

# A BIBLIOMETRIC ANALYSIS OF CYBERSECURITY RESEARCH PAPERS IN EASTERN EUROPE: CASE STUDY FROM THE REPUBLIC OF MOLDOVA

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## **Abstract**

*Nowadays it has become clear that cybersecurity must be an integral and indivisible part of technological progress and it must be integrated at the core of ICTs. Almost all states around the world show their cybersecurity commitment and the Eastern Europe countries, including the Republic of Moldova are no exception. Moldova ranked globally 73rd (out of 165 countries) in the 2017 Global Cybersecurity Index by ITU, ahead of six other countries in the region.*

*Nevertheless, we believe that cybersecurity is not sufficiently addresses by the academic community at the national level. The field of bibliometrics studies publication patterns by using quantitative analysis and statistics. This article aims to explore the level of research in cybersecurity at the national level and compare it with Eastern Europe countries' level, using bibliometric analysis of scientific publications, authored by researches from Moldova. The study is based on data from the national database (National Bibliometric Instrument) with over 68.000 research publications and 2 international databases – Scopus Elsevier and Web of Science.*

## **1. Introduction**

A recent study by Cybersecurity Ventures estimates that the global cost of cybercrime could exceed \$6 trillion annually by 2021. To grasp the magnitude of that figure, note that the IMF has estimated the total costs associated with the 2007–2008 global financial crisis at about \$12 trillion. In other words, every two years cybersecurity will cost the global economy an amount equal to that lost in a financial crisis that many compare with the Great Depression [7]. Cybersecurity and information security do share similarities; they also create maximum protection and efficiency when combined. Despite similarities, there are key differences that distinguish the two. Nevertheless, there is consensus that there is no standard or universally accepted definition of cybersecurity [26]. According to ISO/IEC 27032:2012 [13], cybersecurity is defined as preservation of confidentiality, integrity and availability of information in the cyberspace. At the same time, cybersecurity is considered an interdisciplinary domain, a statement supported by the Cybersecurity Report issued by the High Level Advisory Group of the EC Scientific Advice Mechanism in March 2017, saying that “cybersecurity is not a clearly demarcated field of academic study that lends itself readily to scientific investigation. Rather, cybersecurity combines a multiplicity of disciplines from the technical to behavioural and cultural. Scientific study is further complicated by the rapidly evolving

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nature of threats, the difficulty to undertake controlled experiments and the pace of technical change and innovation. In short, cybersecurity is much more than a science” [23].

Bibliometrics, coined by Pritchard in 1969, as the application of mathematics and statistical methods to books and other media of communication, focuses on the quantitative analysis of scientific and scholarly publications, being therefore considered suitable for the assessment of research [19].

Bibliometric studies measuring the published research outputs of cybersecurity have been few so far at the international level. Some of them have focused on the implementation of cybersecurity in specific areas of activity, such as healthcare [5, 14]. Other studies are more concerned with the bibliometric analysis of various facets and components of cybersecurity, including Big Data [2], malware [1], mobile forensics [10], Cloud forensics studies [4] or reaction to new security threat classes [19]. Other investigations were concerned with bibliometric analyses of recent research on machine learning for cyber security [17] or bibliometric analysis of cyberbehavior [20]. Some works were more specific and investigated the literature on terrorism [10] or aimed to provide a systematic literature review focusing on cybersecurity management, intellectual capital and trust [17].

This paper would like to complement the existing analyses, by presenting a bibliometric study of the development of research in cybersecurity in 10 Eastern European countries during the period 2008-2018, with a case study on the Republic of Moldova. The study investigated cybersecurity research papers indexed in Web of Science and Scopus databases, the publications of authors from the Republic of Moldova were further examined, based on data from the national database of scientific publications – National Bibliometric Instrument [12]. The study aims to answer the following questions: (1) What are the total number and geographical spread of publications in cybersecurity in Eastern Europe? (2) What is the production of cybersecurity papers by authors from the Republic of Moldova according to document types, languages used, authors’ institutions and publications sources? (3) Is there a relationship between the countries’ rankings in terms of bibliometric analyses of cybersecurity papers and in terms of the general level of cybersecurity commitments (such as ITU Global Cybersecurity Index and UN E-Government Survey).

