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Geothermal Energy, Economic Growth, and Econometric Modeling: A Four-Decade Bibliometric Review

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Abstract

Geothermal energy is increasingly recognized not only as a reliable renewable resource but also as an economic asset with the potential to contribute to sustainable growth. While studies of the energy–growth nexus have employed econometric approaches for decades, research on geothermal energy within this framework remains relatively fragmented. To address this gap, this study applies a bibliometric approach to systematically map the research landscape at the intersection of geothermal energy, economic growth, and econometric analysis. Data were retrieved from the Scopus database on 24 September 2025 using a comprehensive Boolean query that integrates geothermal, economic, and econometric terms. After screening through a PRISMA process, 603 final journal articles published between 1980 and 2025 were selected. The metadata were analyzed using VOSviewer (version 1.6.20) for collaboration networks, keyword co-occurrence, and reference co-citation, CiteSpace for keyword burst detection, and Microsoft Excel for descriptive statistics and trend analysis. The results show a decisive expansion of the field after 2010, with publication outputs peaking in 2024 and citations in 2021. Asian institutions, particularly in China, dominate publication and collaboration networks, while the United States, the United Kingdom, Turkey, and Pakistan also contribute significantly. However, participation from Africa and Latin America remains limited. Thematic analysis highlights the prominence of geothermal energy, renewable energy, and sustainable development, yet reveals methodological conservatism and weak integration across econometrics, engineering, and policy perspectives.

Keywords: Bibliometric study, Geothermal energy, Economic growth, Econometric analysis.

1 | Introduction

Geothermal energy has emerged as one of the most promising renewable resources because of its ability to provide stable baseload power with minimal greenhouse gas emissions [1–3]. Unlike intermittent renewables

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such as solar and wind, geothermal systems can operate continuously, making them particularly attractive for countries seeking to decarbonize their electricity mix without compromising energy security [4–6]. The combination of reliability, low operating costs, and environmental benefits positions geothermal energy as a cornerstone of sustainable energy transitions [7], [8].

Beyond its technological appeal, geothermal energy carries significant socioeconomic potential [9], [10]. Its development can stimulate local economies through job creation, infrastructure investment, and regional development [11], [12]. In many resource-rich areas, geothermal projects also contribute to reducing dependence on fossil fuel imports and improving trade balances [13–15]. These attributes indicate that geothermal energy is not merely a clean power source but also a potential driver of inclusive and resilient economic growth [16], [17].

Understanding how geothermal energy interacts with macroeconomic indicators such as GDP growth, investment flows, and regional development has become increasingly important [18], [19]. This is especially true in the context of the Paris Agreement, net-zero targets, and the United Nations Sustainable Development Goals, which call for not only decarbonization but also equitable economic development [20], [21]. As governments and investors weigh the costs and benefits of geothermal projects, robust evidence on their economic impact is crucial for informed policy and financing decisions [22].

Over the past two decades, econometric methods have become central to analyzing energy–economy relationships [6], [23]. The literature on the energy–growth nexus has provided extensive evidence on whether energy consumption drives economic growth, whether growth stimulates energy demand, or whether both processes occur simultaneously. Within this body of work, geothermal energy has begun to attract attention as a distinct research focus, reflecting its unique characteristics among renewable resources [4], [24]. This shift signals a move from purely technical assessments toward integrated evaluations that combine engineering performance with macroeconomic outcomes.

Despite the growing recognition of geothermal energy's potential, research explicitly connecting it with economic growth through econometric approaches remains relatively scarce [25], [26]. Much of the literature continues to emphasize technological feasibility, engineering performance, or localized cost–benefit considerations, while broader macroeconomic implications are less frequently explored. This fragmentation has limited the ability of existing studies to present a holistic picture of geothermal energy's contribution to long-term development.

Methodological conservatism further constrains the field. Analyses often rely on linear regression, panel data models, and cointegration techniques, which are valuable but insufficient to capture the nonlinearity, heterogeneity, and evolving dynamics of energy–economy relationships. More advanced econometric approaches, such as nonlinear models, quantile regressions, or time–frequency analyses, remain underutilized. Without methodological innovation, important aspects of geothermal development, including its variable impacts across different regions and contexts, may remain overlooked.

Another important gap lies in the limited integration of perspectives that connect geothermal development with broader economic and policy dimensions. Studies tend to address technical, financial, or policy issues in isolation, which reduces opportunities to understand geothermal energy as both an energy resource and a catalyst for inclusive and sustainable growth. Stronger multidimensional approaches are needed to explicitly link geothermal development with macroeconomic performance and long-term development strategies.

To respond to these challenges, this study employs a bibliometric approach to systematically map the research landscape on geothermal energy, economic growth, and econometric analysis. By examining publication trends, collaboration networks, thematic structures, and intellectual foundations, the study aims to provide an integrated overview of the field. The contribution lies in identifying both the strengths and limitations of existing research and outlining opportunities for advancing methodological rigor, geographic inclusivity, and multidimensional integration in future studies.

