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Health economics in cervical cancer prevention: A bibliometric analysis of HPV vaccination cost-effectiveness in Brazil

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Abstract

Vaccination against human papillomavirus (HPV) is a key strategy for preventing cervical cancer, particularly in developing countries such as Brazil, where the disease remains a significant public health challenge. Despite well-established clinical efficacy, there is still limited systematic evidence regarding the cost-effectiveness of this intervention in the Brazilian context. This study aims to analyze the scientific production on the cost-effectiveness of HPV vaccination in cervical cancer prevention through a bibliometric approach. Searches were conducted in Scopus, Web of Science, and PubMed/MEDLINE for comparison, and the bibliometric analysis was performed using the Scopus dataset. The results indicate a significant growth in scientific production over time, structured around three main thematic areas: economic modeling, the social impact of immunization, and integration with public health policies. However, Brazilian scientific output remains limited, particularly

regarding economic evaluations within the Unified Health System (SUS), highlighting important gaps in national research. These findings reinforce the importance of strengthening local scientific production and expanding evidence on cost-effectiveness to support more efficient and sustainable public health policies. Bibliometric analysis proves to be a useful tool for identifying trends, gaps, and collaboration patterns, contributing to more informed decision-making in immunization strategies.

Keywords: Health economics; Prevention; Cervical cancer; Bibliometric analysis; Cost-effectiveness; Human papillomavirus

1. Introduction

Cervical cancer remains a significant global public health challenge, particularly in low- and middle-income countries, where it continues to be a leading cause of preventable morbidity and mortality among women (Jouya *et al.*, 2026; Momenimovahed *et al.*, 2023; World Health Organization, 2020). Persistent infection with human papillomavirus (HPV) is the main etiological factor in this type of cancer, which affects millions of people worldwide (Adebamowo *et al.*, 2025; W. Santos *et al.*, 2023). Recent advances in cervical cancer prevention include improvements in diagnosis and early detection, such as the use of artificial intelligence (Zhao *et al.*, 2024), as well as strategies like HPV DNA testing and single-visit screening, which have been shown to be effective and affordable alternatives (Tran *et al.*, 2024).

Human papillomavirus is one of the most prevalent viruses globally, with more than 200 types identified, around 14 of which are oncogenic. Types 16 and 18 are responsible for the majority of cervical cancer cases (Schiffman et al., 2016; Wu et al., 2024). In Brazil, cervical cancer continues to be one of the leading causes of cancer death among women, especially in the North and Northeast, the country's lowest-income regions, where access to health services is more restricted (Bruni *et al.*, 2023).

In addition to cervical cancer, HPV is associated with a broader spectrum of malignancies, contributing significantly to the global cancer burden. Recent estimates indicate that HPV-related cancers account for approximately 1.5 million cases and over 750,000 deaths annually worldwide (Meng *et al.,* 2025). However, the distribution of this burden is highly unequal, with higher mortality rates observed in resource-limited settings (Singh *et al.*, 2023).

Globally, it is estimated that cervical cancer causes around 570,000 new cases and 311,000 deaths annually, with most of these occurrences registered in low- and middle-income countries (Rodrigues *et al.*, 2024; World Health Organization, 2024). In Brazil, despite advances in diagnosis and treatment, the high incidence of the disease still represents a major challenge for public health, especially due to inequalities in access to prevention services and the low adherence of women to HPV screening and vaccination programs, factors that are directly influenced by the level of knowledge about the disease (Domingues *et al.*, 2020; Rodrigues *et al.*, 2024; Santos *et al.*, 2023).

Although the causal role of HPV is well established in cervical cancer, its involvement in other cancers, such as oral cavity malignancies, remains more heterogeneous. Global estimates suggest that HPV is present in approximately 25% of oral cavity squamous cell carcinoma cases, with substantial variation across regions and study designs (Iraqui *et al.*, 2025).

According to Ji *et al.* (2023), HPV vaccination is one of the most effective strategies for eliminating cervical cancer and is widely recommended by the World Health Organization (WHO) as a primary prevention measure. Since its inclusion in the Brazilian National Immunization Program (NIP) in 2014, the vaccine has proved essential in reducing HPV infections and, consequently, in reducing cases of the disease (World Health Organization, 2024). Studies indicate that expanding vaccination coverage (VC), combined with screening strategies, is fundamental to eliminating cervical cancer as a public health problem (Ji *et al.*, 2023; A. Santos *et al.*, 2025).

The Brazilian Ministry of Health incorporated the quadrivalent HPV vaccine into the NIP in 2014, initially targeting adolescent girls, with boys included in 2017. Currently, vaccination is recommended for individuals aged 9 to 14, with a simplified dosing schedule (Brasil,

2014a, 2014b). In addition to the quadrivalent vaccine used in the public system, Brazil also has access to bivalent and nine-valent formulations, the latter approved for private use (W. Santos *et al.*, 2023).

These vaccines provide protection against the most relevant HPV types, particularly types 16 and 18, which are responsible for the majority of cervical cancer cases, and have demonstrated high efficacy and long-term protection against infection and cervical lesions (W. Santos *et al.*, 2023). This evidence reinforces the importance of vaccination as a central preventive strategy, especially when associated with high coverage rates.

In this context, HPV vaccination is not only a clinically effective intervention but also a key component in discussions on cost-effectiveness, particularly in resource-constrained public health systems such as the Brazilian Unified Health System (SUS).

Vaccination coverage is considered a key indicator to monitor vaccine effectiveness. For the HPV vaccine, the NIP uses a cohort-based approach, targeting 90% coverage among adolescents. The monitoring involves calculating the cumulative sum of final doses in a given period divided by the population of the target age group (Brasil, 2024).

Human papillomavirus vaccination is widely recognized as one of the most effective strategies for reducing the incidence of cervical cancer, especially in countries with high VC. Studies such as those by Falcaro et al. (2021) have shown significant reductions in disease incidence in NIPs, and additional research confirms its herd immunity effects (Brisson *et al.*, 2020; Drolet *et al.*, 2019; Kurosawa *et al.*, 2022; Laprise *et al.*, 2019; Narasimhamurthy & Kafle, 2022).

Despite strong evidence, Brazil faces barriers such as low adherence and vaccine hesitancy among certain groups, affecting policy effectiveness (Cerqueira-Silva *et al.*, 2025; Domingues *et al.*, 2020; Moura *et al.*, 2021; W. Santos *et al.*, 2023). This scenario highlights the need for awareness campaigns and cost-effectiveness studies in resource-constrained contexts. Brazil spends 4.5% of its Gross Domestic Product on health, lower than the United Kingdom (10.3%), Canada (9.0%), and Spain (7.0%), emphasizing the need for resource optimization in the SUS (Drummond *et al.*, 2015).

Health economics provides the tools to evaluate preventive interventions such as HPV vaccination, comparing monetary costs to health outcomes and guiding resource allocation (Diaz-Obregón *et al.*, 2025; Neumann, 2017).

The aim of this study is to analyze the scientific production on the cost-effectiveness of HPV vaccination in cervical cancer prevention, with a focus on the Brazilian context. The specific objectives are:

(i) to identify publication trends over time;
(ii) to map collaboration networks among authors, institutions, and countries;
(iii) to analyze thematic patterns through keyword co-occurrence; and
(iv) to identify gaps in the literature, particularly regarding economic evaluations within the Brazilian SUS.

To address these objectives, bibliometric methods were employed as a systematic approach to analyze scientific production in this field.