## **2. Data and methods**

The study is based on data from 3 sources: Web of Science (Core Collection), Scopus and the IBN - National Bibliometric Instrument from the Republic of Moldova, which includes over 68.000 publications from the national scientific journals and conference proceedings. A search was carried out in January 2019 for journal articles, proceedings papers and reviews published in the period 2008-2018 which have “cybersecurity” or “cyber security” (although the one word spelling is considered correct, the two word spelling is used extensively as well [6]) in the title, abstract or keywords, by authors from the Eastern Europe countries. For the purpose of this study, Eastern Europe countries (EEC) are Belarus, Bulgaria, Czech Republic, Hungary, Poland, Republic of Moldova, Romania, Russian Federation, Slovakia and Ukraine, according to UN Statistics Division classification [27].

In order to compare records from WoS and Scopus the following data were extracted:

- Total number of publications with at least one author from each of the EEC;
- Total number of publications on computer science with at least one author from each of the EEC;
- Total number of publications on cybersecurity with at least one author from each of the EEC.

Disambiguation and matching of references was not part of the research described in this article. We then conducted a bibliometric analysis of cybersecurity publications from IBN, by authors from the Republic of Moldova, extracting 28 records, accompanied by the relevant bibliographic information (authors, affiliations, titles, sources, languages, editors, volume, pagination, keywords).

We also extracted data on cybersecurity indicators of the EEC from 2 relevant global rankings: ITU Global Cybersecurity Index [11], which measures the type, level and evolution over time of cybersecurity commitment in countries and UN E-Government Survey [29], because cybersecurity is a key factor in the transformation to resilient e-Government.

### 3. Results

#### 3.1. Production and Impact of Eastern Europe countries' publications

##### *Publications*

During the period established for this study, the 10 Eastern European countries (EEC) produced a total of 441 publications on cybersecurity, according to Scopus and 504 publications according to WoS, as detailed in Table 1, which lists for each country the number of publications, the number of citations and the mean number of citations per publication.

Overall, Scopus is listing 10.026 publications on cybersecurity for the period 2008-2018 and WoS – 9.300 publications, the share of EEC publications being 4.4% in Scopus and 5.4% in WoS. As can be seen, the difference is acceptable and represents about 1%. Just for comparison, the share of BRICS countries' (which include Russia) publications in cybersecurity is 16.7% in WoS and 12.2% in Scopus, while the share of the Commonwealth of Independent States (CIS) countries' (which include Belarus, Moldova and Russia) publications in this area is 1.4% in Scopus and 1.2% in WoS.

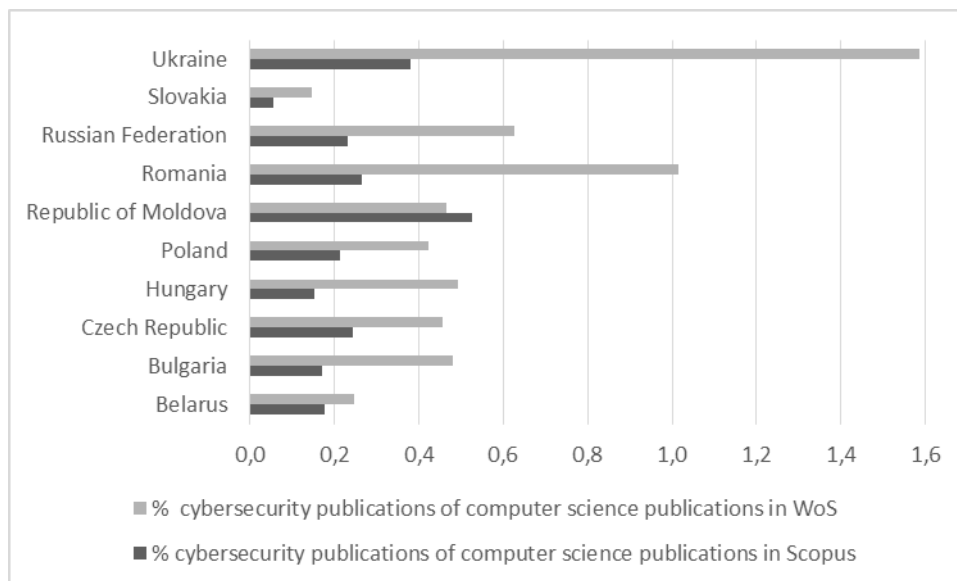
It will be seen that the top 5 most productive countries according to both Scopus and WoS are the Russian Federation, Poland, Romania, Czech Republic and Ukraine, which combined account for 90% of publications according to WoS and 91.6% according to Scopus. The other half of the EEC, the remaining 5 countries have an insignificant contribution from this perspective. The leader in terms of citations is Poland, followed by Russian Federation, Romania and Ukraine. Poland is also the leader in terms of the mean number of citations per publication, according to WoS.