2 | Methods

2.1 | Data Source and Search Strategy

The data for this study were retrieved from the Scopus database, which is one of the most comprehensive sources of peer-reviewed literature in energy, economics, and environmental studies. The search query was designed to capture the intersection of geothermal energy, economic development, and econometric modeling. Specifically, the query applied was: (geothermal OR "geothermal energy" OR "geothermal power" OR "geothermal resource*" OR "geothermal development" OR "geothermal industry") AND ("economic growth" OR "economic development" OR economy OR economics OR "economic impact*" OR "economic performance" OR GDP OR "macroeconomic*" OR "socioeconomic*" OR "cost-benefit" OR "economic analysis" OR "economic evaluation" OR "financial impact*" OR "regional development" OR "sustainable development") AND (econometric* OR "econometric model*" OR "econometric analysis" OR "econometric approach" OR "econometric estimation" OR "time series" OR "panel data" OR "cointegration" OR "regression analysis" OR "statistical modeling").

The search covered the period 1980–2025 in order to capture the earliest relevant studies as well as the most recent publications. Only final articles written in English were included, while other document types, such as conference proceedings, book chapters, editorials, and non-English publications, were excluded. All metadata were retrieved from Scopus on 24 September 2025, and the analyses were based on this dataset.

2.2 | Data Extraction and Screening

The initial query returned 5,400 documents across all fields. Narrowing the search to title, abstract, and keywords reduced the dataset to 876 documents. After restricting the timespan to 1980–2025, the number of records was reduced to 875, and by limiting to the English language, the dataset comprised 857 documents. Finally, restricting the search to final peer-reviewed journal articles resulted in a total of 603 documents, which formed the final dataset. The overall screening and filtering process is summarized in the PRISMA flow diagram (*Fig. 1*).

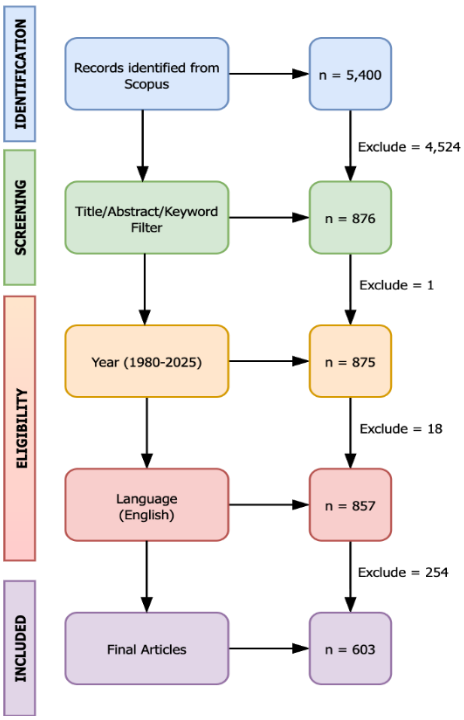

Fig. 1. PRISMA flow diagram of the document screening and selection process.

2.3 | Bibliometric Mapping

The bibliometric analysis was conducted using VOSviewer version 1.6.20, which is widely employed for visualizing bibliometric networks [27–30]. Five types of analysis were performed:

I. Co-authorship by authors–to identify key contributors and collaboration patterns.

II. Co-authorship by organizations–to examine institutional networks.

III. Co-authorship by countries–to highlight global research collaboration.

IV. Keyword co-occurrence–to map thematic clusters and research focus.

V. Reference co-citation–to identify the intellectual foundation of the field.

To capture research frontiers and temporal dynamics, CiteSpace was additionally employed for burst keyword detection. Since CiteSpace requires Web of Science formatting, the Scopus metadata were converted into a compatible template, yielding 6,010 references, of which 4,561 (75.0%) were valid for burst detection. Microsoft Excel was also used to generate descriptive statistics, publication and citation trends, and ranking tables.

2.4 | Analytical Parameters

In VOSviewer, the fractional counting method was applied, with association strength as the normalization technique. For all analyses, the minimum threshold was set to 1 document (for authors, organizations, and countries), 1 occurrence (for keywords), and 1 citation (for references), ensuring comprehensive coverage of the dataset. Only network maps were generated, while overlay and density maps were not employed. No manual cleaning of author names, organizations, or keywords was performed, meaning the analysis relied entirely on the automated normalization and clustering functions of VOSviewer.

While this approach ensures replicability, it may introduce limitations due to variations in author naming conventions or keyword usage. In addition, because the study relied exclusively on Scopus, publications indexed in other databases may have been excluded. These methodological considerations were taken into account in the interpretation of the results.

3 | Results

3.1 | Trends in Publications and Citations

This section presents the annual development of publications and citations on geothermal energy, economic growth, and econometric studies from 1981 to 2025. *Fig. 2* shows the overall trajectory of documents and citations during the entire period. Annual output remained very low through the 1980s and 1990s, with only a few papers each year, then began to rise steadily after 2010. The growth accelerated markedly during the last five years of the study period and reached a peak of 124 documents in 2024, which represents the highest annual publication count in the dataset.

