TRAMES, 2025, **29(79/74)**, 4, 423–448

CHALLENGES IN ESTONIAN RESEARCH POLICY: A BIBLIOMETRIC PERSPECTIVE

Tanel Hirv

University of Tartu

Abstract. Over the past three decades, the Estonian research landscape has evolved from modest beginnings to international recognition. Accession to the European Union, foreign funding, and international collaboration have been key drivers of this progress. However, upon closer inspection, many celebrated scientific achievements have proven to be overstated or methodologically questionable. This article analyses Estonia's scientific development using publication and citation metrics, authorship patterns, and demographic data. It highlights the limitations of citation-based benchmarks for evaluating national research and questions the relevance of bibliometric percentile targets in science policy. The study also challenges the notion that declining PhD graduation rates are primarily due to demographic changes, pointing instead to structural factors. The findings of the study highlight the need to reassess the role of bibliometric indicators in research policy and performance evaluation.

Keywords: bibliometric evaluation, research policy, Web of Science, research consortia, MDPI

DOI: https://doi.org/10.3176/tr.2025.4.07

Received 12 January 2025, accepted 9 September 2025, printed and available online 10 December 2025

1. Introduction

As early as the mid 20th century, De Solla Price (1963) and Eugene Garfield (1955) emphasised that the scientific literature, together with a comprehensive, multidisciplinary citation index, provides an essential means of assessing research activity and monitoring trends. Garfield, often regarded as the father of scientometrics, argued that "the total number of expressions [citations] is about the most objective measure there is of the material's importance to current research" (Thomson Reuters 2014: 2). This perspective laid the foundation for the use of citation metrics as a proxy for scientific impact. Two widely cited studies published in *Nature* and *Science* helped popularize the idea that a country's scientific impact, much like its economic wealth, can be measured using a simple metric: the average number of citations its published papers receive (King 2004, May 1997).

Today, in an era characterised by internationalisation and increasing competition, scientometrics, which commonly refers to the analysis of prior publications and citations, has become an essential tool for evaluating research performance and positioning within the global context.

Over the past three decades, the Estonian research landscape has undergone significant transformation, progressing from modest beginnings toward international visibility and competitive standing. This has been facilitated by Estonia's accession to the European Union, targeted funding, and extensive international collaboration. For example, in the early 1990s, approximately 300 scientific articles were published annually in Estonia, Latvia, and Lithuania, whereas by 2007, the number of articles published in Estonia had risen to 1,295, exceeding both Latvia and Lithuania (Allik 2008). In terms of citations, Estonia ranked 31st globally between 1997 and 2007, surpassing several other postSoviet states (Allik 2008). The period from 2008 to 2018, including Estonia's rise to 17th place globally in terms of citations, attracted international attention and came to be referred to as the 'Estonian paradox' or 'miracle' (Lauk and Allik 2018, Schiermeier 2019).

However, statistics do not always reflect the actual substance of research. The intensification of international collaboration and the global rise of mass authorship have shaped the perception of Estonia's scientific indicators, prompting questions about the extent to which publication metrics truly reflect the contribution of Estonian researchers (Hirv 2019). For example, between 2012 and 2022, the proportion of Estonian researchers listed as authors of Estonian publications decreased from 65% to 51% (Organisation for Economic Co-operation and Development 2025), highlighting the increasing role of large international consortia. While these collaborations have enhanced Estonia's visibility, they also obscure individual contribution and substantive input (Thelwall 2020, Cronin 2001) under these criteria, nearly all (88%).

Understanding the development of Estonian science requires a critical analysis of the various factors that influence research quality and impact. These include the role of research consortia, publishing practices, demographic trends such as an ageing scientific workforce, and the subjective nature of long-term strategic target setting.

This article explores Estonia's bibliometric performance in an international context, evaluates its long-term bibliometric targets, and offers policy recommendations for research assessment. It argues that Estonia's bibliometric ranking varies depending on expert preferences, thereby complicating the establishment of reference values in research evaluation. Since the collapse of the Soviet Union, Estonia has made significant progress relative to other post-Soviet states. However, concerns have emerged regarding questionable publishing practices, particularly involving MDPI journals, which have raised broader issues in Estonia and similar contexts. These concerns have prompted critical reflection on what constitutes the "international standard" in research evaluations. The article also argues that setting percentage-based targets for the share of publications ranked among the top 10% most cited in bibliometric databases is an inappropriate indicator for measuring progress towards the long-term goals of national science and innovation strategies. Furthermore, it challenges the common assumption that declining PhD graduation rates in Estonia are primarily due to low birth rates in previous decades, suggesting that other structural factors play a more decisive role.

2. Bibliometric rankings

2.1. Bibliometric methodology

It is well established that scientific advancement forms the foundation of a nation's economic and cultural development. At the same time, it is important to acknowledge that a nation's scientific progress cannot be evaluated solely on the number of people involved in research or the total amount of government funding invested. As a result, objectively assessing the quality of researchers and research institutions occupies a central position among the indicators used to understand a country's current status and its potential future trajectory (Moed 2005, King 2004, Allik 2013).

Bibliometric analyses and rankings, designed for policymakers, research managers, researchers, journalists, and others interested in assessing the scientific performance of universities and countries, have become a primary method of addressing this challenge. However, ranking countries by the impact of their scientific output is far from straightforward. A key challenge when gathering bibliometric data is determining which types of documents to include (Moed 2005).

The OECD (2025) and European Commission (2024), with the help of Elsevier, collects and analyses a substantial amount of bibliometric data, but this predominantly covers advanced Western nations, overlooking developing countries. As a result, relying exclusively on the data imposes a limitation, narrowing the range of observed values compared to those occurring globally and concealing the differences between countries. In order to address this, researchers (e.g., Universiteit Leiden Centre for Science and Technology Studies 2025, King 2004, Allik et al. 2020) have used databases such as Web of Science and Scopus and applied their criteria to compile international rankings of countries and universities.

In line with the approach used by the Leiden Ranking (2025), this study deliberately restricts its data to articles and reviews published in international journals. This ensures that all included publications follow similar peer-review standards and are indexed in a consistent way. This homogeneity is recommended for making fair, cross-disciplinary comparisons between countries. It should be noted that the chosen method is an important limitation in certain research fields, especially in computer science and engineering (where peer-reviewed conference papers dominate) and humanities (where monographs and edited volumes are central).

To obtain the best possible overview, this study uses the InCites platform, based on the Web of Science database, and includes only those articles in which the contribution of Estonian researchers was substantial. To this end, we exclude any article with more than 30 authors from the database, a threshold inspired by the esteemed journal *The Lancet* (2024). For comparing research fields and countries, citation impact is measured using the Category Normalized Citation Impact (CNCI), which is calculated by dividing the actual number of citations a document receives by the expected citation rate for documents of the same type, publication year, and subject area (Clarivate Plc 2025)

It is important to clarify that national citation counts do not directly reflect the overall quality of a country's scientific output but rather the indexed portion within the database. Consequently, highly populated countries with low per capita GDP and relatively few indexed publications per inhabitant may appear more competitive in science rankings than is truly the case. In such instances, the results largely reflect the performance of elite national institutions working with international partners. To balance such discrepancies, we assess both the quality of scientific articles and their quantity per inhabitant.

Since the number of articles per million inhabitants and the field-normalised citation rate are correlated (r = 0.69), these two metrics can be combined into a composite measure. To this end, the normalised citation rate and the number of articles per million inhabitants are transformed using the formula *(X–M)/SD*, where *M* is the mean value across all observations for that measure, and *SD* is the corresponding standard deviation. Thus, to calculate the index, both components were first standardised (to a mean of zero and a standard deviation of one) and then averaged.

In Section 3.2, the methodology is adjusted to replicate the Estonian Research Council's (2024) settings for establishing reference values. This involves including all publications indexed in the Web of Science and setting the research schema to default settings.

2.2. Disciplinary indicators with and without mass authorship

Between 2018 and 2023, Estonian researchers participated in the publication of 17 587 scientific articles, of which 1836 (or 10.4%) involved an unusually high number of authors exceeding the norms of conventional scientific work. Table 1 below presents consortium publications involving Estonian authors where the number of authors exceeds 30. Unfortunately, consortia do not always treat the indexing of publications in the Web of Science database with full seriousness, so this table should be interpreted with reservations.

