Proceedings of the Estonian Academy of Sciences,
2008, **57**, 4, 255–264
doi: 10.3176/proc.2008.4.08
Available online at www.eap.ee/proceedings

SCIENTOMETRICS

Quality of Estonian science estimated through bibliometric indicators (1997–2007)

Jüri Allik

Department of Psychology, University of Tartu, Tiigi 78, 50410 Tartu, Estonia; juri.allik@ut.ee

Received 25 June 2008, in revised form 15 September 2008

Abstract. The main goal of this paper is to provide an analysis of bibliometric indicators of the quality of Estonian science in comparison to its neighbours Latvia and Lithuania during the 11-year period from 1997 to 2007. Since 1990, Estonian and Lithuanian scientists more than tripled the number of articles they published in journals indexed by the *Thomson Reuters Web of Science*. The number of articles from Latvia has decreased relative to the general increase of published articles in the world. According to the *Essential Science Indicators* database, papers published by Estonian scientists had the highest impact (7.87) compared to all other former Communist bloc countries including Hungary (7.83), Latvia (5.92), Lithuania (4.95), and Russia (3.98). While Latvia failed to increase the productivity and Lithuania to improve the quality of their scientific publications, Estonia succeeded in reducing the gap both in the productivity and impact of its publications compared to the world leading countries. The observation of changes during the last three years allows identifying Agricultural Sciences, Molecular Biology & Genetics, and Social Sciences as three fastest growing fields in Estonia.

Key words: scientometry, bibliometrics, Estonian science.

INTRODUCTION

The idea of bibliometric analysis has transformed from an intriguing possibility (de Solla Price, 1965) into a regular tool for evaluation of the scientific quality of countries and institutions (European Commission, 2005; Moed, 2005; Must, 2006). Estonia, like its two neighbours, Latvia and Lithuania, is an interesting historical case. Before regaining independence in 1991, they belonged to one of the most inefficient scientific systems in the world. At that time 5.5% of all indexed scientific publications in the world were produced by scientists working in the former Soviet Union. At the same time, only 1.7% of all citations were on works authored by Soviet scientists. This rate was about 10 times less than, for example, citations of Dutch scientists. In terms of bibliometric performance one Dutchman alone was equal to the impact of a small research institute in Moscow (Allik, 1998). Although the quality of science has certainly improved in Russia, according to a recent press release (24 February 2008) the percentage of Russia's share of all papers published in the world is about 2.8% while less than 1% of all citations are on works authored by Russian scientists (http://sciencewatch.com/dr/sci/08/feb24-08_1/). Therefore it is not only interesting but also significant to see what has happened to Estonian science after almost two decades of autonomous development.

Bibliometric indicators have shown that although Estonian science has considerably improved during the years of independence, it is still less intensive than science in the most scientifically advanced countries such as Switzerland, Sweden, or Finland (Allik, 1998, 2003). However, nearly two decades is a sufficient period for looking back how political decisions and administrative reforms have influenced the development of scientific research systems in Estonia in comparison to two other Baltic countries, Latvia and Lithuania, with similar historical experience (Kristapsons et al., 2003). This analysis is particularly relevant because the weakness of a set of policies crucial for longer-term development, such as innovation and technology policies, has led in the last decade to a deterioration rather than strengthening of the competitive advantages of Eastern

European economies including Estonia (Tiits et al., 2008).

The main goal of this paper is to provide an analysis of bibliometric indicators of the quality of science in Estonia in comparison to its neighbours, Latvia, Lithuania, and Finland, during the 11-year period from 1997 to 2007.

METHODS

The analysis is based on the Internet version of the *Thomson Reuters Web of Science* (*WoS*) databases covering the period from 1997 to 2007. The *WoS* includes about 11 000 of the most influential research journals in the world. It contains three citation indices: *Science Citation Index* (1900–present), *Social Sciences Citation Index* (1956–present), and *Arts & Humanities Citation Index* (1975–present). The *WoS* also provides different analytical tools for the analysis of countries/territories and research institutions.

The *Essential Science Indicators* (*ESI*) is a resource that provides analytical tools for ranking scientists, institutions, countries, and journals. It is based on journal article publication counts and citation data from the *WoS* and analyses a ten-year and plus n-months rolling period. *ESI* covers 10 million articles in 22 specified fields of research (excluding humanities), and is updated every two months. *ESI* provides both total citation counts and cites per paper scores for different countries or territories. *ESI* is limited to the journal articles indexed in the *WoS* only. No books, book chapters, or articles published in journals not indexed by the *WoS* are taken into account in *ESI*, either in terms of publication or citation counts.

