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Scientific publishing in the Republic of Macedonia analysed with artificial intelligence

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Editorial

Abstract

Aim: The aim of this study was to present current scientific publishing activity of the Republic of Macedonia analysed with artificial intelligence.

Methods: This analysis was performed with the artificial intelligence platform www.wizdom.ai during March 18, 2024.

Results: In the Republic of Macedonia, in 2023 were published 770 publications with closed, 432 with bronze, 200 with hybrid, 805 with gold, and 61 with green access. In the same year, a total number of 27,418 citations were recorded, with the biggest number of collaborations with United States. Total number of researchers that have published articles in 2023 was 2,550, with local co-authors of 2,268, and with international co-authors of 1,027.

Conclusion: The power of artificial intelligence for analysis of scientific publishing is very sensitive and can be used with precautions because of the limited electronic availability of scientific data, as well as of the different inclusion and exclusion criteria for analysis.

Keywords: Scientific publishing; Republic of Macedonia; artificial intelligence

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1. Introduction

There are several scientometric investigations in the former Yugoslav countries. The analysis of scientific-research outputs of the republics of former Yugoslavia for the period 1970-2014 has been published (Ivanovic et al. 2015). It reveals that civil Yugoslav wars affected the republics' productivity and scientific cooperation in different ways. The most affected republics by wars and social crisis were Serbia and Bosnia and Herzegovina, while the least affected republics were Slovenia and Macedonia. However, it seems that in the last five years productivity and scientific cooperation have looked like before the Yugoslav wars (Ivanovic et al. 2015). By comparing the state of medical publishing in Bosnia and Herzegovina with neighbouring countries (Croatia, Serbia, Montenegro), authors concluded that Bosnia and Herzegovina is behind Croatia and Serbia by following parameters: Total Documents, Total Cites and H index but in front of Montenegro (Masic et al. 2016).

An intriguing study by Jovanović et al. (2010) explored the varying impacts of the civil war in former Yugoslavia on its republics. Serbia, heavily involved in the war and bombarded by NATO forces in 1999, experienced a significant decline in publication numbers and cooperation with other Yugoslav states. The social crisis in Serbia is clearly reflected in the bibliometric data. In contrast, Croatia's dominance increased as Serbia's declined, indicating a reciprocal relationship. Slovenia, minimally involved in the civil war and unaffected by other social crises in this study, showed almost continuous growth in publication share and dominance. Bosnia suffered the most during the civil war, with a sharp decline in publication numbers, cooperation, and dominance, but has almost fully recovered to pre-war levels. Macedonia, which did not participate in the civil war, saw growth in publication numbers and a decline in cooperation. However, its dominance fluctuated significantly, and after 2001, Macedonia's metrics stagnated or declined, likely due to insurgency. Montenegro's publication share decreased during the civil war, but cooperation increased around the time of the 1999 bombardment. Kosovo, with fewer publications and cooperation instances, was also negatively impacted by the crises, experiencing a decline in publication share during both conflicts it was involved in. The study's visualization highlights that a strong link between Serbia and Croatia was replaced by a stronger link between Slovenia and Croatia. Interestingly, ethnic tensions did not have a lasting impact on scientific cooperation among Yugoslav scientists (Jovanović et al. 2010). These findings for former Yugoslavia resemble those observed for the Gulf states by de Bruin et al. (1991).

Scientific publishing in the Republic of Macedonia was analysed with scientometrics very rare. First paper about scientific impact of the Institutes, Faculty of Medicine, Ss Cyril and Methodius University of Skopje, Republic of Macedonia was published (Spiroski, M. 2009), next year country rank, journal rank and H-index in the field of medicine in the Republic of Macedonia (1996-2008) using data from SCImago was published (Spiroski, M. 2010). Later, biomedical scientific impact (2013) of institutions, academic journals and researchers in the Republic of Macedonia was published (Spiroski, M. 2014), as well as relative citation ratio of top twenty Macedonian biomedical scientists in PubMed: A new metric that uses citation rates to measure influence at the article level (Spiroski, M. 2016).