The consortia collaborations are most strongly associated with physics. The Compact Muon Solenoid (CMS) experiment is one of two large general-purpose particle detectors built at CERN's Large Hadron Collider in Switzerland and France. The CMS experiment aims to investigate various aspects of physics, including the

Table 1. Consortia associated with Estonian authors

Group Authors	Record Count	% of 1.552
CMS COLLABORATION	557	35.889
LIFELINES COHORT STUDY	14	0.902
PSYCHIAT GENOMICS CONSORTIUM	11	0.709
23ANDME RES TEAM	9	0.580
ESTONIAN BIOBANK RES TEAM	9	0.580
BIOS CONSORTIUM	7	0.451
EQTLGEN CONSORTIUM	6	0.387
TOTEM COLLABORATION	6	0.387
EPI IBD GRP	5	0.322
EPI-IBD GRP	5	0.322
NO GROUP SPECIFIED	648	41.75

Source: author's calculations based on Web of Science and InCites.

search for the Higgs boson and particles that may constitute dark matter (CERN 2025). Other consortia beyond the scope of typical scientific work in which Estonian researchers participate focus on complex health-related issues, leveraging large datasets and genetic analyses.

For the sake of continuity in covering scientific developments in the region (Allik 2003, 2008, Lauk and Allik 2018, 2019), the Essential Science Indicators (ESI) schema is used to cover citation rates of research areas. ESI schema includes all documents from the Science Citation Index Expanded and Social Science Citation Index.

It is important to note that not all fields are equally involved in consortia and mass authorship. Figure 1 shows disciplines with and without mass authorship based on normalized citation rates. The phenomenon of mass authorship explains much of the 'miracle' of Estonian science. While the aggregated normalised citation rate, including mass authorship, is 1.76, without it, the rate drops to 1.20. According to the first indicator, Estonian science is cited 76% more than the global average in the Web of Science database, whereas the second indicator shows 20%.

The most striking observation is the dramatic impact of mass authorship on citation rates in Clinical Medicine, Biology & Biochemistry, and Molecular Biology & Genetics. Clinical Medicine has the highest CNCI with mass authorship at 4.1, but this drops sharply to 1.7 without it, representing a reduction of nearly 60%. Similarly, Biology & Biochemistry falls from 3.7 to 1.9, and Molecular Biology & Genetics from 3.6 to 1.4. This highlights how mass authorship inflates citation metrics in these fields.

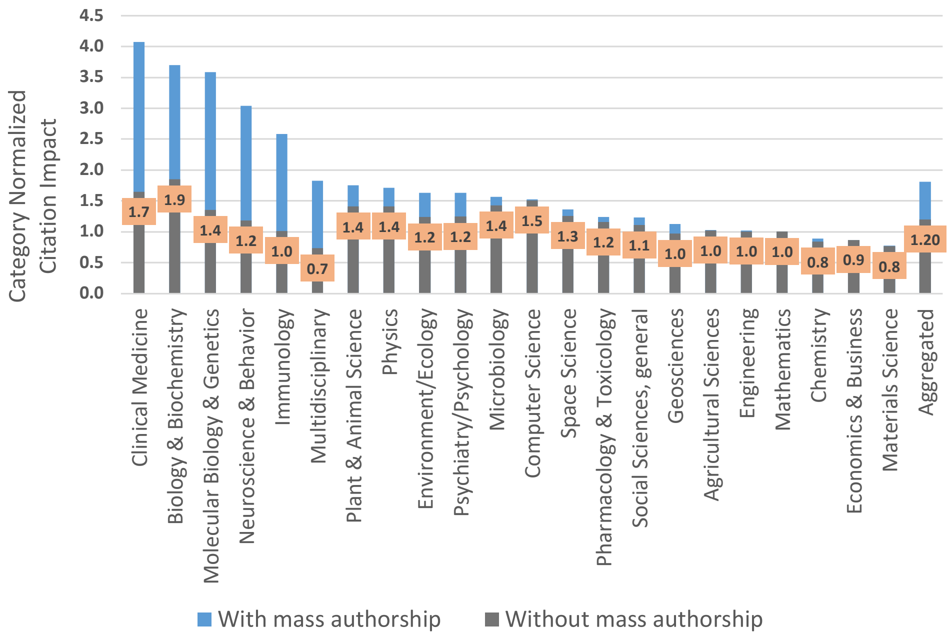

Figure 1. Category normalized citation impact across research areas in Estonia.
Source: author's calculations based on InCites.

Neuroscience & Behaviour, Immunology, and the Multidisciplinary category also show steep declines, though to a slightly lesser extent. These reductions suggest that collaborative, high-profile papers (e.g., from consortia or major initiatives) significantly boost citation impact in these areas.

By contrast, fields like Computer Science, Pharmacology & Toxicology, Economics & Business, and Engineering show little to no difference between the two scenarios, showing that mass authorship is less influential in boosting citation impact within these disciplines. Some fields fall below the global average in citation rates, indicating lower scientific impact. For example, chemistry (0.9), business administration (0.9) and materials science (0.8) display lower citation rates. Multidisciplinary science (0.7) and materials science (0.80) also fall below the global mean.

2.3. Comparison of countries

For country comparisons, we exclude mass-authored articles and look only at those with the number of authors between 1–30. Based on the constructed scientific impact index, Estonia ranks 21st among countries. While this position is not as outstanding as often portrayed in the media, it is by no means something to be ashamed of. Notably, whereas in the early 1990s, the Baltic states exhibited broadly similar scientific capacities, Estonia has since pulled significantly ahead. Estonia is positioned at 24th place in the ranking, whereas Lithuania and Latvia and occupy 55th and 63rd places, respectively. Russia's scientific lag the West is considerable, placing it only 119th.

The Estonian Research Council highlights that experts rated the quality of Estonian science in international comparison as very high – a considerable recognition of the country and its research community's collective efforts (Piirsoo 2025). The bibliometric evaluation aligns with the results of the regular 2024 research assessment. It is important to bring out that only countries with higher economic development are ahead of Estonia.

The table also separately indicates the proportion of articles published by the Multidisciplinary Digital Publishing Institute (MDPI). MDPI has attracted various criticisms in recent years, and some research agencies and universities have restricted or prohibited their researchers from publishing with this publisher. Institutions in Norway, Finland, and Denmark, which assess the quality and significance of scientific journals, have expressed concerns regarding MDPI. In Finland and Denmark, most MDPI journals do not meet the funding support (Fosso and Nøland 2020). Meanwhile, Norwegian policymakers have taken a more lenient stance, classifying most MDPI journals as academic, with only a few deemed unacceptable (Fosso and Nøland 2020). Criticism of MDPI is not confined to Scandinavia; for instance, Malaysian regulators have banned MDPI and several other publishers operating under similar models (Chawla 2023). In general, the high volume of articles published by MDPI complicates bibliometric analyses.

Table 2. Countries rankings based on scientific impact

Rank	Name	Web of Science Documents	MDPI %	Articles per million inhabitants	Category Normalized Citation Impact	Scientific Excellence Index
1	SWITZERLAND	255 001	5%	29 390	1.451	2.53
2	MACAU	17 274	7%	25 423	1.526	2.43
3	SINGAPORE	120 129	5%	21 177	1.641	2.39
4	HONG KONG	148 679	5%	19 940	1.657	2.35
5	DENMARK	160 314	5%	27 368	1.407	2.30
6	SCOTLAND	127 969	5%	23 267	1.394	1.99
7	NETHERLANDS	331 555	5%	18 922	1.419	1.76
8	SWEDEN	229 870	6%	22 157	1.315	1.75
9	AUSTRALIA	560 288	5%	21 789	1.324	1.74
10	NORWAY	125 395	6%	23 204	1.251	1.68
11	ICELAND	9 358	7%	25 203	1.104	1.49

Table 2. (continued)