RESULTS AND ANALYSIS

Productivity from 1990 to 2007

In 1990, just before the collapse of the Soviet Union, Estonia, Latvia, and Lithuania had very similar starting positions. Scientists in each of these three Baltic countries published approximately 300 papers per year in journals indexed by the *WoS*. Seventeen years later, in 2007, Estonians, Lithuanians, and Latvians published 1295, 1067, and 426 articles, respectively. Figure 1 demonstrates the growth of publication in the three Baltic countries from 1990 to 2007.[1] Estonian and Lithuanian contributions to the world science more than tripled even after taking into account the about 60% increase in the total number of publications in the 17-year period. The relative contribution of Latvia, however, even decreased from 0.036% in 1990 to 0.029% in 2007. Thus, Estonia and particularly Lithuania increased their publication activity considerably during the last two decades while Latvia stagnated in the number of publications. Nevertheless, in both absolute and relative terms the intensity of scientific publication in the Baltic countries is still low. Even after taking into account population size Estonian scientists managed to reach 34% level compared to Finnish productivity normalized per one million of population. For comparison, Latvia and Lithuania produced 10% and 13% of the number of papers that Finnish scientists produced per capita of their country.

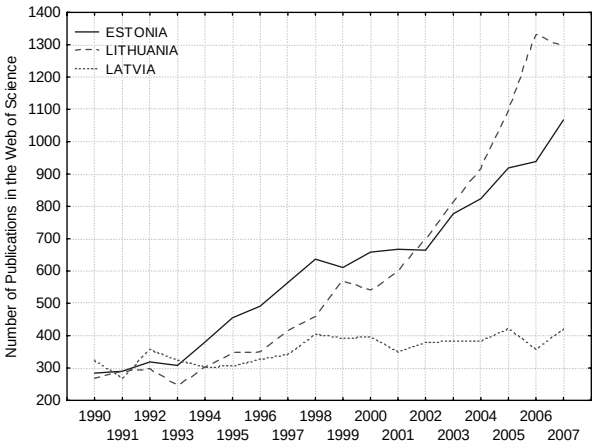

Fig. 1. Total number of publications in the *Web of Science* database authored by Estonian, Latvian, and Lithuanian scientists.

The impact of Estonian science (1997–2007)

Table 1 presents the ranking of countries/territories on the basis of their impact, i.e. the number of citations per article. Only these countries/territories are listed that were able to exceed the 50% threshold of the essential science established for countries/territories and to publish 2000 or more articles during the last 11-year period, from 1 January 1997 to 31 December 2007. As it can be seen by the impact, Estonia (31) is ahead of all former Communist bloc countries including Hungary (32) and the Czech Republic (44), also ahead of some older EU members like Portugal (37) and Greece (40). Nevertheless, the impact of Estonian articles is still 17.2% below the world average.

Papers published by Estonian scientists attracted 22% of citations compared to the total number of Finnish citations normalized per capita. Latvian and Lithuanian publications received both approximately

[1] Figure 1 counts all publications (also abstracts) included in the *WoS* based not on their nominal publication date but on the actual time they were entered into the database. All publications were included since it has been argued that conference presentations are more important vehiches of scientific communication in some areas than others.

Table 1. Ranking of countries/territories according to the number of citations per paper in the *Essential Science Indicators* during the 11-year period 1 January 1997–31 December 2007