The aim of this study was to present current scientific publishing activity of the Republic of Macedonia (March 18, 2024) analysed with the artificial intelligence platform (www.wizdom.ai).

2. Methodology

This analysis was performed with the artificial intelligence platform www.wizdom.ai during March 18, 2024 (PLC I. 2024). With this platform we chose "Countries" "Macedonia" and analysed: Stats Overview, Subject Area, Researchers, Journals, Publishers, Institutions, and Funders in the Republic of Macedonia.

We used access categories in scientific publishing as classified generally by the level of openness and accessibility of the content, as well as the business model behind its dissemination. Here's an explanation of each: (a) Closed Access: This refers to publications that are only available to subscribers or those who pay for access. In this model, readers typically need to purchase individual articles or subscribe to the journal to read its content. Closed access can create barriers for researchers and the public who may not have access to subscription services or cannot afford to pay for access; (b) Bronze Access: Bronze access typically involves making articles freely available to read online, but without allowing reuse or redistribution rights. This model may provide immediate access to research findings without requiring payment, but it still imposes restrictions on how the content can be used; (c) Hybrid Access: In hybrid access models, journals offer a combination of open access and closed access options. Authors may have the choice to make their articles open access by paying an additional fee, while other articles remain behind a paywall. This model has been criticized for allowing publishers to profit from both subscription fees and article processing charges for open access; (d) Gold Access (or Gold Open Access): Gold access refers to publications that are freely available to readers without any barriers, often immediately upon publication. In this model, authors typically pay article processing charges (APCs) to cover the costs of publication, and the articles are usually licensed under open licenses, such as Creative Commons, allowing for reuse and redistribution; (e) Green Access (or Green Open Access): Green access involves authors self-archiving their work in institutional repositories or other online platforms. This allows for free access to research articles that may have originally been published in

closed-access journals. However, the version available through green access may not always be the final published version, as it could be a preprint or postprint version of the article (Björk et al. 2014).

The Relative Citation Ratio (RCR) we used in scientometrics to assess the influence of a scientific publication or a researcher's body of work. Unlike traditional metrics, RCR aims to provide a more normalized measure of impact: (a) Normalization: RCR normalizes citation counts by comparing the citation rate of an article to the expected citation rate for articles of similar age, subject area, and publication type. This normalization helps to mitigate biases arising from differences in citation practices across fields and over time; (b) Benchmarking: RCR uses a benchmarking approach, where each article's citation rate is compared to a reference set of articles from the same field and publication year. By comparing an article's citations to those of its peers, RCR provides a more meaningful measure of impact; (c) Relative Measure: RCR is a relative measure, meaning it quantifies the influence of an article relative to other articles in its field rather than providing an absolute measure of impact. This makes it particularly useful for comparing the impact of research across different disciplines. Researchers and institutions use RCR to evaluate the impact of individual publications, research projects, or entire research portfolios. It provides a nuanced understanding of research impact that considers factors like field-specific citation practices and publication age, making it a valuable tool for assessing scientific productivity and influence (Hutchins et al. 2017).

3. Results

3.1 Stats Overview

Figure 1 shows the year-wise publication output of the Republic of Macedonia in different access categories. In 2023 were published 770 publications with closed, 432 with bronze, 200 with hybrid, 805 with gold, and 61 with green access (Figure 1a). Next graph shows the citations that publications from the country have received over time, which is based on all publication data available on the country. In 2023 year, a total number of 27,411 citations were recorded (Figure 1b). In the past, Republic of Macedonia collaborated with 175 countries. The biggest number of collaborations are noted with United States - 2.18K publications and 4.71K researchers (Figure 1c). Collaboration with the countries gradually increase with maximal number of 13,225 authors in 2023 (Figure 1d).