Rank	Name	Web of Science Documents	MDPI %	Articles per million inhabitants	Category Normalized Citation Impact	Scientific Excellence Index
12	ENGLAND	882 417	5%	15 618	1.361	1.41
13	FINLAND	108 780	7%	19 631	1.231	1.39
14	BELGIUM	183 016	7%	15 789	1.346	1.39
15	UNITED KINGDOM	1 005 694	5%	14 953	1.341	1.32
16	LUXEMBOURG	11 238	7%	17 651	1.235	1.27
17	WALES	44 978	5%	14 509	1.329	1.26
18	IRELAND	78 108	7%	15 513	1.261	1.18
19	AUSTRIA	136 623	9%	15 246	1.244	1.13
20	NORTHERN IRELAND	23 797	6%	12 525	1.312	1.09
21	CANADA	576 306	5%	15 034	1.227	1.08
22	NEW ZEALAND	83 026	6%	16 375	1.147	0.99
23	QATAR	23 250	10%	8 488	1.303	0.80
24	**ESTONIA**	**15 751**	**11%**	**11 777**	**1.199**	**0.80**
25	CYPRUS	14 157	13%	11 415	1.182	0.74
26	USA	3 183 789	4%	9 614	1.219	0.70
27	GERMANY (FRG)	880 744	7%	10 556	1.188	0.69
28	ISRAEL	119 315	6%	12 821	1.112	0.68
29	ITALY	608 474	15%	10 243	1.166	0.62
30	SAUDI ARABIA	208 300	16%	5 782	1.283	0.58
31	LEBANON	18 705	9%	3 317	1.353	0.57
32	PORTUGAL	132 038	16%	12 744	1.054	0.54
33	UNITED ARAB EMIRATES	44 659	12%	4 788	1.293	0.53
34	SPAIN	504 516	14%	10 626	1.105	0.51
35	SLOVENIA	32 040	16%	15 250	0.956	0.50
36	FRANCE	566 786	6%	8 376	1.157	0.48
37	GREECE	93 760	17%	8 858	1.114	0.41
38	BRUNEI	2 760	17%	6 223	1.143	0.30
39	SOUTH KOREA	500 565	13%	9 678	0.987	0.19
40	CHINA MAINLAND	3 884 227	7%	2 756	1.194	0.18

Table 2. (continued)

Rank	Name	Web of Science Documents	MDPI %	Articles per million inhabitants	Category Normalized Citation Impact	Scientific Excellence Index
41	YEMEN	5 298	15%	162	1.269	0.17
42	BANGLADESH	33 744	11%	200	1.251	0.13
43	OMAN	10 649	11%	2 324	1.181	0.12
44	CZECH REPUBLIC	109 542	12%	10 261	0.936	0.12
45	TAIWAN	213 072	14%	9 106	0.969	0.11
46	MALTA	3 798	11%	7 335	0.998	0.06
47	PAKISTAN	145 522	11%	634	1.192	0.03
48	PALESTINE	5 021	11%	1 032	1.173	0.02
49	MALAYSIA	112 866	14%	3 382	1.088	-0.01
50	EGYPT	147 333	12%	1 360	1.138	-0.03
51	HUNGARY	59 337	13%	6 113	0.960	-0.11
52	VIETNAM	60 277	10%	622	1.126	-0.11
53	JORDAN	24 006	13%	2 187	1.066	-0.14
54	IRAQ	28 082	11%	652	1.090	-0.19
55	LITHUANIA	21 152	24%	7 512	0.848	-0.26
56	CROATIA	31 970	19%	8 064	0.821	-0.28
57	KUWAIT	10 745	11%	2 485	0.991	-0.28
58	CHILE	78 824	10%	4 085	0.940	-0.29
59	IRAN	323 300	3%	3 694	0.950	-0.29
60	SOUTH AFRICA	123 029	8%	2 086	0.997	-0.30
61	PANAMA	4 038	6%	935	1.029	-0.30
62	LIBYA	2 546	13%	381	1.035	-0.33
63	LATVIA	7 622	24%	4 016	0.918	-0.34
64	POLAND	248 604	23%	6 627	0.836	-0.34
65	REPUBLIC OF GEORGIA	4 469	7%	1 200	1.001	-0.35
66	BAHRAIN	3 178	13%	2 147	0.957	-0.38
67	JAPAN	625 577	6%	4 971	0.868	-0.38
68	MOROCCO	28 141	9%	763	0.993	-0.39
69	KENYA	19 958	7%	380	1.002	-0.40

Table 2. (continued)

Rank	Name	Web of Science Documents	MDPI %	Articles per million inhabitants	Category Normalized Citation Impact	Scientific Excellence Index
70	ROMANIA	68 919	27%	3 585	0.883	-0.45
71	UZBEKISTAN	4 601	11%	133	0.986	-0.45
72	PHILIPPINES	15 188	9%	134	0.976	-0.47
73	THAILAND	85 209	11%	1 192	0.942	-0.48
74	SERBIA	40 658	13%	5 958	0.772	-0.53
75	GHANA	17 623	7%	542	0.935	-0.54
76	ZAMBIA	4 126	8%	215	0.926	-0.58
77	NIGERIA	40 550	7%	192	0.915	-0.60
78	SRI LANKA	9 834	9%	448	0.907	-0.60
79	TURKIYE	279 558	4%	3 342	0.815	-0.61
80	URUGUAY	9 425	7%	2 751	0.828	-0.62
81	SLOVAKIA	31 876	21%	5 855	0.733	-0.62
82	SUDAN	5 590	14%	124	0.904	-0.63
83	PERU	15 735	11%	471	0.892	-0.63
84	MACEDONIA	3 365	11%	1 819	0.847	-0.64
85	RWANDA	3 203	8%	241	0.894	-0.64
86	INDIA	694 604	3%	496	0.886	-0.64
87	TUNISIA	37 907	9%	3 106	0.806	-0.65
88	SYRIA	2 522	9%	119	0.889	-0.66
89	ECUADOR	15 591	18%	883	0.861	-0.67
90	MYANMAR	2 998	9%	56	0.884	-0.68
91	NEPAL	10 046	8%	338	0.875	-0.68
92	MOZAMBIQUE	3 204	9%	101	0.882	-0.68
93	UGANDA	11 992	5%	266	0.877	-0.68
94	TANZANIA	10 867	7%	173	0.872	-0.70
95	COSTA RICA	6 225	9%	1 213	0.838	-0.70
96	AZERBAIJAN	4 863	7%	483	0.855	-0.71
97	CAMEROON	10 576	7%	394	0.857	-0.72
98	ARGENTINA	71 815	4%	1 575	0.820	-0.72

Table 2. (continued)

Rank	Name	Web of Science Documents	MDPI %	Articles per million inhabitants	Category Normalized Citation Impact	Scientific Excellence Index
99	BULGARIA	17 619	17%	2 597	0.788	-0.72
100	ZIMBABWE	4 712	5%	297	0.851	-0.74
101	MALAWI	5 251	6%	267	0.848	-0.74
102	ALGERIA	32 177	7%	735	0.827	-0.76
103	CONGO DEMOCRATIC REPUBLIC	3 412	10%	36	0.845	-0.77
104	BOTSWANA	3 475	6%	1 355	0.801	-0.77
105	INDONESIA	41 348	14%	152	0.836	-0.78
106	ETHIOPIA	29 667	6%	250	0.832	-0.78
107	COLOMBIA	48 978	12%	961	0.808	-0.78
108	SENEGAL	3 945	9%	237	0.820	-0.81
109	BRAZIL	398 620	6%	1 867	0.766	-0.82
110	CAMBODIA	2 724	11%	165	0.817	-0.82
111	KAZAKHSTAN	12 837	17%	674	0.774	-0.88
112	COTE IVOIRE	3 109	8%	114	0.779	-0.90
113	BURKINA FASO	3 604	8%	165	0.772	-0.92
114	MONGOLIA	2 787	12%	841	0.749	-0.92
115	MEXICO	133 886	11%	1 060	0.730	-0.95
116	BENIN	3 334	9%	260	0.749	-0.96
117	BOSNIA & HERZEGOVINA	5 230	16%	1 585	0.684	-1.02
118	VENEZUELA	5 284	7%	184	0.712	-1.05
119	RUSSIA	299 075	10%	2 065	0.608	-1.15
120	BELARUS	7 693	8%	825	0.632	-1.18
121	UKRAINE	32 260	9%	767	0.616	-1.22
122	CUBA	5 539	10%	492	0.612	-1.25
123	ARMENIA	4 497	7%	1 605	0.518	-1.38

Source: InCites and author's calculations.

A study conducted among the Hungarian research community (Csomós and Farkas 2023) reveals that researchers generally regard MDPI journals as sufficiently prestigious, emphasising the importance of MDPI's inclusion in the Scopus and Web of Science databases and their relatively high impact factors. However, questions have been raised about the methods MDPI employs to achieve these impact factors, casting doubt on their reliability (Copiello 2019, Oviedo-García 2021). Nevertheless, most researchers cited the rapid publication times offered by MDPI journals as a primary reason for choosing to publish there (Csomós and Farkas 2023).

Since MDPI is criticised for possibly publishing lower-quality articles, countries where it's more popular may have citation rates and publication counts that do not accurately reflect their scientific strength. In Estonia, the proportion of articles published in MDPI journals is 11%, while in Finland it is 6.5%. In Romania, Latvia, Lithuania, and Poland, where MDPI publishing is most prevalent, the share reaches as high as 27%. Meanwhile, in Malaysia, where the Ministry of Education has passed a policy to discontinue funding for publications in MDPI journals, the corresponding figure stands at 14%.