Bibliometric methods have gained recognition as strategic tools to evaluate scientific production and inform public health decision-making. The journal *Vaccines* has published several bibliometric analyses focusing on vaccine research in Latin America (Parodi *et al.*, 2025), Africa (Iwu-Jaja *et al.*, 2025), and global immunization patterns (Zeng *et al.*, 2023). These studies validate the methodological relevance of bibliometric approaches in vaccine research and highlight the journal's editorial openness to this analytical perspective. Building on these precedents, the present study addresses a previously unexplored intersection: the scientific landscape of cost-effectiveness research on HPV vaccination in Brazil.

Although bibliometric studies are sometimes criticized for their descriptive nature, this study addresses a clearly defined and policy-relevant question. It examines how the cost-effectiveness of HPV vaccination has been approached in the scientific literature, with specific attention to the Brazilian context.

The main contribution of this study is to organize and interpret the existing body of research by identifying publication trends, collaboration patterns, and thematic concentrations. In doing so, it also reveals gaps in the Brazilian literature, particularly in studies focused on economic evaluation within the SUS.

By connecting these findings to the context of public health decision-making, the study provides a structured basis for understanding how scientific production can support more consistent and economically grounded vaccination policies in Brazil. This study does not propose a new method; instead, it applies established bibliometric techniques to a specific public health context, combining different analytical approaches to provide a more integrated understanding of the field.

Despite the growing global literature on HPV vaccination and its cost-effectiveness, there is still a lack of systematized and context-specific evidence on how this

topic has been developed in Brazil, particularly from a health economics perspective.

This study aims to analyze the scientific production on the cost-effectiveness of HPV vaccination in cervical cancer prevention, with a particular focus on the Brazilian context. Specifically, it seeks to identify publication trends over time, map collaboration networks, examine thematic patterns, and highlight research gaps, especially regarding economic evaluations within the SUS.

By addressing these objectives, this study contributes to a more structured understanding of how scientific evidence supports public health decision-making and resource allocation in vaccination strategies.

The remainder of this paper is structured as follows: Section 2 describes the materials and methods, including the bibliometric procedures and data analysis. Section 3 presents and discusses the main findings. Finally, Section 4 provides the conclusions, limitations, and implications for future research and public health policy.

2. Methodology

This study adopted a bibliometric approach to systematically analyze the scientific literature on the cost-effectiveness of HPV vaccination. The methodological procedure was structured in the following stages: (i) definition of research objectives; (ii) selection of databases and search strategy; (iii) data extraction and cleaning; (iv) bibliometric analysis, including co-authorship, co-citation, and keyword co-occurrence; and (v) visualization and interpretation of the results.

The search was conducted based on titles, abstracts, and keywords, with no restrictions on publication year.

Bibliometric analysis is a quantitative methodology used to understand academic literature from different perspectives and identify patterns, trends, and gaps in scientific knowledge (Aria & Cuccurullo, 2017; Y. Li *et al.*, 2025; Lu *et al.*, 2025). In addition to describing the evolution of scientific production, it allows for the identification of patterns in collaboration, thematic development, and concentration of research efforts. This is particularly relevant in the field of public health, where understanding how knowledge is produced and distributed can support more consistent and evidence-based decision-making.

In the context of this study, the use of bibliometric methods makes it possible to identify gaps in the literature on the cost-effectiveness of HPV vaccination in Brazil, as well as to examine how international research networks influence the development of this field.

Figure 1 presents an outline of the research method, covering the definition of the study approach, the development of the search strategy, data collection from the selected database, data export and processing using VOSviewer, and the subsequent bibliometric analysis. This structured workflow supports a systematic examination of the literature and enables the identification of patterns, trends, and relationships within the scientific production.

VOSviewer (version 1.6.20) is open-access software for analyzing bibliometric data from different databases, allowing the individual processing of each database (Van Eck & Waltman, 2010; Vittori *et al.*, 2022). In this study, three databases were considered: Web of Science, Scopus, and Medline/PubMed. These databases were selected due to their wide coverage, high-quality indexing, and relevance for multidisciplinary and health-related research.

Among these, Scopus stood out for encompassing the largest number of subject-related articles and for indexing all publications from Medline/PubMed and Web of Science.



Figure 1. Outline of the research method. Source: Authors' own elaboration. Original figure created by the authors.

Therefore, Scopus was selected due to its comprehensive coverage, high-quality indexing, and detailed, robust metadata—all essential for a solid bibliometric analysis (Falagas et al., 2008).

Table 1 presents the search strategy, as well as the databases consulted, and the database ultimately selected for this study.

Before conducting the analysis, the dataset underwent a data cleaning process to ensure consistency and reliability. This process included the removal of duplicate records, standardization of author names and keywords, and verification of incomplete or inconsistent entries. These procedures are essential in bibliometric studies to avoid distortions in network analysis and ensure the accuracy of the results (Lu *et al.*, 2025).

The search strategy consisted of the following terms: ("HPV vaccination" OR "human papillomavirus vaccine") AND ("cervical cancer prevention" OR "cervical cancer") AND ("cost-effectiveness" OR "economic evaluation") AND "Brazil". The term "HPV vaccination" was combined with "human papillomavirus vaccine" using the OR operator to encompass all possible terminologies related to HPV vaccination. This broadened the search scope, ensuring that studies employing different nomenclatures were included.

Additionally, the terms "cervical cancer prevention" and "cervical cancer" were combined using the OR operator to include both studies focused on the prevention of cervical cancer and those that directly addressed the relationship between HPV and the onset of cervical cancer. To identify studies related to economic analysis, the terms "cost-effectiveness" and "economic evaluation" were applied. These are the most common terms used to describe this type of research in public health, particularly in the field of health economics. Finally, the term "Brazil" was included in the search string to restrict the results to the Brazilian context, as the study primarily focuses on the national scenario.

The search strategy applied to the Scopus database returned a total of 489 articles. All retrieved documents were initially included in the analysis, as bibliometric methodology relies on the examination of large, comprehensive samples to scrutinize research patterns and networks. An automated screening stage was also carried out to remove duplicate or irrelevant documents, ensuring the completeness and quality of the data analyzed.

Co-authorship analysis was used to identify collaboration networks among researchers and institutions, highlighting patterns of scientific cooperation (Guyottot & Le Fur, 2022). Co-citation analysis allowed the identification of influential publications and the intellectual structure of the field, based on how frequently documents are cited together (Islam *et al.*, 2025). Keyword co-occurrence analysis was applied to detect thematic patterns and research trends, based on the frequency and co-presence of terms within the literature.

All valid data were processed using VOSviewer, which enabled the construction and visualization of bibliometric networks, supporting the identification of patterns and trends in the literature. This software is particularly effective for analyzing bibliometric networks, as it facilitates the identification of research groups and emerging trends (Islam *et al.*, 2025; Van Eck & Waltman, 2010).

The visualization of bibliometric networks was performed using VOSviewer, which generates maps based on nodes and links. In these maps, nodes represent elements such as authors, keywords, or publications, while links indicate relationships between them (Triantafyllopoulos *et al.*, 2024). The size of each node reflects its frequency or relevance, and the proximity between nodes indicates

Table 1. Search strategy

Database	Search date	Search string	No. of documents retrieved
Medline/PubMed	August 9, 2024	("HPV vaccination"[Title/Abstract] OR "human papillomavirus vaccine"[Title/Abstract]) AND ("cervical cancer prevention"[Title/Abstract] OR "cervical cancer"[Title/Abstract]) AND ("cost-effectiveness"[Title/Abstract] OR "economic evaluation"[Title/Abstract]) AND ("Brazil"[Title/Abstract])	5 articles
Scopus	August 9, 2024	("HPV vaccination" OR"human papillomavirus vaccine") AND ("cervical cancer prevention" OR "cervical cancer") AND ("cost-effectiveness" OR "economic evaluation") AND ("Brazil")	489 articles
Web of Science	August 9, 2024	TS=("HPV vaccination" OR "human papillomavirus vaccine") AND TS=("cervical cancer prevention" OR"cervical cancer") AND TS=("cost-effectiveness" OR "economic evaluation") AND TS=("Brazil")	9 articles

the strength of their association. This visual approach facilitates the identification of clusters, research trends, and structural patterns within the scientific literature.

