

Evolution of Lattice Field Theory: a Statistical Study

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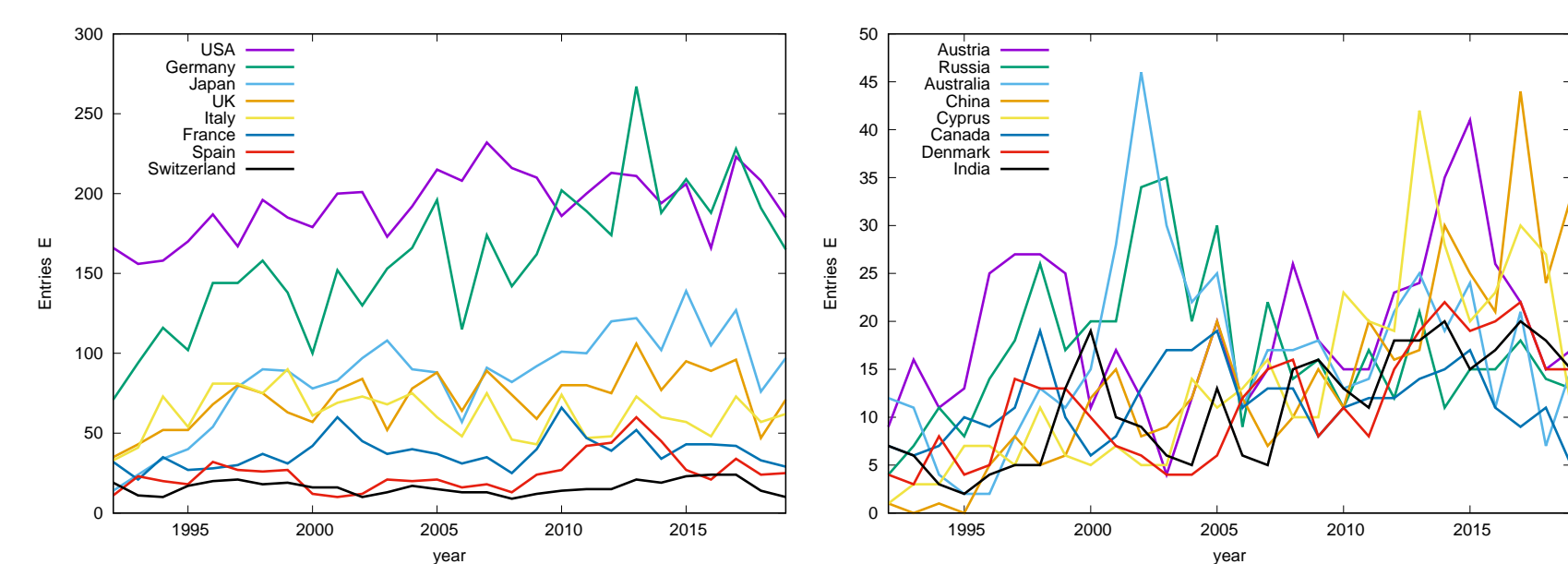
Since the early 1990s, lattice physicists form an established, intercontinental community. At the same time, in 1991/2, the arXiv became operational. Its hep-lat section provides a unique opportunity to statistically monitor the evolution of lattice activities.

We used INSPIRE to count:

- E : Entries, all articles with primary arXiv section hep-lat
- P : Papers, subset of E published as regular papers
- C : Citations to all articles in E
- H : Hirsch Index, based on E

We compare it to the sum over 7 related arXiv sections: hep-ph, hep-th, hep-lat, gr-qc, nucl-th, quant-ph, cond-mat* (all subsections).

As a single parameter, we also display $\Sigma := E + P + 0.05C$ (weights according to statistical trends).



Evolution of the number of hep-lat entries (E) of the 8 leading nations (left) and of the nations ranking 9...16 (right).