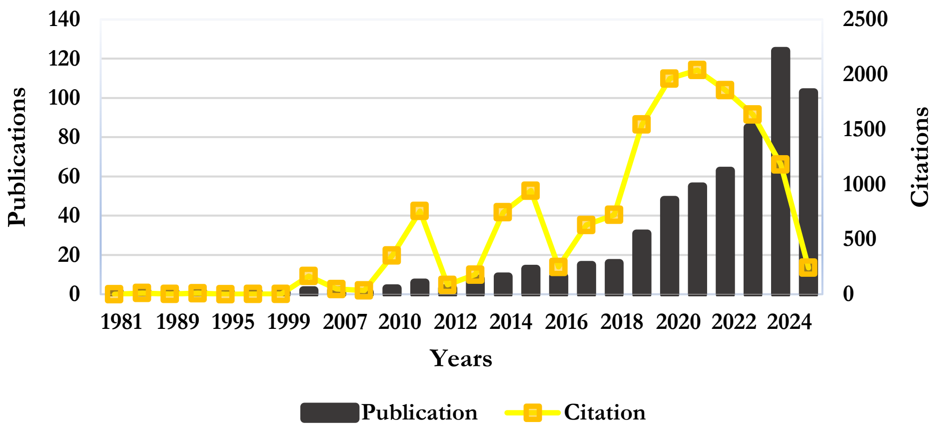

Fig. 2. Trends of publications and citations in the field of geothermal energy, economic growth, and econometric studies (1981–2025).

Citation activity followed a similar pattern, as illustrated by the citation curve in *Fig. 2*, with gradual accumulation in the early decades and a pronounced increase in the 2010s. Total annual citations climbed sharply after 2015 and culminated in 2,039 citations in 2021, the highest citation count recorded for a single publication year. Other high-impact years include 2020 with 1,963 citations and 2022 with 1,857 citations.

Table 1. The top five years by publications and citations in geothermal-related economic growth research.

Year	Doc.	Cit.	N-Doc.	N-Cit.	OS
2024	124	1182	1.000	0.580	0.790
2023	85	1634	0.683	0.801	0.742
2021	55	2039	0.439	1.000	0.720
2022	63	1857	0.504	0.911	0.707
2020	48	1963	0.382	0.963	0.672

Note: Doc = documents; Cit = citations; N-Doc/Cit = normalized values (max = 1.000); OS = Overall Score (composite index).

Further details of the most productive and most cited years are summarized in *Table 1*, which lists the top five publication years along with normalized document and citation values and the composite Overall Score. In *Table 1*, 2024 ranks first for documents (N-Doc = 1.000) and scores 0.790 on the Overall Score, while 2021 leads citations (N-Cit = 1.000) with an Overall Score of 0.720. The consistent rise in both publications and citations over the past decade highlights the sustained expansion of research linking geothermal energy to economic development using econometric methods.

3.2 | Author Collaboration Network

This section explores collaboration patterns among authors to understand the structure of scholarly networks in the field. It highlights the extent of cooperation, clustering behavior, and the formation of research communities. The analysis helps identify influential researchers and the degree of interconnectedness within the literature.

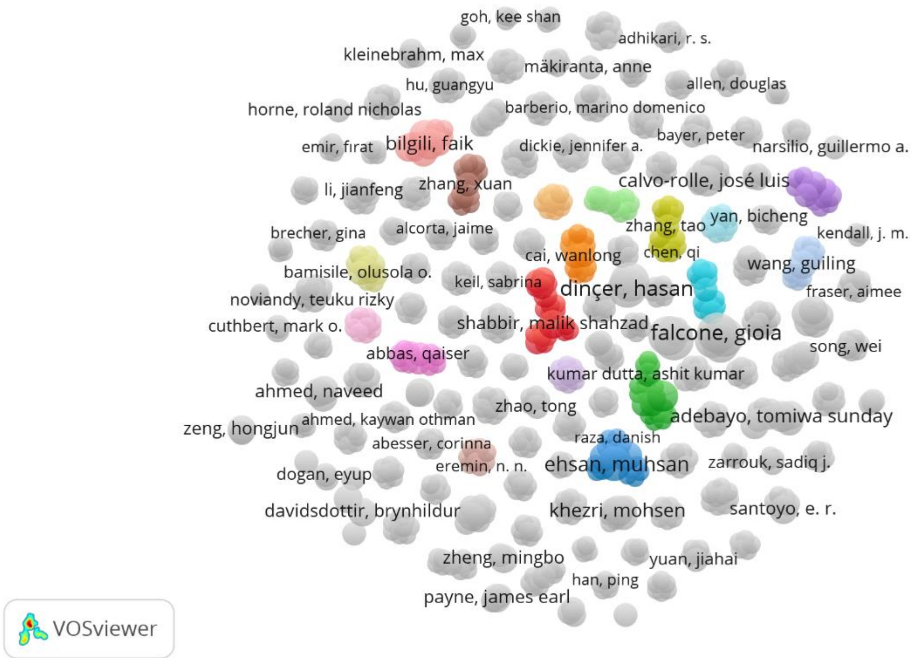

Fig. 3. Authors' Co-Authorship network in geothermal energy, economic growth, and econometric research (Items: 1000, Cluster: 143, Links: 3175, TLS: 3332).

