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NATIONAL ENERGY SECURITY: FINANCIAL DETERMINANTS

ABSTRACT

The snowballing economic growth has reached the level where the energy industry has a crucial impact on the future pace of development. National energy security influences the adequate performance of all economic spheres and stable government processes. Systematization of the relevant scientific treatises showed that comprehensive national energy security assessment involves institutional, ecological, and behavioral determinants as crucial pillars of national energy security. Besides, the financial conditions play a pivotal role in ensuring national energy security since the undisturbed operations in the energy industry require investing in equipment modernization, implementing modern technologies and innovations, research and development, etc. Under the above mentioned, the scholars worldwide consider the financial determinants under elaborating on the improvements of national energy security. This study aims to interpret and visualize the bibliometric data of the scientific background related to exploring the role of financial determinants in national energy security. The bibliometric data for analysis were retrieved from the Scopus, and Web of Science interdisciplinary bibliographic databases. The collected data cover 770 publications indexed by the keywords: 'energy', 'security, and 'finance' in the titles, keywords, and abstracts of publications. The publication period covers 2000-2021. The VOSviewer software, Scopus and Web of Science toolkits for search results analysis were applied. The procedures of bibliographic analysis employed evaluative and relational techniques. The obtained results revealed publication activity's annual and relative growth rates, the main research directions by term co-occurrence, co-authorship, citation network, the most productive authors, journals, affiliations, and the geographical distribution of analyzed papers. The findings of this study give the theoretical contributions to the further development of the comprehensive assessment model of national energy security toward the carbon-free economy.

Keywords: sustainable development, energy sector, carbon-free economy, bibliographic analysis, green finance

JEL Classification: H56, Q42, O13

INTRODUCTION

The urgent need to mitigate and overcome adverse climate changes, alleviate the energy crisis, and strengthen energy security is on the global agenda and the blueprint for national development. Energy security is a priority for national governments that define energy policy goals and the implementation mechanisms considering the national political regime, resource potential, public interest, etc. In 2019, the European Commission announced the European Green Deal (EGD) as a set of policies aimed to reach carbon neutrality by 2050 [1]. EGD is to accelerate the green transition and contribute to economic and social development, enhancing public health and the quality of life.

In this line, the exploration of renewable energy sources and energy-efficient technologies is considered to be a crucial decision. Energy-efficient technologies gain wide use worldwide due to the interplay of political and economic factors, technological progress, and international cooperation [2]. Thus, *Figure 1* demonstrates that compared to 2000, the number of environment-related inventions per capita significantly increased in almost all EU countries in 2018. In turn, Ukraine showed a 42.5% rise in developing environment-related inventions.

