extracted from the database.

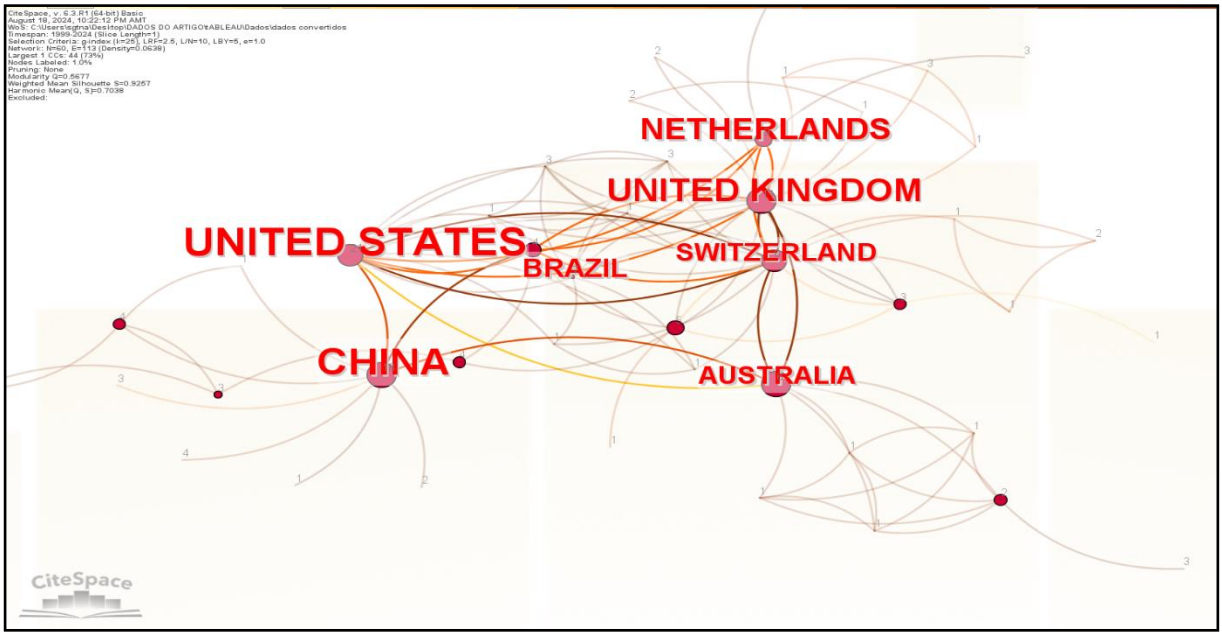
Initially, the collaboration network of countries is presented, with the United States of America (USA) (21 articles), China (18 articles), and England (11 articles) standing out. However, the Asian country has the greatest representation in the network, as shown in Figure

8. It is no coincidence that a factor that may be significantly impacting the distribution of scientific productions on PPP and technology may be the financial incentive for developing scientific studies. This statement is supported by Figure 9, which shows the funders of studies in this paper's portfolio.

Correlating Figure 8 and Figure 9, it is possible to verify that China is the country with the greatest representation to funding through the National Natural Science Foundation of China (China) with 9 funded articles, followed by the National Institutes of Health – NIH (USA), with 4 articles, and the European Commission with 3 articles.