Patterns of author collaboration in geothermal energy and economic growth research are illustrated in *Fig. 3*, which displays a co-authorship network containing 1,000 author nodes grouped into 143 clusters and connected by 3,175 links with a TLS of 3,332. These clusters represent groups of authors who collaborate more frequently with each other.

Table 2. Leading authors by publications, citations, and TLS.

Author	Doc.	Cit.	TLS.	N-Doc.	N-Cit.	N-TLS.	OS	Cluster
Falcone, Gioia	8	136	19	1.000	0.285	0.826	0.704	111
Abdul-Rahim, A. S.	7	340	11	0.857	0.711	0.478	0.682	95
Brown, Christopher S.	7	127	18	0.857	0.266	0.783	0.635	111
Dinçer, Hasan	7	308	9	0.857	0.644	0.391	0.631	122
Yüksel, Serhat	7	308	9	0.857	0.644	0.391	0.631	122

Note: Doc = documents; Cit = citations; N-Doc/Cit = normalized values (max = 1.000); OS = Overall Score (composite index).

Details of the leading contributors are summarized in *Table 2*, which also shows the cluster assignment of each author. Gioia Falcone (cluster 111) ranks first with eight documents, 136 citations, and a TLS of 19. A. S. Abdul-Rahim (cluster 95) follows with seven documents and 340 citations, achieving a TLS of 11. Other notable authors include Christopher S. Brown (cluster 111) with seven documents and 127 citations, Hasan Dinçer (cluster 122) with seven documents and 308 citations, and Serhat Yüksel (cluster 122) with seven documents and 308 citations. Normalized indicators in *Table 2* show that Falcone holds the maximum document score (N-Doc = 1.000), while Abdul-Rahim records the highest normalized citation score (N-Cit = 0.711).

Overall, the author collaboration network demonstrates a broad yet moderately interconnected scholarly community. The existence of many clusters indicates a mix of tight regional groups and cross-border research partnerships within geothermal-econometric studies.

3.3 | Institutional Collaboration Network

This section investigates institutional collaboration to reveal how organizations contribute to and shape the research landscape. It focuses on inter-institutional linkages, research clusters, and collaborative intensity. The findings provide insights into the role of leading universities and research centers in advancing the field.

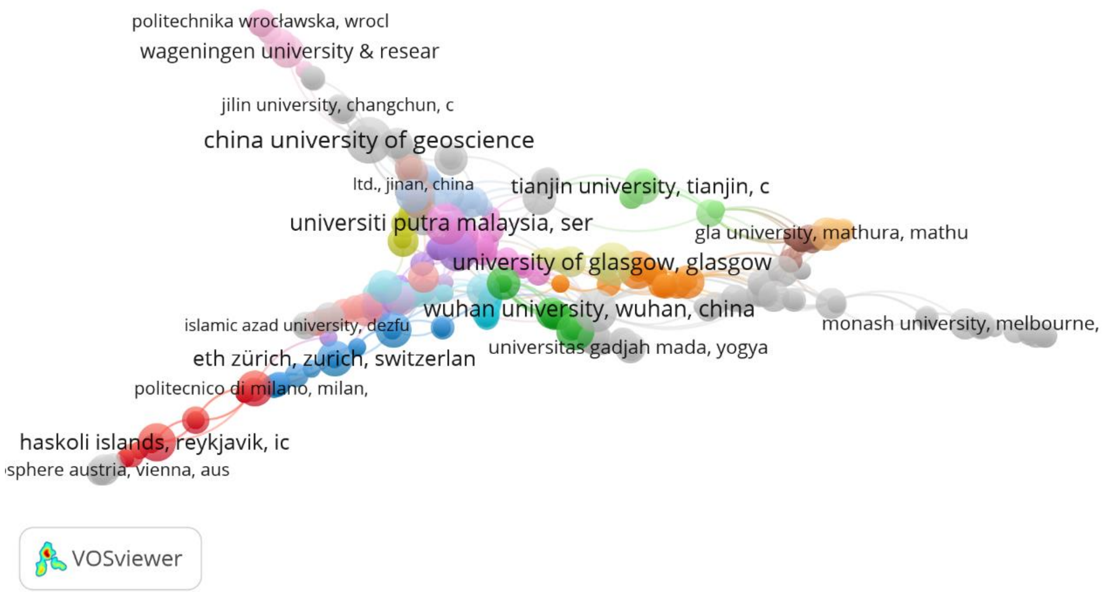

Fig. 4. Institutional Co-Authorship network on geothermal energy, economic growth, and econometric studies (Item: 570, Cluster: 34, Links: 1524, TLS: 1585).

The inter-organizational co-authorship network is shown in *Fig. 4*, encompassing 570 institutional items grouped into 34 clusters and connected through 1,524 links with a TLS of 1,585. These clusters represent groups of institutions that collaborate more frequently with each other, indicating the presence of regional or thematic research communities.

Table 3. Top contributing organizations by publications, citations, and collaboration strength.