As cybersecurity is part of computer science [24], we also examined the share of publications in cybersecurity from the total number of publications in computer science produced by EEC, as listed by Scopus and WoS (Figure 1).

Nr	Country	Nr publications in WoS	Nr citations in WoS	Mean number of citations per publications in WoS
1	Romania	129	122	0,9
2	Poland	106	244	2,3
3	Russian Federation	104	78	0,8
4	Czech Republic	63	45	0,7
5	Ukraine	50	17	0,3
6	Hungary	32	34	1,1
7	Bulgaria	11	11	1,0
8	Slovakia	7	6	0,9
9	Belarus	1	0	0,0
10	Republic of Moldova	1	0	0,0
	<i>Total</i>	504	557	

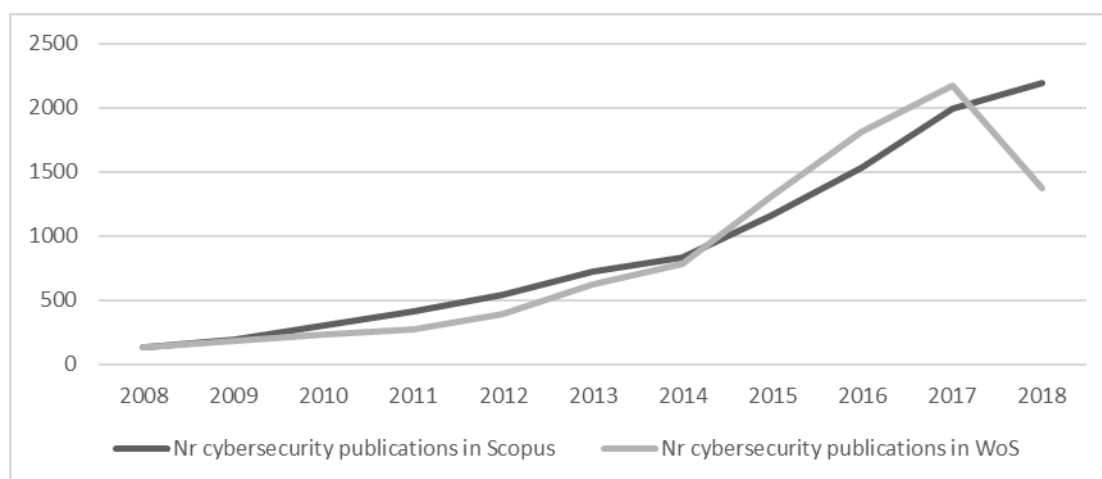
Nr	Country	Nr publications in Scopus	Nr citations in Scopus	Mean number of citations per publications in Scopus
1	Russian Federation	116	163	1,4
2	Poland	104	198	1,9
3	Czech Republic	67	93	1,4
4	Ukraine	60	107	1,8
5	Romania	57	85	1,5
6	Hungary	19	24	1,3
7	Bulgaria	8	4	0,5
8	Slovakia	5	12	2,4
9	Belarus	3	13	4,3
10	Republic of Moldova	2	0	0,0
	<i>Total</i>	441	699	

**Table 1. Cybersecurity publications by 10 EEC during 2008-2018 indexed in WoS and Scopus**



**Figure 1. Share of EEC cybersecurity publications of computer science publications in WoS and Scopus**

According to Scopus data, none of EEC exceeds the share of 1%, while WoS data demonstrates that only 2 countries pass the 1% threshold – Ukraine and Romania. The scarcity of research works on cybersecurity proves this area is not yet commanding enough attention of the research community, especially in developing countries. On the global level, three countries – USA, UK and China – produce 56% of research publications in cybersecurity, according to both Scopus and WoS records. The dynamics of cybersecurity publications is also impressive, as shown in Figure 2, with a steady growth, having increased roughly 20 times during this decade.