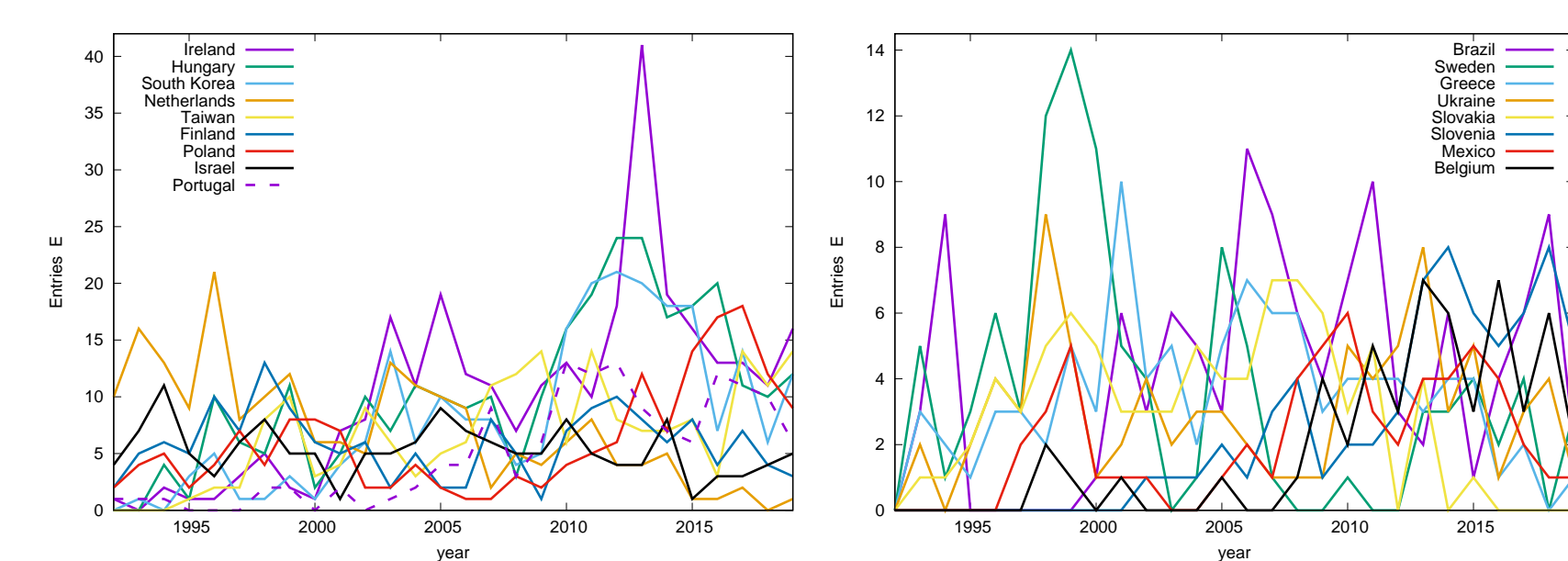
Generally there is a slight trend up.

During the last decade, Germany caught up with the USA as the most productive countries, followed by Japan, UK, Italy, France, ... cf. Table 1. Peaks for Austria, Cyprus, Australia, Russia. Lately China is moving up.

We present global and national statistics, with extensive and intensive data (i.e. absolute and relative to the population), along with socio-economic indices: GDP (Gross Domestic Product), GDPpp (GPD per capita), and EI (Education Index) $:= \frac{1}{2} \left(\frac{EYS}{18} + \frac{MYS}{15} \right)$
EYS: expected schooling years of children, normalized by duration for a Master's degree
MYS: mean schooling years of adults, normalized by the projected maximum in 2025
[Source: United Nations Development Programme, <http://hdr.undp.org/en/>]

An article counts for a country if at least one author has a working address there. Data were taken in July 2020 from <https://old.inspirehep.net>; this INSPIRE version is deactivated now.

[The new version gives with "date" much larger numbers, apparently due to multiple counting (date when submitted, revised, published). The command "de" ("date earliest") is supposed to avoid this, but it returns weird results, which are much too low (e.g. just one hep-lat entry in 2019). Moreover, the new INSPIRE version does not have the option "country code", hence it does not provide national statistics.]



Evolution of the number of hep-lat entries (E) of the nations ranking 17...25 (left), and 26...33 (right), with strong relative fluctuations.

Entire national productions, 1991 – July 2020, are given in Table 1, along with the total Hirsch Index H , $\Sigma = E + P + 0.05C$, population, and GDP. Table 2: same for sum over 7 arXiv sections.