Organization	Doc.	Cit.	TLS.	N-Doc.	N-Cit.	N-TLS.	OS	Cluster
Wuhan University	10	259	36	0.818	0.542	1.000	0.787	20
China University of Geosciences (Wuhan)	12	160	30	1.000	0.335	0.833	0.723	25
Universiti Putra Malaysia	9	355	22	0.727	0.743	0.611	0.694	9
Xi'an Jiaotong University	8	325	22	0.636	0.680	0.611	0.642	5
Al-Mustaqbal University	5	71	34	0.364	0.149	0.944	0.486	16

Note: Doc = documents; Cit = citations; N-Doc/Cit = normalized values (max = 1.000); OS = Overall Score (composite index).

Key contributing organizations are presented in *Table 3*, which also reports the cluster assignment for each institution. China University of Geosciences (Wuhan) (cluster 25) leads publication output with 12 documents and a normalized document score (N-Doc) of 1.000. Wuhan University (cluster 20) records the highest TLS of 36 and an overall score of 0.787, reflecting its strong collaborative role within the network. Universiti Putra Malaysia (cluster 9) follows with nine documents and 355 citations, achieving a high normalized citation score of 0.743. Other active institutions include Xi'an Jiaotong University (cluster 5) and Al-Mustaqbal University (cluster 16), which also demonstrate notable collaboration strength.

Overall, the institutional collaboration network reveals a widely distributed yet interconnected research landscape. The presence of 34 clusters highlights both regional concentration and cross-institutional partnerships, underscoring the global reach of geothermal-econometric studies.

3.4 | International Collaboration by Country

This section analyzes international collaboration patterns across countries engaged in geothermal-econometric research. It aims to uncover global research networks, regional partnerships, and dominant contributors. The results illustrate the geographic distribution and interconnectedness of scholarly activity worldwide.

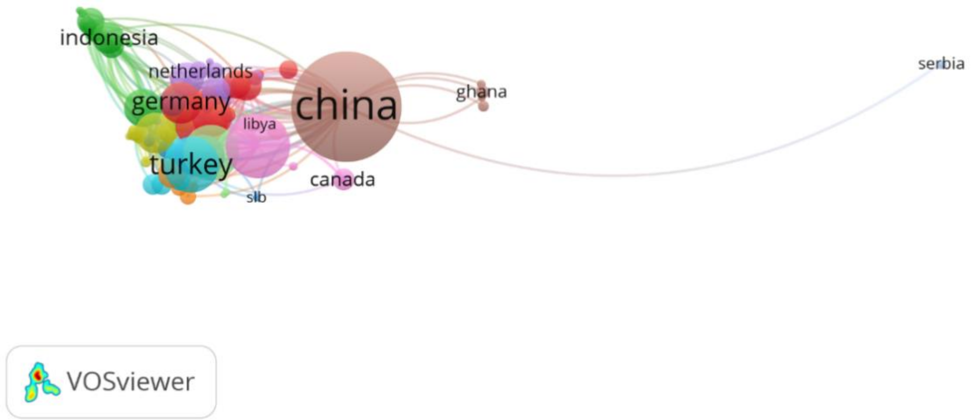

Fig. 5. International Co-Authorship network of countries in geothermal energy and economic growth research (Items: 82, Cluster: 12, Links: 444, TLS: 730).

The global co-authorship network of countries engaged in geothermal energy and economic growth research is illustrated in *Fig. 5*. The network includes 82 country nodes organized into 12 clusters and connected by 444 links with a TLS of 730. These clusters indicate groups of countries with more frequent collaborative relationships.

Table 4. Top countries by publications, citations, and TLS.

Countries	Doc.	Cit.	TLS.	N-Doc.	N-Cit.	N-TLS.	OS	Cluster
China	186	4773	162	1.000	1.000	1.000	1.000	8
United States	69	2624	59	0.368	0.550	0.364	0.427	9
United Kingdom	54	1935	64	0.286	0.405	0.395	0.362	11
Turkey	54	1945	61	0.286	0.408	0.377	0.357	6
Pakistan	33	1223	77	0.173	0.256	0.475	0.302	3

Note: Doc = documents; Cit = citations; N-Doc/Cit = normalized values (max = 1.000); OS = Overall Score (composite index).

Details of the most active countries are provided in *Table 4*, which also lists each country's cluster membership. China (cluster 8) ranks first with 186 documents, 4,773 citations, and a TLS of 162, achieving the maximum normalized scores for documents, citations, and TLS (all N values = 1.000). The United States (cluster 9) follows with 69 documents, 2,624 citations, and a TLS of 59. Other key contributors include the United Kingdom (cluster 11) with 54 documents and 1,935 citations, Turkey (cluster 6) with 54 documents and 1,945 citations, and Pakistan (cluster 3) with 33 documents and 1,223 citations.

Overall, the country-level collaboration network demonstrates a wide geographic spread with China occupying a central and highly connected position. The presence of multiple clusters shows that regional groups, such as Asian and European collaborations, play a significant role in shaping the international research landscape on geothermal energy and economic growth.