Figure 8

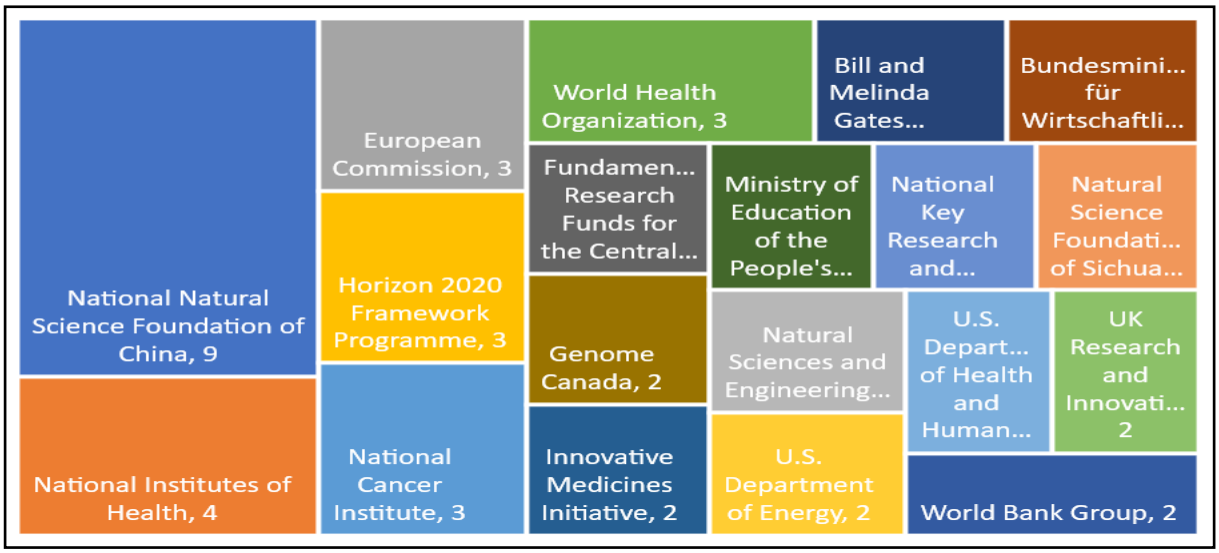
Country-based publication network generated in CiteSpace



Note. Source: research data

Figure 9

Funding institutions and the number of funded works highlighted by Web of Science

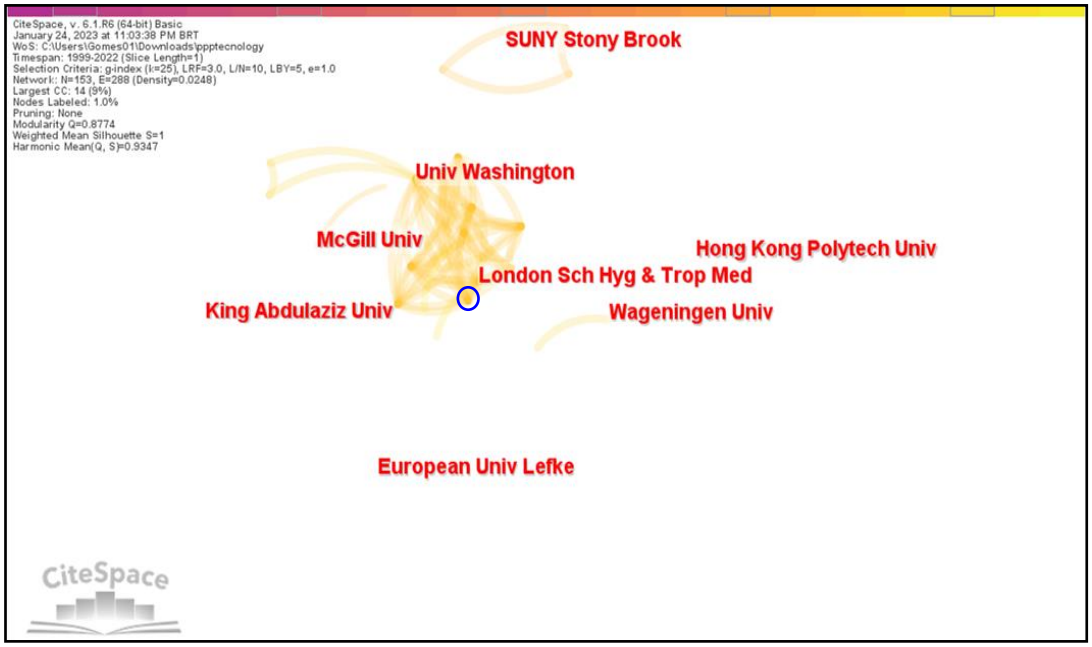


Note. Source: research data

Figure 10 presents the collaboration network between institutions. In Figure 10, it can be seen that the United Kingdom London School of Hygiene and Tropical Medicine (London University), a graduate organization that presents as a global reference for research and education in public health, is the institution with the greatest representation in the network, as well as several interactions that start from the node that represents it (London University, 2024), although it is not the most cited institution.

Figure 10

Collaboration network between institutions generated in CiteSpace



Note. Source: research data

The analysis can be complemented by the citation table shown in Table 4, presenting the 5 main institutions cited in the portfolio.