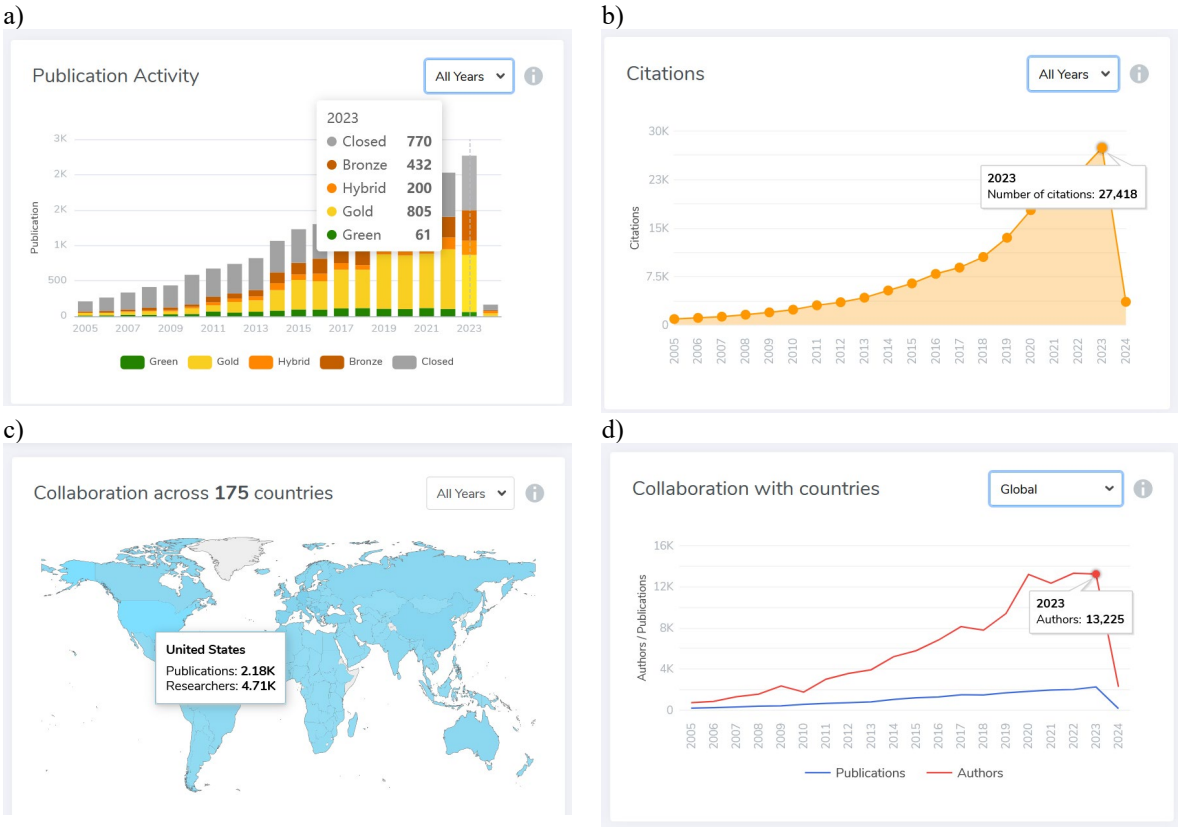

Fig. 1: *a) Scientific publication activity; b) Citations of Macedonian scientific papers in the past years; c) Scientific collaboration across 176 countries; d) Collaboration with countries in the Republic of Macedonia (March 18, 2024) (Source: wisdom.ai)*

Figure 2 shows the total number of researchers from the country that have published articles over time. The number of authors in 2023 was 2,550 from the Republic of Macedonia (Figure 2a). Collaboration with local co-authors in 2023 was 2,268 and with international co-authors was 1,027 (Figure 2b).
Most of the Macedonian scientists published their papers in Elsevier, De Gruyter Poland Sp. z o.o, and Springer Nature. From the Macedonian publishers, Scientific Foundation SPIROSKI and Macedonian Pharmaceutical Association are between the top 10 publishers (Figure 2c). The trend of patent applications the Republic of Macedonia has received or granted over the years is shown on Figure 2d and show very low numbers.