Rank		Country/Territory	Papers	Citations	Citations per paper
Papers >2000*	World ranking				
1	2	Switzerland	167 118	2 481 447	14.85
2	5	USA	2 986 569	42 332 176	14.17
3	6	Denmark	91 326	1 230 868	13.48
4	7	Netherlands	231 072	3 093 182	13.39
5	8	Scotland	106 594	1 399 170	13.13
6	10	Iceland	4 191	54 365	12.97
7	11	Sweden	175 569	2 230 827	12.71
8	12	England	681 819	8 647 781	12.68
9	13	Finland	85 516	1 028 069	12.02
10	14	Hong Kong	11 527	136 074	11.80
11	15	Canada	411 730	4 769 621	11.58
12	16	Belgium	123 955	1 415 215	11.42
13	17	Germany	769 257	8 609 811	11.19
14	18	Israel	110 411	1 192 527	10.80
15	19	Austria	86 942	936 697	10.77
16	21	Norway	61 758	663 009	10.74
17	22	France	551 081	5 869 472	10.65
18	23	Wales	35 312	367 136	10.40
19	25	Australia	262 001	2 671 361	10.20
20	26	Italy	389 473	3 914 198	10.05
21	27	Ireland	35 818	355 994	9.94
22	28	North Ireland	17 377	169 440	9.75
23	32	New Zealand	52 072	476 094	9.14
24	33	Uganda	2 338	20 911	8.94
25	34	Japan	808 301	7 151 726	8.85
26	36	Costa Rica	2 958	25 991	8.79
27	37	Spain	283 934	2 465 253	8.68
28	40	Kenya	6 496	55 577	8.56
29	46	Peru	2 928	23 554	8.04
30	48	Uruguay	3 888	30 803	7.92
31	50	**Estonia**	**7 207**	**56 684**	**7.87**
32	51	Hungary	47 910	375 151	7.83
33	52	Chile	26 058	195 667	7.51
34	53	Senegal	2 056	15 388	7.48
35	58	Philippines	4 724	34 928	7.39
36	61	Tanzania	3 036	21 649	7.13
37	62	Portugal	45 812	325 088	7.10
38	66	Argentina	50 870	339 202	6.67
39	67	South Africa	45 527	301 413	6.62
40	68	Greece	68 230	444 493	6.51
41	71	Zimbabwe	2 368	15 232	6.43
42	72	Singapore	50 931	327 120	6.42
43	73	Indonesia	5 189	33 324	6.42
44	74	Czech Republic	55 945	350 623	6.27
45	77	Colombia	8 060	49 427	6.13
46	78	Latvia	3 672	21 750	5.92
47	79	Armenia	3 838	22 683	5.91
48	80	Cyprus	2 561	15 086	5.89
49	82	Mexico	62 578	362 710	5.80
50	85	Vietnam	4 667	26 775	5.74
51	86	Thailand	20 622	118 021	5.72
52	87	Poland	126 684	719 262	5.68
53	90	Slovenia	18 384	103 412	5.63
54	91	Cameroon	2 792	15 702	5.62

Table 1. *Continued*

Rank		Country/Territory	Papers	Citations	Citations per paper
Papers >2000*	World ranking				
55	92	Venezuela	11 198	62 678	5.60
56	93	Ghana	2 100	11 740	5.59
57	94	Taiwan	137 846	765 570	5.55
58	95	Brazil	145 267	796 761	5.48
59	96	South Korea	203 637	1 114 544	5.47
60	99	Sri Lanka	2 383	12 672	5.32
61	100	Slovakia	22 668	118 218	5.22
62	101	Bulgaria	17 917	92 506	5.16
63	105	Lebanon	4 013	20 157	5.02
64	106	Lithuania	7 350	36 371	4.95
65	107	Ethiopia	2 885	13 940	4.83
66	108	Bangladesh	4 963	23 908	4.82
67	109	Cuba	6 684	31 659	4.74
68	111	Croatia	16 207	74 782	4.61
69	112	Yugoslavia	9 599	43 809	4.56
70	113	Republic of Georgia	2 961	13 447	4.54
71	115	India	227 761	991 151	4.35
72	116	People's Republic of China	508 561	2 147 166	4.22
73	120	Romania	23 705	97 064	4.09
74	121	Russia	286 153	1 140 087	3.98
75	122	Kuwait	5 882	23 370	3.97
76	123	Malaysia	13 059	51 706	3.96
77	124	Morocco	10 786	42 146	3.91
78	125	Egypt	29 138	111 841	3.84
79	126	Saudi Arabia	15 799	60 014	3.80
80	127	Turkey	101 843	386 169	3.79
81	128	United Arab Emirates	4 601	17 411	3.78
82	129	Moldova	2 001	7 488	3.74
83	130	Pakistan	9 606	34 617	3.60
84	131	Oman	2 555	9 041	3.54
85	133	Belarus	11 636	39 987	3.44
86	135	Ukraine	44 635	145 914	3.27
87	136	Iran	32 050	104 631	3.26
88	137	Tunisia	9 408	29 709	3.16
89	138	Algeria	6 393	20 024	3.13
90	139	Jordan	6 061	18 971	3.13
91	140	Nigeria	9 663	30 127	3.12
92	142	Kazakhstan	2 306	6 695	2.90
93	143	Uzbekistan	3 510	9 203	2.62
94	147	Azerbaijan	2 090	4 044	1.93

Notes: * = Only countries that published 2000 or more papers during the 11-year period.
The first 22 countries/territories are above the world average (9.5).

5% of the comparable Finnish citation intensity. This is only slightly more citations per capita (4%) than papers authored by Russian scientists.