The analysis of the networks allowed the identification of the main contributors in the field studied, the most researched topics, and the interconnections among different areas of investigation. In the co-authorship analysis, a distribution of authors was adopted that included at least five publications, which facilitated the identification of the most relevant researchers in the field.

For the analysis of keyword co-occurrence, the terms in the Author Keywords and Index Keywords columns were utilized. The software automatically excluded generic and irrelevant terms, thus focusing on the terms relevant to the topic. Maps of co-authorship, co-citation, and co-occurrence of keywords were generated, enabling the identification of research clusters and major scientific trends related to the cost-effectiveness of vaccination.

In addition to network visualization, a detailed quantitative data analysis was performed, which included the annual publication count and the identification of the most influential journals, institutions, and countries. Citation analysis was used to identify the most relevant articles and understand how knowledge about HPV vaccination has evolved and been influenced by public health policies, especially in the Brazilian context (Bornmann & Leydesdorff, 2014). Finally, this methodology allowed for the systematic mapping and visualization of data, highlighting key trends (Aria & Cuccurullo, 2017; Pilone et al., 2023).

Compared to traditional literature reviews and systematic reviews, bibliometric analysis provides a quantitative and visual approach to examining large volumes of scientific production (Aria & Cuccurullo, 2017; Lu *et al.*, 2025). While systematic reviews offer in-depth qualitative assessments of selected studies, bibliometric methods enable the identification of broader patterns, trends, and collaboration networks within the literature. Therefore, this approach complements other research methods by providing a comprehensive overview of the scientific landscape.

3. Results and discussion

The bibliometric analysis made it possible to map out the scenario of scientific production on the cost-effectiveness of HPV vaccination in Brazil, with a focus on its contributions to the prevention of cervical cancer. Figure 2, derived from the co-authorship analysis, illustrates the main collaboration networks between researchers investigating the cost-effectiveness of HPV vaccination in the prevention of cervical cancer.

Figure 2 shows the predominance of authors such as Jane J. Kim, Sue J. Goldie, and Mireia Diaz in the collaborative production of research on the cost-effectiveness of HPV vaccination. These authors are prominent in the field and form a well-established scientific network. Their centrality in the clusters reflects their influence in shaping collaborative research in this field.

Co-authorship analysis is particularly useful for understanding how scientific knowledge is produced collaboratively, as it reveals the structure of relationships between researchers and institutions and the dynamics of scientific cooperation (Duan, 2024; Machado *et al.*, 2023). It also allows for the identification of leading contributors and the extent of international collaboration, which is especially relevant in this field, given the observed concentration of research outside Brazil. This type of analysis helps to contextualize the position of Brazilian research within the global scientific network.

A broad and diverse network of collaborations between authors can be seen in **Figure 2** (research network), which indicates technical-scientific cooperation, an important characteristic that helps to reduce disciplinary insularity. This interdisciplinary characteristic, identified in Figure 2, demonstrates the induction of research, as it enables a broader analysis of the economic impacts of HPV vaccination. In this context, these collaborations bring together experts from different fields and cover diverse perspectives, such as health economics, epidemiology, and public health.

It should be noted that although authors such as Eduardo L. Franco are present on the map, Brazilian scientific production on the subject is still limited compared to other countries that have a longer tradition of research in the area. This indicates the need for greater national scientific involvement in order to strengthen the Brazilian evidence base and improve the robustness of public health recommendations. The thematic clusters identified in this bibliometric analysis reflect the main topics and actors influencing scientific production on the cost-effectiveness of HPV vaccination. Table 2 shows the comparison between the main clusters identified.

Each cluster maps the main contributions of the most influential authors and journals, as well as indicating the periods of greatest scientific activity in each topic. Three main themes stand out: the development of economic models, the analysis of social impact through collective immunity, and the integration of vaccination into public policies.

Figure 3 illustrates the distribution of publications on

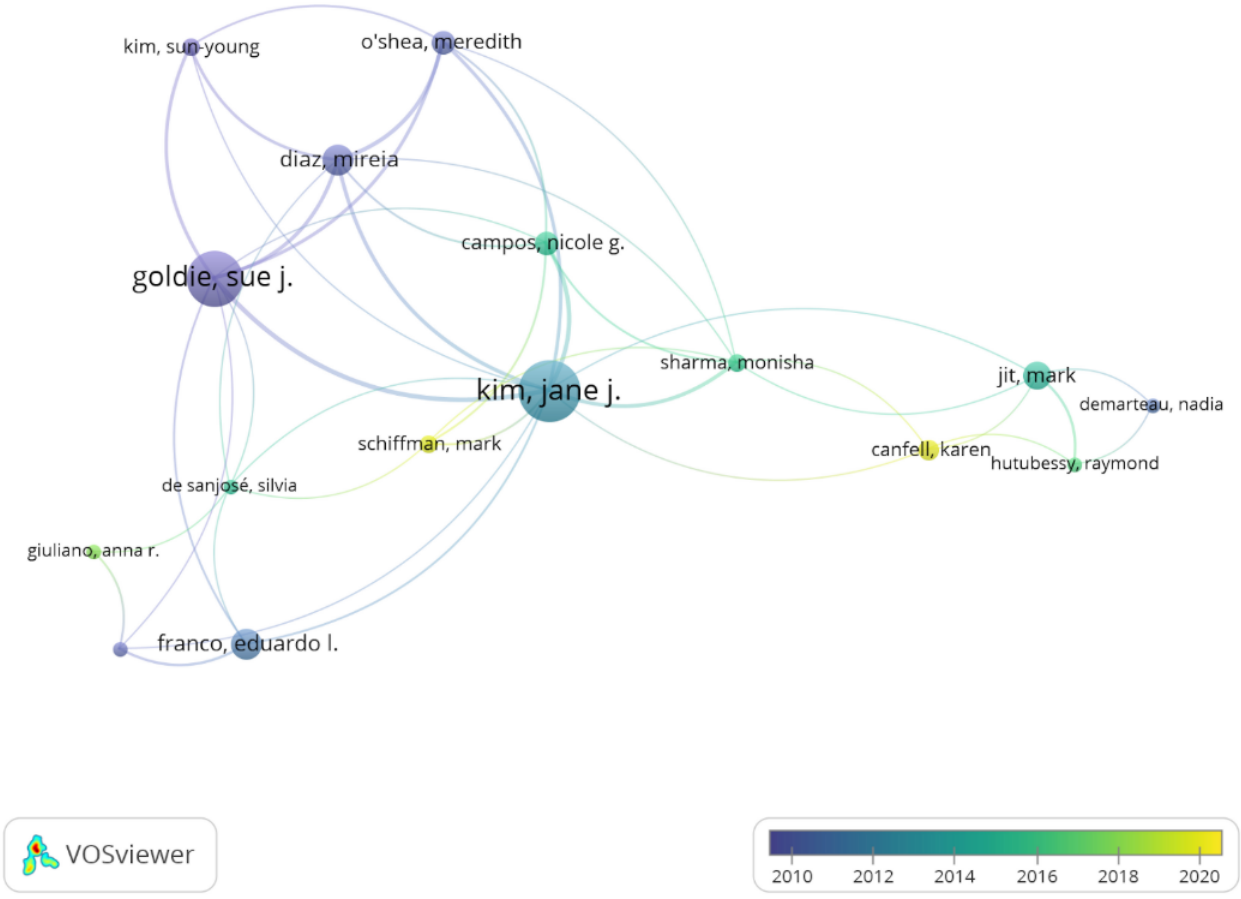


Figure 2. Co-authorship analysis: Collaboration networks on the topic. Source: Authors' own elaboration using VOSviewer. Original figure created by the authors.