Σ -rank	E	P	C	Σ	H
1. USA	85601	63422	4006414	349343.7	583
European Union	147464	106804	4961069	502321.4	548
2. France	28598	21090	1368170	118096.5	394
3. Germany	45242	35533	1713406	166445.3	390
4. UK	26174	19927	1089933	100597.7	339
CERN	9836	7253	682730	51225.5	333
5. Italy	27034	19875	949801	94399.1	309
6. Spain	16466	12223	601111	58744.6	267
7. Russia	22429	15260	586236	67000.8	257
8. Canada	12364	9696	469849	45552.5	250
9. Japan	24611	18620	690235	77742.8	249
10. Switzerland	5734	4142	290056	24378.8	227
11. Netherlands	5634	4307	262786	23080.3	207
12. Poland	8205	5660	245108	26120.4	191
13. China	20475	16372	444642	59079.1	186
14. India	14374	10925	332859	41942.0	186
15. Sweden	4973	3753	198321	18642.1	178
16. Belgium	4955	3798	201122	18809.1	171
17. Israel	5085	3943	176081	17832.1	166
18. Brazil	11460	8961	222670	31554.5	146
19. South Korea	7627	6096	196954	23570.7	142
20. Portugal	4166	3087	128890	13697.5	139
21. Austria	3885	2563	112541	12075.1	137
22. Greece	3505	2748	107266	11616.3	134

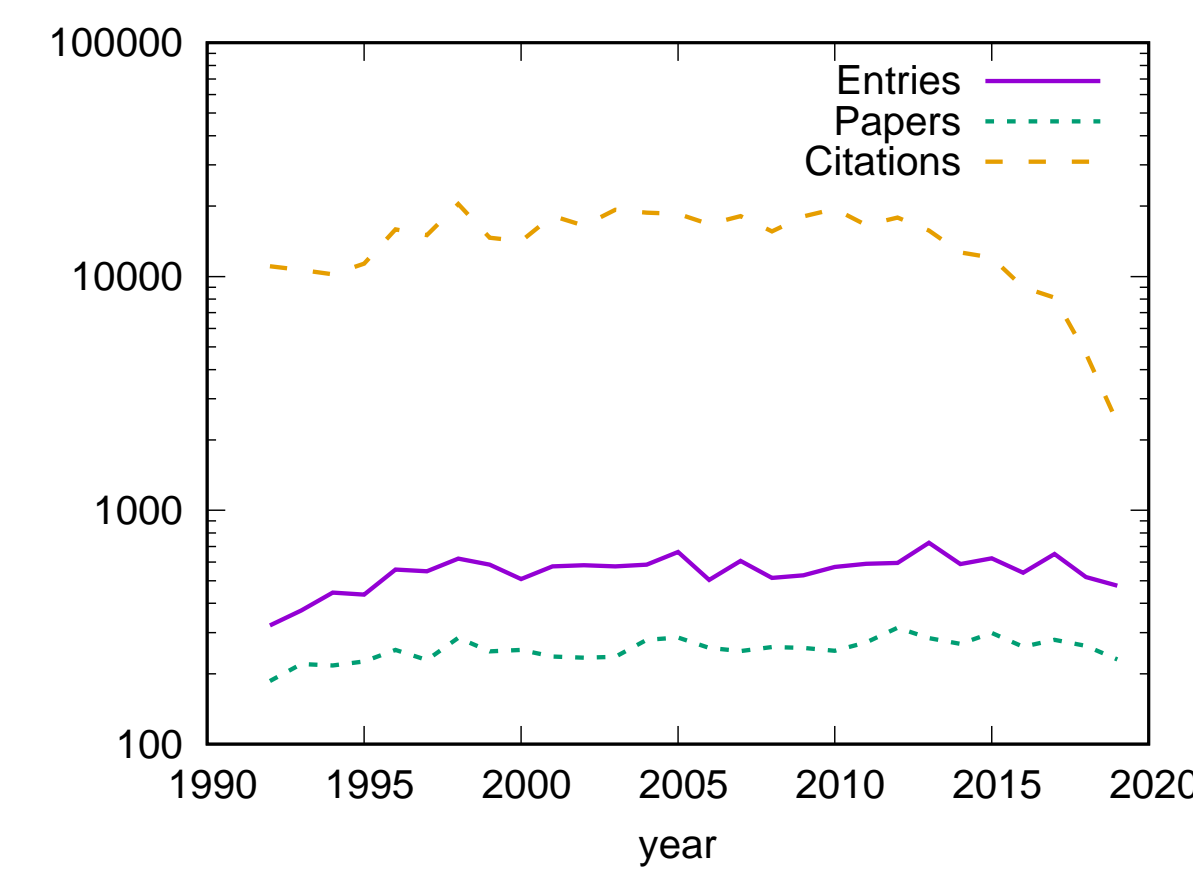
Σ -rank	E	P	C	Σ	H
23. Australia	4185	3219	136125	14210.3	133
24. Denmark	27	3006	2248	10420.4	133
25. Taiwan	21	4110	3186	13424.3	129
26. Finland	29	2460	1818	8610.1	128
27. Hungary	30	2274	1586	8834.7	121
28. Chile	28	3089	2567	7718.3	108
29. Argentina	31	2576	2179	6389.9	104
30. Mexico	25	4450	3232	7568.7	101
31. Ireland	36	1476	1078	4329.8	97
32. Iran	26	4054	3398	6452.6	89
33. South Africa	34	1903	1483	4456.6	85
34. Slovenia	41	718	484	2821.9	85
35. Norway	37	1242	923	3519.8	84
36. Ukraine	33	2508	1674	4241.1	82
37. Czech Rep.	35	2106	1501	3775.4	78
38. Bulgaria	40	1040	684	2484.9	73
39. Croatia	38	1035	778	2521.6	71
40. Estonia	47	425	336	2005.6	71