3. Selected topics for policy discussion

3.1. What does MDPI and CERN mean from the evaluation perspective?

In general, evaluation refers to the international assessment of the performance level of a research and development institution within a specific scientific or R&D field based on the internationally recognised standards of that field (e.g. Estonian Ministry of Education and Research 2025, Redman 2023).

Research and development evaluation generates considerable debate in Estonia and many other countries. The reason is clear: the evaluation process demands substantial time and effort from researchers and institutions, yet the tangible benefits often remain limited. Moreover, there is no unified or widely accepted methodology for conducting such assessments. Understandings of scientific quality vary not only among researchers themselves but also among other stakeholders within the field (Piirsoo 2025: 82).

Within this evaluative context, the proportion of publications in MDPI and similar journals increasingly highlights a situation where assessments of research institutions may depend less on the substantive and more on policymakers' or evaluation systems' stances regarding whether MDPI as a publisher is considered acceptable or not. In this evaluative context, the increasing volume of publications in MDPI and similar journals highlights a shift in how research institutions are assessed. Evaluations may now depend less on the substantive quality of research and more on the position of policymakers or evaluation systems regarding the legitimacy of MDPI as a publisher. Traditionally, assessments have focused on an institution's contribution to international science, measured through citations, impact factors, collaboration, and overall research quality. However, the stance adopted by a given country or evaluation body towards publishing models is playing an increasingly significant role. For instance, how can Estonian metrics and articles published be compared to those of Scandinavian countries, where a critical stance towards such publishers is commonly adopted?

A particularly troubling aspect is the fact that many studies published in journals associated with so-called predatory publishers are, in fact, of high or even excellent quality. However, much like a single drop of tar can spoil a whole jar of honey, it takes only a few instances of poorly executed or dubious work for an entire journal or even publisher(s) to be dismissed as illegitimate.

Although many MDPI journals are indexed in international databases such as Scopus and Web of Science and have high impact factors, this alone may not constitute sufficient evidence of their acceptability if policymakers and evaluators have pre-formed critical opinions about the publisher. For example, in Finland, Denmark, and Malaysia, funding rules and restrictions often do not recognise work published in MDPI journals as fully valid.

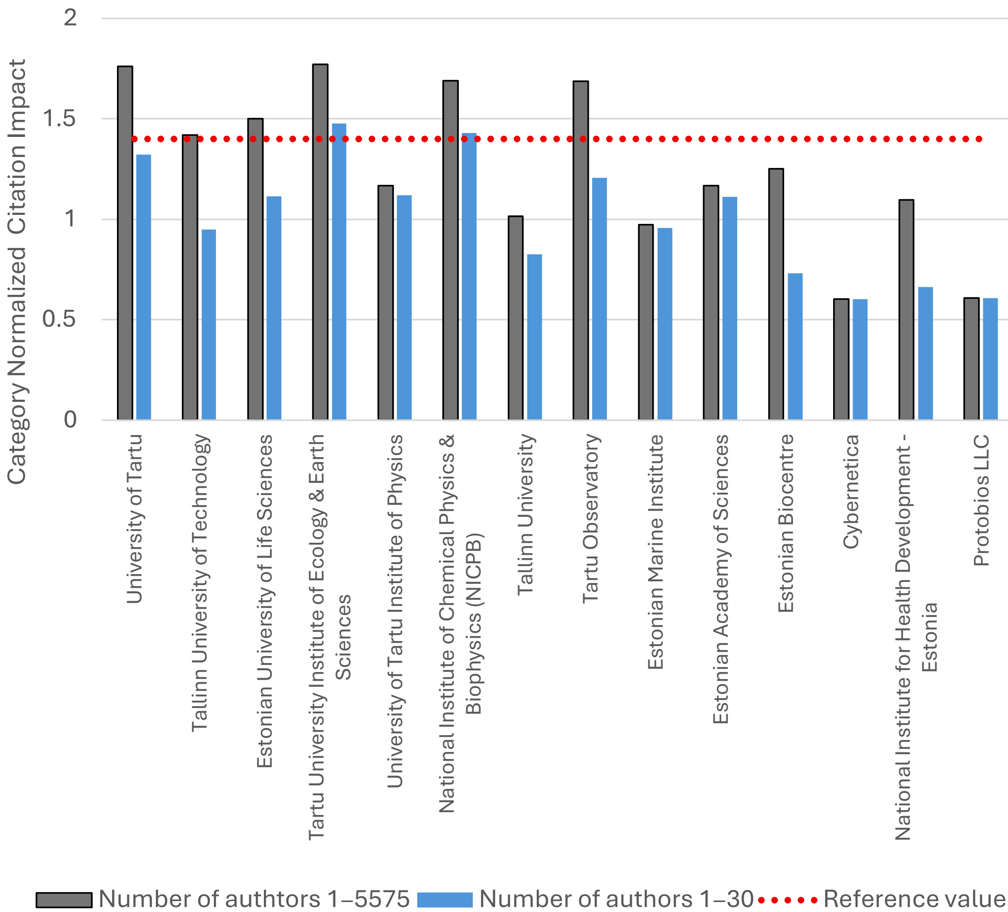

Figure 2. Estonian research institutions and their institute's normalised research impact. Note: calculations based on all types of sources indexed in Web of Science 2018-2023.

In Estonia, where approximately 11% of publications appear in MDPI journals, this situation may imply that evaluation outcomes hinge less on actual scientific strength and more on whether the evaluation committee or policymakers regard MDPI journals as legitimate scientific outlets. Such a development risks undermining the neutrality of evaluation, rendering it less substantive and more a reflection of regulatory attitudes.

For instance, how should international evaluators from Finland or Sweden assess Poland or Latvia in comparison with international standards? What precisely constitutes 'international level' in this context? This question will become critically important for the forthcoming national evaluation cycle in 2031.

The prevalence of mass-authored articles is another key question that needs to be considered for the next national evaluation cycle. For instance, Assessment guidance for regular evaluation of research and development In Estonia for 2024 states (Estonian Research Council 2024) references values for the six Frascati research areas for normalised citation impact and share of publications included in the 10% most cited publications (2018–2023) determined in InCites. In the context of evaluating research institutions, 'reference values' are essentially benchmarks or standards used for comparison to understand the performance of the institution being evaluated. It has been found that at the national level, mass authorship has a massive impact on citations (Hirv 2019, 2022), especially in small states. Using reference values that include mass-authored publications may disadvantage institutions not involved in such large-scale collaborations, putting them at risk of falling below targeted benchmarks (Figure 2).

As we can see from the figure, mass authorship affects research institutions and their subunits differently. Based on entities indexed in InCites, only the University of Tartu's Institute of Ecology and Earth Sciences and the National Institute of Chemical Physics and Biophysics (NICPB) meet the reference value without relying on mass-authored articles. Suppose evaluators accept these reference values without critical scrutiny and believe them unquestioningly. In that case, it leads to a highly distorted picture of the landscape of the natural sciences –high impact relies too heavily on external parties.

3.2. The percentage of highly cited papers is a relative measure

The Estonian Research, Development, Innovation, and Entrepreneurship Development Plan (2021) for 2021–2035 sets the proportion of Estonian research articles within the top 10% of the world's most highly cited papers as one of its key indicators. This metric aims to reflect Estonia's research system's quality and its international impact. The target is set at 12.5% by 2035, while the figure stood at 8.4% in 2020.

Although this metric may initially seem a suitable measure for assessing the quality of scientific output, it is important to bear in mind that it is a relative, rather than an absolute, indicator. Papers are compared with other publications from the same field and year, which means that changes in the database structure can significantly affect the results. Database(s) upon which this measure is based, is a dynamic resource that constantly incorporates new journals (Mabe and Amin 2001, Gu and Blackmore 2016, Thelwall and Sud 2022), including those with lower average citation counts. As a result, reaching the top 10% may become technically easier over time, even if the actual scientific quality of published articles has not increased.

For instance, Thelwall and Sud (2022) found that the number of journals indexed in Scopus grew exponentially over the 121 years from 1900. They also observed that the number of articles published per journal remained relatively stable until approximately 1980, after which it tripled, mainly due to the emergence of mega journals and online-only publishing platforms. Also, it is worth considering that if the Web of Science and other indexing platforms expand to include more journals from emerging research countries (Kanyika and Kim 2025), nations with already strong research bases, such as Estonia, may appear even stronger.