Table 4

Number of institutions mentioned, top five

Institutions	Number
LEFKE AVRUPA UNIVERSITY	4
UNIVERSITY OF CAMBRIDGE	4
LONDON SCHOOL OF HYGIENE & TROPICAL MEDICINE	3
ULUSLARARASI KIBRIS ÜNIVERSITESI	3
UNIVERSITY OF JOHANNESBURG	2

Note. Source: research data

The analysis of institutions may indicate that there is a low concentration of knowledge production in reference institutions or even in a certain geographic region. Based on the data, it is possible to verify that the institution Lefke Avrupa University (LAU), a private university

located in Lefke, Turkish Republic of Northern Cyprus, is tied for first place with four citations, together with the University of Cambridge, in the United Kingdom.

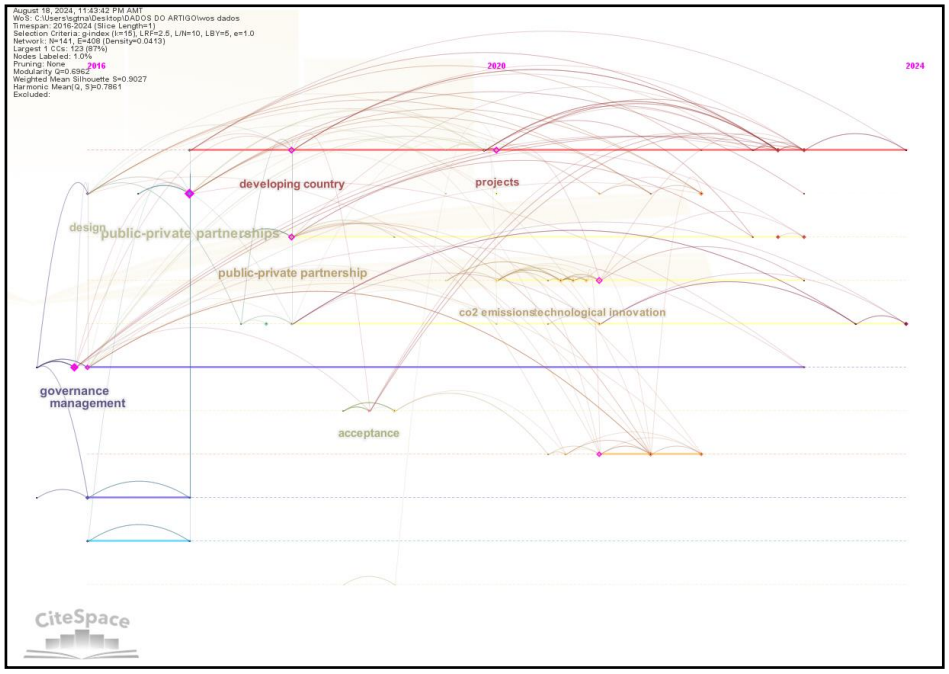
It was not possible to establish a relationship between the variables raised in the study to explain these findings for the number of co-cited institutions; however, a possible explanation for the finding may be associated with the fragmentation of the discussion of the topic due to its development being little advanced, reflecting in a low value of co-citations of institutions. A future analysis after discussions have matured may better highlight the co-citation network of institutions.

The evolution of main topics and analysis of co-occurrence of keywords.

To conduct the keyword occurrence analysis, sequences of network-shaped visualizations were created, as shown in Figure 11. In this graphical representation, the salience of the nodes and their labels in relation to the frequency of co-occurrence of the keywords makes it possible to highlight which terms were most repeated over time. Thus, Figure 11 represents the main terms related to technology in public-private partnerships, where the following stand out: (i) public-private partnership; (ii) project; (iii) innovation; (iv) China; and (v) design.

Figure 11

Keyword co-occurrence network by year generated in CiteSpace



Source: authors, 2023

An automatic time frame was created using the CiteSpace software (2001–2024) due to the lack of significance that the terms from previous years presented to the current terms. Thus, the most evident terms according to the network analysis are listed in Table 5.

