THE TOP 100 SCIENCE AND TECHNOLOGY CLUSTERS

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Measuring innovation performance across the world needs to go beyond national economies as the unit of analysis. For several years, the Global Innovation Index has provided a perspective on the spatial distribution of innovative activity. In particular, it has identified the world's most vibrant clusters of science and technology (S&T) activity and has ranked the top 100.

The approach towards identifying the most vibrant S&T clusters is "bottom up", meaning it ignores any existing administrative or political borders and instead pinpoints geographical areas showing a high density of inventors and scientific authors. While mostly associated with large urban agglomerations, the resulting S&T clusters often encompass several municipal districts, sub-federal states, and sometimes even two or more countries. The microdata underlying this measurement approach, in turn, enables a rich characterization of S&T clusters.

The compilation of this year's top 100 list relies on the same methodology as the one used last year. It thus allows for an assessment of how the performance of different clusters has evolved over time. In a nutshell, our methodology relies on:

- Inventors listed in patent applications under WIPO's Patent Cooperation Treaty (PCT), spanning the years 2014 to 2018.
- Authors listed in scientific publications in the Web of Science's Science Citation Index Expanded (SCIE) and covering the same period.
- The geocoding of inventor and author addresses and the use of density-based spatial clustering of applications with noise (DBSCAN) algorithm to the geocoded inventor and author points.[1]

Readers interested in a more detailed description of the cluster identification and performance measurement methodology are referred to last year's Special Section.[2]

This year's top 100 list

Table S-1.1 presents this year's top 100 S&T clusters. As in previous years, Tokyo-Yokohama comes out as the top-performing cluster. Its lead mainly reflects the cluster's strong patenting performance. Its overall total score—reflecting combined patenting and scientific publication performance—is still considerably higher than that of 2nd-ranked Shenzhen-Hong Kong-Guangzhou. However, Tokyo-Yokohama's lead has narrowed. This mainly reflects that the inclusion of the 2018 data led to a merger of the previously distinct Shenzhen-Hong Kong and Guangzhou clusters.[3] This enlarged cluster has, in turn, cemented its 2nd position, and it continues to be followed by Seoul, Beijing, and San Jose-San Francisco.

There is considerable stability among the top 100 clusters. This is partly due to the 5-year time window on which our ranking is based. It arguably also reflects the stability of local innovation ecosystems that often take a long time to form, but, once established, show remarkable persistence.

While the ranks of the first eight clusters have remained the same, Shanghai moved up from 11th to the 9th position. As a result, Paris and San Diego each moved down one position to rank 10th and 11th, respectively. More generally, all Chinese clusters—other than the already highly ranked Shenzhen-Hong Kong-Guangzhou and Beijing—saw rank improvements.