This does not necessarily imply an actual improvement in the quality of their scientific output. Instead, it reflects changes in the database structure and the overall expansion of global scientific publishing. The European Innovation Scoreboard (2024) has the same flaw in its methodology since they do not differentiate reasons citation impact is increasing or decreasing. This dynamic can create a misleading impression of rising scientific quality if one does not consider the evolving nature of the database and the expanding comparative base. It would, therefore, be prudent to complement this indicator with comparative data from peer countries or universities, ensuring temporal comparability and a more meaningful interpretation (Wang and Jeppsson 2022).

Linking this top article measure with comparable data from other countries would provide a more robust and temporally stable assessment of the quality of the country's science. Given the constantly evolving nature of the Web of Science database, the absolute proportion of papers within the top 10% of the most highly cited bracket may not necessarily reflect a genuine scientific advance in quality. Comparison with other nations or institutions would enable an assessment of whether a country's position has improved due to substantive advances, as opposed to purely methodological reasons.

3.3. The sustainability of Estonian science

Estonia's performance in international research rankings is strong, but serious questions remain about its longterm sustainability. The future of Estonianlanguage research and teaching depends exclusively on a new generation of researchers proficient in the Estonian language. The academic workforce in Estonia is ageing rapidly, and the number of young doctoral graduates available to replace senior researchers and drive scientific advancement is low (Kindsiko 2021). Although the overall number of researchers is increasing, the number of doctoral candidates in Estonia is lower than it was a decade ago (Vaimann 2025). The number foreign researchers cannot compensate for lack of Estonia PhD graduates indefinitely, unless Estonia can make an academic career more attractive for young researchers and increase the number of specialists holding doctoral degrees, it risks a loss of scientific innovation and generational continuity, which could impede the long-term progress of Estonian research.

A 2023 study conducted by the Estonian Research Council (2023), which aimed to map researchers with doctoral degrees working in evaluated institutions, suggests that the ageing of the research workforce may be an even greater challenge than previously thought (Figure 3).

Although the average age of researchers increased only slightly between 2012 and 2022 (from 50.1 to 50.8), significant differences emerged across disciplines (see Figure 3). The crisis in the Estonianlanguage academic workforce, highlighted earlier by Kindsiko (2021), is affecting some disciplines more severely than others. For example, in 2022, the average age of researchers in agriculture and veterinary medicine was 57.2, and in medical and health sciences, 52.9. The issue is not only the high average ages themselves but also the rising trend: the average increased by 3.4 years in medical and health sciences and by 2.2 years in agriculture and veterinary sciences since 2012. By contrast, a reversal of this trend can be observed in the fields of exact sciences, engineering, and technology, where the average age decreased by 2.6 years.

The fact that researchers are younger in engineering and technology disciplines raises the question of whether the ageing of the academic workforce is influenced, at least in part, by regulations governing doctoral studies. A doctoral degree generally requires a minimum of three research publications, but this requirement may not be equally suitable across disciplines, as the intensity and nature of collaboration vary significantly (Figure 4). In certain disciplines, an older average age may be explained by the more individual nature of research, which takes longer to produce the required number of publications.

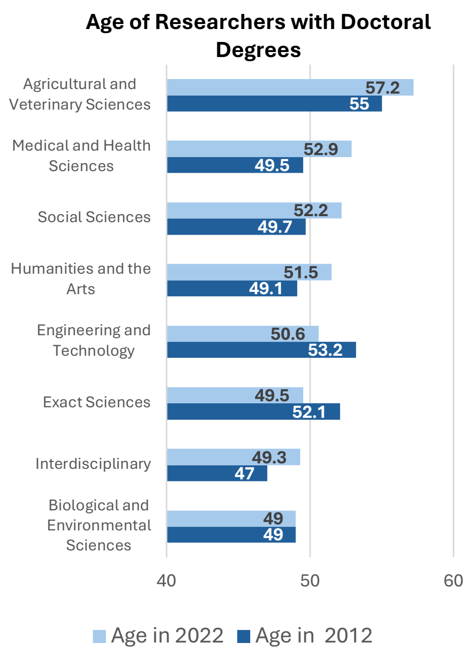

Figure 3. The age of doctoral researchers in positively evaluated institutions. Source: Estonian Research Council (2023)

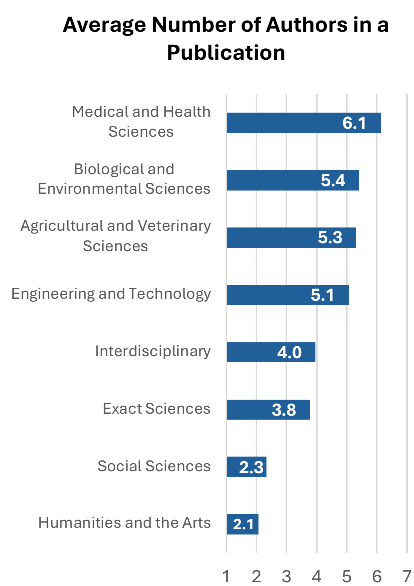

Figure 4. Number of authors per publication. Source: Estonian Research Council (2023)

Although low birth rates are frequently cited as the primary cause of the declining number of doctoral graduates in Estonia (e.g. Reimann 2025), the relationship is not as straightforward as it may appear. When focusing solely on doctoral graduates of Estonian origin, while excluding international candidates, and comparing their numbers with the national birth rate 28 years earlier, a moderate positive correlation emerges.

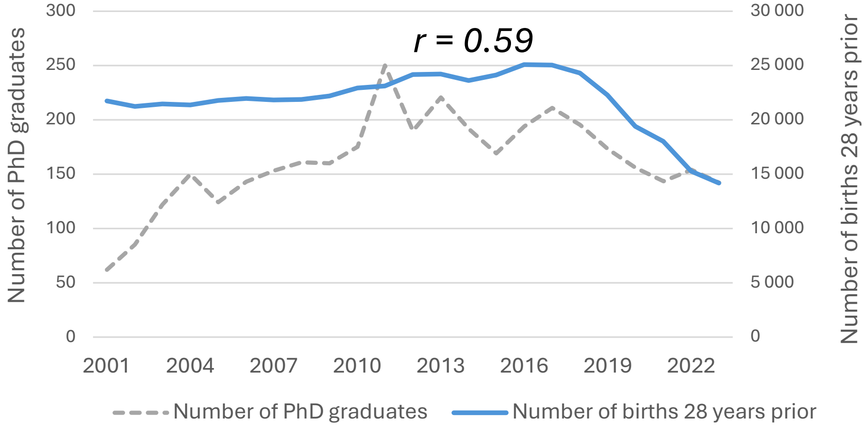

Figure 5. Doctoral graduation rates of Estonians compared with the birth rate 28 years earlier. Source: Author's calculations based on data from Statistics Estonia (2025a, 2025b) and Estonian Research Council (2025a).

This corresponds to a coefficient of determination (R^2) of approximately 0.35, suggesting that around 35% of the variation in doctoral graduate numbers can be statistically explained by birth rates in previous periods.

$$R^2 = 0.59^2 = 0.348 \approx 0.35 \tag{1}$$

Assuming birth rates are independent of other variables,, the remaining 65% is attributable to other factors, such as PhD students, intake, the efficiency of universities, higher education funding, societal attitudes, and various other socioeconomic influences (e.g. Niinemets 2019).

$$1 - 0.35 = 0.65 \tag{2}$$

It is worth noting, however, that it is a common error to compare these percentages directly as if 35% represented a 'small' contribution from the birth rate compared with the 65% associated with 'everything else'. Such an interpretation can be misleading, as the coefficient of determination operates on a squared scale and does not reflect effect size in a linear manner (Del Giudice 2021). A more accurate approach is to compare the relative effects using the square root of the ratio, thereby returning the comparison to its original scale:

$$\sqrt{\frac{0.35}{0.65}} = \sqrt{0.53} = 0.73 \tag{3}$$

This value (approximately 0.73) indicates that the explanatory power of birth rates, relative to the unexplained variance from other factors, is substantial but not dominant. Specifically, it shows that the contribution of birth rates to the variability in doctoral graduate numbers is about three-quarters as strong as the combined contribution of all other factors. In other words, while birth rates have a significant influence, other factors collectively play a larger role in explaining the variation in doctoral completions.

When international comparisons are considered, Estonia's underperformance in PhD graduation rates becomes even clearer, as shown in Figure 6. This metric, which measures doctoral graduates per 1,000 people aged 25 to 34, offers a standardized basis for comparison and highlights that Estonia's relatively low doctoral output is influenced more by structural and institutional barriers than by inevitable demographic trends.

With a doctoral graduation rate of 0.9 per 1,000 people aged 25–34, Estonia falls below the EU average of 1.3, and lags significantly behind leading countries such as Switzerland (3.1), Germany (2.0), and the United Kingdom (2.0). Estonia underperforms even in comparison with its Nordic peers, namely Finland, Sweden, and Norway, all of which are at 1.0. These differences suggest that the country is not fully converting its educational potential into doctoral-level qualifications.