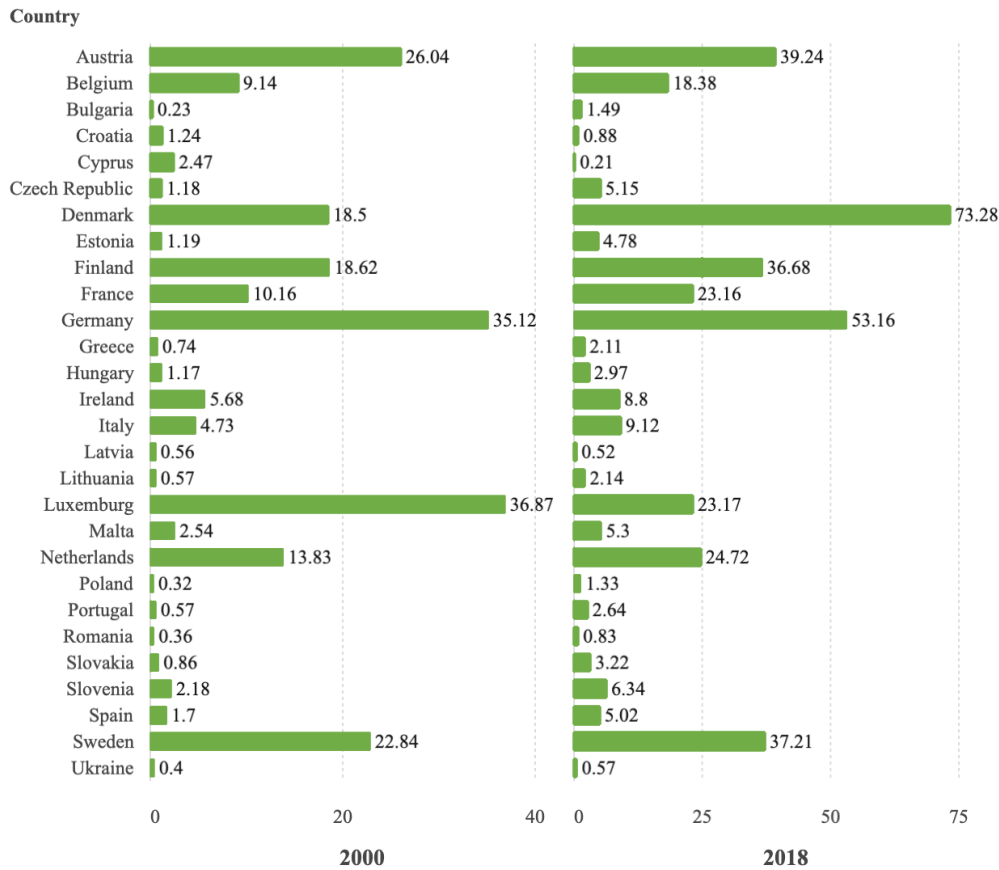


Figure 1. Changes in the number of environment-related technologies in 2000 and 2018 (inventions per capita) (Sources: developed by the authors based on (OECD, Stat, 2021))

Even though Ukraine has accepted the obligation to decarbonize the national economy under EGD until 2070 [3], it requires the state government to modernize and develop new economic transformation policies to enhance energy security, attracting green finance into all economic spheres [4; 5; 6; 7; 8; 9; 10; 11]. Moreover, national energy security highly depends on three pillars of green transformations: institutional (government efficiency, infrastructure, etc.), ecological (emissions, environment quality, etc.), and behavioral (eco-friendliness of population, readiness to implement energy-efficient projects, etc.) [12; 13]. Therefore, the efficiency of national energy management depends on the rational use of resource potential, overcoming the legislative, political, economic, and financial barriers. The government should implement the agreed and consistent policies and measures in the energy sector. As a result, it would contribute to the rising in investment and financial flows in energy-efficient projects and renewable sources exploration towards gaining national energy security [14; 15].

RECENT RESEARCH ANALYSIS AND PROBLEM STATEMENT

A large stream of literature highlights the financial matter in environmental concern [16; 17; 18]. Based on the Namibia experience, Amesho and Edoun [19] gave cross-country proof that financial advancement positively impacts renewable energy development and decreases CO2 emissions. Therefore, the scholars insisted on increasing public and private investments while attracting great external financial support for the modernization of the energy sector. In this line, Mungai et al. [20] analyzed the investment potential of West, Central, Southern, and East African countries to determine its effect on renewable energy development and energy-efficient growth. Based on the findings, the authors concluded that the institutional knowledge and policy gaps are the main challenge in exploiting the renewable energy and energy-efficient investment potential.

The difference-in-difference propensity score matching method applied for the panel data of 30 Chinese regions for 2011-2019, is the evidence that green finance policy contributes to reducing environmental pressure [21]. Thus, following these results, this study suggested improving the green finance infrastructure, developing the green evaluation standards, and

promoting the green policy in business to create green finance on the local level.

The paper [22] developed the green finance development index, which includes the data on green investments, green securities, green credit, and green insurance. The vector error correction model on the data for 2000-2018 proved that green finance reduces fossil fuel consumption and develops the carbon trading market.

The scholars [23] discussed the impact of major components of green finance such as green investments (asset-backed securities, Yieldcos, and green bonds) and carbon taxes on the sustainable development of the energy system.

Song et al. [24] applied the DEA-like composite index to check the impact of financial indicators on the environment in G-7 countries during 2008-2018. The study concluded that the financial index positively impacts reducing gas emissions and ensuring sustainable energy sector development. Furthermore, Iqbal [25] applied the data envelopment analysis to develop the green finance index, which allows defining the role of green finance in environmental advancement.