TABLE S-1.1

Top 100 cluster rankings

Rank	Cluster name	Economy	PCT applications	Scientific publications	Share of total PCT filings, %	Share of total pubs, %	Total	Rank 2013-17	Rank change
1	Tokyo-Yokohama	JP	113,244	143,822	10.81	1.66	12.47	1	0
2	Shenzhen-Hong Kong-Guangzhou	CN/HK	72,259	118,600	6.90	1.37	8.27	2	0
3	Seoul	KR	40,817	140,806	3.90	1.63	5.52	3	0
4	Beijing	CN	25,080	241,637	2.40	2.79	5.18	4	0
5	San Jose-San Francisco, CA	US	39,748	89,974	3.8	1.04	4.83	5	0
6	Osaka-Kobe-Kyoto	JP	29,464	67,514	2.81	0.78	3.59	6	0
7	Boston-Cambridge, MA	US	15,458	128,964	1.48	1.49	2.96	7	0
8	New York City, NY	US	12,302	137,263	1.17	1.58	2.76	8	0
9	Shanghai	CN	13,347	122,367	1.27	1.41	2.69	11	2
10	Paris	FR	13,561	93,003	1.30	1.07	2.37	9	-1
11	San Diego, CA	US	19,665	34,635	1.88	0.40	2.28	10	-1
12	Nagoya	JP	19,327	24,582	1.85	0.28	2.13	12	0
13	Washington, DC-Baltimore, MD	US	4,592	119,647	0.44	1.38	1.82	13	0
14	Los Angeles, CA	US	9,764	69,161	0.93	0.80	1.73	14	0
15	London	GB	4,281	107,680	0.41	1.24	1.65	15	0
16	Houston, TX	US	10,852	51,163	1.04	0.59	1.63	16	0
17	Seattle, WA	US	11,558	34,143	1.10	0.39	1.50	17	0
18	Amsterdam-Rotterdam	NL	4,409	78,602	0.42	0.91	1.33	18	0
19	Cologne	DE	7,827	47,161	0.75	0.54	1.29	20	1
20	Chicago, IL	US	6,167	57,976	0.59	0.67	1.26	19	-1
21	Nanjing	CN	1,662	84,789	0.16	0.98	1.14	25	4
22	Daejeon	KR	8,306	26,037	0.79	0.30	1.09	22	0
23	Munich	DE	7,532	31,259	0.72	0.36	1.08	24	1
24	Tel Aviv-Jerusalem	IL	7,076	31,086	0.68	0.36	1.03	23	-1
25	Hangzhou	CN	4,832	48,627	0.46	0.56	1.02	30	5
26	Stuttgart	DE	8,336	18,241	0.80	0.21	1.01	26	0
27	Taipei-Hsinchu	TW	2,721	62,420	0.26	0.72	0.98	43	16
28	Singapore	SG	4,019	46,037	0.38	0.53	0.92	28	0
29	Wuhan	CN	1,796	63,837	0.17	0.74	0.91	38	9
30	Minneapolis, MN	US	6,444	25,157	0.62	0.29	0.91	27	-3
31	Philadelphia, PA	US	3,173	50,847	0.30	0.59	0.89	29	-2
32	Moscow	RU	2,060	58,153	0.20	0.67	0.87	33	1
33	Stockholm	SE	5,736	27,409	0.55	0.32	0.86	32	-1
34	Eindhoven	BE/NL	8,226	6,067	0.79	0.07	0.86	31	-3
35	Melbourne	AU	1,975	56,632	0.19	0.65	0.84	35	0
36	Raleigh, NC	US	2,949	47,499	0.28	0.55	0.83	34	-2
37	Sydney	AU	2,498	49,298	0.24	0.57	0.81	37	0
38	Frankfurt Am Main	DE	5,167	24,848	0.49	0.29	0.78	36	-2
39	Toronto, ON	CA	2,336	48,017	0.22	0.55	0.78	39	0
40	Xi’an	CN	775	60,017	0.07	0.69	0.77	47	7
41	Brussels	BE	3,171	39,066	0.30	0.45	0.75	40	-1
42	Portland, OR	US	6,270	12,349	0.60	0.14	0.74	45	3
43	Tehran	IR	149	62,530	0.01	0.72	0.74	46	3
44	Berlin	DE	3,333	35,640	0.32	0.41	0.73	41	-3
45	Madrid	ES	1,521	50,547	0.15	0.58	0.73	42	-3
46	Barcelona	ES	2,326	43,209	0.22	0.50	0.72	44	-2
47	Chengdu	CN	1,449	48,095	0.14	0.56	0.69	52	5
48	Milan	IT	2,205	38,821	0.21	0.45	0.66	48	0
49	Zürich	CH/DE	3,117	29,945	0.30	0.35	0.64	50	1
50	Denver, CO	US	2,789	32,387	0.27	0.37	0.64	49	-1