Table 2: Like Table 1, but joint statistics for the 7 arXiv sections under consideration, for all nations with $H > 62$. Based on the Σ -rank, Turkey (32) and Romania (39) would enter the top 40.

e-rank	GDPpp	EI	e	p	c	Σ /GDP	σ	
1. Cyprus	30386	0.725	383.32	190.18	8665.6	44.17	1006.78	
2. Switzerland	52698	0.823	81.46	39.14	3194.0	5.27	280.30	
3. Ireland	42903	0.832	70.27	28.16	2061.1	4.56	201.48	
4. Denmark	42671	0.854	59.22	32.00	1873.8	4.31	184.02	
5. Germany	38719	0.866	55.60	25.90	1766.1	4.36	169.81	
6. Austria	40348	0.776	64.31	30.59	1240.4	3.90	156.92	
7. Hungary	2	20738	0.766	29.04	15.02	1872.0	6.64	137.66
8. UK	34770	0.850	32.99	15.47	1097.4	2.97	103.33	
9. Slovenia	7	25235	0.824	33.01	16.26	1071.1	4.08	102.83
10. Finland	10	36205	0.837	31.18	15.30	842.7	2.45	88.61
11. Italy	12	35411	0.733	30.19	15.00	705.6	2.28	80.47
12. Australia	14	38067	0.900	24.95	13.25	752.8	1.79	75.84
13. Israel	11	27906	0.832	22.58	14.55	700.3	2.41	72.14
14. France	15	35303	0.763	17.52	8.42	688.8	1.66	60.80
15. USA	19	47324	0.874	18.59	8.72	596.9	1.20	57.15
European Union	31966	0.792	18.22	8.62	503.5	1.62	52.01	
16. Japan	17	35125	0.782	18.96	8.45	436.8	1.41	49.25
17. Spain	16	30406	0.743	16.24	8.48	442.8	1.54	46.86
18. Slovakia	13	20657	0.760	15.19	7.78	435.9	2.17	44.76
19. Netherlands	24	42689	0.850	12.48	6.02	279.3	0.76	32.46
20. Portugal	20	25515	0.687	13.33	5.31	217.5	1.16	29.52
21. Canada	25	38828	0.841	10.01	5.05	258.4	0.72	27.98
22. Sweden	26	39526	0.859	10.77	5.44	235.3	0.70	27.98

e-rank	GDPpp	EI	e	p	c	Σ /GDP	σ	
23. Taiwan	23	30654	0.865	8.70	4.44	243.7	0.81	25.33
24. Greece	22	25240	0.736	8.84	4.51	161.7	0.85	21.43
25. Belgium	31	38398	0.848	5.07	2.63	168.1	0.42	16.10
26. Iceland	34	38087	0.825	3.33	3.33	143.3	0.36	13.83
27. South Korea	30	25473	0.811	4.93	1.70	92.1	0.44	11.24
28. Poland	27	18267	0.795	4.72	2.14	83.3	0.61	11.02
29. New Zealand	35	30601	0.883	2.66	1.93	101.4	0.31	9.66
30. Russia	32	19274	0.748	3.27	1.73	59.2	0.41	7.96
31. Albania	21	7683	0.644	4.96	0.66	35.4	0.98	7.39
32. Georgia	18	5752	0.761	2.52	1.60	54.0	1.32	6.82
33. Norway	43	59066	0.884	2.96	1.27	17.6	0.09	5.11
34. Singapore	46	63641	0.705	2.22	1.11	25.0	0.07	4.58
35. Belarus	33	11763	0.738	0.93	0.62	54.4	0.36	4.27
36. Uruguay	36	15032	0.681	2.11	1.51	8.1	0.27	4.03

Table 3: Intensive hep-lat statistics, ordered according to $\sigma = \Sigma/\text{pop}$. We include further intensive quantities: GDPpp, EI, $(e, p, c) := (E, P, C)/\text{pop}$. Ranking according to σ , for all nations with $\sigma > 3.7$. We also display the economic rank, e-rank, based on $\Sigma/\text{GDP} \propto \sigma/\text{GDPpp}$. In that regard, Armenia (28) and Ukraine (29) would enter the top 36.