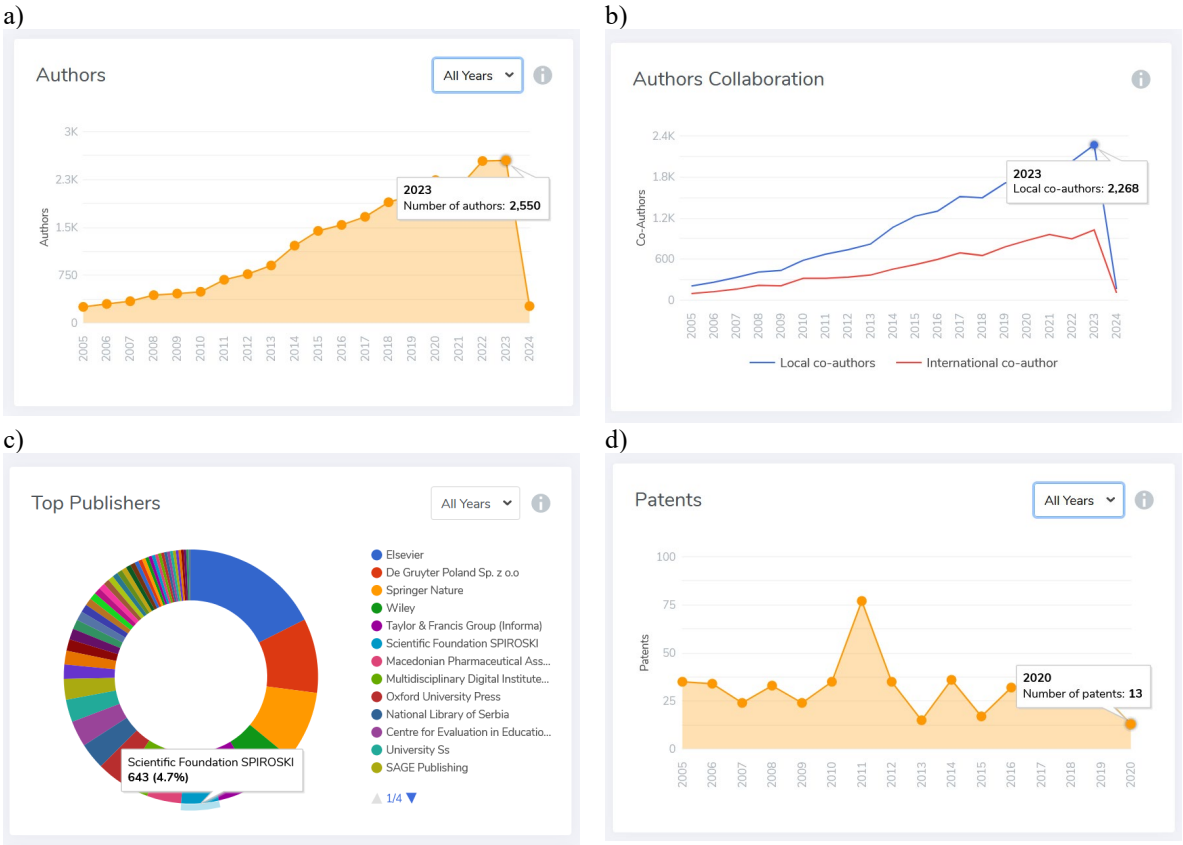

Fig. 2: *a) Authors; b) Authors collaboration; c) Top publishers; d) Patents in the Republic of Macedonia (March 18, 2024) (Source: wisdom.ai)*

In 2023 non-Open Access publications were 770 publications or publications share of 36.8% in comparison with Open Access publications share of 66% or 1498 publications (Figure 3a). In 2023 global Publication Share was 0.03% and global Citation Share was 0.02% (Figure 3b). The European Commission financed scientific research in the Republic of Macedonia in the past years with 99.9% or 2,026,287,851 USD. All other funders share only 0.01% (Figure 3c). In 2021 funding of science in the Republic of Macedonia was 2,245,218 USD. In 2016, there was absence of funding (Figure 3d).