Another strand of the literature revealed that corporate social responsibility has a tremendous contribution to gaining the SDGs [26; 27; 28; 29; 30]. In this line, Herboht et al. [31] applied the International Finance Corporation's Measuring Sustainability Framework to design the suitability performance of energy companies. Wanke et al. [32] developed the novel Robust Bayesian Stochastic Frontier Analysis to check the relationship between the energy sector and the business environment. The findings proved that financial stability contributes to the growth of energy efficiency. Besides, the scholars highlighted the necessity to increase the research and development expenses in the energy industry.

Remarkably, there is a large stream of literature that highlights the core role of renewable energy sources in strengthening national energy security [33; 34; 35]. The study [36] insisted on the importance of raising the climate change expenditure to mitigate climate change by exploring different energy sources. Bobinaite [37] applied the financial ratio technique to determine the role of the financial aspects of the wind electricity sector in ensuring energy security and sustainable development.

Most studies addressing environmental issues indicated that energy security is crucial for economic prosperity nowadays [38; 39; 40]. Therefore, national energy security is in high priority to investigate. In this line, building the cooperation between the scholars from different countries to share the knowledge and ideas helps explore the modern solution to overcoming the energy crises [41; 42]. It could be an accelerator in gaining national energy security and contribute to achieving the Sustainable Development Goal 7: Affordable and clean energy.

Under the mentioned above, this study aims to conduct a bibliometric analysis of the scientific background devoted to exploring the role of financial determinants in national energy security assessment.

METHODOLOGY AND RESEARCH METHODS

Invoking the Scopus and Web of Science (WoS) scientific research engines, this study browsed the publications related to the financial determinants in energy security published by the end of 2021. It stands to mention that Scopus and WoS are the most authoritative and influential multidisciplinary citation databases. Thus, Scopus presents more than 84 million documents. There are involved about 18 million researchers worldwide from about 95 thousand affiliations. In turn, the major subject areas are Social Sciences (35%), Physical Sciences (27%), Health Sciences (23%), and Life Sciences (15%) [43].

On the other hand, the interdisciplinary platform WoS collects over 171 million high-quality records in more than 250 subject areas such as social sciences, arts & humanities, etc. Besides, the number of WoS affiliated profiles overcomes nine thousand [44].

In the beginning, this study involved the dataset of 510 documents retrieved from the Scopus and 430 from WoS gathered under search by the keyword's 'security', 'energy' and 'finance' and basic boolean operator 'AND' in the titles, keywords, and abstracts of publications (*Figure 2*). However, to eliminate the duplicates of publications, some documents were warded off from the initial data set. In this case, Microsoft Excel instruments were applied. Although the first paper related to the investigated topic was published in 1974, this study operates with documents published from 2000 to 2021. Thus, the total sample of publications gathered 770 documents (*Figure 2*). Noteworthy here, the study limitation is that the single keyword 'security' could have several meanings. Therefore, the indexed keywords were revised to avoid any search negligence.

According to the study by Soliman et al. [45], there are three approaches to bibliometric analysis: review, evaluative and relational methods. In turn, this paper applied the evaluative and relational techniques.

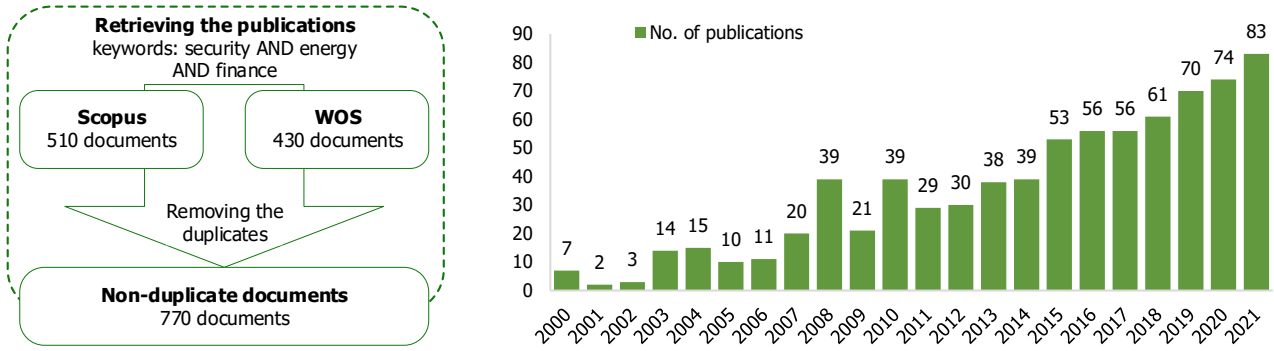


Figure 2. Design of study sample (Sources: elaborated by the authors)