By analyzing the keyword competition network together with the summary table of the most evident terms by period, some considerations can be made about the terms that are stable, increasing and decreasing. Therefore, there is an evolution of the most cited terms up to 2024. It is initially noted that the term PPP (*public and private partnership*) is the most cited, having a peak in 2018 (21 citations), a decrease in 2022 and remaining stable until 2024. Other terms that proved stable over time were: (i) country development, (ii) governance, (iii) energy, (iv) innovation, and (v) projects.

Table 5

List of topics identified in the database

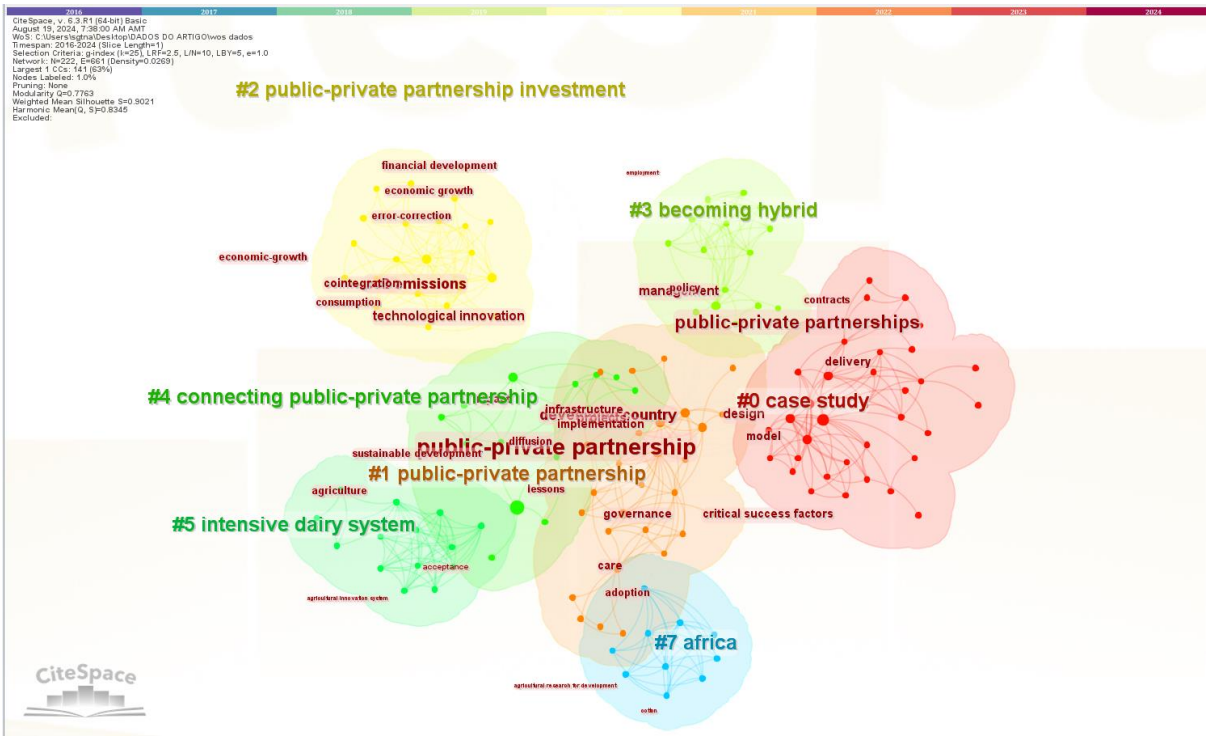
Order	Freq	Year	Keyword	Order	Freq	Year	Keyword
1st	32	2018	public-private partnership	7th	5	2016	management
2nd	5	2018	design	8th	4	2017	care
3rd	5	2018	developing country	9th	4	2021.	cointegration
4th	5	2020	co2 emissions	10th	4	2016	governance
5th	5	2018	projects	11th	3	2021	infrastructure
6th	5	2021	technological innovation	12th	3	2021	impact

Note. Source: research data

In order to complement the evolution analysis of the keyword topics of the articles listed in the portfolio under analysis, a clustering was performed, where the output of this grouping generated Figure 12.