3.2 Subject area

This interactive sunburst chart visualizes the breadth of research focus in the country. The wheel groups subjects and subcategories together. You can adjust the period, which allows you to view how the research output of the country has developed over time. The biggest number of scientific publications in the Republic of Macedonia belongs to health sciences (Figure 4).

3.3 Researchers

Author's publications from Republic of Macedonia, Author's total publications, and Authors overall average RCR for the first ten authors are shown on Table 1. On the 1st place is Trajče Stafilov with 249 publications in Republic of Macedonia, 267 author's total publications and average RCR of 0.63; followed by Goce Spasovski with 243 publications in Republic of Macedonia, 256 author's total publications, and 1.04 average RCR; and Ljupco Kocarev with 169 publications in Republic of Macedonia, 242 author's total publications, and 0.99 average RCR (Table 1).

Fig. 3: *OA Growth Over Years (3a), Global Share in all years (3b), Funding Bodies in all years (3c), and Funding in all years (3d) (March 18, 2024) (Source: wisdom.ai)*

Fig. 4: Interactive sunburst chart of groups subjects and subcategories (March 18, 2024) (Source: wisdom.ai)

3.4 Journals

Publications from the Republic of Macedonia, total publications in the journal, and journals average RCR for the first 10 scientific journals are presented on Table 2. Journal analysis of published papers from the Republic of Macedonia have shown that on the 1st place is journal Prilozi form Macedonian Academy of Sciences and Arts with 759 publications from the Republic of Macedonia, on the 2nd place is Macedonian Pharmaceutical Bulletin with 592 publications, and on the 3rd place is Open Access Macedonian Journal of Medical Sciences with 495 publications. According the average RCR on the first place is Journal of Molecular Structure with 0.43 average RCR, on the second place is Nephrology Dialysis Transplantation with 0.37 average RCR, and on the third place are Macedonian Journal of Chemistry and Chemical Engineering and Procedia - Social and Behavioral Sciences with 0.32 average RCR (Table 2).

Table 1: Researchers analysis (March 18, 2024) (Source: wisdom.ai)

Name	Author's publications from Republic of Macedonia	Author's total publications	Authors overall average RCR
1. Trajče Stafilov	249	267	0.63
2. Goce Spasovski	243	256	1.04
3. Ljupco Kocarev	169	242	0.99
4. Sasko Kedev	149	151	1.62
5. Liljana Gavrilovska	136	159	0.30
6. G D Efremov	130	130	0.26
7. Vladimir Trajkovik	127	135	0.79
8. Eftim Zdravevski	122	136	1.28
9. Momir Polenakovic	119	119	0.60
10. Valentin Mirčeski	118	141	0.83

Table 2: Journal analysis of published papers from the Republic of Macedonia (March 18, 2024) (Source: wisdom.ai)

Journal	Publications from the Republic of Macedonia N (%)	Total publications in this journal	Journals average RCR
1. Prilozi	759 (81.70)	929	0.10
2. Macedonian Pharmaceutical Bulletin	592 (66.89)	885	0.09
3. Open Access Macedonian Journal of Medical Sciences	495 (8.39)	5.9K	0.24
4. Nephrology Dialysis Transplantation	170 (0.43)	39.9K	0.37
5. Journal of Morphological Sciences	167 (92.78)	180	0.00
6. Knowledge International Journal	165 (13.64)	1.21K	0.01
7. SEEU Review	135 (66.83)	202	0.13
8. Macedonian Journal of Chemistry and Chemical Engineering	125 (33.78)	370	0.32
9. Journal of Molecular Structure	116 (0.29)	40K	0.43
10. Procedia - Social and Behavioural Sciences	95 (0.31)	30.6K	0.32

3.5 Publishers

The list of first 10 publishers where Macedonian scientists published their results are shown on Table 3. According to the total publications, on the 1st place is Elsevier with 2.38K, on the 2nd place is De Gruyter Poland Sp. z o.o with 1.28K, and on the 3rd place is Springer Nature with 1.2K.