Estonia occupies the 61st place in the ranking of papers and the 52nd place in the ranking of citations. This indicates that Estonian scientists are not especially prolific but if they publish their papers they have a relatively high impact. One of the possible reasons for the relatively high impact is that until 2008 only one local Estonian journal, *Oil Shale* with the impact factor IF_{2006} = 0.371, was indexed by the *WoS*.[2] It seems to be a general

[2] Since the middle of 2008 four more Estonian journals – *Proceedings of the Estonian Academy of Sciences*, *Estonian Journal of Earth Sciences*, *Trames: Journal of the Humanities and Social Sciences*, and *Linguistica Uralica* – started to be indexed by the *WoS*.

rule that local national journals have lower impact than the mainstream international publications. For example, Lithuania has several journals indexed by the *WoS* (*Medicina-Lithuania*, *Veterinarija ir Zootechnika*, *Transformations in Business & Economics*, *Lithuanian Journal of Physics*, *Baltic Forestry*, etc.) but its 11-year impact is 4.95 (65th), which is even lower than 5.92 of Latvia (46th). Another example is Croatia with 13 journals indexed by the *WoS* (Andreis & Jokic, 2008) and the impact factor of 4.61 (68th).

Growth rate in different fields

Table 2 compares two *ESI* 11-year periods, 1994–2004 and 1997–2007, for Estonian science. In the *ESI* the whole area (except Humanities) is divided into 22 categories. For the period 1997–2007, Estonia exceeded the threshold for countries/territories (50%) in all areas except Economics & Business. All fields are ranked according to the increase of their impact (citation per paper) from 2004 to 2007 (the last column).

On average, the impact of Estonian science increased by 24.4% during the last three years. The most remarkable increase was achieved in Agricultural Sciences, which was unable to surpass the threshold of essential science in 2004 but did it in 2007. The largest increase (+68.8%) was in Molecular Biology & Genetics followed by Social Sciences general (+38.8%), Geosciences (+35.8%), and Environment/Ecology (+32.5%). The only field whose impact declined was Space Science (–1.8%). Pharmacology & Toxicology managed to stay close to the world average level and its increase was marginal (0.3%).

Comparison with Latvia and Lithuania

In the year 2002, the impact of Estonia, Latvia, and Lithuania was 5.03, 3.52, and 3.97, respectively (Allik, 2003). According to the release of the *ESI*, from 1 January 1997 to 31 December 2007, the impact factors for Estonia, Latvia, and Lithuania increased to 7.87, 5.92, and 4.95, respectively. The increase during the last five years was 56.5%, 68.2%, and 24.7%, respectively, for Estonia, Latvia, and Lithuania. Thus, although the total number of Latvian papers did not increase their quality improved considerably. At the same time Lithuania remarkably improved in the number of publications but their quality improved at a much more modest rate.

Table 3 compares strengths and weaknesses in 22 fields of science in Estonia, Latvia, and Lithuania. It is

Table 2. Estonian *Essential Science Indicators* (*ESI*) for two periods, 1997–2007 and 1994–2004, and increase in citations per paper (CPP) 2004–2007

	Field	*ESI* 1997–2007			*ESI* 1994–2004			CPP increase 2004–2007, %
		Papers	Citations	CPP	Papers	Citations	CPP	
	All fields	7 207	56 684	7.87	5 821	36 834	6.3	24.4
1	Agricultural Sciences	83	368	4.43	–	–	–	–
2	Molecular Biology & Genetics	219	4 945	22.58	173	2 315	13.4	68.8
3	Social Sciences general	250	680	2.72	164	322	2.0	38.8
4	Geosciences	672	3 287	4.89	559	2 014	3.6	35.8
5	Environment/Ecology	511	5 129	10.04	342	2 592	7.6	32.5
6	Clinical Medicine	895	8 257	9.23	737	5 199	7.1	30.9
7	Biology & Biochemistry	422	5 311	12.59	341	3 288	9.6	30.6
8	Psychiatry/Psychology	169	967	5.72	122	535	4.4	30.3
9	Neuroscience & Behavior	234	2 976	12.72	193	1 933	10.0	26.9
10	Engineering	341	1 028	3.01	301	715	2.4	26.5
11	Materials Science	257	1 898	7.39	180	1 055	5.9	26.1
12	Microbiology	143	1 554	10.87	124	1 086	8.8	24.1
13	Computer Science	92	120	1.30	50	53	1.1	22.6
14	Plant & Animal Science	758	5 101	6.73	553	3 171	5.7	17.5
15	Immunology	100	1 083	10.83	80	742	9.3	16.7
16	Multidisciplinary	8	54	6.75	10	58	5.8	16.4
17	Chemistry	782	6 661	8.52	689	5 139	7.5	14.2
18	Physics	837	4 609	5.51	794	3 844	4.8	13.8
19	Mathematics	159	327	2.06	141	257	1.8	13.2
20	Pharmacology & Toxicology	78	820	10.51	86	901	10.5	0.3
21	Space Science	170	1 480	8.71	182	1 615	8.9	–1.8
22	Economics & Business	–	–	–	–	–	–	–

– Below the *ESI* threshold.

