Bibliometric Analysis of the Nanotechnology Research Area in the Republic of Moldova

A. I. Rosca, I. P. Cojocaru, and A. Gh. Turcanu

Abstract

A bibliometric analysis was performed to evaluate nanotechnology research area in the Republic of Moldova during ten years, 2009–2018. For comparative purposes, the results were benchmarked against the findings of Germany, France, USA, China, Japan, Romania, Russia, and Ukraine. In our research, it was found that the Republic of Moldova holds the first places in the world on two StatNano indicators: national priority and local share in nanoscience, and the fourth position in the world on the number of nano-articles per GDP. Investigations results show that Moldovan nanoscience is defined by a high level of share of international collaboration, the number of nano-articles per million people corresponds to the average figure worldwide and the medium citation per nano-article within the investigated countries is almost at the same level as for Japan. Study of collaboration patterns enables us to identify the active collaborative networks among the scientists from the Republic of Moldova and Germany, USA, Russia, France, Romania. Analysis of the total number of citations to nano-articles and *h*-index shows that the Moldovan nanotechnology scientific community needs to work on improving its research impact.

Keywords

Nanotechnology • Nanoscience • Bibliometric • Citation

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1 Introduction

At the beginning of XXI century the scientists proposed to use bibliometrics for understanding the trajectory development of an emerging technology [1]. Bibliometrics, or the study of publication-based output, is a method widely applied in evaluation. The bibliometric investigation of research and development activities remains one of the most challenging issues in program evaluation despite the effort devoted over the last few decades to develop and test reliable and accurate measures of research output [2].

Bibliometric and thematic analyses performed with the use of scientific and technological electronic information resources, such as databases, have shown that the nanotechnology field in the world has been growing exponentially since the early 1990s. Only about 20% of papers in that period used nano-prefixed terms in their titles and abstracts. Toward the end of the second decade of the nanotechnology's emergence, words became more standardized with 80% of papers having nano-prefixed terms in their titles and abstracts [3].

The nanotechnology area is a highly dynamic global phenomenon with a complex inherently interdisciplinary internal structure. The analysis of WoS nano papers shows a concentration of research publications in traditional nanotechnology core disciplines such as physics, chemistry, and materials science. As the same time, there are secondary areas of concentration in bioscience fields on health- and environmental-related research [4].

This specific characteristic significantly complicate the monitoring, the data search, including selection of information resources and formulation of search queries. However, nowadays scientific and technological data systematization is essentially important. Global frameworks include the classification of nanostructures of the International Organization for Standardization (ISO) [5] and several others, for example, the PACS (Physics and Astronomy Classification Scheme) classification of the American

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Institute of Physics [6]. All of these frameworks greatly simplify the search for information.

A lot of investigations have been carried out in the field of bibliometric study on nanoscience and nanotechnology. Heinze et al. [7] carried out and identified the research results on nanotechnology and human genetics, Kostoff et al. [8] revealed the structure and infrastructure of the global nanotechnology research output, Lee [9] investigated the nanotechnology patents, Porter (2008) analyzed the research papers and citations on nanotechnology [10]. Interactions between nanotechnology and agriculture have been assessed from a bibliometric point of view, with a focus on co-word analysis to examine aspects of agro-nano applications related to plant protection [11].

Visualizing the global nanotechnology output based on data from WoS, Core Collection database, Thomson Reuters, Philadelphia, the specialists concluded that the maximum numbers of outputs were published by the USA, which ranks first. The next 2 positions have gone to China and Germany (data during 1989–2014) [12]. Spikala and Amudha [13] published in Eureka Journal a bibliometric investigation of nano-articles in IEEE (Institute of Electrical and Electronics Engineers, USA) during 2010–2016. The study analyzed authorship patterns, degree of collaboration among the authors and geographical distribution of papers [13].

The comprehensive statistical database portal StatNano was established in 2010 as a gateway to the latest information and statistics in nano-based Science, Technology and Industry [13]. Its mission is to monitor the status of nanotechnology development and policies in 107 countries. StatNano is today one of the most reliable references of researchers and policymakers around the world. The statistics of nano-articles published by each country are reported by StatNano on a monthly basis taking into account the Web of Science (WoS) platform data.