To evaluate the main trends regarding the investigated topic, this study appealed to the productive and impact parameters. Thus, the productive metrics included the annual and relative growth rates of publication activity, number of cited articles, the most productive authors, journals, affiliations, and countries. Besides, to calculate the annual and relative growth rates of publication activity, this study applied the formulas by Shi et al. [46] (1-2):

$$AGR_{ij} = \frac{N_i - N_j}{N_j} \times 100\% \quad (1)$$

where AGR_{ij} – the annual growth rate, N_i – the number of documents in the current year; N_j – the number of documents in $i-1$ year.

$$RGR_{ij} = \frac{\log_e N_i - \log_e N_j}{N_j - N_j} \times 100\% \quad (2)$$

where RGR_{ij} – the relative growth rate of publication activity.

On the other hand, the impact parameters included the data on the citation activity by source and authors, the annual citation and the total number of citations.

In turn, the relative relational techniques involved the co-occurrence, co-authorship and co-citation analyses to visualize the relationship between the analyzed data regarding the collaboration and main research directions. The 1.6.16 software toolkit was employed to visualize the obtained results under the distance-based approach.

RESEARCH RESULTS

Table 1 proves the annual growth rate of the number of publications devoted to the financial determinants of energy security indexed in Scopus and WoS databases since 2000. Noteworthy here, the number of documents published in 2021 exceeded the ones in 2000 more than 11 times.

In turn, the cumulative number of publications by the end of 2021 was 770 documents. 2013 year could be considered to be the starting point for activating the publication activity. Besides, it is clear that the previous pronounced increase in the investigation of financial determinants of energy security was in 2008 that the global financial crisis could cause.

Table 1. Publications on financial determinants of energy security in Scopus and WoS (2000-2021)

Year	No. of publications	Cumulative No. of publications	Annual growth rate	Relative growth rate
2000	7	7	-	-
2001	2	9	-71,43%	25,06%
2002	3	12	50,00%	40,55%
2003	14	26	366,67%	14,00%
2004	15	41	7,14%	6,90%
2005	10	51	-33,33%	8,11%
2006	11	62	10,00%	9,53%
2007	20	82	81,82%	6,64%

(continued on next page)

Table 1. (continued)

Year	No. of publications	Cumulative No. of publications	Annual growth rate	Relative growth rate
2008	39	121	95,00%	3,51%
2009	21	142	-46,15%	3,44%
2010	39	181	85,71%	3,44%
2011	29	210	-25,64%	2,96%
2012	30	240	3,45%	3,39%
2013	38	278	26,67%	2,95%
2014	39	317	2,63%	2,60%
2015	53	370	35,90%	2,19%
2016	56	426	5,66%	1,84%
2017	56	482	0,00%	0,00%
2018	61	543	8,93%	1,71%
2019	70	613	14,75%	1,53%
2020	74	687	5,71%	1,39%
2021	83	770	12,16%	1,28%

Sources: developed by the authors based on the Scopus and WoS data

Figure 3 demonstrates that the scholars chose the highly ranked journal to publicize their findings. Thus, the peer-reviewed journal Energy Policy addressing environmental science (management, monitoring, policy, and law) and general energy could be considered to be the most abundant source regarding the investigated topic. This journal has published 22 papers since 2000. In turn, Energy Policy is a reliable and highly ranked international scientific journal under the study topic (10.2 of Cite Score 2020; 2.093 of SJR 2020; 1.941 of SNIP 2020).