A second negative consideration is that Estonian research has been highly dependent on European Union Structural Funds (Schiermeier 2019). For example, in 2018, these funds accounted for as much as 42% of Estonia's research and development budget (Koppel 2019: 12). Although this may not have appeared to be a pressing concern on paper, given that Structural Fund allocations are treated as part

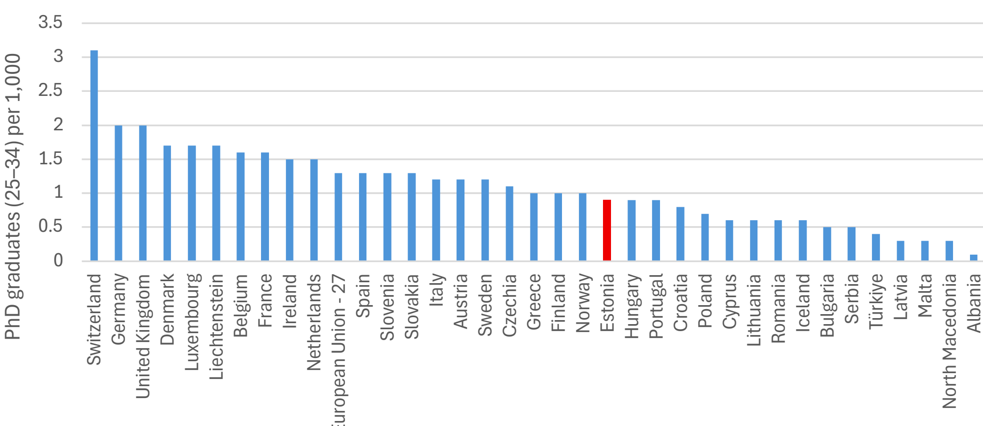

Figure 6. Graduates at doctoral level by sex and age groups – per 1000 of population aged 25-34. Source: Eurostat (2022).

of the state budget, it nonetheless reflects the vulnerability and external dependence of Estonia's research funding.

A similar concern has been expressed by Tarmo Soomere (2025), who has highlighted the instability of financing for research infrastructure. Between 2010 and 2024, approximately €135.5 million was invested in selected research infrastructures, roughly half of which came from EU Structural Funds. In recent years, the focus of financing has shifted towards the national state budget, which in theory should offer greater stability, but this shift has introduced new challenges. For example, significantly higher cofinancing requirements for participating institutions. One best-known example is Estonia's participation in CERN, which allows domestic researchers to access cutting-edge facilities without requiring full national ownership or investment.

4. Discussion

Firstly, Estonia should continue participating in internationally coordinated research initiatives to access high-level research infrastructure and expert knowledge. Such collaborations may seem like a financial burden, but they help align national research priorities with national strategic objectives. In the long term, ongoing involvement in international initiatives will raise the scientific standard, enhance international reputation, and foster sustainable research networks.

On the other hand, internationally coordinated research presents a challenge for bibliometricians assessing the impact of scientific output, an issue that must be recognised. In the case of smaller research systems, an inappropriate methodology may yield an unrealistic picture of scientific performance. Awareness of the effects of mass authorship is essential, and the methodology for compiling indicators related to publishing activity must be adjusted accordingly. Not all that glitters is gold. Although analyses of Estonian science are often presented in a positive light, the overall picture is not as rosy, and earlier narratives about an Estonian science 'miracle' tend to be overstated.

To obtain a more balanced view, policymakers and independent bibliometricians should collaborate to establish common principles for measuring scientific impact. Failing to do so risks sending misleading signals to the public about the country's scientific capabilities. A good example can be found in two recent bibliometric analyses "published in the local daily newspaper *Postimees*. The first asserted that, based on the last 11 years of research publications, Estonia ranked as the fifthmost impactful country globally (Allik and Lauk 2023b). The second stated that, in terms of impact, the University of Tartu outperformed all Nordic universities (Allik and Lauk 2023a). These reports illustrate the issue raised in 2019 by *Times Higher Education* journalist Simon Baker (2019) that research papers with large numbers of authors can distort performance metrics like citation impact, giving an inflated impression of a country's, institution's, or researcher's influence.

When comparing countries and disciplines, it would be prudent to exclude publications with mass authorship, as proposed by Hirv (2019) and implemented within the Estonian Research Council's (2025c) TeadusSilm initiative where they exclude papers with more than 100 authors. Alternatively, bibliometric rankings focusing on Estonia could adhere to the national institutional baseline funding regulations, as the Ministry of Education and Research (2020) has adopted. These regulations state that articles with more than 100 authors be counted with a coefficient of 0.5, and those with more than 1000 with a coefficient of 0.3.

However, it is debatable whether these coefficients are optimal, especially as the framework for baseline institutional funding itself needs review. Since funding is allocated based on publication counts, evaluated institutions whose researchers participate extensively in mass authorship consortia may gain an unfair competitive advantage. Considering that nearly one in ten publications (9.2%) falls into this category, this has significant financial implications for certain institutions and institutes.

Moreover, the proliferation of massauthorship affects the preparation of bibliometric reviews for grant applicants submitted to the Estonian Research Council. In the review process for research grants, it is common practice to evaluate not only the proposal's content but also the applicant's track record (Estonian Research Council 2025b). The Estonian Research Council also supplies bibliometric data to expert panels and review boards, aiding in their evaluation of each applicant's scientific achievement. As a result, evaluators often consider metrics such as citation counts and journal prestige associated with the applicant's prior publications Applicants who have published extensively in massauthorship consortia may gain an advantage if this phenomenon is not considered. A clear position is required as to whether such publications should be regarded as an applicant's personal scientific output. This is especially relevant where physicists and mathematicians are assessed within the same panel for personal research grants, as physicists with extensive consortia affiliations may be disproportionately advantaged.

A similarly clear stance is required from policymakers concerning the role of MDPI and other academic publishers with comparable business models. While the shift towards open access is generally positive, it must be asked whether this is the type of open access that is desirable when it comes with a tarnished reputation. In this respect, Estonia is at risk of following a trend observed in other Central and Eastern European countries, which publish disproportionately with such outlets. Against the backdrop of high doctoral requirements, low doctoral completion rates, and the academic pressure to "publish or perish", the described scenario is very plausible. It has already been discussed how doctoral candidates might attempt to benefit from MDPI's business model to fulfil their requirements.

This issue has also been raised before. For example, Kirsimäe (2024) draws attention to the fact that doctoral candidates in Estonia are subject to exceptional pressure. Unlike in many other countries, Estonian doctoral candidates are in most cases required to have published at least three peer-reviewed articles in high-impact journals as a condition for obtaining their PhD. This situation creates a challenging environment for candidates, making the option of submitting work to journals with an easier and faster review process, such as those published by MDPI, a realistic alternative. Such a trend could lead candidates to prioritise convenience over quality, thereby raising serious questions about the standard of doctoral research.

The issue of developing the next generation of scientists is also critical and requires more urgent attention. An increasing average age of researchers in certain disciplines signals a serious threat to the sustainability of scientific work. As the number of senior researchers grows and the proportion of younger researchers declines, the continuity of research may be jeopardised. This is especially critical in fields where the average age is already high and rising, such as agricultural sciences, veterinary medicine, and medical and health sciences. Demographic data indicates that earlier birth rates are not the primary reason for the low number of doctoral graduates. Rather, the main causes relate to policies that can be intentionally shaped and improved.

Although the growing proportion of English-speaking staff in the research community is a natural consequence of academic publishing being largely conducted in English, but preserving teachings in Estonian requires lecturers who are proficient in the national language. If universities have consistently failed to meet state-mandated quotas for PhD graduates, it is justified to question the justification for requiring lecturers at the largest higher education institutions to hold a doctoral degree. Might such strict requirements, when coupled with a structural shortage of doctoral graduates, ultimately jeopardise both the quality and accessibility of higher education delivered in the Estonian language?

A useful approach to improving doctoral graduation rates could involve revising the current doctorate requirements. For example, taking advantage of the flexibility provided by the Universities Estonia (2020) doctoral study quality agreement, universities could consider reducing the number of mandatory publications. This change may facilitate more timely degree completion without too much compromising academic standards. Alternatively, institutions might introduce discipline-specific publishing requirements to better reflect the diverse research practices and expectations across academic fields.