3.5 | Author Keyword Co-Occurrence Analysis

This section examines the co-occurrence of author keywords to identify major research themes and conceptual structures. It highlights dominant topics, emerging trends, and the multidisciplinary nature of the field. The analysis provides insight into how research priorities have evolved.

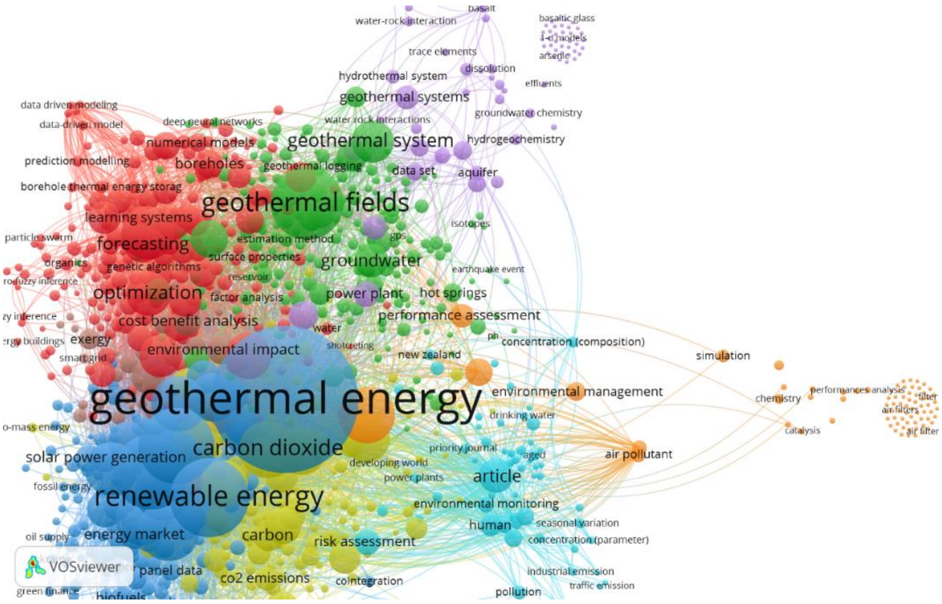

Fig. 6. Author keyword co-occurrence network in geothermal energy, economic growth, and econometric studies (Items: 1000, Cluster: 8, Links: 41676, TLS: 60398).

The co-occurrence network of author keywords is presented in *Fig. 6*, comprising 1,000 keyword items grouped into 8 clusters, connected by 41,676 links with a TLS of 60,398. These clusters represent thematic groupings of frequently associated research topics within geothermal energy, economic growth, and econometric studies.

Table 5. Top 10 author keywords.

Keyword	Occurrences	Cluster
Geothermal energy	302	3
Renewable energy	111	3
Alternative energy	104	3
Renewable energies	102	3
Geothermal fields	99	2
Energy policy	75	3
Carbon dioxide	67	4
Investments	67	3
Energy utilization	64	3
Sustainable development	64	7

The most frequent keywords are summarized in *Table 5*, which lists the top ten author keywords and their cluster assignments. The keyword "Geothermal Energy" (cluster 3) leads with 302 occurrences, followed by "Renewable Energy" (cluster 3, 111 occurrences), "Alternative Energy" (cluster 3, 104 occurrences), "Renewable Energies" (cluster 3, 102 occurrences), and "Geothermal Fields" (cluster 2, 99 occurrences). Other prominent terms include "Energy Policy" (cluster 3, 75 occurrences), "Carbon Dioxide" (cluster 4, 67 occurrences), "Investments" (cluster 3, 67 occurrences), "Energy Utilization" (cluster 3, 64 occurrences), and "Sustainable Development" (cluster 7, 64 occurrences).

Table 6. Top 10 author keywords with the strongest citation bursts.

Keywords	Year	Strength	Begin	End	1981 - 2025
Renewable resource	2011	7.48	2011	2015	
Cost-benefit analysis	2015	6.2	2015	2020	
Renewable energy source	2015	6.1	2021	2022	
Economic development	2021	5.93	2021	2023	
Geothermal power plants	2020	5.88	2020	2021	
Geothermal energy	2010	5.04	2017	2019	
Regression analysis	2015	4.75	2017	2019	
Energy policy	2014	4.41	2019	2021	
Geothermal heat pumps	2015	4.39	2015	2018	
Economic and social effects	2019	4.36	2019	2022	

Temporal trends in keyword influence are highlighted in *Table 6*, which identifies the ten author keywords with the strongest citation bursts. Examples include “Renewable Resource” with a burst strength of 7.48 during 2011–2015, “Cost Benefit Analysis” with a strength of 6.2 during 2015–2020, and “Economic Development” with a strength of 5.93 during 2021–2023. These bursts indicate periods when specific topics experienced intensified scholarly attention.

Overall, the keyword co-occurrence analysis reveals a strong emphasis on renewable and alternative energy concepts, along with growing attention to economic and policy dimensions, reflecting the multidisciplinary nature of geothermal-econometric research.