**Figure 2. Total number of cybersecurity publications listed in Scopus and WoS during 2008-2018**

Table 2 shows the distribution of document types of EEC cybersecurity publications during the study period. Not surprisingly, conference paper account for roughly 60% of all publications both in Scopus and WoS, followed by journal articles with 32% and book chapters. This might be explained by the fact, that journals usually have stricter and more rigorous requirements or there is an adequate number of specialised conferences, which enable faster communication of research results.

Document type	Count in WoS	%	Count in Scopus	%
Conference paper	332	66,5	265	60,1
Article	160	32,1	141	32,0
Book chapter	19	3,8	18	4,1
Book	0	0,0	4	0,9
Review	2	0,4	6	1,4

**Table 2. Document types and their counts of EEC cybersecurity publications, as listed in Scopus and WoS**

Based on Scopus records, we also investigated international collaborations of EEC and revealed that, as a whole, the majority of joint publications of EEC countries are with the world leaders in cybersecurity research – UK (4.3%), the USA (4.1%), followed by Italy (2.7%), France (1.8%) and Germany (1.4%). As can be noted, the majority of collaborations involve countries outside Eastern Europe, most probably due to the higher level of expertise available, beneficial for the EEC. The collaborations that lie within the Eastern Europe boundaries are less popular, accounting per total only 4%, with most publications co-authored, in decreasing order, with Poland, Ukraine, Russia, Romania and Belarus.

It should also be pointed out that we are only examining research publications for our bibliometric analysis, while the number of publications produced by cybersecurity professional communities is usually much higher, as shown in [9].

### *Cybersecurity rankings*

Having performed the bibliometric analysis of research publications in cybersecurity of EEC and revealing that the most productive countries were the Russian Federation, Poland, Romania, Czech Republic and Ukraine, both in terms of publications count, as well as citations, we set to find if the same situation applied in terms of cybersecurity rankings. The goal of such rankings is to measure the countries' commitment towards cybersecurity, assessing the legal, technical, organizational, capacity-building and cooperation frameworks necessary to ensure a robust and resilient e-government system.

Nr	Country	EGDI score	EGDI level
1	Russian Federation	0,7969	(Very high)
2	Poland	0,7926	(Very high)
3	Belarus	0,7641	(Very high)
4	Hungary	0,7265	(High)
5	Bulgaria	0,7177	(High)
6	Slovakia	0,7155	(High)
7	Czech Republic	0,7084	(High)
8	Romania	0,6671	(High)
9	Republic of Moldova	0,659	(High)
10	Ukraine	0,6165	(High)
	<i>Europe average EGDI</i>	<i>0,77</i>	<i>(Very high)</i>

**Table 3. Eastern Europe countries' rankings according to ITU GCI and UN EGDI (source [2, 6])**

Nr	Country	ITU Cybersecurity score	ITU Cybersecurity Global rank
1	Russian Federation	0,788	10
2	Poland	0,622	33
3	Czech Republic	0,609	35
4	Belarus	0,592	39
5	Romania	0,585	42
6	Bulgaria	0,579	44
7	Hungary	0,534	51
8	Ukraine	0,501	59
9	Republic of Moldova	0,418	73
10	Slovakia	0,362	82