From the Macedonian publishers Scientific Foundation SPIROSKI is on the 6th place with 643 publications and on the 7th place is Macedonian Pharmaceutical Association with 592 publications.

According to Publisher's average RCR on the 1st place is Multidisciplinary Digital Institute (MDPI) with 0.31 RCR, on the 2nd place is Scientific Foundation SPIROSKI with 0.22 RCR, and the 3rd place are Elsevier and Spring Nature with 0.18 RCR (Table 3).

3.6 Institutions

Total publications, international collaboration percentage, and average RCR for the first 10 institutions are given on the Table 4. On the first place from the total publications is Ss Cyril and Methodius University of Skopje with 9.04K publications, on the second place is Republic of Macedonia (undefined) with 2.07K publications, and on the 3rd place is Goce Delchev University from Shtip with 1. 56K publications. According the average RCR on the first place is University Clinical Centre Mother Teresa Skopje with 1.04 average RCR, followed by Macedonian Academy of Sciences and Arts with 0.90 average RCR, and Saints Cyril and Methodius University of Skopje with 0.50 average RCR (Table 4).

Table 3: Publisher Analysis in Republic of Macedonia (March 18, 2024) (Source: wisdom.ai)

Publisher	Total publications from Republic of Macedonia N (%)	Total Publications of this publisher	Publisher's average RCR
1. Elsevier	2.38K (0.010)	20.5M	0.18
2. De Gruyter Poland Sp. z o.o	1.28K (1.164)	110K	0.08
3. Springer Nature	1.2K (0.012)	10.1M	0.18
4. Wiley	734 (0.008)	9.25M	0.14
5. Taylor & Francis Group (Informa)	695 (0.014)	5.06M	0.09
6. Scientific Foundation SPIROSKI	643 (10.421)	6.17K	0.22
7. Macedonian Pharmaceutical Association	592 (66.892)	885	0.09
8. Multidisciplinary Digital Institute (MDPI)	485 (0.037)	1.3M	0.31
9. Oxford University Press	456 (0.012)	3.64M	0.15
10. National Library of Serbia	454 (0.632)	71.8K	0.06

Table 4: Institutional Analysis in the Republic of Macedonia (March 18, 2024) (Source: wisdom.ai)

Institution	Total Publications	International Collaboration Percentage	Average RCR
1. Saints Cyril and Methodius University of Skopje	9.04K	247%	0.50
2. Republic of Macedonia	2.07K	265%	0.40
3. Goce Delchev University	1.56K	204%	0.47
4. Macedonian Academy of Sciences and Arts	1.14K	920%	0.90
5. South East European University	932	56%	0.28
6. University Clinical Centre Mother Teresa Skopje	722	1020%	1.04
7. European University	616	140%	0.33
8. University St. Clement of Ohrid	519	131%	0.22
9. Mother Teresa University	482	140%	0.24
10. University American College Skopje	444	419%	0.45

3.7 Funders

The biggest funder of science in the Republic of Macedonia is European Commission with 2B USD, followed by Engineering and Physical Sciences Research Council with 1M USD, Economic and Social Research Council with 314K USD, and National Engineering Robotics Contest with 204K USD (Table 5).