Table 3. Essential science in Estonia, Latvia, and Lithuania, 1 January 1997–31 December 2007. Percentages above the world average are highlighted in bold

Field	Estonia				Latvia				Lithuania				World average citations per paper
	Papers	Citations	Citations per paper	Relative to world average, %	Papers	Citations	Citations per paper	Relative to world average, %	Papers	Citations	Citations per paper	Relative to world average, %	
All fields	7 207	56 684	7.87	–17.2	3 672	21 750	5.92	–37.7	7 350	36 371	4.95	–47.9	9.50
Agricultural Sciences	83	368	4.43	–23.8	–	–	–	–	130	603	4.64	–20.1	5.81
Biology & Biochemistry	422	5 311	12.59	–22.0	181	1 611	8.90	–44.9	438	4 474	10.21	–36.8	16.15
Chemistry	782	6 661	8.52	–6.3	782	3 510	4.49	–50.6	1 177	5 558	4.72	–48.1	9.09
Clinical Medicine	895	8 257	9.23	–19.7	289	3 571	12.36	**7.6**	644	5 723	8.89	–22.6	11.49
Computer Science	92	120	1.30	–54.4	64	151	2.36	–17.2	138	173	1.25	–56.1	2.85
Economics & Business	–	–	–	–	–	–	–	–	–	–	–	–	4.81
Engineering	341	1 028	3.01	–17.8	344	896	2.60	–29.0	746	2 097	2.81	–23.2	3.66
Environment/Ecology	511	5 129	10.04	**10.5**	84	438	5.21	–42.7	229	655	2.86	–68.5	9.09
Geosciences	672	3 287	4.89	–41.0	39	593	15.21	**83.5**	118	666	5.64	–32.0	8.29
Immunology	100	1 083	10.83	–46.8	46	528	11.48	–43.6	71	790	11.13	–45.3	20.34
Materials Science	257	1 898	7.39	**43.5**	477	1 423	2.98	–42.1	678	1 808	2.67	–48.2	5.15
Mathematics	159	327	2.06	–29.0	–	–	–	–	442	710	1.61	–44.5	2.90
Microbiology	143	1 554	10.87	–26.2	67	741	11.06	–24.9	113	1 014	8.97	–39.1	14.72
Molecular Biology & Genetics	219	4 945	22.58	–9.9	73	1 028	14.08	–43.8	119	1 434	12.05	–51.9	25.06
Multidisciplinary	8	54	6.75	**82.4**	–	–	–	–	–	–	–	–	3.70
Neuroscience & Behavior	234	2 976	12.72	–27.7	29	268	9.24	–47.5	71	662	9.32	–47.0	17.60
Pharmacology & Toxicology	78	820	10.51	**1.1**	29	420	14.48	**39.2**	64	486	7.59	–27.0	10.40
Physics	837	4 609	5.51	–28.8	843	4 946	5.87	–24.2	1 365	6 628	4.86	–37.2	7.74
Plant & Animal Science	758	5 101	6.73	**0.0**	150	1 073	7.15	**6.2**	403	1 560	3.87	–42.5	6.73
Psychiatry/Psychology	169	967	5.72	–38.7	10	299	29.90	**220.5**	51	300	5.88	–37.0	9.33
Social Sciences general	250	680	2.72	–30.3	–	–	–	–	142	162	1.14	–70.8	3.90
Space Science	170	1 480	8.71	–31.2	–	–	–	–	158	813	5.15	–59.3	12.66

certainly not a coincidence that Economics & Business failed to break the threshold in all three countries. In addition, Latvia is not represented in Agricultural Sciences, Mathematics, Social Sciences, Space Science, and like Lithuania, in Multidisciplinary sciences. Like Estonia, Latvia is above the world average in five fields while Lithuania has not yet attained the world average in any of the fields.

Across all fields, Estonia is 17.2% below the world average (Latvia 37.7% and Lithuania 47.8%). There were only eight Estonian papers published between 1997 and 2007 that were classified as multidisciplinary.[3] These few papers were cited +82.4% more frequently than papers of this category on average, suggesting that this was due to lucky coincidences. Another small number anomaly is 10 Latvian papers in Psychiatry/Psychology, which were cited +220% above the world average. The most successful subfield in Estonian science is certainly Material Science, which exceeds the world average citation rate by +43.5%. Traditionally strong is the research in Environment/ Ecology and Plant & Animal Science categories (+10.5% and 0%, respectively). In addition, Pharmacology & Toxicology, Chemistry, and Molecular Biology & Genetics are the fields that are very close to the world average level.