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TABLE S-1.1

Top 100 cluster rankings, continued

Rank	Cluster name	Economy	PCT applications	Scientific publications	Share of total PCT filings, %	Share of total pubs, %	Total	Rank 2013-17	Rank change
51	Istanbul	TR	2,677	31,709	0.26	0.37	0.62	54	3
52	Montréal, QC	CA	2,027	36,816	0.19	0.42	0.62	51	-1
53	Heidelberg-Mannheim	DE	3,913	20,814	0.37	0.24	0.61	53	0
54	Copenhagen	DK	2,958	27,267	0.28	0.31	0.60	55	1
55	Atlanta, GA	US	1,646	36,533	0.16	0.42	0.58	56	1
56	Tianjin	CN	812	41,989	0.08	0.48	0.56	60	4
57	Cambridge	GB	2,623	26,033	0.25	0.30	0.55	58	1
58	Rome	IT	791	40,233	0.08	0.46	0.54	57	-1
59	Cincinnati, OH	US	3,900	14,133	0.37	0.16	0.54	61	2
60	Bengaluru	IN	3,289	17,021	0.31	0.20	0.51	65	5
61	São Paulo	BR	751	37,675	0.07	0.43	0.51	59	-2
62	Dallas, TX	US	3,157	17,340	0.3	0.20	0.50	64	2
63	Nuremberg-Erlangen	DE	3,729	12,515	0.36	0.14	0.50	62	-1
64	Pittsburgh, PA	US	1,617	29,864	0.15	0.34	0.50	63	-1
65	Ann Arbor, MI	US	1,355	30,856	0.13	0.36	0.49	66	1
66	Changsha	CN	502	37,115	0.05	0.43	0.48	67	1
67	Delhi	IN	855	33,570	0.08	0.39	0.47	70	3
68	Helsinki	FI	2,789	17,047	0.27	0.20	0.46	68	0
69	Qingdao	CN	2,074	22,957	0.20	0.26	0.46	80	11
70	Vienna	AT	1,551	27,119	0.15	0.31	0.46	69	-1
71	Oxford	GB	1,430	27,016	0.14	0.31	0.45	71	0
72	Suzhou	CN	2,627	15,129	0.25	0.17	0.43	81	9
73	Cleveland, OH	US	1,456	24,679	0.14	0.28	0.42	73	0
74	Vancouver, BC	CA	1,460	24,514	0.14	0.28	0.42	72	-2
75	Busan	KR	2,190	17,982	0.21	0.21	0.42	75	0
76	Lyon	FR	2,328	16,665	0.22	0.19	0.41	74	-2
77	Chongqing	CN	689	30,023	0.07	0.35	0.41	88	11
78	Phoenix, AZ	US	2,469	13,701	0.24	0.16	0.39	76	-2
79	Hefei	CN	536	29,536	0.05	0.34	0.39	90	11
80	Harbin	CN	168	31,980	0.02	0.37	0.39	87	7
81	Ottawa, ON	CA	1,964	16,842	0.19	0.19	0.38	78	-3
82	Jinan	CN	511	27,956	0.05	0.32	0.37	89	7
83	Brisbane	AU	1,174	22,184	0.11	0.26	0.37	83	0
84	Bridgeport-New Haven, CT	US	1,298	20,993	0.12	0.24	0.37	82	-2
85	Hamamatsu	JP	3,407	3,433	0.33	0.04	0.36	102	17
86	Austin, TX	US	2,184	13,501	0.21	0.16	0.36	79	-7
87	Changchun	CN	209	29,720	0.02	0.34	0.36	93	6
88	Ankara	TR	430	27,758	0.04	0.32	0.36	77	-11
89	Lausanne	CH/FR	1,921	14,682	0.18	0.17	0.35	86	-3
90	Hamburg	DE	1,806	15,146	0.17	0.17	0.35	84	-6
91	Kanazawa	JP	2,987	4,537	0.29	0.05	0.34	106	15
92	Grenoble	FR	1,950	12,854	0.19	0.15	0.33	85	-7
93	Manchester	GB	938	21,115	0.09	0.24	0.33	92	-1
94	St. Louis, MO	US	948	21,012	0.09	0.24	0.33	94	0
95	Basel	CH/DE/FR	2,020	12,133	0.19	0.14	0.33	91	-4
96	Lund-Malmö	SE	2,037	11,980	0.19	0.14	0.33	95	-1
97	Columbus, OH	US	961	20,411	0.09	0.24	0.33	96	-1
98	Mumbai	IN	1,196	18,213	0.11	0.21	0.32	97	-1
99	Warsaw	PL	436	23,981	0.04	0.28	0.32	100	1
100	Göteborg	SE	1,806	12,613	0.17	0.15	0.32	101	1

Source: WIPO Statistics Database, March 2020.