Table 2. Comparison of the main clusters in scientific production on human papillomavirus vaccination

Cluster	Relevant authors	Key journals	Main contributions	Period of highest activity
Cost-effectiveness and economic modeling	Kim JJ, Goldie SJ, Diaz M.	*Vaccines*, *Jornal de Assistência Farmacêutica e Farmacoeconomia*	Development of economic models and the financial impact of vaccination	2008–2021
Collective immunity and social impact	Franco EL, Jit M.	*Human Vaccines & Immunotherapeutics*, *BMC Public Health*	Evaluation of herd immunity and strategies to increase vaccination coverage	2018–2023
Public policies and preventive health	Campos NG, Sharma M, Demarteau N.	*PLOS ONE*, *Revista Brasileira de Ginecologia*	Analysis of the integration of vaccination with public policies in the Brazilian context	2017–2024

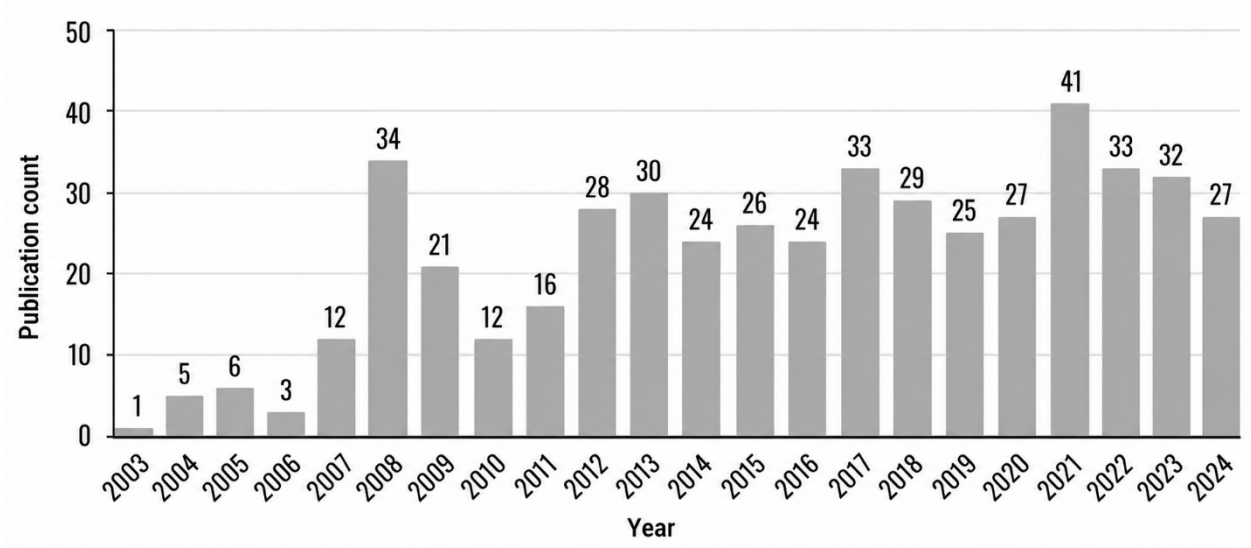


Figure 3. Annual distribution of publications on human papillomavirus vaccination and cost-effectiveness. Source: Authors' own elaboration using VOSviewer. Original figure created by the authors.

HPV vaccination and its cost-effectiveness analysis over the years (2003 to 2024). These data complement the information discussed in Table 2, which deals with the periods of greatest scientific activity.

The increase in publications may be related to the Productive Development Partnership (PDP) for the HPV vaccine in Brazil (Brasil, 2013) and the subsequent incorporation of the vaccine into the NIP, in line with the effort to produce the immunizer nationally. However, this increase in literature occurred mainly in international publications, while Brazilian academic production remained limited, highlighting the need for more focused studies in the context of the SUS.

This movement is in line with the strategies within the framework of policies around the health economic-industrial complex, which seeks to strengthen national production of strategic inputs and reduce dependence on imported products. PDPs are part of the health economy agenda by promoting sustainable and economically viable interventions in the SUS. In this case, HPV vaccination has become an important public health policy to ensure the effectiveness and sustainability of the Brazilian health system (Brasil, 2013).

By promoting the local production of vaccines through PDPs, Brazil is adopting a strategy that guarantees economic sustainability and strengthens preventive interventions in the SUS. PDPs help to promote national technological autonomy by reducing dependence on imported inputs, contributing to the analysis of SUS operating costs (Fernandes et al., 2023; Varrichio, 2017). This process becomes fundamental in a context of limited resources, as it optimizes the allocation of public resources and boosts the Health Economic-Industrial Complex (HEIC), both on the supply side, by promoting technological innovation and strengthening national production, and on the demand side, by ensuring the immunization of the Brazilian population (Silva & Silva Elias, 2017).

These discussions on PDP have not only boosted scientific publications but have also reinforced the importance of cost-effectiveness analyses. This type of economic evaluation was necessary to support the feasibility of incorporating the HPV vaccine. These studies considered the costs of implementation in the NIPs versus the long-term benefits for public health. Cost-effectiveness studies, such as those by Goldie *et al.* (2004), Fonseca et al. (2013), and Mongan *et al.* (2025), have shown that, even with high initial costs, HPV vaccination is an economically advantageous choice by preventing future costs associated with cervical cancer treatment (Rosettie *et al.*, 2021; Şahin & Karabey, 2025).

This finding is consistent with global evidence. A large-scale meta-regression analysis conducted across 195 countries demonstrates that HPV vaccination is highly cost-effective worldwide, with particularly favorable incremental cost-effectiveness ratio values in low- and middle-income settings, where the burden of cervical cancer is higher (Rosettie *et al.*, 2021).

The bibliometric analysis shows a significant increase

in publications from 2016 onwards, two years after the introduction of the HPV vaccine in the NIP in Brazil in 2014 (Domingues *et al.*, 2015). This initial growth can be attributed to the scientific community's efforts to understand the clinical and economic impacts of vaccination. It is important to note that at the end of 2012, the Brazilian Ministry of Health began investigating the cost-effectiveness of incorporating the HPV vaccine into the SUS. During this period, the criteria for the call for laboratories and the best proposal for the PDP were evaluated (Brasil, 2013).

Between 2016 and 2020, Figure 3 shows a more consistent phase of scientific production, characterized by publications on economic models and the social impacts of vaccination in Brazil, already instituted in the NIP. This finding reinforces the fact that following the introduction of HPV vaccination through the NIP in Brazil, research into cost-effectiveness in this area has been expanded in the country in view of the greater availability of cost and outcome data at a national level.

This change has the potential to encourage and induce new studies in Brazil, focused on the effectiveness and adherence to the new vaccine policy, in addition to evaluating the long-term economic benefits in the context of the SUS, especially with the expansion of HPV vaccine target populations over the years after initial incorporation in 2014. Figure 3 shows fluctuations in publication output, with particularly high numbers in 2008, 2017, 2021, and 2022, and the highest value observed in 2021. These indications suggest moments of greater academic interest, possibly driven by the discussion on the incorporation of technologies and public policies. Mapping these trends contributes to the formulation of public health policies based on scientific evidence.