Figure 12

Clustered keyword network based on keyword terms generated in CiteSpace



Note. Source: research data

As one can see, Figure 12 shows the occurrence of keywords from all years merged and clustered by keyword convergences. This clustering makes it possible to create common topics for occurrences that may lack evidence when analyzed in a dispersed manner. From the cluster analysis, it was possible to highlight the frequency and the most cited terms per cluster, which are respectively: cluster 0 (public-private partnerships, design, and model); cluster #1 (developing country, projects, and implementation); cluster #2# (co2 emissions, technological innovation, and cointegration); cluster #3# (management, policy, and employment); cluster #4 (public-private partnership, impact, and sustainable development) . It was found that there is a concentration of relevant terms from 2019 to 2021, probably because it was when publications on this topic gained numerical significance. Despite the different approaches to the evolution of topics in keywords, Table 6 quantitatively describes the representation of clustering by keywords.

Table 6

Keyword clustering data generated in CiteSpace

Frequency	Year	Keywords in LSI algorithm	Keywords in LRR algorithm	Keywords in MI algorithm
35	2019	*case study*	*case study*	*supervision behavior*
28	2021	*public-private partnership*	*public-private partnership*	*political cooperation*
21	2020	*energy*	*public-private partnership investment*	*environmental sustainability*
15	2017	*public-private partnership*	*becoming hybrid*	*charging system (0.09)*
14	2021	*public-private partnership*	*connecting public-private partnership*	*related form*

Note. Source: research data

Most of the highlighted topics point to research in three thematic groups of greatest relevance in the database: (i) PPPs integrated with the development of countries with a focus on solving social, economic, and environmental problems (reference keywords, public-private partnerships, cointegration, sustainable environment); (ii) investment partnerships and financing-based projects (reference keywords, investment PPPs, projects, and political cooperation); and (iii) efficiency and effectiveness of partnerships and their relevance to society (reference keywords, governance, impact, technological innovation, energy, and investment partnerships).

Thus, it can be seen that the evolution of the topics of this research, in other words, shows the complexity of the PPP theme as it covers both Macro issues, such as the economy, society, and the environment, goes through investment strategies and delves into more specific issues such as the social impact of these strategies for certain groups in society. To facilitate visualization of the propositions, Table 7 was prepared with the three possible aspects and the insights that support these propositions.

It is believed that future research on public-private partnerships and technology will continue in the dynamics of three aspects that seek to: identify society's demands and the most appropriate response strategy, with technology being a fundamental variable to be considered; identify possible sources of resources to meet society's demands; and also, what is the impact and social value of the actions to the resources invested.

The direction of future research based on the three aspects can direct the field of research on PPPs towards areas further away from pure economic efficiency, highlighting the growing importance of not quantitatively measurable issues: social issues, political issues at an international level, and the relevance of PPP projects for society. In this context, the planning and implementation of public-private partnerships, which were already considered non-elementary processes, become even more complex when inserted into the context of solving contemporary problems, which have a strong dependence on technological solutions.

Table 7

Future research development on public-private partnerships and technology

Keywords:	Thematic group	Proposals for developing research on PPP and technology, "aspects"
(reference keywords, public-private partnerships, cointegration, sustainable environment);	**(i) PPP integrated with the development of countries with a focus on solving social, economic, and environmental problems**	- demands of society and the most appropriate response strategies, with technology being a fundamental variable to be considered
(reference keywords, investment PPP, projects and political cooperation); and	**(ii) investment partnerships and financing-based projects**	- possible sources of resources to meet society's demands
(reference keywords, governance, impact, technological innovation, energies, and investment partnerships)	**(iii) efficiency and effectiveness of partnerships and their relevance to society**	- impact and social value of actions relative to the resources invested

Note. Source: research data

As practical implications of this direction, technology or frontier technological innovation cited in the World Economic Forum (WEF, 2024) report becomes a necessary ally for solving contemporary problems and one of the forces that will direct the course of countries in the coming years. Associated with the potential of the private sector (flexibility, private investment, innovation) and the public sector (economic power, public policies, institutions), frontier technologies constitute a fundamental element to formulate strategies for addressing issues that go beyond national borders.

However, there are possible obstacles to be overcome regarding the establishment of these partnership strategies, such as: political, where government policies interfere in long-term, economic projects, with emphasis to budget restrictions, especially in underdeveloped

countries; structural, related to technical capacity, experience, and learning in adopting PPP strategies.

Final remarks and future studies

Final remarks

This paper aimed to identify the status of research development on public-private partnerships in the context of technological advancement, using a bibliometric review based on network analysis as a research method. Using the Web of Science database, it was possible to obtain diverse information about the development of research within the theme and also conduct the network analysis provided by the CiteSpace software.