This reflects the relatively fast growth in patents and scientific publications attributable to these clusters.

Figure S-1.1 compares the net change in clusters' S&T output to their change in rank from last year to this year. The net change in cluster output reflects the S&T output for 2018 less the S&T output for 2013. As can be seen, rank changes correlate closely with output performance changes. In other words, movements up and down the ranks mostly reflect differences in S&T output growth rates. However, there are some notable exceptions. Taipei-Hsinchu, Hamamatsu, and Kanazawa see rank improvements that are disproportionately greater than their net change in S&T output. This is due to a substantial expansion in these three clusters' geography.[4] By contrast, the enlarged Shenzhen-Hong Kong-Guangzhou cluster did not see any rank improvement, which reflects the cluster's already high 2nd position. There are also a considerable number of clusters—such as Phoenix and Ottawa—that have registered increases in net S&T output but have nonetheless fallen in the ranking. This reflects the relative nature of the ranking, as those clusters were overtaken by others that registered even higher increases in net S&T output.

The composition of countries hosting S&T clusters is similar to that of last year—which, again, is a result of the overall stability of the top 100 clusters. The United States of America (U.S.) accounts for 25 clusters—one less compared to last year.[5] With 17 clusters, China's count remains the same, if one takes into account the Shenzhen-Hong Kong-Guangzhou merger. Germany follows with 10 clusters. Japan increased its count from 3 to 5, as 2 smaller clusters—Hamamatsu and Kanazawa—entered the ranking. The top 100 clusters are located in 26 countries, of which 6—Brazil, China, India, Iran, Turkey, and Russia—represent middle-income economies.[6]

S&T intensity of the top 100 clusters

Our top 100 clusters pinpoint the geographical areas accounting for most S&T activity in the world. However, they differ vastly in size and population density. For example, Istanbul (51st) and Montréal (52nd) show similar S&T performance, but the Istanbul metropolitan area has a population of 15.5 million, whereas the Montréal metropolitan area has a population of 4.1 million.[7] In other words, S&T activity is comparatively more intense in Montréal than in Istanbul.

To capture the S&T intensity of our top 100 clusters, we measure per capita S&T output. Given that we identify clusters using a bottom up method, this is not a straightforward exercise. The boundaries of our clusters do not coincide with municipal districts for which population data are readily available. We, therefore, need to draw on geospatial imagery that estimates population levels at a more granular level. In particular, we draw on the Global Human Settlement Population Grid dataset of the European Commission's Joint Research Centre that provides such imagery at a resolution of 250–300 square meters. The Appendix describes in detail how we match our clusters to the population imagery.

Table S-1.2 presents our top 100 clusters ranked by their S&T intensity. Our measure of S&T intensity is the sum of patent and scientific publication shares associated with a cluster, divided by its population. As can be seen, Cambridge and Oxford in the United Kingdom (U.K.) emerge as the most S&T-intensive clusters. Both clusters host highly productive scientific organizations in relatively small urban agglomerations. Cambridge additionally has a relatively large presence of tech companies—for example, ARM and Nokia—which results in a patent output normally seen in agglomerations with twice the population.[8] In the case of 3rd-ranked Eindhoven, the high S&T intensity principally stems from high patenting output. Interestingly, 4th-ranked San Jose-San Francisco illustrates that high S&T intensity does not have to be associated with small size. This cluster hosts a population of more than six million, and it is the fifth-largest S&T cluster in absolute terms (Table S-1.1).

Figure S-1.2 compares the absolute and per capita ranks of the 100 S&T clusters in a scatterplot. It confirms, first of all, that there is no obvious correlation between the rankings. There is wide variation in the S&T intensity of both small and large clusters. For example, Shanghai—ranked 9th in absolute size—holds only the 82nd position in the intensity ranking. By contrast, Lund-Malmö is only the 96th largest cluster but occupies the 10th position in the intensity ranking.