Figure 4 highlights the terms "human," "female," "vaccination," and "cancer screening" as centers in the co-occurrence network, markers that reflect the focus of research on cervical cancer prevention strategies, primarily focused on women.

Figure 4 also shows the co-occurrence analysis of all the keywords proposed by the authors of the articles and by the indexing database, in this case Scopus. The term "human" indicates that most of the studies are related to humans, while the term "female" refers to research on HPV as a cause of cervical cancer, the target group for HPV vaccination to prevent this public health problem.

This emphasis is crucial to understanding how public health interventions, such as vaccinations, are aimed at preventing cervical cancer. In addition, terms such as "cost-benefit analysis," "economic evaluation," and "preventive health services" indicate that a significant part of the literature is focused on economic evaluations of preventive interventions, such as HPV vaccination.

The association of these terms with "vaccination" and "HPV" reveals that many studies analyze the financial impact and economic benefits of vaccination, mainly focused on avoided medical expenses (Nandi & Shet, 2020). In this context, HPV vaccination has emerged as an essential preventive intervention, capable of reducing the costs of future treatment and improving population health outcomes.

In the scenario of Brazilian public health, whose system is historically underfunded—with per capita spending of US$ 610 in purchasing power parity, three times lower than the average of the Organization for Economic Cooperation and Development (Couto & Rodrigues, 2022)—immunization strategies can have a direct impact on the cost-effectiveness of public health and available resources, i.e. they can produce more positive results for the health system. Among the countries recognized for having public and universal health systems, Brazil stands out for having one of the lowest shares of public spending on health in 2014, with only 46% of total health spending going to the public subsystem, while in countries such as the United Kingdom and France, this percentage was 83% and 78%, respectively (Figueiredo *et al.*, 2018).

Another highlight is the presence of terms such as "developing countries" and "health economics", which suggest the importance of discussing the cost-effectiveness of immunization in developing countries, such as Brazil. This is especially relevant given the budgetary constraints faced by these countries, considered to be low- and middle-income, which need to maximize the impact of public health policies (Kiendrébéogo *et al.*, 2023; Moura *et al.*, 2021; Rosettie *et al.,* 2021).

The cited-reference co-citation network (Figure 5) highlights that those labeled Cutts (2007), Kim (2008), Goss (2013), and Ozawa (2012) are the most cited authors together, reflecting their importance in the debate on the cost-effectiveness of HPV immunization. The centrality of Cutts (2007) and Kim (2008) suggests that their studies have provided the basis for much subsequent research and have been widely used in economic analyses of public health interventions.

These studies can also contribute to the formulation of policies and the reformulation of existing immunization programs in Brazil. They discuss and present models that take into account the economic and social particularities of developing countries. They discuss and present models that take into account the economic and social particularities

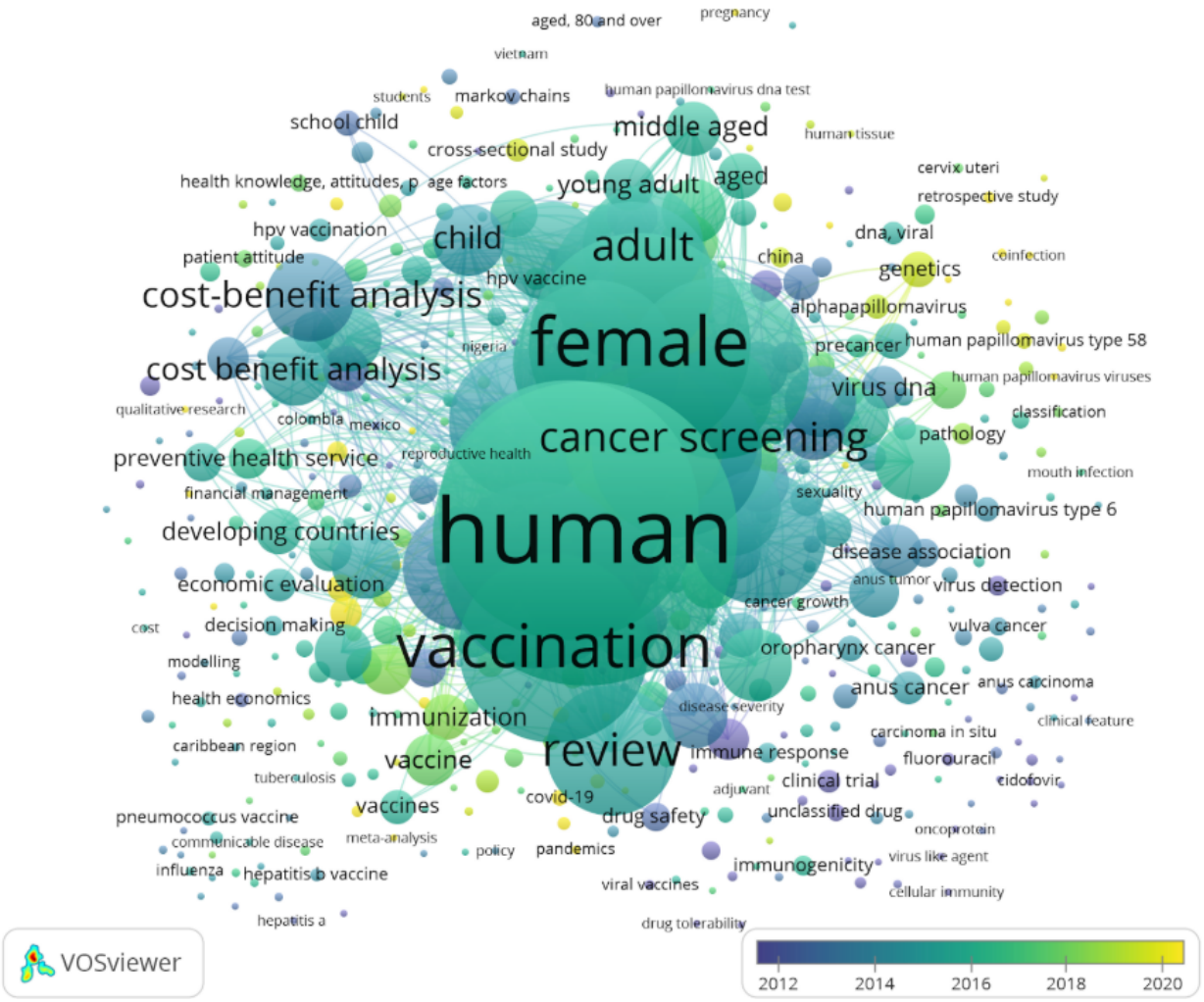


Figure 4. Analysis of co-occurrence networks of all keywords. Source: Authors' own elaboration using VOSviewer. Original figure created by the authors.

of developing countries. Cost-effectiveness analyses were also carried out, which showed that it was a viable and sustainable approach for the Brazilian health system (Brasil, 2024b).

In contexts where the efficient allocation of resources and the pursuit of equity are a challenge, cost-effectiveness analysis has been fundamental for informing decisions on public health interventions (J. Li *et al.*, 2025). Studies show that the introduction of universal HPV vaccination in Brazil is an economically viable strategy, significantly reducing the burden of disease and the costs associated with cervical cancer treatment (Novaes *et al.*, 2015). The implementation of strategies such as primary screening based on DNA-HPV tests has also proven to be cost-effective, allowing for more sensitive and accessible screening (Teixeira *et al.*, 2020). By incorporating this evidence into policy decisions, such as the adoption of the single dose, Brazil optimizes its investments, reduces spending on future treatments, and expands VC in a sustainable way (Tejada *et al.*, 2022; Campos *et al.*, 2024).