2 Objectives

The *main aim* of this study was to perform the bibliometric assessment of the nanotechnology area in the Republic of Moldova (RM) in the period 2009–2018.

The *specific objectives* of paper are:

- to identify the country's contribution in international nanotechnology information flow;
- to establish the current country's situation in this field.

3 Methodology

StatNano and the National Bibliometric Instrument (Instrumentul Bibliometric Național—IBN) [14] have been used to identify the Moldovan contribution on the field of nanoscience and nanotechnology.

4 Results

According to the data of StatNano database, for the indicator "*National priority in nanoscience*" (ratio of share of nano-articles of a country of total nano-articles to the share of articles of the country of total articles in the same period) [15], the RM is ranked first in the world, being followed by Singapore and North Korea. At international level, the average number is 1.0, the figure for the RM is 2.39 (average data for 2009–2018) Fig. 1.

The analysis of data provided by WoS, SCOPUS and IBN regarding to Moldovan scientists' articles in international journals revealed that they are mostly in collaboration with researchers from Germany, USA, Russia, France, Romania, and in national ones from Ukraine, Russia, Poland.

Among the investigated countries, the RM is ranked first for the indicator "*Share of international collaboration in nanoscience (Percent)*" (Share of joint nano-articles between

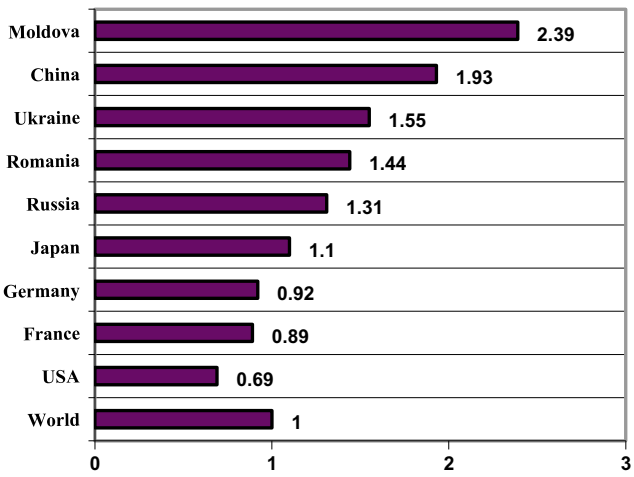

Fig. 1 National priority in nanoscience of selected countries (%), average 2009–2018 StatNano. *Source* Web of Science (ISI Web of Knowledge)

one country and other countries) [16]. In the period 2009–2018 worldwide leaders for this indicator are Liechtenstein, Nepal, and Senegal. The average indicator figure in the world is 66; the data for the RM is 81, with 21% above the average world figure. Less cooperation is characteristic for Iran, China, and India (Fig. 2).

The indicator "*Number of nanotechnology articles indexed in ISI*" is regarded as the simplest and as the same time, the most renowned quantitative indicator for knowledge generation in the field of nano-science. The StatNano database displays that the total number of ISI indexed nano-articles in WoS in the period 2009–2018 was 1,230,738. The leaders in this indicator are China, USA and India [17]. The number of the Moldovan ISI publications in this period represents 0.05% from the global ISI indexed nano-articles.

To the indicator "*Number of nano-articles per Million people*" (Ratio of nano-articles to country population (per million people) the average 2009–2018 figure for the RM is almost the same as for Ukraine and as the world average number, in medium 16 articles per million people per year. Here the world leaders are Singapore, Switzerland, and Finland [18].

Is to be underlined that in the indicator "*Number of nano-articles per GDP"* (Number of nano-articles per billion $ GDP) [19], the RM outperforms the most developed countries, being ranked fourth in the world, after Singapore, South Korea, Slovenia, the average data for 2009–2018. The world medium number is 1.0 (Fig. 3).

The data analysis of the indicator "*Local share in nanoscience (%)*", which is the ratio of the nano-articles carried in a country to the total articles of that country, places the RM on the first position in the world (19.3), being followed by Singapore and North Korea (Fig. 4). The world average figure for the investigated period is 8.3 [20].