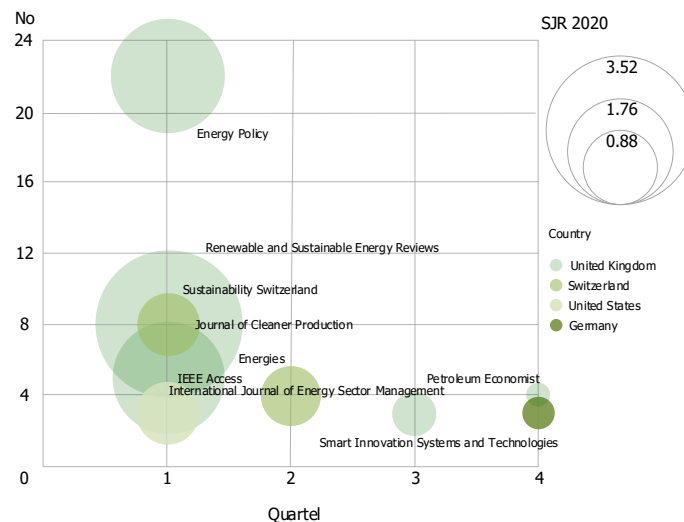


Figure 3. The most productive sources of publications (2000-2021) (Sources: developed by the authors using the VOSviewer tools)

Then, well behind is the UK scientific journal Renewable and Sustainable Energy Reviews and Sustainability (Switzerland). Both scientific sources have published eight papers in the subject areas: energy, environmental and social sciences. According to the citation ranking, Renewable and Sustainable Energy Reviews is more cited. The following scores characterize it: 30.5 of Cite Score 2020; 3.522 of SJR 2020; 4.684 of SNIP 2020). In turn, these scores for Sustainability are as follows: 3.9 of Cite Score 2020; 0.612 of SJR 2020; 1.242 of SNIP 2020).

Then, both Journal of Cleaner Production (13.1 of Cite Score 2020; 1.937 of SJR 2020; 2.475 of SNIP 2020) and Oil and Gas Journal (0.5 of Cite Score 2020; 0.101 of SJR 2020; 0.091 of SNIP 2020) have five publications addressing the energy security issues.

According to the Scopus database (Figure 4), TOP-10 most productive countries investigating the financial determinants in energy security were the United States (112 papers), the United Kingdom (63 papers), China (61 papers), India (31 papers), Australia (26 papers), Germany (24 papers), Canada (20 papers), Netherlands (16 papers), Japan (14 papers), and South Africa (11 papers). In turn, this rating slightly differs in the WoS database (FIG.4). Thus, along the same line, the leader is the United States (84 papers), the United Kingdom (56 papers), China (68 papers), India (26 papers), Australia (18 papers), Germany (25 papers), Canada (16 papers), Netherlands (17 papers), then Poland (19 papers), and Russia (19 papers).

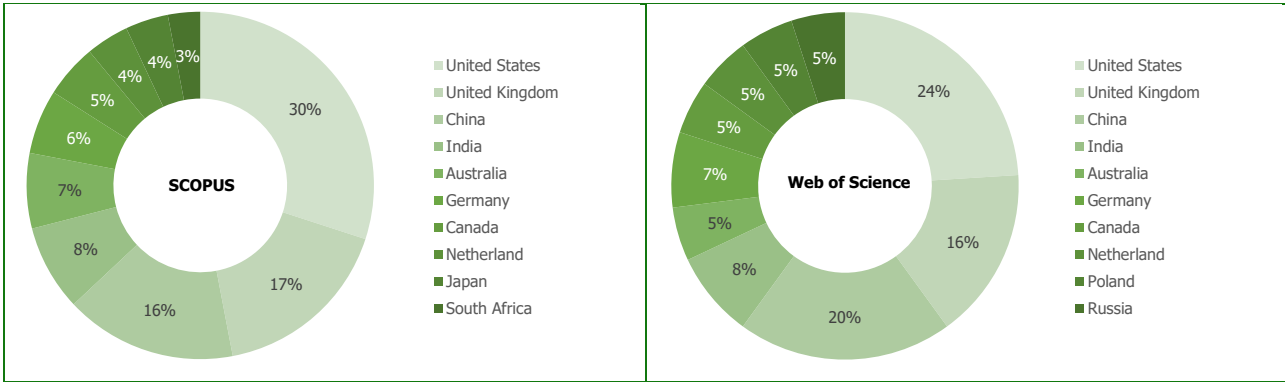


Figure 4. Network visualization of co-authorship worldwide (2000-2021)

The co-authorship map was built to identify the collaboration between the scholars worldwide, avoiding the duplicates of publications. The main threshold was a minimum of 5 documents per country. As a result, 36 out of 434 countries met this limitation. Therefore, the network map of co-authorship by country visualizes four clusters (*Figure 5*):