In the Brazilian context, the use of these studies as a reference has directly influenced the implementation of the HPV immunization program in the SUS. The work of Kim (2008), for example, is often cited in Brazilian studies that seek to adapt cost-effectiveness models to the local reality. These studies take into account the great socio-economic disparity and regional particularities in Brazil. These models are important because they help organize the distribution of vaccines in Brazil, which contributes to coverage targets in the country's most vulnerable areas and to reducing inequalities.

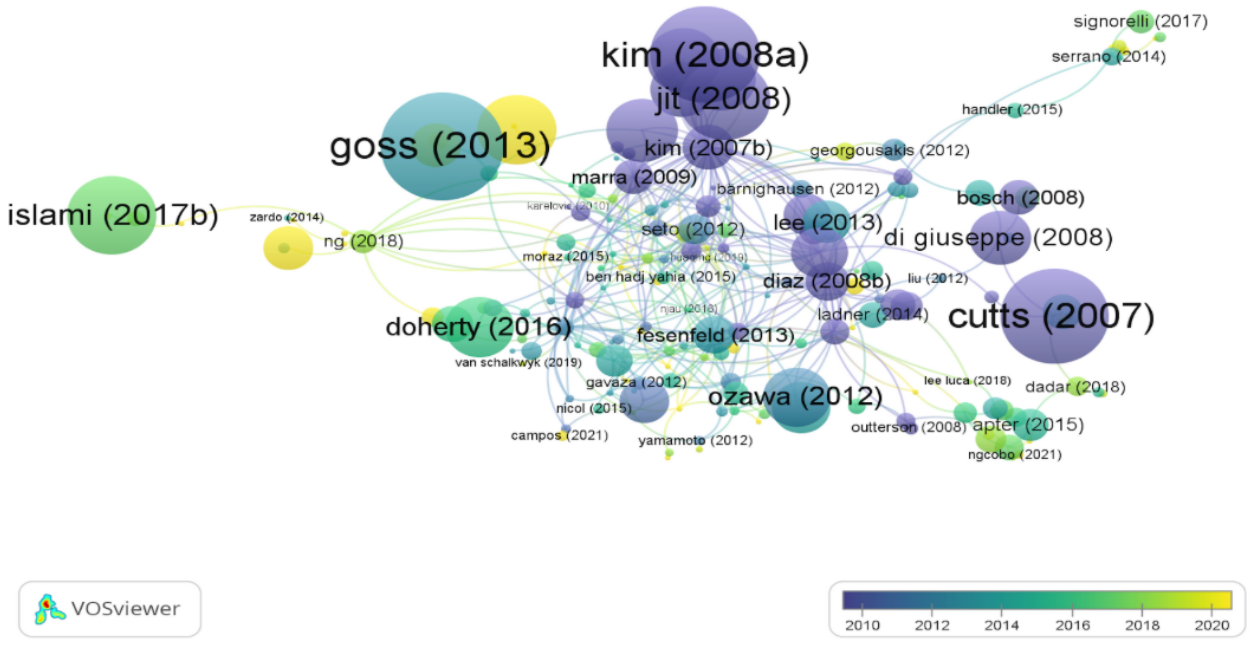


Figure 5. Citation analysis of articles. Source: Authors' own elaboration using VOSviewer. Original figure created by the authors.

The cluster of those labeled Islami (2017) and Ng (2018), more distant from the central authors, points to new approaches, such as the adaptation of economic models to specific contexts and the consideration of new epidemiological data. For Brazil, these studies are relevant because they provide up-to-date information that can help create more efficient and effective health policies, as they take into account regional specificities and the need to expand VC throughout the country.

The co-citation analysis (Figure 6) shows that *Vaccine* was the most frequently represented journal in the dataset, standing out as a global reference in publications on immunization and vaccines, including those on HPV. In the Brazilian context, this journal plays a crucial role, as its publications are widely used to support the NIP and its strategies in the response to HPV. The research evidence published by *Vaccine* supports the implementation of vaccination programs and strategies in Brazil, especially with regard to cost-effectiveness analysis in the public health system.

It should be noted that journals such as *Human Vaccines & Immunotherapeutics* and *BMC Public Health* also appear as relevant in the co-citation network. Studies in these journals provide evidence relevant to policymakers and health managers in the global context. The published studies assess the economic impact of vaccines in developing countries. In the Brazilian case, the evidence presented in this research helps to justify the continuation and expansion of vaccination programs, such as the prevention of cervical cancer through HPV immunization.

Also noteworthy is the presence of the journal *PLOS ONE*, which combines research into public health and economic evaluations. For Brazil, the publications in this journal allow for a more integrated approach and help to adapt cost-effectiveness analysis models to the country's socio-economic reality.

The *Brazilian Journal of Gynecology and Obstetrics* is also represented, although less centrally, which indicates that Brazil is already beginning to contribute to the global health discussion on the impact of HPV vaccination. However, this still modest presence signals the need for more Brazilian studies investigating the cost-effectiveness of vaccines in the local context, with the aim of strengthening public health policies with national data and evidence.

The VOSviewer tool made it possible to analyze networks of journal publications, taking into account both the number of articles and their respective citations, together with other elements present in the scope of this study. For a more in-depth understanding of this relationship, the following table shows the total number of publications and the corresponding citations (Table 3).