The final policy recommendation concerns the Estonian Research, Development, Innovation, and Entrepreneurship Development Plan (2021–2035), which sets a target for 12.5% of Estonian scientific publications to be among the top 10% most cited globally by 2035, up from 8.4% in 2020. Although this indicator is intended to reflect research quality and impact, it is inherently relative. Its value depends on comparisons with global outputs and is sensitive to changes in databases such as the Web of Science and Scopus. As a result, Estonia's share may increase for methodological rather than substantive reasons, particularly as the database expands through the inclusion of lower-impact journals. Therefore, this metric should be interpreted in comparison to peer countries, rather than in isolation.

5. Conclusion

Based on the calculated scientific impact index, Estonia currently occupies 30th place among countries. Although this position may not be as impressive as often claimed in the media, it is nonetheless an outcome the country can be proud of. Estonia has significantly outpaced its Baltic neighbours since the early 1990s, with Lithuania and Latvia ranking 55th and 63rd, respectively. Russia lags far behind at 117th, highlighting the broader regional divergence in scientific performance.

The pressing question now is how the scientific landscape will evolve in the years to come. From an evaluation standpoint, there are several critical issues that policymakers and research administrators must address, preferably before the next targeted evaluation in 2035. One such issue is how to evaluate papers arising from mass authorship. How should such articles be assessed, and to what extent can indicators influenced by consortia research be considered reliable, particularly in the context of regular evaluations and reference values?

Another unresolved issue is the direction the Estonian research system will take with regard to publishers such as MDPI. Will Estonia align itself with the Scandinavian model, where such publishers are viewed critically, or with Eastern European countries, where their share of publication activity is significantly higher? These decisions will have long-term consequences for the visibility, credibility, and impact of Estonian science.

Policymakers also appear to have overlooked the evolving nature of bibliometric databases and how their metrics shift over time. For example, the goal of increasing the proportion of Estonian research articles ranked among the top 10% most cited globally may reflect methodological artefacts rather than genuine scientific progress, particularly if database expansions begin to include lower-impact journals, thereby inflating the percentiles. Without a nuanced understanding of these shifts, such targets risk being misleading.

The decline in the number of doctoral graduates in Estonia is often attributed to low birth rates; however, this relationship is more complex than it may initially appear. While demographic changes undoubtedly play a role, the decrease in birth rates alone cannot fully explain the persistent failure to meet the targeted annual number of doctoral graduates. This points to broader systemic and institutional issues which warrant serious attention.

The policy proposals put forward, which range from refined bibliometric methods and evaluation criteria to doctoral training and strategic publication practices, offer concrete ways to strengthen Estonia’s research environment.

Declaration of generative AI and AI-assisted technologies in the writing process. During the preparation of this work, the author used ChatGPT and Grammarly to improve language and readability. After using these tools/services, the author reviewed and edited the content as needed and takes full responsibility for the content of the publication.

Address:
Tanel Hirv
School of Economics and Business Administration
University of Tartu
Narva mnt 18
Tartu, 51009, Estonia
E-mail: tanel.hirv@ut.ee, tanelhirv@gmail.com

References

Allik, Jüri (2013) "Factors affecting bibliometric indicators of scientific quality". *Trames* 17, 3, 199–214. DOI: https://doi.org/10.3176/tr.2013.3.01

Allik, Jüri (2008) "Quality of Estonian science estimated through bibliometric indicators (1997–2007)". *Proceedings of the Estonian Academy of Sciences* 57, 4, 255–264. DOI: https://doi.org/10.3176/proc.2008.4.08

Allik, Jüri (2003) "The quality of science in Estonia, Latvia, and Lithuania after the first decade of independence". *Trames* 7, 1, 40–52. DOI: https://doi.org/10.3176/tr.2003.1.05

Allik, Jüri and Kalmer Lauk (2023a) "Tartu Ülikool – Põhjamaade mõjukaim ülikool". [University of Tartu – The most influential university in the Nordic countries.] *Postimees*. Available online at https://arvamus.postimees.ee/7778287/ak-tartu-ulikool-pohjamaade-mojukaim-ulikool. Accessed on 07.08.2025.

Allik, Jüri and Kalmer Lauk (2023b) "Teadusrikkuselt on Eesti maailmas viie esimese riigi seas". [Estonia is among the top five countries in the world in terms of scientific richness.] *Postimees*. Available online at https://arvamus.postimees.ee/7751118/juri-allik-ja-kalmer-lauk-teadusrikkuselt-on-eesti-maailmas-viie-esimese-riigi-seas. Accessed on 07.08.2025.

Allik, Jüri, Kalmer Lauk, and Anu Realo (2020) "Indicators of the scientific impact of nations revisited". *Trames* 24, 2, 231–250. DOI: https://doi.org/10.3176/tr.2020.2.07

Baker, Simon (2019) "Call to remove 'hyper-authored' papers from research metrics". *Times Higher Education*. Available online at https://www.timeshighereducation.com/news/call-remove-hyper-authored-papers-research-metrics. Accessed on 07.08.2025.

CERN (2025) CMS. Available online at https://home.cern/science/experiments/cms. Accessed 07.08.2025.

Chawla, Dalmeet Singh (2023) "Malaysia won't pay for researchers to publish in certain journals". Available online at https://cen.acs.org/policy/publishing/Malaysia-wont-pay-researchers-publish/101/i35. Accessed 24.06.2025.

Clarivate Plc (2025) "Category Normalized Citation Impact (CNCI)". *Indicators handbook*. InCites Help Center. Available online at https://incites.zendesk.com/hc/en-gb/articles/25087312115601-Category-Normalized-Citation-Impact-CNCI. Accessed on 07.08.2025.

Copiello, Sergio (2019) "On the skewness of journal self-citations and publisher self-citations: cues for discussion from a case study". *Learned Publishing* 32, 3, 249–258. DOI: https://doi.org/10.1002/leap.1235

Cronin, Blaise (2001) "Hyperauthorship: a postmodern perversion or evidence of a structural shift in scholarly communication practices?" *Journal of the American Society for Information Science and Technology* 52, 7, 558–569. DOI: https://doi.org/10.1002/asi.1097

Csomós, György and Jenő Zsolt Farkas (2023) "Understanding the increasing market share of the academic publisher 'Multidisciplinary Digital Publishing Institute' in the publication output of Central and Eastern European countries: a case study of Hungary". *Scientometrics* 128, 1, 803–824. DOI: https://doi.org/10.1007/s11192-022-04586-1

Del Giudice, Marco (2021) "Are we comparing apples or squared apples? The proportion of explained variance exaggerates differences between effects". *OpenPsych*. DOI: https://doi.org/10.26775/OP.2021.06.15

Estonian Ministry of Education and Research (2020) "Teadus- ja arendusasutuste baasfinantseerimise määramise tingimused ja kord". [Conditions and procedure for determining the base funding of research and development institutions.] Available online at https://www.riigiteataja.ee/akt/109102020013. Accessed 07.09.2025.

Estonian Ministry of Education and Research (2025) *Teadussüsteemi riiklik korraldus*. [National organization of the research system.] Available online at https://hm.ee//korgharidus-ja-teadus/teadus-ja-arendustegevus/teadussusteemi-riiklik-korraldus#item-1. Accessed on 07.08.2025.

Estonian Ministry of Education and ResearchandMinistry of Economic Affairs and Communications (2021) "Estonian Research and Development, Innovation and Entrepreneurship Strategy 2021–2035". Available online at https://www.hm.ee/sites/default/files/documents/2022-10/taie_arengukava_kinnitatud_15.07.2021_211109a_en_final.pdf. Accessed on 07.08.2025.

Estonian Research Council (2024) "Assessment guidance for regular evaluation of research and development 2024". Available online at https://etag.ee/wp-content/uploads/2024/05/Regular-Evaluation-Guidance-2024.pdf. Accessed on 07.08.2025.

Estonian Research Council (2025a) "Estonian research 2025". DOI: https://doi.org/10.58009/TEAD/010

Estonian Research Council (2025b) "Guidelines for applicants regarding bibliometric background information". Available online at https://etag.ee/wp-content/uploads/2025/03/Guidelines-regarding-bibliometric-background-information-2025.pdf. Accessed on 07.08.2025.

Estonian Research Council (2025c) *TeadusSilm*. [Scientific eye.] Available online at https://www.etis.ee/Teadussilm. Accessed on 07.08.2025.

European Commission (2024) *European Innovation Scoreboard 2024 Methodology Report*. Available online at https://research-and-innovation.ec.europa.eu/document/download/074d5495-433a-440f-bcf9-dc620fce7af1_en?filename=ec_rtd_eis-2024-methodology-report.pdf. Accessed on 07.09.2025.