According to bibliometric criteria the weakest field in Estonian science is Economics & Business, the only one which failed to exceed the threshold of essential science. Relatively modest impact is in Geosciences, Immunology, and Computer Science.

Productivity of research institutions

Table 4 lists 20 most productive research institutions with regard to the number of papers authored by Estonian scientists in the period between 1997 and 2007. Of these top 20 institutions, 11 are not located in Estonia but in some other countries (five in Sweden, four in Finland, and one both in Germany and Russia). The University of Helsinki is the fourth most productive research institution contributing to Estonian science. These 20 institutions produced virtually all Estonian papers because the total score is above 100% (a considerable number of papers have authors from several listed institutions).

[3] The category 'Multidisciplinary' is formed as a residual of articles published in approximately 60 journals, including journals such as *Science*, *Nature*, and the *Proceedings of the National Academy of Sciences of the USA* (*PNAS*); afterwards most of these papers are reassigned to the field with the largest number of references and citations to them.

Table 4. The top 20 of the most productive research institutions contributing to papers authored by Estonian scientists (1997–2007)

Rank	Institution	Number of papers	Percent of total
1	University of Tartu[a]	4523	59.2
2	Tallinn University of Technology[b]	1353	17.7
3	Estonian University of Life Sciences[c]	535	7.0
4	University of Helsinki*	376	4.9
5	National Institute of Chemical Physics & Biophysics[d]	302	4.0
6	Uppsala University*	265	3.5
7	Tartu Observatory[e]	236	3.1
8	Estonian Academy of Sciences	181	2.4
9	Karolinska Institute*	163	2.1
10	Estonian Biocentre	148	1.9
11	Tartu University Clinic[f]	142	1.9
12	Tallinn University[g]	124	1.6
13	Russian Academy of Sciences*	123	1.6
14	National Institute for Health Development[h]	122	1.6
15	Lund University*	90	1.2
16	University of Hamburg*	77	1.0
17	Helsinki University of Technology*	72	0.9
18	Swedish University of Agricultural Sciences*	72	0.9
19	University of Kuopio*	70	0.9
20	University of Turku*	70	0.9
	Total	9095	119.1

Notes: Conference abstracts were excluded (N = 7636).
Formerly: [a] – Institute of Physics, Tartu State University; [b] – Tallinn Technical University; [c] – Institute of Zoology and Botany, Estonian Agricultural University; [d] – Institute of Chemical Physics & Biophysics; [e] – Institute of Astrophysics and Atmospheric Physics; [f] – Tartu University Hospital; [g] – Tallinn University of Educational Sciences, Tallinn Pedagogical University; [h] – Institute of Experimental and Clinical Medicine.
* – Foreign institutions.

Collaboration with other countries

Table 5 provides a list of the top 20 countries/territories contributing to papers authored by Estonian scientists. As expected, the largest number of papers were written in collaboration with colleagues from Sweden, Finland, Germany, USA, and England (almost 50% of all papers). The proportion of papers written in collaboration with Russian scientists has decreased and is now only 4.2%. There is no doubt that the re-orientation towards scientifically stronger partners appears to be one of the success factors of Estonian science. At the same time it may be a weakness as well because of the

Table 5. The top 20 countries/territories contributing to papers authored by Estonian scientists (1997–2007)

Rank	Country/Territory	Number of papers	Percentage of total
1	Sweden	951	12.5
2	Finland	927	12.1
3	Germany	679	8.9
4	USA	645	8.4
5	England	418	5.5
6	Russia	319	4.2
7	France	315	4.1
8	Italy	273	3.6
9	Netherlands	209	2.7
10	Norway	199	2.6
11	Denmark	193	2.5
12	Spain	169	2.2
13	Latvia	140	1.8
14	Poland	137	1.8
15	Canada	134	1.8
16	Switzerland	133	1.7
17	Lithuania	125	1.6
18	Japan	116	1.5
19	Czech Republic	108	1.4
20	Belgium	94	1.2
	Total:	6284	82.3

lack of sufficient autonomy. For example, according to the latest *ESI* release (1 May 2008), there were 58 papers co-authored by Estonian scientists that were within the top 1% of the most cited papers in their particular fields. From these highly cited papers relatively few have exclusively Estonian authorship (Aarik et al., 1999; Niinemets, 1999; Raidal, 2004; Kaljurand et al., 2005).[4]