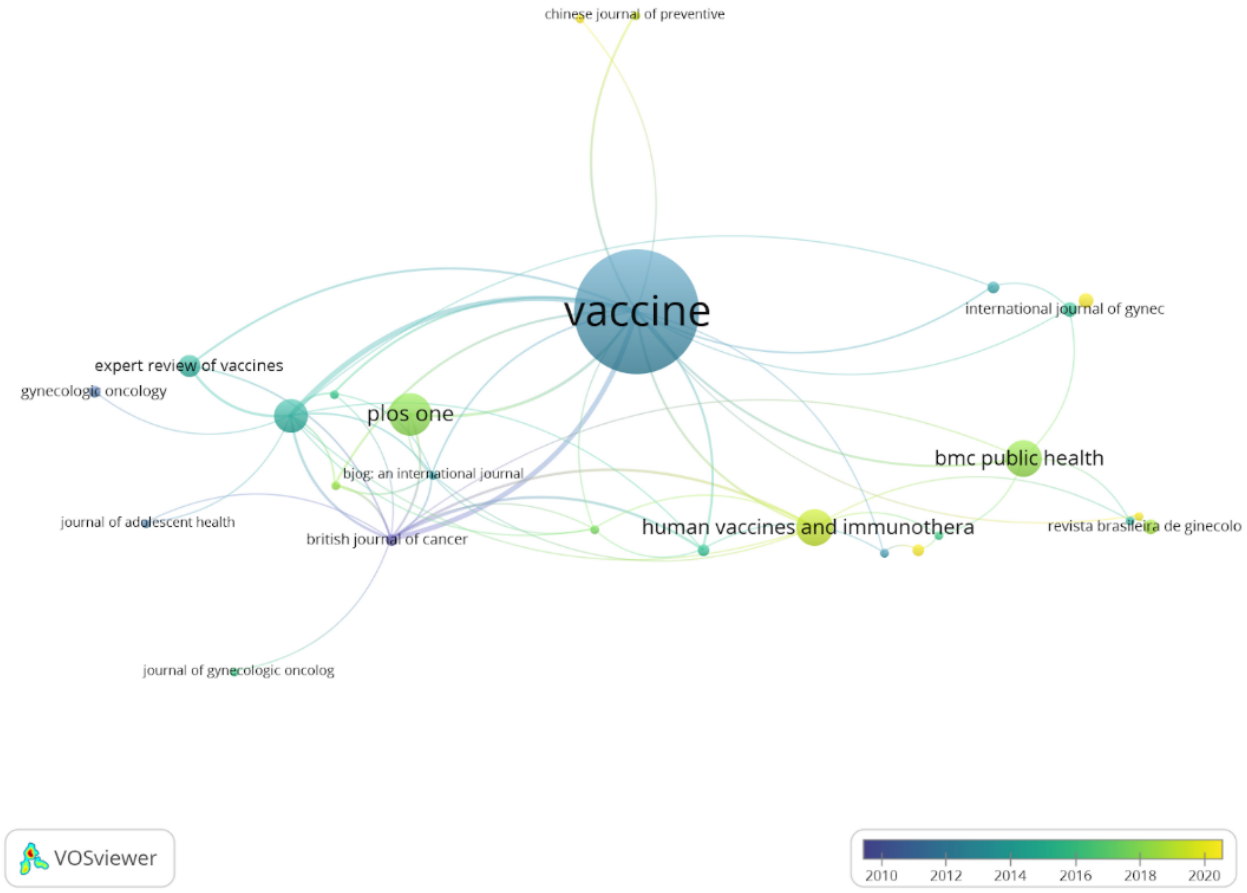


Figure 6. Analysis of journal co-citation. Source: Authors' own elaboration using VOSviewer. Original figure created by the authors.

Table 3. Main journals by number of publications and citations

Journal	Number of publications	Citations
Vaccine	42	2,601
Plos ONE	14	291
BMC Public Health	12	271
Human Vaccines and Immunotherapeutics	12	412
Pharmaco Economics	11	599
Expert Review of Vaccines	7	126
International Journal of Gynecology and Obstetrics	5	188
Brazilian Journal of Gynecology and Obstetrics	5	13

In the analysis of co-authorship between institutions (Figure 7), it can be seen that PATH in Seattle, Washington, in the United States, is one of the main research centers leading global collaborations in the field of vaccination, particularly in the area of HPV vaccines. PATH is strongly connected to institutions such as the WHO and the Harvard Global Health Institute, which play crucial roles in formulating public health policies and analyzing the cost-effectiveness of preventive interventions.

These connections indicate that these institutions play a leading role in guiding global vaccination policies, employing robust economic analysis models that influence public health decisions in several countries, including Brazil. The Pan American Health Organization (PAHO) is interconnected with several of these institutions, reflecting Latin America's active participation in HPV vaccination research (Pan American Health Organization, n.d.).

The presence of PAHO in this network is especially important for Brazil, as it indicates that public health discussions in Latin America, including HPV vaccination, are shaped by collaborations between global and regional institutions. PAHO, together with the WHO, have

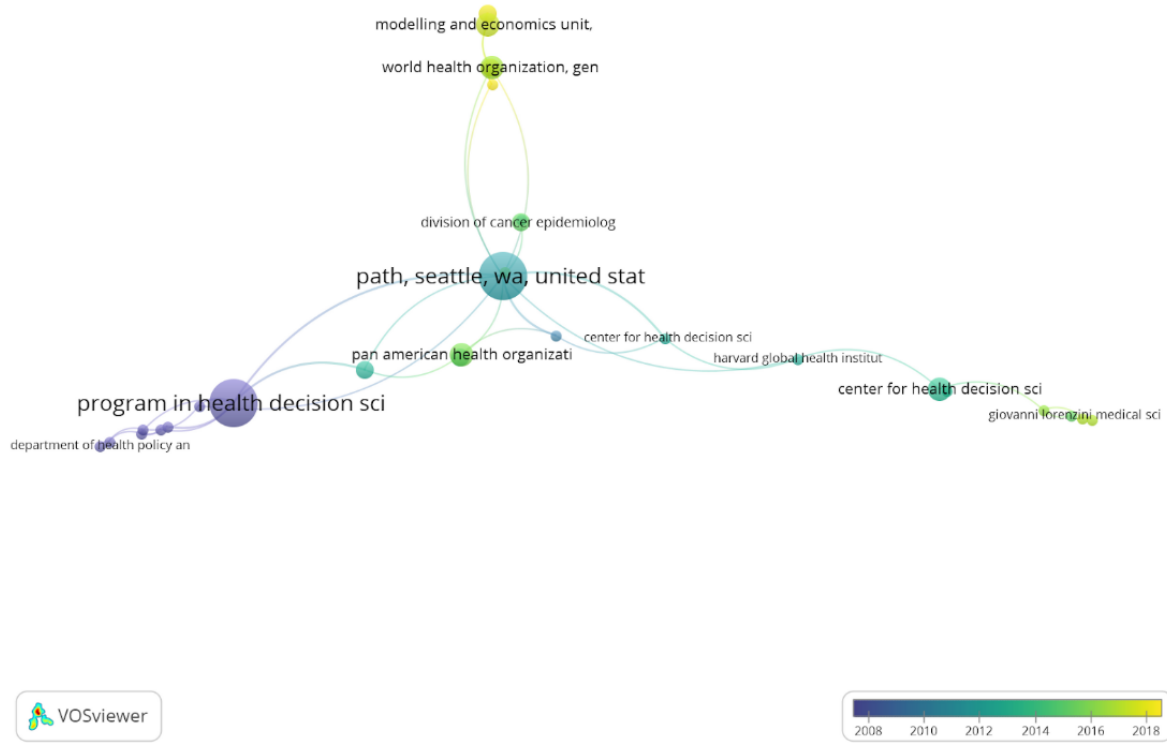


Figure 7. Analysis of co-authorship networks between institutions. Source: Authors' own elaboration using VOSviewer. Original figure created by the authors.

contributed significantly to the production of guidelines to guide immunization policies in Brazil, in which the prevention of cervical cancer through vaccination has been a public health priority—since it is on the Brazilian public health agenda through the SUS.

The centrality of programs such as the Program in Health Decision Science and other academic centers highlights the importance of combining epidemiological knowledge with economic modeling. This collaboration between public and academic health institutions is key to creating evidence-based health policies adapted to local realities. By adopting these global guidelines, Brazil can further strengthen its approach to cervical cancer prevention, based on cost-effectiveness models validated by these research institutions, which submit their studies to the rigor of peer review.

Figure 8 shows the co-authorship network between countries and reveals that the United States is at the center of international collaborations in HPV vaccination research. This reflects its dominant role in both conducting and funding global studies and its direct influence on public health policies in several countries, including Brazil. The recent changes, in 2025, in the United States policies regarding support for research and vaccination programs, and the country's withdrawal from the WHO, should have an impact on production in this country. This should be pointed out in future studies.

France, Italy, the United Kingdom, and Australia appear as relevant partners, often involved in multicenter studies that evaluate the effectiveness of vaccination policies in different economic and cultural contexts. These studies could also be valuable for the Brazilian health system, as there are similarities between the health systems of these countries and Brazil.

Emerging countries such as China and India, with large populations, have a significant share in the collaborations, reflecting their interest in adapting HPV vaccination strategies to their national realities. This is especially relevant for Brazil, which, despite having already implemented vaccination, still faces challenges in regional coverage, requiring new, less endogenous strategies to maximize the preventive impacts of the vaccine.