- *the first cluster (red-colored)* is headed by Germany, which published 38 documents cited 1077 times. This cluster shows the close cooperation among EU countries (Belgium, Finland, France, Germany, Spain, Sweden, etc.) and Canada, Brazil, Turkey, Indonesia, Iran, and Kenya.
- *the second cluster (green colored)* consists of 8 countries, China, Japan, Malaysia, Pakistan, Poland, Russia, South Africa, and Taiwan. The researchers from China (101 papers cited 811 times, and 53 of the total link strength) head this cluster.
- *the third cluster (blue colored)* indicates the close relationship between the scholars from Australia, Egypt, India, New Zealand, Nigeria, Thailand, the United Kingdom, and the United States. The scholars from the United States issued 119 documents. In turn, these papers were cited by 2097 times while the total link strength is 68. Besides, the researchers from the United Kingdom published 62 documents cited by 1600 times with 36 of the total link strengths.
- *the fourth cluster (yellow colored)* is headed by Austria (17 papers cited 274 times). This cluster unveils the cooperation between the researcher from Austria, Denmark, Greece, Italy, Norway, and the United Arab Emirates.

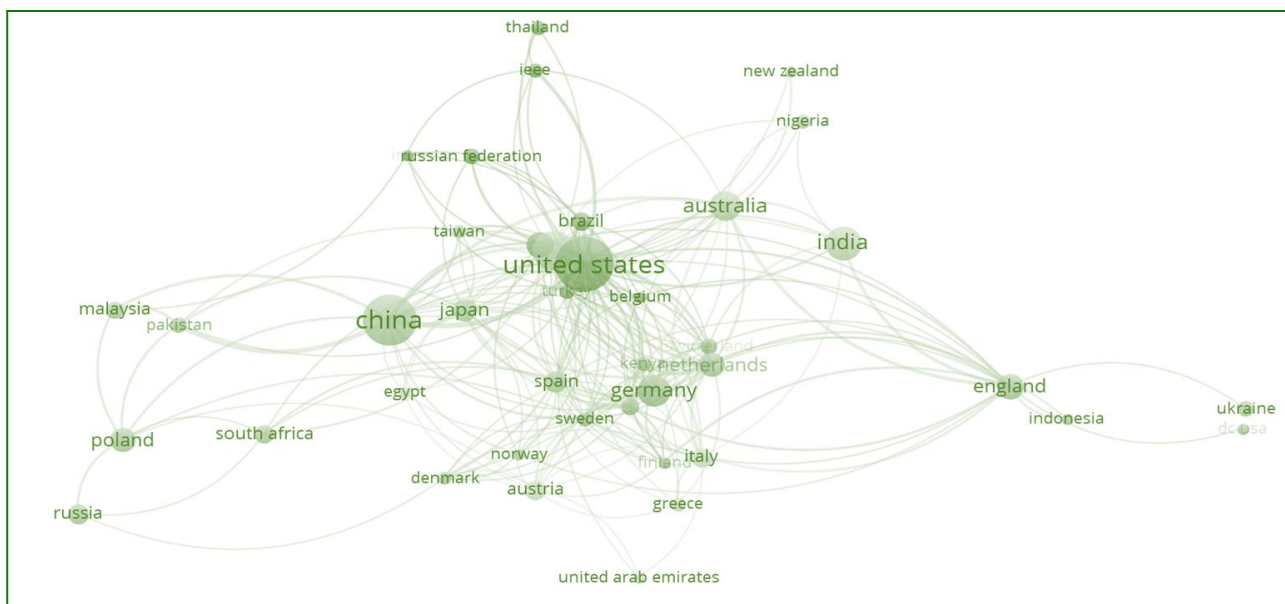


Figure 5. Co-authorship network visualization by countries (2000-2021) (Sources: developed by the authors using the VOSviewer tools)

Concerning the most prolific authors who contributed to the development of the analyzed topic from 2000 to 2021, it is appropriate to mention that the authors published at least three works. Therefore, the list of most engaged authors

includes S. Fuchs Ewald F.F. representing the University of Colorado Boulder in the United States (h-index: 26), Matthews Nathaniel – Global Water Partnership in Sweden (h-index: 18), Romaniuk Ryszard (h-index: 44) and Modelski Józef W. – Politechnika Warszawska in Poland (h-index: 12), Sicker Douglas C. – Carnegie Mellon University in the United States (h-index: 22), etc.