Humanities

Because the humanities are not included into the *ESI*, the *Arts & Humanities Citation Index* (*A&HCI*) in the *WoS* was analysed separately. Estonian authors published 128 articles in journals indexed by the *A&HCI* during the 11-year period. These 128 papers, from which almost a half (40%) were book reviews, were cited 192 times (1.5 times per article; H-Index = 5). The average publication intensity was rather low (less than 12 articles per year), reaching its maximum in 2007 with 20 publications. For comparison, Finnish scholars published 1401 articles in the *A&HCI* journals during the same period, which were cited 1322 times (0.94 times per article; H = 15). Thus, after normalization for the population sizes the productivity of Estonian authors comprises 37% of the average level of Finnish humanitarians. It is interesting to note that the most cited article is identical for both Estonia and Finland (Cheour et al., 1998) with 137 citations (as of 16 May 2008), which is 71% of all Estonian citations. Thus, somewhat surprisingly the productivity of Estonian humanitarians compared to their Finnish colleagues is in the same proportion to what we observed for the 'hard' sciences. Nevertheless, it is necessary to remind that the *A&HCI* coverage of the humanities and arts is the lowest among all disciplines (Moed, 2005, p. 126).

DISCUSSION AND CONCLUSIONS

Although the productivity of Estonian scientists is still far behind the most advanced R&D countries, the quality of publications improved considerably during the last eleven years. Somewhat surprisingly Estonian science has the highest impact (7.87) compared to all other former Communist bloc countries including Hungary (7.83), Latvia (5.92), Lithuania (4.95), and Russia (3.98). Every paper authored by scientists working in Estonia attracted two times more citations than an average paper written by their Russian colleagues although the *WoS* includes hundreds of Russian own journals. Thus, Estonia has achieved, with one of the smallest R&D expenditures (0.77% of the GDP in 2003), quite a remarkable increase in the quality of scientific research.

The analysis revealed how political decisions taken by governments of Estonia, Latvia, and Lithuania during the last 17 years of independence have differently shaped the scientific productivity and quality. Latvia failed to increase the productivity of its scientists although the quality of a relatively small number of papers published in international peer-reviewed journals has increased considerably during the last five years. In five fields it exceeds the world average level. Although Latvia succeeded in maintaining the high quality of its publications, several political decisions have put Latvian science very close to a critical mass that is necessary to keep up the research activity (Allik, 2003).

Lithuania, in turn, demonstrated a considerable increase in the total number of publications in peer-reviewed international journals, including their own journals indexed in the *WoS*, but without parallel increase in their overall quality. It is not because Lithuania failed to re-orient the network of its scientific collaboration. Among papers published between 1997 and 2007, 8.6%, 8.5%, 7.7%, and 5.7% of all articles were written in collaboration with scientists from Germany, USA, Sweden, and France, respectively. The

[4] Some very recent entries were discarded because of unreliability of very small numbers. Unfortunately, I was not able to analyse separately papers in which Estonian authors were listed first or where they were indicated as the principal or corresponding authors.

role of collaboration with Russia (3.6%) was even lower than that in Estonia (4.2%) and Latvia (7.9%). There is also no evidence that Lithuania supports fields with smaller impacts because Physics and Chemistry are the two most productive research areas. It is also stressed that the number of *WoS* publications has been one of the main criteria for financing decisions in Lithuanian science (Kristapsons et al., 2003). One possible explanation is that the increase of Lithuanian publications in journals indexed by the *WoS* was achieved mainly by the increase of publications in low-impact journals including their own local ones. In any case, this could serve as a warning for science administrators that the number of *WoS* publications alone cannot serve as the criterion for decisions, including financing ones.

Estonia succeeded in exceeding the threshold of essential science in all 22 categories except Economics & Business. For a country with a research community of about 1500 actively publishing authors this is a remarkable achievement. However, even Iceland, four times smaller than Estonia, is represented in 20 fields of the 22. In several fields, particularly Agricultural Sciences, Molecular Biology & Genetics, Social Sciences, Geosciences, Environment/Ecology, and Clinical Medicine, the growth of the impact during the last three years has been noteworthy. Some of these fast developing fields are already on a high international level, such as Environment/Ecology and Molecular Biology & Genetics, but some of them, like Geosciences and Social Sciences, are still behind the world average.