Another interesting pattern emerging from Figure S-1.2 is that many of the U.S. clusters appear in the upper right corner of the scatterplot—they are large in absolute and relative terms. Important exceptions are New York City and Los Angeles, which rank in the top 20 clusters mainly because of their large size and not their S&T intensity. Many Chinese clusters, in turn, do not exhibit high S&T intensity, which reflects the large populations covered by them.[9] One exception is the 4th ranked Beijing cluster, which still shows considerable S&T intensity and has a performance similar to that of Seoul. Interestingly, Tokyo-Yokohama—the top S&T and second most populous cluster—still shows high S&T intensity notwithstanding its large size.

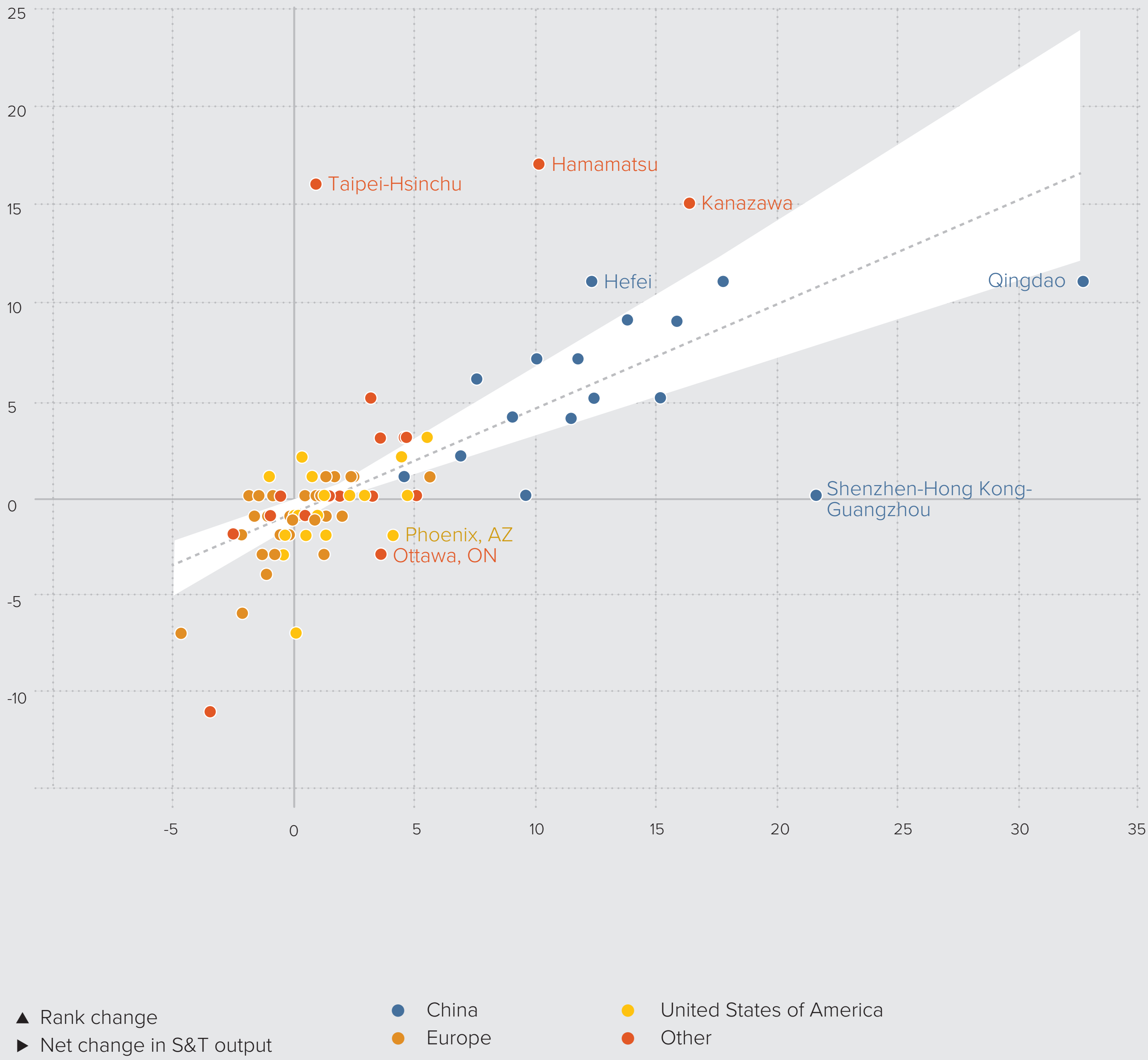
Many of the European clusters show above-average S&T intensity, but do not necessarily feature among the top-ranked clusters. This reflects the different agglomeration patterns in Europe, which have resulted in smaller cities compared to North America and East Asia.