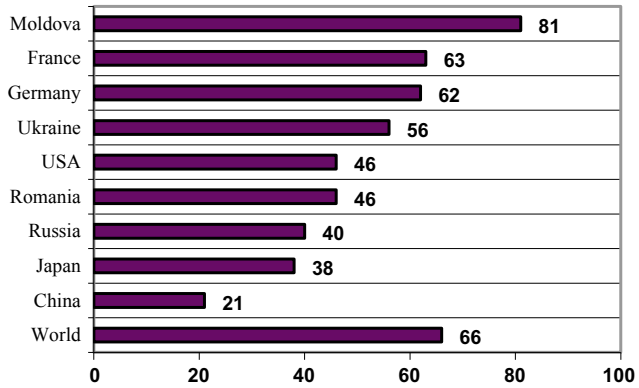

Fig. 2 Share of international collaboration in nanoscience (%), average 2009–2018 StatNano. *Source* Web of Science (ISI Web of Knowledge)

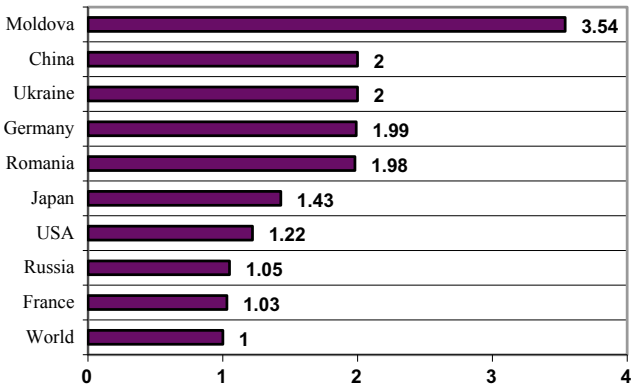

Fig. 3 Number of nano-articles per GDP (ppp), average 2009–2018 StatNano. *Source* Web of Science (ISI Web of Knowledge)

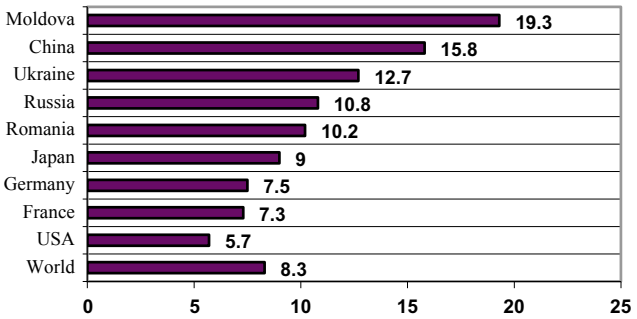

Fig. 4 Share of ISI-indexed nano-articles of total ISI-indexed articles, average for 2009–2018 StatNano. *Source* Web of Science (ISI Web of Knowledge)

With the reference to the indicator "*Total number of citations to nano-articles (Citation)*": the total number of times all records have been cited: this field displays the total number of citations to all of the nano-articles in the set of search results [21] the top positions in the list of analyzed countries are held by China, USA and Germany (average data for 2009–2018) (Fig. 5). Moldovan scientists need to

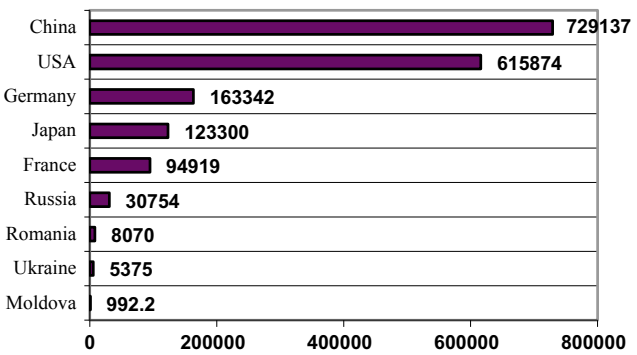

Fig. 5 Total number of citations to nano-articles (Citation), average for 2009–2018 StatNano. *Source* Web of Science (ISI Web of Knowledge)

make a significant effort to improve their standing regarding to this indicator.