Evolution of hep-lat entries (E), papers (P) and citations (C) from 1992 to 2019. Here we exclude 1991 (only few sporadic entries), and 2020 (we could only capture the first half). The recent decrease of C is simply because these articles had less time to be cited.

	Σ -rank	population	GDP	E	P	C	Σ	H
European Union		495.0	15900.4	9020	4265	249236	25746.8	182
1. USA	1	294.3	14050.1	5472	2565	175639	16818.9	167
2. Germany	2	81.3	3167.4	4523	2107	143667	13813.3	155
3. UK	3	61.4	2136.2	2026	950	67386	6345.3	121
4. Japan	4	127.6	4458.1	2419	1078	55729	6283.5	103
5. France	6	61.1	2232.9	1070	540	42060	3713.0	101
6. Italy	5	58.5	2066.6	1765	877	41252	4704.6	89
CERN				615	306	27553	2298.7	79
7. Switzerland	7	7.5	400.7	614	295	24073	2112.7	75
8. Spain	8	43.6	1326.8	708	370	19310	2043.5	71
9. Australia	9	18.9	801.9	471	250	14208	1431.4	64
10. Hungary	10	10.1	208.5	292	151	18824	1384.2	61
11. Cyprus	14	1.0	23.1	389	193	8794	1021.7	54
12. Austria	11	8.3	333.8	534	254	10300	1303.0	51
13. China	13	1326.5	9638.8	415	223	9708	1123.4	50
14. Denmark	15	5.4	233.1	322	174	10188	1005.4	50
15. Russia	12	145.5	2822.8	475	252	8608	1157.4	48
16. Canada	17	32.5	1269.4	325	164	8387	908.3	46
17. India	16	1142.0	4509.3	316	183	8198	908.9	45
18. Ireland	18	4.2	183.7	292	117	8565	837.3	45
19. Taiwan	20	22.5	702.2	196	100	5491	570.6	40
20. Finland	23	5.3	191.6	165	81	4460	469.0	36
21. Netherlands	19	16.3	696.5	203	98	4544	528.2	35
22. Israel	22	6.6	197.8	149	96	4622	476.1	35