Table 2 lists the TOP-10 affiliations most contributed to the investigated topic considering the number of issued papers. Therefore, according to the Scopus database, the most influential affiliation is the Institute of Electrical and Electronics Engineers (IEEE) (10 papers).

Table 2. TOP-10 most prolific affiliations (2000-2021)

Nº	Affiliation	Country	No of papers by database
1	The Institute of Electrical and Electronics Engineers (IEEE)	United States	10 (Scopus)
2	Chinese Academy of Sciences	China	6 (Scopus & WoS)
3	Politechnika Warszawska	Poland	4 (Scopus)
4	Wageningen University & Research	Netherlands	4 (Scopus & WoS)
5	University of Leeds	United Kingdom	7 (Scopus & WoS)
6	Imperial College London	United Kingdom	4 (Scopus & WoS)
7	University of Sussex	United Kingdom	6 (Scopus & WoS)
8	International Institute for Applied Systems Analysis, Laxenburg	Austria	8 (Scopus & WoS)
9	Griffith University	Australia	4 (Scopus & WoS)
10	The University of New South Wales (UNSW) Sydney	Australia	4 (Scopus & WoS)

Sources: elaborated by the authors.

Table 3 reveals the highly cited and most representative papers published from 2000 to 2021 in both databases. These papers could be considered to be the most influential in developing the research on the financial determinants of national energy security. Noteworthy here, TOP-10 cited publications represent 19% of total citations for the investigated scope of studies in the Scopus database. Thus, according to both databases, the study by Frondel, M., Ritter, N., Schmidt, C. M., and Vance, C. [47] published in 2010 is the most cited. However, the number of citations by the Scopus database is higher (325 citations) compared to WoS (309 citations). Besides, most considered TOP-10 papers are published in the scientific journals indexed by both databases.

Table 3. TOP-10 representative papers in Scopus (2000-2021)

Nº	Author(s)/ Year	Title	Citations	Database
1	Frondel, M., Ritter, N., Schmidt, C. M., & Vance, C., 2010 [47]	Economic impacts from the promotion of renewable energy technologies: The German experience	325/309	Scopus/ WoS
2	Awerbuch, S., 2006 [48]	Portfolio-based electricity generation planning: Policy implications for renewables and energy security	181	Scopus
3	Lei Wu, M. Shahidehpour, Tao Li, 2008 [49]	Cost of reliability analysis based on stochastic unit commitment	156/135	Scopus/ WoS
4	Kok, M. T. J., & de Coninck, H. C., 2007 [50]	Widening the scope of policies to address climate change: directions for mainstreaming	147/123	Scopus/ WoS
5	Linetsky, V., 2004 [51]	Spectral expansions for Asian (average price) options	129/115	Scopus/ WoS
6	Carmona, R., & Ludkovski, M., 2010 [52]	Valuation of energy storage: An optimal switching approach	100/87	Scopus/ WoS
7	Sarkar, A., & Singh, J., 2010 [53]	Financing energy efficiency in developing countries-lessons learned and remaining challenges	93/79	Scopus/ WoS
8	Van Eijck, J., Romijn, H., Balkema, A., & Faaij, A., 2014 [54]	Global experience with jatropha cultivation for bioenergy: An assessment of socio-economic and environmental aspects	92/89	Scopus/ WoS
9	Dutta, P., Choi, T. -, Somani, S., & Butala, R., 2020 [55]	Blockchain technology in supply chain operations: Applications, challenges and research opportunities	88/75	Scopus/ WoS
10	Lüthi, S., & Prässler, T., 2011 [56]	Analyzing policy support instruments and regulatory risk factors for wind energy deployment-A developers' perspective	82/80	Scopus/ WoS

Sources: systematized by the authors.

To determine the research directions of analyzed publications under the analysis of the most used keywords in the study literature, the network of keywords' co-occurrences was developed using VOSviewer functionality. The threshold was a

published in the interdisciplinary scientometric databases Scopus and Web of Science during 2000-2021.