Among the investigated countries to the indicator "*Average citation per nano-article (Citation per article)*" (the average number of times the nano-articles published within a year has been cited in the Journal Citation Reports) [22] the average data for the RM is almost the same as for Japan (Fig. 6). The leaders for the period 2009–2018 are Singapore, USA and Switzerland.

As it is known the h-index by comparison rewards both productivity and impact, since a high number of highly cited articles are required to push up the value. While the h-index is certainly not a perfect metric for comparing, it is one that has gained enormous popularity in a relatively short period [23]. Thus the *h*-Index of the nano-articles, published by the Moldovan scientists in the period 2009–2018, is 14 [24]. The top countries in this indicator are USA, China and Germany (Fig. 7).

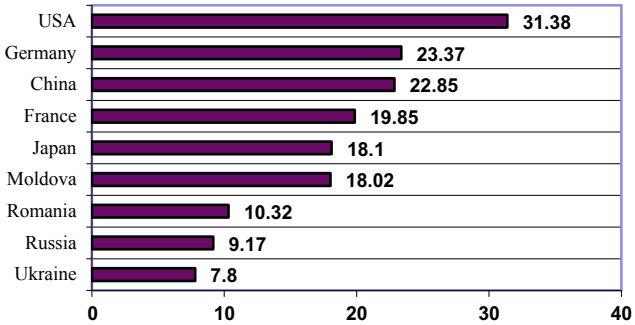

Fig. 6 Average citation per nano-article, average for 2009 – 2018 StatNano. *Source* Web of Science (ISI Web of Knowledge)

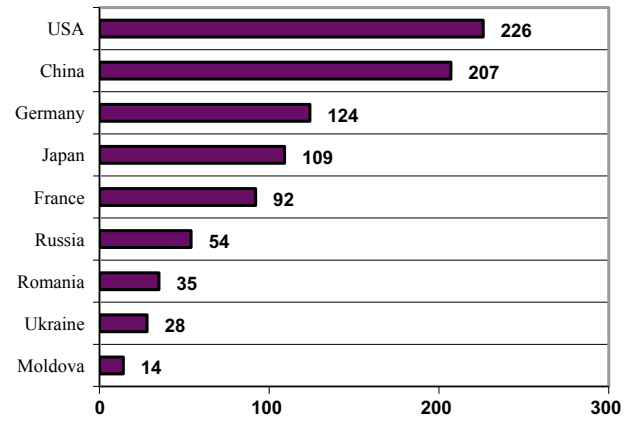

Fig. 7 h-Index of nano-articles, average for 2009–2018 StatNano. *Source* Web of Science (ISI Web of Knowledge)

5 Conclusions

On basis of some bibliometric indicators analyses, for the period 2009–2018, we identified the contribution of the scientists of the Republic of Moldova to the global information flow in nanotechnology area, revealed the country's situation in this field. We can conclude that the Moldova is relatively well positioned, in terms of global research outputs in this area. According to the StatNano database the Moldovan nanotechnology research area is ranked first in the world for two indicators: national priority in nanoscience and share of ISI-indexed nano-articles of total ISI-indexed articles, it holds the fourth place in the world on the number of nano-articles per GDP. In the period 2009–2018 Moldovan nanoscience features a high share of international collaboration; the number of nano-articles per million people corresponds to the average worldwide figure. The medium citation per nano-article within the investigated countries is almost at the same level as for Japan. Nevertheless, Moldovan nanotechnology researchers need to work on improving their research impact, by means of increasing the total number of citations to nano-articles and *h*-index.

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Conflict of Interest The authors declare that they have no conflict of interest.

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18. Number of graduated Masters students whose thesis pertains to nanotechnology regardless of their academic major. Report Toolbox at http://statnano.com/report/r63
19. Number of nano-articles per Million people (Article per million people). Report Toolbox at http://statnano.com/report/s33
20. Number of nano-articles per GDP(ppp) (Article per billion $), Report Toolbox at https://statnano.com/report/s81
21. Local share in nanoscience. Report Toolbox at http://statnano.com/report/s75
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23. Average citation per nano-article (Citation per article). Report Toolbox at http://statnano.com/report/s55
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