Intensive Statistics

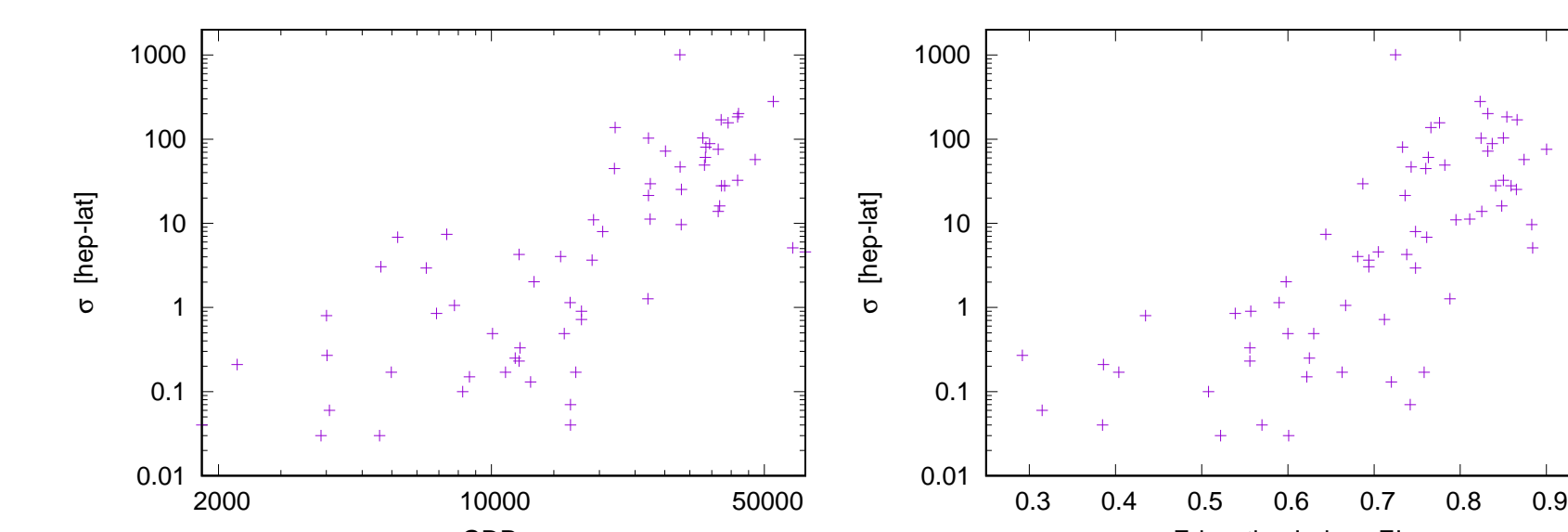
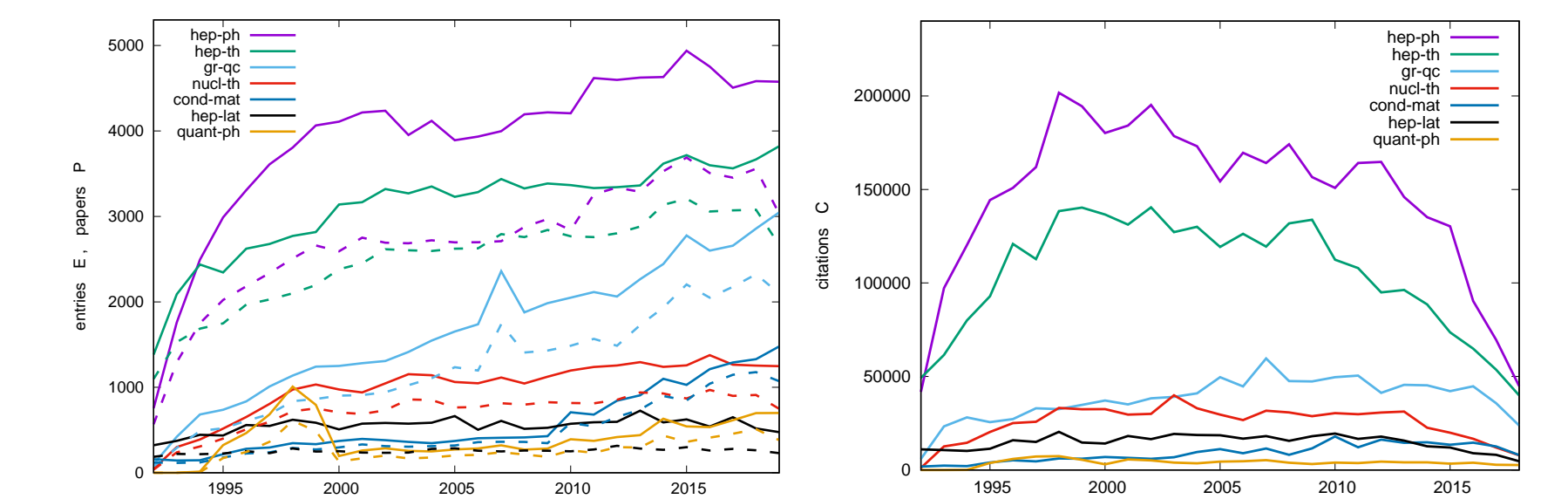


Figure 1: Scatter plot for the 66 nations which contributed hep-lat entries. We show $\sigma := \Sigma/\text{pop}$ (pop = population in millions) vs. GDPpp (left), and vs. EI (right). A monotonic trend is visible, but not as clearly as one might expect. The top 36 nations can be identified from Table 3. Nations with σ -values higher than economically expected: Cyprus, Hungary, Georgia (very high); Slovenia, Slovakia, Albania, Armenia (high).



Evolution of E [solid] and P [dashed], 1992 to 2019 (left); and of C , 1992 to 2018, in hep-ph, hep-th, gr-qc, nucl-th, cond-mat, hep-lat, quant-ph.

Total from 1991 to July 2020 (note for hep-lat: $P < E/2$):

	hep-ph	hep-th	gr-qc	nucl-th	cond-mat	hep-lat	quant-ph
E	111515	89279	48927	28522	16969	15610	11602
P	76520	70561	35703	20215	13677	7165	7484
C	3960720	2857462	1043823	682874	247734	402121	106901