The results allowed us to identify **a low concentration** of publications in **a few authors and journals**, leading us to assume that research on PPP technology is a topic that is under explored and well distributed among current researchers on the subject. On the other hand, there is a concentration of the main authors in China, the United States of America, and England, respectively, in addition to a concentration of the collaboration network between countries and institutions, Asian countries, specifically China. A contributing factor to this concentration may be related to research funding in the area, as the study found that the National Natural Science Foundation of China presented the largest number of financial contributions to research identified in the analysis portfolio, a number that represents twice the number of studies of the second largest funder, the European Commission. This report deduces that where there is greater investment in research, there is also a more and more significant scientific contributions to technology within the PPP theme.

As a final part of the analysis, the evolution of the topics was presented, based on the keywords of the papers that, when clustered, showed topics that indicate that studies on PPP and technology tend to follow three paths: (i) PPP integrated with the development of countries with a focus on solving social, economic, and environmental problems; (ii) investment partnerships and projects based on financing; and (iii) efficiency and effectiveness of partnerships and their relevance to society.

The main contribution of this study was to reveal the state of the art of PPP research development in technology, pointing out the main authors, institutions, references, the distribution of the knowledge base in the world, and trend topics for future studies. The study indicates that technology in PPPs is an under-explored field and demands attention due to the importance of technology in the information age. Public organizations sometimes face bureaucratic, technical, and even financial barriers to adopting and sustaining technologies in

their core and strategic activities. A possible solution to these barriers is to seek collaborative strategies with the private sector, taking advantage of the flexibility, dynamism, and technological competitiveness of this sector to enable progress in terms of converting resources into results in the public sector.

The research results generally point to the need to expand the justification for the use of PPPs to issues that go beyond the purely economic borders of countries, with technology being a key factor in this process. The construction of the most relevant topics and terms identified in the research portfolio directs the construction of PPPs at an international level, seeking financing projects for relevant demands of society. Therefore, at the end of this research, more than answers, questions arise. They can direct future research about the role of nations and organizations in the face of demands that go beyond the borders of countries, about the need to search for projects with sustainability within their scope and the resolution of various contemporary problems (social, economic, sustainability, and energy), or even about the role of individuals as players in the process of formulating, implementing, and managing PPPs.

Finally, one can only seek ways to shed light on the benefits and risks that adopting PPPs as a strategy by the public sector for technological advancement can bring with it and, in this context, research on this topic should seek to create a robust theoretical framework that will assist in this process. However, as a way of starting a discussion focused on the context presented, the following topic will present suggestions for future studies.

Suggestions for Future Studies

In order to support future studies, it is suggested to conduct a subjective analysis of the portfolio of articles presented, with the purpose of deepening the research findings and identifying three elements: (a) the technical procedures and situations in which research on PPP and technology is being developed; (b) the theories that are used as a basis for research on PPP and also; (c) the importance of the technology context for studies on PPP, verifying whether this is a factor that contributes to achieving the objectives of PPP.

It is also suggested that future studies focus on three thematic groups: (a) PPPs integrated with the development of countries with a focus on solving social, economic, and environmental problems, seeking to shed light on the barriers and facilitators of PPPs and the role of organizations and individuals in responding to global problems, with technology being a decisive factor in this collaborative strategy; (b) investment partnerships and financing-based projects, identifying possible sources of financing for structuring PPPs, seeking how investment partnerships can contribute to the technological advancement of the public sector, or even on

how financing innovations can emerge in the structuring of PPPs with a focus on technology, considering the association of countries; and (c) PPP as a source of technological innovations and their impact on society and the public sector, seeking to identify the capacity of PPPs to generate technology and innovation, the specific impact of technology on PPP results, and also, investigate the relevance of collaborative PPP strategies for society and how to balance between the value invested (objective) and the social value generated (subjective) from the implementation of a PPP with regard to technology gains from its implementation. Despite the suggested agenda for future studies, the topic is extremely relevant and an appropriate approach to the topic can facilitate the advancement of the discussion on the topic. However, there is also a need to discuss the appropriate methodological strategies for investigating this topic, which is open to new discoveries and possibilities.

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