**Table 3 (cont). Eastern Europe countries' rankings according to ITU GCI and UN EGDI (source [2, 6])**

The data on cybersecurity indicators of the EEC from 2 relevant global rankings: ITU Global Cybersecurity Index 2017 and UN E-Government Survey 2018, presented in Table 3, revealed that both in terms of e-Government development and cybersecurity commitments Russian Federation and Poland maintain the leading positions. According to the ITU report, the Russian Federation scores best in cybersecurity capacity building: its commitments range from developing cybersecurity standards to R&D and from public awareness to a home-grown cybersecurity industry, such as Kaspersky Labs [11]. The same similarity applies to the Czech Republic in terms of cybersecurity score (3<sup>rd</sup> among EEC in ITU ranking). The “intruder” here is Belarus, which although positioned low in cybersecurity research publications, is on leading positions in terms of e-Government development (3<sup>rd</sup> among EEC in EGDI) and cybersecurity development (4<sup>th</sup> in ITU ranking), which is due to coherent implementation of relevant strategies aiming to enhance ICTs in the provision of e-government services [29]. Ukraine, although in top 5 Eastern Europe countries in terms of cybersecurity publications productivity, isn't doing so well in terms of e-Government development (10<sup>th</sup> position among EEC in EGDI), as well as cybersecurity (8<sup>th</sup> position in ITU ranking). This can probably be explained by the unstable political situation in the country, affecting its development in all areas.

### 3.2. Case study: Republic of Moldova

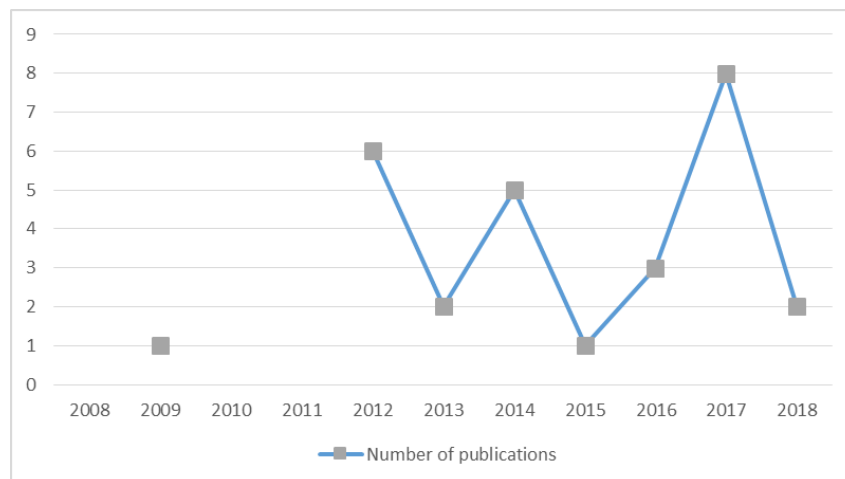
Moldova is a parliamentary republic in Eastern Europe, bordering Ukraine and Romania, with a resident population of 3.5 million, as of October 2018 [28] and GNI per capita at \$2180 in 2017 [21]. Moldova's EGDI is estimated as high, with a score of 0.659 (lower than Europe average of 0.77, but higher than world average of 0.55), which positions it on the 9<sup>th</sup> place among EEC in terms of e-Government development. Republic of Moldova is second in the top 10 countries for e-Government among landlocked developing countries, scoring high values for 2 out of the 3 indices making the EGDI - Human Capital Index (0.7274) and Online Service Index (0.7708) [29]. This is mostly due to the consistent implementation of the e-Transformation Agenda, funded by the World Bank and partially by the national government. This strategic program provides a unified vision to modernize and improve the efficiency of public services through IT governance, enhancing the IT capacity of the public sector. In terms of cybersecurity, Moldova is again on the 9<sup>th</sup> position among EEC. Moldova ranked globally 73<sup>rd</sup> (out of 165 countries), ahead of six other countries in the CIS region.

This is due to the presence and development of sections devoted to cybersecurity in government ICT programs, legal and regulatory framework, provided by the legislation on preventing and combating digital crimes [16] and on personal data protection [15], as well as the existence of the relevant national institutions, such as the IT and Cybersecurity Division, Division for Cybercrime Investigation at the General Prosecutor's Office, national CERTs etc. A lot of awareness raising and capacity building activities and campaigns on cybersecurity are being carried out as well, such as the Moldova Cyber Week [20], CyberSec conferences, ALERT Cyber Drill for CIS and EU representatives etc.