Finally, Figure S-1.3 plots the S&T intensity of clusters against their population levels. It also indicates whether a cluster's S&T output is mainly driven by patenting, mainly driven by scientific publication, or equally driven by both types of S&T output. Two insights emerge.

First, there is a negative correlation between S&T intensity and population, especially for populations below 3.3 million. This reflects the presence of select small and midsize cities specializing in S&T activities. In larger cities, this specialization effect seems less pronounced, and the S&T intensity of clusters becomes more similar. Again, San Jose-San Francisco emerges as the most significant outlier in this respect, suggesting a disproportionately high degree of S&T specialization notwithstanding the cluster's large size.

FIGURE S-1.1

Rank change versus net change in S&T output for the top 100 clusters



Source: WIPO Statistics Database, March 2020.
Notes: "Rank change" is the change in a cluster's rank compared to last year. "Net change in S&T output" is defined as the (new) S&T output for 2018 minus the (removed) S&T output for 2013, holding clusters' geographies constant using this year's geographies

TABLE S-1.2

Ranking of S&T intensity

Intensity rank	Cluster name	Economy	Estimated cluster population	PCT applications per capita (a)	Scientific publications per capita (a)	Total S&T share per capita (b)
1	Cambridge	GB	449,129	584	5,796	1.23
2	Oxford	GB	508,033	282	5,318	0.88
3	Eindhoven	BE/NL	1,008,639	816	602	0.85
4	San Jose-San Francisco, CA	US	6,056,626	656	1,486	0.80
5	Ann Arbor, MI	US	620,199	218	4,975	0.78
6	Boston-Cambridge, MA	US	4,029,151	384	3,201	0.74
7	Daejeon	KR	1,683,639	493	1,546	0.65
8	Seattle, WA	US	2,315,154	499	1,475	0.65
9	San Diego, CA	US	3,552,659	554	975	0.64
10	Lund-Malmö	SE	595,436	342	2,012	0.56
11	Raleigh, NC	US	1,554,250	190	3,056	0.53
12	Grenoble	FR	642,565	303	2,000	0.52
13	Lausanne	CH/FR	691,003	278	2,125	0.51
14	Stockholm	SE	1,905,106	301	1,439	0.45
15	Munich	DE	2,480,475	304	1,260	0.44
16	Göteborg	SE	781,819	231	1,613	0.41
17	Kanazawa	JP	859,213	348	528	0.39
18	Helsinki	FI	1,197,375	233	1,424	0.39
19	Nuremberg-Erlangen	DE	1,304,244	286	960	0.38
20	Copenhagen	DK	1,561,237	189	1,746	0.38
21	Portland, OR	US	2,073,296	302	596	0.36
22	Pittsburgh, PA	US	1,399,419	116	2,134	0.36
23	Minneapolis, MN	US	2,545,762	253	988	0.36
24	Zürich	CH/DE	1,831,070	170	1,635	0.35
25	Basel	CH/DE/FR	960,928	210	1,263	0.35
26	Tokyo-Yokohama	JP	36,229,685	313	397	0.34
27	Stuttgart	DE	3,015,276	276	605	0.33
28	Bridgeport-New Haven, CT	US	1,110,364	117	1,891	0.33
29	Ottawa, ON	CA	1,216,805	161	1,384	0.31
30	Heidelberg-Mannheim	DE	1,964,398	199	1,060	0.31
31	Houston, TX	US	5,227,899	208	979	0.31
32	Hamamatsu	JP	1,188,729	287	289	0.31
33	Cleveland, OH	US	1,385,879	105	1,781	0.31
34	Cincinnati, OH	US	1,776,679	220	795	0.30
35	Washington, DC-Baltimore, MD	US	6,231,144	74	1,920	0.29
36	Beijing	CN	19,661,686	128	1,229	0.26
37	Seoul	KR	21,845,038	187	645	0.25
38	Austin, TX	US	1,492,160	146	905	0.24
39	Nagoya	JP	8,785,429	220	280	0.24
40	St. Louis, MO	US	1,422,096	67	1,478	0.23
41	Sydney	AU	3,450,163	72	1,429	0.23
42	Atlanta, GA	US	2,529,174	65	1,444	0.23
43	Denver, CO	US	2,806,543	99	1,154	0.23
44	Vancouver, BC	CA	1,862,596	78	1,316	0.23
45	Columbus, OH	US	1,444,747	67	1,413	0.23
46	Lyon	FR	1,831,493	127	910	0.23
47	Osaka-Kobe-Kyoto	JP	16,182,399	182	417	0.22
48	Philadelphia, PA	US	4,023,359	79	1,264	0.22
49	Frankfurt Am Main	DE	3,562,097	145	698	0.22
50	Chicago, IL	US	5,777,498	107	1,003	0.22