In the context of Latin America, Brazil's collaboration with European and Latin American countries, such as Mexico, stands out, showing its gradual inclusion in global

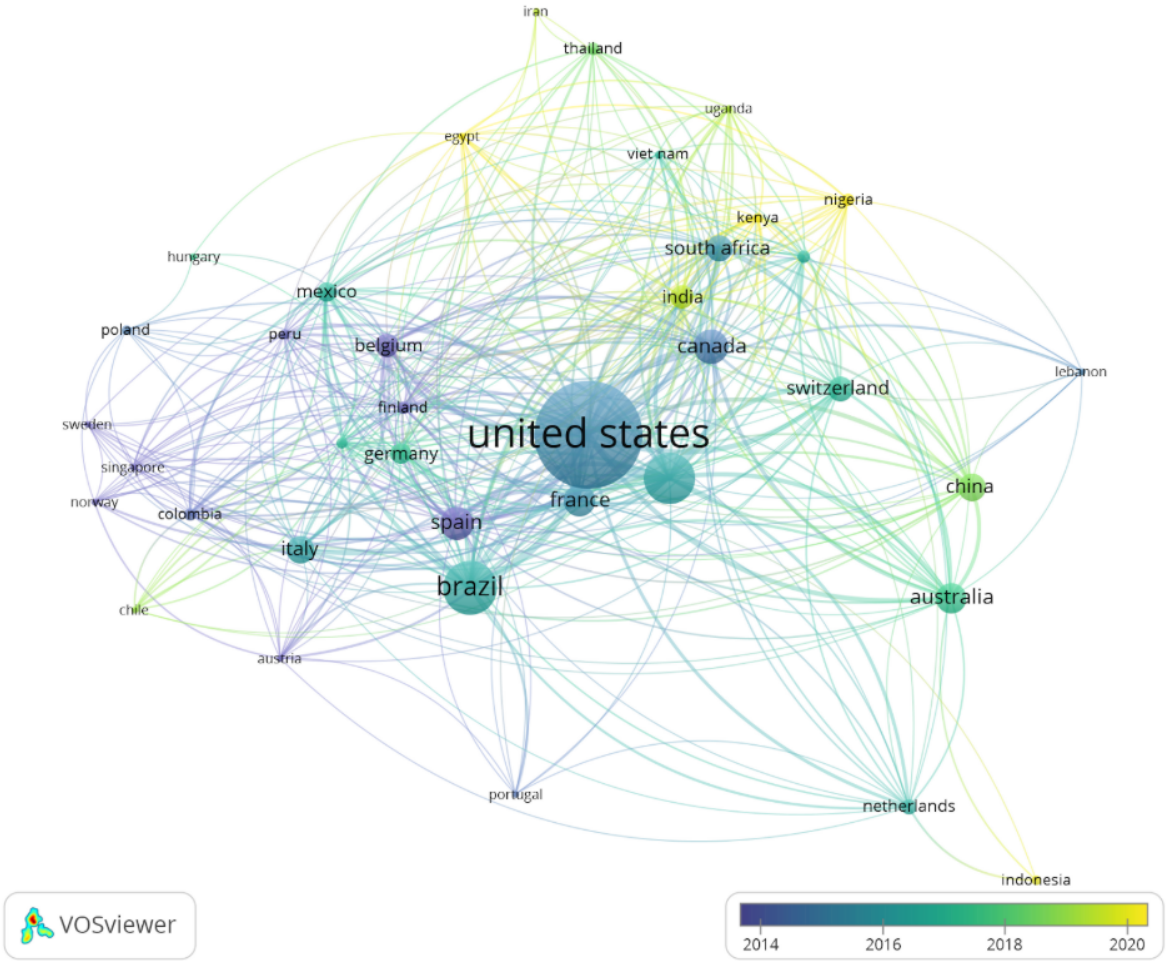


Figure 8. Analysis of co-authorship networks between countries. Source: Authors' own elaboration using VOSviewer. Original figure created by the authors.

discussions on public health, but it still has significant room to expand its scientific involvement and academic production when compared to the performance of other countries. This is essential if Brazilian studies are to advance and overcome the limitations of their borders, which often result in research with more endogenous characteristics. Sharing experiences and knowledge through international research networks can help Brazil incorporate innovations that are more beneficial to public health and its health system (Lima *et al.*, 2024). This strengthening is especially relevant in the area of cost-effectiveness studies, and is essential for improving the allocation of resources in Brazil's SUS.

The number of cervical cancer cases in Brazil, one of the highest among Latin American countries, makes HPV vaccination a crucial intervention. Brazil's alignment with global cost-effectiveness studies, as evidenced by international collaborations, reinforces the importance of optimizing public health resource allocation, balancing clinical efficacy and economic forecasts to maximize the impact of this preventive health policy.

Faced with the challenges related to low vaccine adherence and the operating costs of multi-dose schedules, the adoption of a single-dose policy in Brazil is a relevant solution. In 2024, the Ministry of Health made this change official, increasing VC and simplifying logistics, especially in vulnerable populations (Brasil, 2024b).

A meta-analysis carried out by Setiawan *et al.* (2024), involving 902,368 vaccinated women, shows that the

immunological protection provided by a single dose is comparable to that obtained with two- or three-dose regimens, especially against the most prevalent oncogenic subtypes, such as HPV 16 and 18. This scientific evidence supports the adoption of simplified regimens as a cost-effective solution, particularly in public health systems.

The PAHO reinforces that a single-dose policy can help overcome logistical and operational barriers, such as dropout before subsequent doses and vaccine hesitancy, as well as reducing transportation costs. Eliminating cervical cancer as a public health problem by 2030 is one of the targets. However, PAHO emphasizes that the success of this strategy depends on continuous monitoring and longitudinal studies to ensure that the protection provided by a single dose is durable and effective.

The bibliometric results highlight the relevance of HPV vaccination not only as an effective cervical cancer prevention strategy but also as a sustained economic investment (Cerqueira-Silva *et al.*, 2025; Kiendrébéogo *et al.*, 2023; Rosettie *et al.*, 2021). This analysis reinforces the potential of vaccination to reduce future costs in the SUS, bringing down demand for high-cost treatments and strengthening the financial sustainability of the system. In addition, the international collaboration networks and thematic clusters suggest the importance of integrating the results of this study into the formulation of public policies in Brazil, with a view to increasing equity in access to prevention and providing clear evidence to support informed decision-making specific to the Brazilian context.

This study has some limitations, including the exclusive use of the Scopus database and reliance on a single bibliometric tool, which may restrict the scope and interpretation of the findings. Future research should incorporate multiple databases and explore longitudinal approaches to better assess the long-term economic and epidemiological impacts of HPV vaccination, as well as regional inequalities in access and coverage.

4. Concluding remarks

This study aimed to analyze the scientific production on the cost-effectiveness of HPV vaccination in cervical cancer prevention, with a focus on the Brazilian context. The findings provide a comprehensive overview of the field, showing a clear increase in publication trends over time, the presence of structured international collaboration networks, and the concentration of research around key thematic areas such as economic modeling, social impact, and public health policy. In addition, the analysis identified significant gaps in Brazilian scientific production, particularly regarding economic evaluations within the SUS.

These gaps are partly associated with structural challenges, including limited investment in health economics research and the still restricted participation of Brazilian researchers in international collaboration networks. Expanding scientific cooperation and strengthening national research capacity are essential to improve the visibility and impact of Brazilian studies and to support more context-specific evidence for decision-making.

From a policy perspective, the study reinforces the importance of cost-effectiveness analysis as a key tool for guiding vaccination strategies. The recent adoption of a single-dose HPV vaccination schedule in Brazil represents an important advancement, with the potential to increase coverage, reduce operational costs, and improve the sustainability of immunization programs.

Overall, this study provides a structured and policy-relevant understanding of the scientific landscape, while emphasizing the need to strengthen national research efforts to support more effective and economically sustainable immunization policies in Brazil and other low- and middle-income settings.

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Conflict of interest

The authors declare that they have no competing interests.

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Writing–review and editing: All authors.

All authors have read and agreed to the published version of the manuscript.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data

The bibliographic metadata analyzed in this study were retrieved from Scopus. The search strategy is provided in Table 1, and the processed dataset is available from the corresponding author upon reasonable request.

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