Although Moldova's standing in e-Gov and cybersecurity rankings is good, the productivity of national research publications in cybersecurity is quite low. Scopus is listing 2 publications by authors from Moldova, and WoS just one. For a more detailed assessment, we decided to further examine the publications of authors from the Republic of Moldova, based on data from the national database of scientific publications – National Bibliometric Instrument (IBN). We extracted 28 records according to our search criteria, accompanied by the relevant bibliographic information (authors, affiliations, titles, sources, languages, editors, volume, pagination, keywords). Despite the small number of records, we attempted to present a bibliometric analysis, although we are aware that some of the findings may not be representative.

These 28 publications are distributed quite unevenly during the study period, as shown in Figure 3, with almost 60% of them being conference papers. The publication peaks usually occur in years when conferences focusing on cybersecurity were organised (2017).

In terms of publications language, more than half of the publications are written in Romanian, about 40% are in English and the remaining 7% are in Russian. Almost all publications in English are conference proceedings, produced as a result of specialised international conferences that were organised in Moldova.



**Figure 3. Number of publications in individual years, based on data from IBN ([www.ibn.idsi.md](http://www.ibn.idsi.md))**

The largest share of records under investigation (60%) are “solo” publications, written by a single author, 36% of publications have 2 authors and only one is authored by 3 persons, denoting that collaborative writing in this area is not very common.



Nr	Organisation	Publications count
1	Academy of Economic Studies	5
2	Ministry of Defense of RM	4
3	Technical University of Moldova	4
4	Academy of Public Administration	3
5	Military Academy of the Armed Forces	3
6	International Relations Institute from Moldova	2
7	State University of Moldova	2
8	Free International University of Moldova	2
9	Police Academy of the Ministry of Internal Affairs of RM	1
10	National Regulatory Agency for Electronic Communications and Information Technology	1
11	Information and Documentation Centre on NATO from Moldova	1
12	National Council for Accreditation and Attestation	1
13	Institute for Juridical and Political Research	1

**Table 4. Publications distribution per organisations**

At the level of organisations (Table 4), the top 3 most productive institutions are the Academy of Economic Studies, the Ministry of Defence and the Technical University of Moldova. This is due to the fact, that both of these higher education institutions have extensive IT training courses and specialisations, as well as specialised departments dealing with training in various aspects of cybersecurity. The top 3 most frequent keywords used by authors are “cybersecurity”, “strategy” and “threat”. As far as the publication sources are concerned, the spread of papers in many journals and conferences in this phase of bibliometric analysis did not exhibit a real core.

In terms of the publications’ subjects, these vary greatly, including a wide range of issues such as cybersecurity strategies development, cyber defence, combating cyberbullying, cyber warfare. More specialised papers focus on the role and importance of cybersecurity in different areas: e-Government systems, provision of electronic services, healthcare sector, nuclear security, terrorism, human right and the digital economy. Some of the publications are of a more technical nature, dealing with specific issues, such as email security, data protection, networks and different types of attacks.

#### 4. Conclusions

Based on the findings from the study we can state that cybersecurity research publications are only starting to gain momentum, as cybersecurity becomes one of the main concerns in our digital, information driven world.

Based on the key results we achieved, we may conclude that the most productive Eastern Europe countries in cybersecurity according to both Scopus and WoS are the Russian Federation, Poland, Romania, Czech Republic and Ukraine, which combined account for 90% of publications. The dynamics of cybersecurity publications exhibits a steady growth, having increased roughly 20 times during this decade. As compared to the research publications productivity, both in terms of e-Government development and cybersecurity commitments Russian Federation and Poland maintain

the leading positions. In contrast, Belarus, which although positioned low in cybersecurity research publications, is on leading positions in terms of e-Government and cybersecurity development.

Among the Eastern Europe countries, the Republic of Moldova has an infinitesimal contribution in terms of international research publications on cybersecurity both in Scopus and WoS. At the national level, the productivity in this area is also quite low, with publications being distributed unevenly during the study period, written mostly in Romanian and the majority being conference papers.

The situation of scarcity in the information concerning research in cybersecurity proved clearly the need for systemic exploration. The current study provides a good foundation and appropriate framework for further analyses.

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