The above-presented analysis provides also some evidence that one potential factor behind the relative success of Estonian science could be partnership with scientifically more advanced countries, particularly with Sweden, Finland, Germany, and the United States. A considerable proportion of publications is prepared and published in co-authorship with colleagues from countries that are ahead of Estonia both in terms of the intensity and impact of research. This is a kind of 'hidden money' that is difficult to take into account in the statistics on R&D (Allik, 2003). In the list of the 20 most productive research institutions contributing to Estonia's international publications a half are located outside the border. However, a more detailed analysis is required to reveal how the international network of collaboration stimulates or inhibits Estonian science.

REFERENCES

Aarik, J., Aidla, A., Kiisler, A. A., Uustare, T., and Sammelselg, V. 1999. Influence of substrate temperature on atomic layer growth and properties of HfO_2 thin films. *Thin Solid Films*, **340**(1–2), 110–116.

Allik, J. 1998. Thoughts about the quality of social sciences in Estonia. *Trames*, **2**, 91–107.

Allik, J. 2003. The quality of science in Estonia, Latvia, and Lithuania after the first decade of independence. *Trames*, **7(57/52)**, 40–52.

Andreis, M. and Jokic, M. 2008. An impact of Croatian journals measured by citation analysis from SCI-expanded database in time span 1975–2001. *Scientometrics*, **75**(2), 263–288.

Cheour, M., Ceponiene, R., Lehtokoski, A., Luuk, A., Allik, J., Alho, K., et al. 1998. Development of language-specific phoneme representations in the infant brain. *Nat. Neurosci.*, **1**(5), 351–353.

de Solla Price, D. 1965. Networks of scientific papers. *Science*, **149**, 510–515.

European Commission. 2005. *Key Figures 2005. Towards a European Research Area Science, Technology and Innovation*. Office for Official Publications of the European Communities, Luxembourg.

Kaljurand, I., Kütt, A., Sooväli, L., Rodima, T., Mäemets, V., Leito, I., and Koppel, I. A. 2005. Extension of the self-consistent spectrophotometric basicity scale in acetonitrile to a full span of 28 pK_a units: unification of different basicity scales. *J. Org. Chem.*, **70**(3), 1019–1028.

Kristapsons, J., Martinson, H., and Dagyte, I. 2003. *Baltic R&D Systems in Transitions: Experiences and Future Prospects*. Zinatne, Riga.

Moed, H. F. 2005. *Citation Analysis in Research Evaluation*. Springer, Dordrecht.

Must, Ü. 2006. "New"countries in Europe – research, development and innovation strategies vs bibliometric data. *Scientometrics*, **66(**2), 241–248.

Niinemets, U. 1999. Components of leaf dry mass per area – thickness and density – alter leaf photosynthetic capacity in reverse directions in woody plants. *New Phytol.*, **144**(1), 35–47.

Raidal, M. 2004. Relation between the neutrino and quark mixing angles and grand unification. *Phys. Rev. Lett.*, **93**(16).

Tiits, M., Kattel, R., Kalvet, T., and Tamm, D. 2008. Catching up, forging ahead or falling behind? Central and Eastern European development in 1990–2005. *Innovation – Eur. J. Social Sci. Res.*, **21**(1), 65–85.

*Proceedings of the Estonian Academy of Sciences, 2008, **57**, 4, 255–264*

Eesti teaduse kvaliteet hinnatuna bibliomeetriliste indikaatorite vahendusel (1997–2007)

Jüri Allik

Artikli eesmärgiks on analüüsida Eesti teaduse kvaliteeti ajavahemikul 1997–2007 Läti ja Leeduga võrreldes, kasutades selleks bibliomeetrilisi indikaatoreid. Võrreldes 1990. aastaga, on Eesti ja Leedu teadlased enam kui kolmekordistanud artiklite arvu, mida nad on avaldanud Web of Science'i (Thomson Reuters) indekseeritud ajakirjades. Lätist pärit artiklite arv on aga kahanenud, kui arvestada üldist artiklite arvu kasvu maailmas. Vastavalt Essential Science Indicatorsi andmebaasile on Eestist pärit tööde mõjukus suurim (7,87) endise kommunismibloki maade hulgas, kaasa arvatud Ungari (7,83), Läti (5,92), Leedu (4,95) ja Venemaa (3,98). Samal ajal kui Läti ei ole suutnud suurendada artiklite hulka ja Leedu artiklite kvaliteeti, on Eestil õnnestunud vähendada vahet juhtivate teadusriikidega nii publikatsioonide arvus kui nende mõjukuses. Viimase kolme aasta muutuste jälgimine näitab, et kolmeks kõige kiiremini arenevaks teadusvaldkonnaks Eestis on põllumajandus, molekulaarbioloogia-geneetika ja sotsiaalteadused.