Eurostat (2022) "Graduates at doctoral level by sex and age groups – per 1000 of population aged 25–34". DOI: https://doi.org/10.2908/EDUC_UOE_GRAD06

Fosso, Olav Bjarte and Jonas Kristiansen Nøland (2020) "Forskere blir ledet til etiske overtramp". [Researchers are being led into ethical transgressions.] *Universitetsavisa*. Available online at https://www.universitetsavisa.no/ytring/forskere-blir-ledet-til-etiske-overtramp/114691. Accessed on 07.08.2025.

Garfield, Eugene (1955) "Citation indexes for science: a new dimension in documentation through association of ideas". *Science* 122, 3159, 108–111. DOI: https://doi.org/10.1126/science.122.3159.108

Gu, Xin and Karen L. Blackmore (2016) "Recent trends in academic journal growth". *Scientometrics* 108, 2, 693–716. DOI: https://doi.org/10.1007/s11192-016-1985-3

Hirv, Tanel (2019) "Research consortia determine a significant part of the bibliometric visibility of Estonian science". *Trames* 23, 3, 287–308. DOI: https://doi.org/10.3176/tr.2019.3.02

Hirv, Tanel (2022) "The interplay of the size of the research system, ways of collaboration, level, and method of funding in determining bibliometric outputs". *Scientometrics* 127, 3, 1295–1316. DOI: https://doi.org/10.1007/s11192-021-04232-2

Hirv, Tanel and Marko Piirsoo (2023) *Muutused Eesti teadlaskonnas 2012–2022*. [Changes in the Estonian scientific community 2012-2022.] Eesti Teadusagentuur. DOI: https://doi.org/10.58009/AERE-PERENNIUS0076

Kanyika, Martin Elihaki and Eungi Kim (2025) "Continued struggle: the growth of Scopus-indexed journals in Africa over the last decade". *Journal of Librarianship and Information Science*. DOI: https://doi.org/10.1177/09610006251319546

Kindsiko, Eneli (2021) "Eestikeelse akadeemilise tööturu kriis". [The crisis in the Estonian-language academic labor market.] *Sirp* (Tallinn). Available online at https://www.sirp.ee/eestikeelse-akadeemilise-tooturu-kriis/. Accessed on 07.09.2025.

King, David A. (2004) "The scientific impact of nations". *Nature* 430, 6997, 311–316. DOI: https://doi.org/10.1038/430311a

Kirsimäe, Kalle (2024) "Teadlase pilguga: ohtlikud trendid, mis viivad rämpsajakirjadest rämpsteaduseni". [By a scientist's eye: dangerous trends leading from junk journals to junk science.] *Postimees*. Available online at https://arvamus.postimees.ee/8126423/teadlase-pilguga-ohtlikud-trendid-mis-viivad-rampsajakirjadest-rampsteaduseni. Accessed on 07.09.2025.

Koppel, Andres (2019) "Research and development expenditure: expectations and reality". In *Estonian Research* 2019, 9–19. Tartu: Estonian Research Council. Available online at http://hdl.handle.net/10062/63035. Accessed on 24.06.2025.

Lauk, Kalmer and Jüri Allik (2018) "A puzzle of Estonian science: how to explain unexpected rise of the scientific impact". *Trames* 22, 4, 329–344. DOI: https://doi.org/10.3176/tr.2018.4.01

Lauk, Kalmer and Jüri Allik (2019) "The state of Estonian research in mid-2018". In *Estonian Research* 2019, 41–46. Tartu: Estonian Research Council. Available online at http://hdl.handle.net/10062/63035. Accessed 24.06.2025.

Mabe, Michael and Mayur Amin (2001) "Growth dynamics of scholarly and scientific journals". *Scientometrics* 51, 1, 147–162. DOI: https://doi.org/10.1023/a:1010520913124

May, Robert M. (1997) "The scientific wealth of nations". *Science* 275, 5301, 793–796. DOI: https://doi.org/10.1126/science.275.5301.793

Moed, Henk F. (2005) *Citation analysis in research evaluation*. Vol. 9. (Information Science and Knowledge Management.) Berlin and Heidelberg: Springer-Verlag. DOI: https://doi.org/10.1007/1-4020-3714-7

Niinemets, Ülo (2019) "Career models and job opportunities for the researchers in Estonia: where are we coming from, and where are we heading to?". In *Estonian Research* 2019, 21–40. Tartu: Estonian Research Council. Available online at http://hdl.handle.net/10062/63035. Accessed on 24.06.2025.

OECD (2025) "Science and Bibliometric Indicators". Available online at https://www.oecd.org/en/data/datasets/science-and-bibliometric-indicators.html.

Oviedo-García, M. Ángeles (2021) "Journal citation reports and the definition of a predatory journal: the case of the Multidisciplinary Digital Publishing Institute (MDPI)". *Research Evaluation* 30, 3, 405–419a. DOI: https://doi.org/10.1093/reseval/rvab020

Piirsoo, Marko (2025) "Research and development evaluation in Estonia". In *Estonian Research* 2025, 82–83. Tartu: Estonian Research Council. Available online at https://hdl.handle.net/10062/106522. Accessed on 22.06.2025.

Price, Derek J. de Solla (1963) *Little science, big science*. New York: Columbia University Press.

Redman, Barbara (2023) "Science evaluation: peer review, bibliometrics, and research impact assessment". In *Reconstructing research integrity*, 133–151. Cham: Springer International Publishing. DOI: https://doi.org/10.1007/978-3-031-27111-3_8

Reimann, Andres (2025) "Noorteadlaste nappus seab küsimärgi alla eestikeelse kõrghariduse jätkumise". [The shortage of young researchers calls into question the continuation of Estonian-language higher education.] *Novaator*. Available online at https://novaator.err.ee/1609618568/noorteadlaste-nappus-seab-kusimargi-alla-eestikeelse-korghariduse-jatkumise. Accessed on 07.09.2025.

Schiermeier, Quirin (2019) "How Estonia blazed a trail in science?". *Nature* 565, 7740, 416–418. DOI: https://doi.org/10.1038/d41586-019-00209-7

Soomere, Tarmo (2025) "Strategic support of excellent science and influential innovation". In *Estonian Research 2025*, 73–75. Tartu: Estonian Research Council. Available online at https://hdl.handle.net/10062/106522. Accessed on 22.06.2025.

Statistics Estonia (2025a) "HT290: acquisition of higher education by level of study and type of study". Available online at https://andmed.stat.ee/en/stat/sotsiaalelu__haridus__kergharidus/HT290. Accessed on 07.08.2025.

Statistics Estonia (2025b) "RV030: births, deaths and natural increase by year and indicator". Available online at https://andmed.stat.ee/en/stat/rahvastik__rahvastikunaitajad-ja-koosseis__demograafilised-pehinaitajad/RV030/table/tableViewLayout2. Accessed on 07.08.2025.

The Lancet (2024) "Information for authors". *The Lancet,* October 2025. Available online at https://www.thelancet.com/pb-assets/Lancet/authors/ebm-info-for-authors-1723037816697.pdf. Accessed on 13.10.2015.

Thelwall, Mike (2020) "Large publishing consortia produce higher citation impact research but coauthor contributions are hard to evaluate". *Quantitative Science Studies* 1, 1, 290–302. DOI: https://doi.org/10.1162/qss_a_00003

Thelwall, Mike and Pardeep Sud (2022) "Scopus 1900–2020: growth in articles, abstracts, countries, fields, and journals". *Quantitative Science Studies* 3, 1, 37–50. DOI: https://doi.org/10.1162/qss_a_00177

Thomson Reuters (2014) *InCites indicators handbook.* Version 2.1. Philadelphia. Available online at https://services.anu.edu.au/files/system/indicators-handbook.pdf. Accessed on 07.08.2025.

Universiteit Leiden Centre for Science and Technology Studies (2025) *WTS Leiden Ranking*. Available online at https://www.leidenranking.com/. Accessed 07.09.2025.

Universities Estonia (2020) "Doktoriõppe arendamise ühised põhimõtted". [Common principles for the development of doctoral education.] Available online at https://ern.ee/wp-content/uploads/2022/11/doktori-ppe-kvaliteedilepe.pdf. Accessed on 07.09.2025.

Vaimann, Toomas (2025) "Human resources in Estonian research". In *Estonian Research* 2025, 37–51. Estonian Research Council. Available online at https://hdl.handle.net/10062/106522. Accessed on 07.09.2025.

Wang, Qi and Tobias Jeppsson (2022) "Identifying benchmark units for research management and evaluation". *Scientometrics* 127, 12, 7557–7574. DOI: https://doi.org/10.1007/s11192-022-04413-7