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TABLE S-1.2

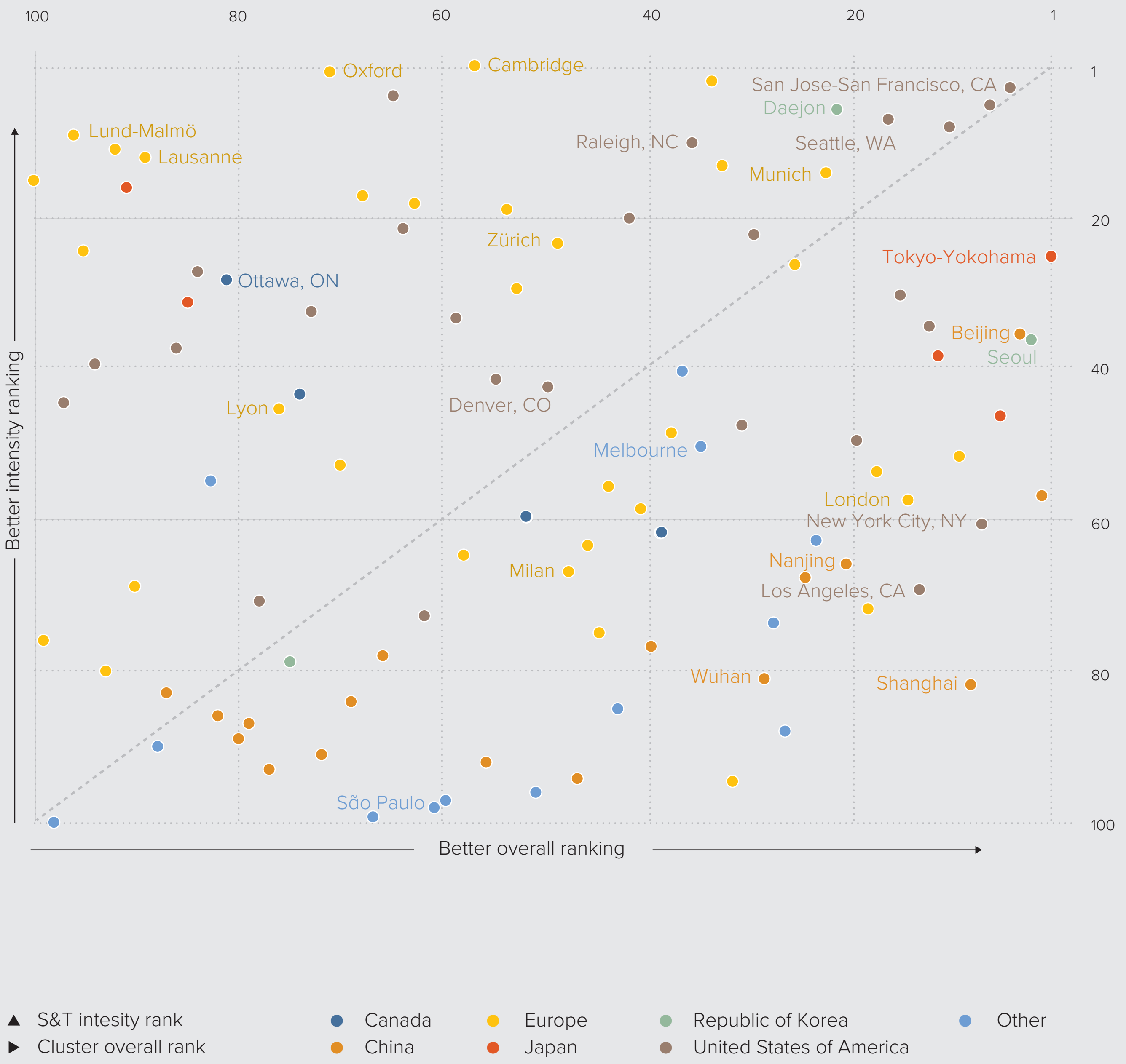
Ranking of S&T intensity, continued

Intensity rank	Cluster name	Economy	Estimated cluster population	PCT applications per capita (a)	Scientific publications per capita (a)	Total S&T share per capita (b)
51	Melbourne	AU	3,875,256	51	1,461	0.22
52	Paris	FR	10,986,036	123	847	0.22
53	Vienna	AT	2,220,257	70	1,221	0.21
54	Amsterdam-Rotterdam	NL	6,725,574	66	1,169	0.20
55	Brisbane	AU	1,907,143	62	1,163	0.19
56	Berlin	DE	3,874,431	86	920	0.19
57	Shenzhen-Hong Kong-Guangzhou	CN/HK	44,965,775	161	264	0.18
58	London	GB	9,015,343	47	1,194	0.18
59	Brussels	BE	4,159,224	76	939	0.18
60	Montréal, QC	CA	3,415,241	59	1,078	0.18
61	New York City, NY	US	15,539,937	79	883	0.18
62	Toronto, ON	CA	4,408,712	53	1,089	0.18
63	Tel Aviv-Jerusalem	IL	6,207,321	114	501	0.17
64	Barcelona	ES	4,349,072	53	994	0.17
65	Rome	IT	3,319,490	24	1,212	0.16
66	Nanjing	CN	7,029,606	24	1,206	0.16
67	Milan	IT	4,234,696	52	917	0.16