3.6 | Reference Co-Citation Analysis

This section presents the reference co-citation structure to uncover the intellectual foundation of the field. It identifies key studies, influential authors, and thematic clusters shaping current research. The analysis helps trace the development of core ideas and methodological approaches.

Fig. 7. Reference Co-Citation network in geothermal energy, economic growth, and econometric research (Items: 676, Cluster: 35, Links: 2295, TLS: 2550).

The reference co-citation network is illustrated in *Fig. 7*, which maps the relationships among the most frequently co-cited sources in geothermal energy, economic growth, and econometric research. The network contains 676 reference items organized into 35 clusters and connected by 2,295 links with a TLS of 2,550. These clusters represent groups of publications that are often cited together, indicating shared themes or methodological approaches.

Table 7. Top five most Co-Cited references.

Author	Title	Year	Citations	Cluster
Anderson [31]	Geothermal technology: trends and potential role in a sustainable future	2019	11	17
Apergis and Payne [37]	Renewable energy consumption and economic growth: evidence from a panel of OECD countries	2010	11	1
Apergis and Payne [37]	On the causal dynamics between emissions, nuclear energy, renewable energy, and economic growth	2010	10	6
Ando et al. [32]	Quantile connectedness: modeling tail behavior in the topology of financial networks	2022	7	12
Baruník and Křehlík [33]	Measuring the frequency dynamics of financial connectedness and systemic risk	2018	7	12

The most frequently co-cited references are listed in *Table 7*, along with their cluster assignments. Leading the list are works by Anderson, Austin (cluster 17) with Geothermal Technology: Trends and Potential Role in a Sustainable Future (2019, 11 citations) and Nicholas Apergis [34] (cluster 1) with Renewable Energy Consumption and Economic Growth: Evidence from a Panel of OECD Countries (2010, 11 citations). Other key references include another study by Apergis (cluster 6) on emissions, nuclear energy, and economic growth (2010, 10 citations), Ando et al. [32] (cluster 12) on quantile connectedness (2022, 7 citations), and Barunik and Křehlík (cluster 12) on frequency dynamics of financial connectedness (2018, 7 citations).

Overall, the reference co-citation analysis highlights a set of foundational studies that shape the intellectual structure of geothermal-econometric research. The 35 clusters reveal a diverse range of thematic areas, including renewable energy economics, financial network modeling, and sustainable development, which together inform current work at the intersection of geothermal energy and economic analysis.

4 | Discussion

The bibliometric evidence confirms that research linking geothermal energy to economic growth through econometric analysis has expanded significantly over the past four decades. From a marginal topic in the 1980s and 1990s, the field began to gain momentum after 2010, culminating in a peak of publications in 2024 and a peak of citations in 2021, as illustrated in *Fig. 2* and *Table 1*. This rapid increase reflects a shift in perception, as geothermal energy is increasingly recognized not only as a technological or geological issue but also as an economic asset with broader policy implications [35]. At the same time, the acceleration in output raises questions regarding the consistency of methodological quality, since many studies still rely heavily on conventional econometric approaches without fully addressing heterogeneity across regions or the structural limitations of available data.

The dominant methodological orientation remains centered on panel data analysis, cointegration tests, and regression-based causality frameworks [36]. While these methods have played a critical role in shaping the energy-growth nexus, their continued dominance reveals a degree of methodological conservatism. Table 2 shows that authors such as Abdul-Rahim, Dinçer, and Yüksel are central in applying these econometric frameworks, yet few studies move beyond them toward nonlinear models, quantile regressions, structural break tests, or time–frequency techniques. Without adopting more innovative approaches, the literature risks oversimplifying the complex and dynamic relationships between geothermal development, macroeconomic growth, and policy environments. Future research should therefore broaden the econometric toolkit, incorporating hybrid strategies that combine traditional econometric models with machine learning or mixed-method designs that embed quantitative rigor in broader contextual analysis [37].

The intellectual structure of the field also highlights notable fragmentation. *Fig. 3* and *Table 2* reveal the coexistence of distinct clusters: Abdul-Rahim and colleagues concentrate on econometric modeling of the energy-growth nexus (cluster 95), Falcone and Brown emphasize engineering and applied geoscience (cluster 111), and Dinçer and Yüksel contribute to renewable finance and policy analysis (cluster 122). Each cluster has advanced its respective domain, but limited cross-citation and collaboration have prevented the emergence of a more integrated understanding of geothermal energy. This separation restricts opportunities to connect engineering performance metrics, such as drilling efficiency or capacity factors, with econometric evaluations of cost–benefit and macroeconomic impacts, and to align both with investment and policy frameworks [38]. Stronger integration across these domains would yield richer, multidimensional insights into geothermal's economic role [39].