The findings of the bibliometric analysis showed the growing scientific interest in the investigated topic. Thus, in 2021, the number of publications increased by approximately 11 times since 2000. The geographical distribution of analyzed documents showed that the scholars from the United States and the United Kingdom were most engaged in investigating the role of finance in energy security. In turn, the highly ranked journals are most requested for publicizing the findings. Remarkably, the most popular source was a highly ranked international scientific journal *Energy Policy* with 10.2 of Cite Score 2020, 2.093 of SJR 2020, and 1.941 of SNIP 2020. Besides, according to both databases, the study by Frondel, M., Ritter, N., Schmidt, C. M., and Vance, C. [14] published in 2010 is the most cited.

The study determined four clusters of co-authorship by the country where Germany heads the first cluster, China – the second, the United States – the third, and Austria – the fourth cluster. The most prolific authors who contributed to the development of the analyzed topic are S. Fuchs Ewald F.F. (the United States), Matthews Nathaniel (Sweden), Romaniuk Ryszard and Modelski Józef W. (Poland), Sicker Douglas C. (the United States), etc. Herewith, the Institute of Electrical and Electronics Engineers (IEEE) is the institution that highly contributed to the investigated topic.

The visualized network of keywords' co-occurrences identified four clusters indicating the research direction of the investigated scope of studies. Thus, the first cluster indicates the studies devoted to energy security sustainable development, energy efficiency, climate change, air quality, economic growth, international cooperation, trade, etc.; the second cluster mostly focused on finance, budget control, energy markets, investments, especially foreign direct investments, costs, technologies, energy and power markets, electric power, etc.; the third blue cluster combines the studies in electric industry, alternative and renewable energy, energy conversation, energy access, environmental protection, etc.; the fourth cluster focused on security under the view of big data, cloud computing, commerce, digital storage, energy utilization, national security, risk assessment, supply systems.

It stands to mention that this study has a limitation since the single keyword 'security' could have several meanings. Nevertheless, the indexed keywords were revised to avoid any search negligence and make the data more accurate. In view of some data that had to be omitted, this study gives a relatively comprehensive overview of the theory concerning the financial determinants in ensuring national energy security. The obtained results give the theoretical contributions and could be considered for designing the comprehensive national energy security assessment model towards carbon-free economic development.

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ЕНЕРГЕТИЧНА БЕЗПЕКА КРАЇНИ: ФІНАНСОВІ ДЕТЕРМІНАНТИ

Забезпечення національної енергетичної безпеки є основою ефективного функціонування всіх сфер економіки та стабільності державних процесів. Систематизація наукового доробку з досліджуваної тематики засвідчила, що комплексна оцінка національної енергетичної безпеки включає інституційні, екологічні та поведінкові детермінанти як найважливіші засади національної енергетичної безпеки. При цьому значну роль у забезпеченні національної енергетичної безпеки відіграє фінансова складова, оскільки безперебійна робота енергетичної галузі потребує постійного залучення інвестицій у модернізацію обладнання, упровадження сучасних енергоефективних технологій та інновацій, проведення досліджень тощо. Таким чином, необхідним є врахування фінансових детермінантів при забезпеченні національної енергетичної безпеки. Метою цього дослідження є аналіз та візуалізація наукового доробку, присвяченого дослідженню фінансових детермінантів у забезпеченні національної енергетичної безпеки. Джерелами даних для здійснення бібліографічного аналізу є міждисциплінарні наукові бази даних Scopus та Web of Science. Вибірка дослідження складається із 770 публікацій, які індексуються за ключовими словами: «енергія», «безпека» та «фінанси» в назвах, ключових словах та анотаціях публікацій. Період дослідження охоплює 2000–2021 роки. Для аналізу результатів пошуку застосовувалися програмне забезпечення VOSviewer та аналітичний інструментарій баз даних Scopus і Web of Science. У ході бібліографічного аналізу було застосовано оцінювальні та відносні методи дослідження. Отримані результати дозволили виявити річні та відносні темпи зростання публікаційної активності; географічний розподіл досліджуваних публікацій; головні напрями досліджень за збігом ключових слів; мережі співавторства та співцитування; найбільш продуктивних авторів, впливові журнали та афіліації. Отримані результати мають теоретичне значення та можуть бути враховані при розробці моделі комплексної оцінки національної енергетичної безпеки.

Ключові слова: сталий розвиток, енергетичний сектор, безвуглецева економіка, бібліографічний аналіз, зелене фінансування

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