Table 5: Funders of science in the Republic of Macedonia (March 18, 2024) (Source: wisdom.ai)

Name	Grant amount from this funder	Total grant amount of funder	Distinct grant count
1. European Commission	2B	293B	256
2. Engineering And Physical Sciences Research Council	1M	23B	2
3. Economic And Social Research Council	314K	5B	1
4. National Engineering Robotics Contest	204K	5B	1

4. Discussion

In this paper we presented that in 2023, the Republic of Macedonia published 770 papers with restricted access, 432 with bronze access, 200 with hybrid access, 805 with gold access, and 61 with green access. During the same period, a total of 27,411 citations were recorded, with the most significant collaborative efforts involving the United States (contributing 2.18K publications and involving 4.71K researchers). We can see that the biggest number of published papers from the Republic of Macedonia in 2023 are in the journals with the gold access (open access without publication fee) and the lowest number is in the journals with the green access (open access with publication fee) indicating that financial position of scientists

is crucial for the publication of their research. It was previously published that of a total number of 222 countries for the period of 1996-2008, the Republic of Macedonia with H-index of 20 was placed on the 118th position of the country rank, the percentage of citable documents in the field of medicine was 88.92%, and the percentage of relative production of documents in the world is below 0.01. In 2008, Macedonian biomedical journal Prilozi was ranked on the 2484th place with 0.048 SJR of citable documents in the previous three years (Spiroski M. 2010).

The total number of researchers who published articles in 2023 amounted to 2,550, with 2,268 collaborating locally and 1,027 collaborating internationally. Notable contributors included Trajče Stafilov, Goce Spasovski, and Ljupco Kocarev.

The Relative Citation Ratio (RCR) is a new metric, recently endorsed by the National Institutes of Health. It is based on weighting the number of citations a paper receives to a comparison group within the same field (Hutchins et al. 2016). The iCite tool (Hutchins et al. 2017) may be used to generate RCR metrics for articles with PubMed IDs. The Field Citation Ratio (FCR) is a citation-based measure of scientific influence of one or more articles. It is calculated by dividing the number of citations a paper has received by the average number received by documents published in the same year and in the same Fields of Research (FoR) category (Purkayastha et al. 2019). They compare the RCR to the Field-Weighted Citation Impact (FWCI), also an article level, field-normalised metric, and present the first results of correlations, distributions and application to research university benchmarking for both metrics. Their analyses demonstrate that FWCI and RCR of articles correlate with varying strengths across different areas of research. Additionally, they observe that both metrics are comparably stable across different subject areas of research (Purkayastha et al. 2019).

Relative Citation Ratio (RCR) above 1.0 had only Sasko Kedev, Goce Spasovski, and Eftim Zdravevski. Similar results were published in 2016 for the Top Twenty Macedonian Biomedical Scientists (Spiroski M. 2016). The biggest number of top twenty Macedonian biomedical scientists has RCR lower than one. Only four Macedonian biomedical scientists have bigger RCR in comparison with those in PubMed. The most prominent RCR of 2.29 has Rosoklija G. RCR of the most influenced individual papers deposited in PubMed has shown the biggest value for the paper of Efremov D (35.19). This paper has the biggest number of authors (860) (Spiroski M. 2016).

Journal analysis according to the publications from the Republic of Macedonia, revealed Prilozi in first place, followed by the Macedonian Pharmaceutical Bulletin and the Open Access Macedonian Journal of Medical Sciences. According to the total publications in this journal, on the first place is Open Access Macedonian Journal of Medical Sciences (5.9K), on the second is Prilozi (929), and on the third please is Macedonian Pharmaceutical Bulletin (885). The percentage of publications from the Republic of Macedonia as a part of total publications in particular journal indicate national (local) journal. On the top of national journals is Journal of Morphological Sciences (92.78%), followed by Prilozi (81.70%), Macedonian Pharmaceutical Bulletin (66.89%), and SEEU Review (66.83%). The most international journals are Open Access Macedonian Journal of Medical Sciences with 8.39% published papers and Macedonian Journal of Chemistry and Chemical Engineering with 33.78% published papers from the Republic of Macedonia. Journals average RCR depends on the citation of published papers in PubMed database and shows international quality of the journals. Therefore, Macedonian Journal of Chemistry and Chemical Engineering with RCR of 0.32 and Open Access Macedonian Journal of Medical Sciences with RCR of 0.24 are on the top, and Journal of Morphological Sciences with RCR of 0.00 is on the bottom.