Institutional and country-level patterns reinforce these imbalances. *Table 3* shows that China University of Geosciences leads in publication volume, Wuhan University plays a pivotal role in collaboration, and Universiti Putra Malaysia demonstrates high citation impact, underscoring Asia's central role in geothermal econometric expertise. *Table 4* further illustrates this pattern, with China dominating output and citations, while the United States, United Kingdom, Turkey, and Pakistan contribute significantly but with a narrower thematic focus. Yet, Africa and Latin America remain underrepresented despite their substantial geothermal potential. This exclusion reflects structural challenges such as limited funding, data scarcity, and weaker research infrastructure. It also represents a missed opportunity, as these regions could benefit disproportionately from geothermal development. Future collaboration frameworks should therefore prioritize inclusivity through shared databases, capacity building, and co-authorship initiatives that bridge the gap between established centers and underrepresented regions.

Keyword analysis provides further evidence of thematic evolution. *Table 5* confirms that geothermal energy and renewable energy dominate as author keywords, while *Table 6* highlights citation bursts in cost–benefit analysis, economic development, and regression analysis, underscoring the growing role of econometrics in evaluating geothermal projects. However, social outcomes such as employment, income distribution, and community resilience remain underexplored. This omission reduces the policy relevance of geothermal econometric research, particularly in relation to the Sustainable Development Goals. Expanding the thematic scope to encompass these socio-economic dimensions will strengthen the contribution of geothermal studies to debates on inclusive and sustainable development.

The co-citation network adds further depth to this picture. *Table 7* shows that Apergis and Payne [34] provide a foundational econometric framework for the energy–growth nexus, Anderson [31] emphasizes geothermal technology's role in sustainability transitions, and more recent contributions by Ando et al. [32] and Baruník and Křehlík [33] introduce advanced financial econometric approaches. Together, these references demonstrate the multidisciplinary roots of the field, spanning econometrics, engineering, and finance. Yet, the limited cross-pollination across these domains suggests that opportunities for intellectual integration remain underutilized. For example, financial risk modeling could be incorporated into geothermal investment analysis, while engineering performance studies could directly inform econometric models of GDP impact and regional development.

Overall, the evidence suggests that geothermal-econometric research has entered a more mature phase, where econometric analysis has become central to evaluating the economic implications of geothermal energy [40]. Nevertheless, three priorities are essential for advancing the field. First, methodological innovation must be embraced to capture nonlinearities, regional heterogeneity, and policy dynamics more effectively. Second, greater inclusivity is required to incorporate perspectives and data from underrepresented regions such as Africa and Latin America. Third, stronger integration across engineering, econometric, and policy perspectives is needed to produce holistic insights that connect technological performance, macroeconomic growth, and social outcomes. Addressing these challenges will allow geothermal research to move beyond documenting correlations and toward providing robust, policy-relevant evidence that informs sustainable energy transitions. Ultimately, geothermal energy, when rigorously assessed through advanced econometric and multidisciplinary approaches, holds the potential not only to contribute to clean energy strategies but also to foster equitable and resilient economic growth worldwide.

5 | Conclusion

This bibliometric study provides a comprehensive mapping of research at the intersection of geothermal energy, economic growth, and econometric analysis. Based on 603 Scopus-indexed publications between 1980 and 2025, the findings reveal a decisive expansion of scholarly activity after 2010, with publication outputs peaking in 2024 and citations reaching their highest level in 2021. The results demonstrate that geothermal energy is increasingly analyzed not only as a technical subject but also as an economic asset, where econometric approaches such as panel data analysis, cointegration, and regression have become central tools for evaluation.

The analysis further highlights significant disparities in the global distribution of research. Asian institutions, particularly those in China, dominate publication volume, collaboration networks, and citation impact, while contributions from the United States, the United Kingdom, Turkey, and Pakistan are also notable. However, participation from Africa and Latin America remains limited, underscoring the need for more inclusive international collaboration to ensure that regions with significant geothermal potential are adequately represented. Keyword and co-citation analyses confirm the thematic prominence of geothermal energy, renewable energy, and sustainable development, but also reveal persistent gaps in methodological innovation and limited integration across econometrics, engineering, and policy perspectives.

Overall, the findings suggest that geothermal econometric research has entered a mature yet uneven phase. To advance the field, future studies should adopt more sophisticated econometric techniques, strengthen cross-disciplinary integration, and expand geographic coverage to underrepresented regions. By addressing these gaps, research on geothermal energy can provide not only robust academic insights but also actionable guidance for policymakers and investors. In doing so, geothermal energy can be properly evaluated as a renewable resource with the potential to contribute to both sustainable energy transitions and inclusive economic development.

Authors' Contributions

G. M. I: Writing-original draft, Methodology, Data Curation, Conceptualization, Software, and Visualization, and Validation. Q. S. F.: Validation, Writing-Review & Editing, and Formal Analysis. I. S. H.: Validation, Writing-Review & Editing, and Formal Analysis. I. H.: Validation, Writing-Review & Editing, and Formal Analysis. T. R. N.: Validation, Writing-Review & Editing, and Formal Analysis. D. B. W.: Validation, Writing-Review & Editing, and Formal Analysis. The authors have read and agreed to the published version of the manuscript.

Data Availability

The data is available on request from the corresponding author.

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Conflict of Interest

There are no competing interests to declare.

Consent for Publication

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Ethics Approval and Consent to Participate

The authors confirm that this research did not involve human participants or animal subjects.

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