Among publishers, Elsevier took the lead, followed by De Gruyter Poland Sp. z o.o, and Springer Nature. Locally, the Scientific Foundation SPIROSKI and the Macedonian Pharmaceutical Association ranked sixth and seventh place, respectively. Total percentage of the publications from Republic of Macedonia, as a part of total Publications of publisher, have shown that Macedonian Pharmaceutical Association published 66.892%, and Scientific Foundation SPIROSKI published 10.421%. All other publishers published less than 1%, except De Gruyter Poland Sp. z o.o (1.164%), probably because Prilozi, Balkan Journal of Medical Genetics, and Macedonian Veterinary Review are co-published with Sciendo (De Gruyter Poland Sp. z o.o).

Institutionally, Ss Cyril and Methodius University of Skopje led in total publications, followed by an unspecified entity representing the Republic of Macedonia, and Goce Delchev University from Shtip. The first institutional analysis in Republic of Macedonia was performed on twelve institutes at the Faculty of Medicine in Skopje, with 140 authors analyzed with Harzing's Publish or Perish software (Harzing AW, 2007) for their current scientific impact (August 2009). A total number of 348 published papers with 473 citations by the academic staff employed at the Institutes were analysed. Scientific impact of the Institutes at the Faculty of Medicine, University "Ss Kiril and Metodij", Skopje, Republic of Macedonia was very heterogeneous - with higher, intermediate and low scientific rate (Spiroski M. 2009).

Non-open access publications accounted for 36.8% of the share compared to 66% for open access. Globally, the publication share was 0.03%, and the citation share was 0.02%.

Over the past years, the European Commission has funded scientific research in the Republic of Macedonia by 99.9%. The biggest funder of the science in the Republic of Macedonia is European Commission with 2B USD which should be much bigger with the

inclusion of country in the EU. From the former Yugoslav countries funding from the European Commission on the first place is Slovenia followed by Serbia, Croatia, North Macedonia, Bosnia and Herzegovina, and Montenegro. A comparative analysis of the scientific production of authors from six countries, former Yugoslav republics, was given, analysed over the five-year period (2008–2012). The analysis revealed that all countries, which emerged from the former Yugoslavia, except Slovenia and Croatia significantly lagged other selected countries. Research and development expenditure (% of GDP) in the countries arose from the former Yugoslavia is the lowest (except in Slovenia and Croatia) and amounts to < 0.5 %, compared with other analysed countries. To improve the situation in these countries, the investment in science must be increased (at least up to 1 % of GDP) and the conditions for research and development including infrastructure should be improved (Roglić-Korica V, & Milonjić SK. 2017).

5. Limitations

Several limitations can be applied in this research. There are not publicly defined inclusion and exclusion criteria for scientific papers defined in this AI platform (www.wisdom.ai). There are no verified scientific institutions, scientific journals, scientific authors and/or scientific publishers from the Republic of Macedonia. It seems that the presented results are partial, and the conclusions could be significantly biased. Presented results for scientific publishing in the Republic of Macedonia are analysed on March 18, 2024, and some of the data can be significantly different in different time frames.

6. Conclusions

The power of artificial intelligence for analysis of scientific publishing is very sensitive and can be used with precautions because of the limited electronic availability of scientific data, as well as of the different inclusion and exclusion criteria for analysis. The responsibility for the objective results should be shared between the authors, institutions, publishers, databases, and artificial platforms designed for presentation and/or analysis of the data. Now, there are no verified scientific institutions, scientific journals, scientific authors and/or scientific publishers from the Republic of Macedonia. It seems that the presented results are partial, and the conclusions could be significantly biased

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