68	Hangzhou	CN	6,849,815	71	710	0.15
69	Hamburg	DE	2,364,204	76	641	0.15
70	Los Angeles, CA	US	11,851,722	82	584	0.15
71	Phoenix, AZ	US	2,707,525	91	506	0.15
72	Cologne	DE	9,057,074	86	521	0.14
73	Dallas, TX	US	3,763,640	84	461	0.13
74	Singapore	SG	6,993,405	57	658	0.13
75	Madrid	ES	5,570,432	27	907	0.13
76	Warsaw	PL	2,435,166	18	985	0.13
77	Xi’an	CN	6,203,467	12	967	0.12
78	Changsha	CN	3,912,227	13	949	0.12
79	Busan	KR	3,529,905	62	509	0.12
80	Manchester	GB	2,835,900	33	745	0.12
81	Wuhan	CN	8,107,626	22	787	0.11
82	Shanghai	CN	24,341,974	55	503	0.11
83	Changchun	CN	3,397,721	6	875	0.11
84	Qingdao	CN	4,346,522	48	528	0.11
85	Tehran	IR	7,000,893	2	893	0.11
86	Jinan	CN	3,668,439	14	762	0.10
87	Hefei	CN	4,232,996	13	698	0.09
88	Taipei-Hsinchu	TW	10,638,072	26	587	0.09
89	Harbin	CN	4,190,433	4	763	0.09
90	Ankara	TR	4,444,779	10	625	0.08
91	Suzhou	CN	5,238,169	50	289	0.08
92	Tianjin	CN	7,663,741	11	548	0.07
93	Chongqing	CN	5,630,242	12	533	0.07
94	Chengdu	CN	9,476,676	15	508	0.07
95	Moscow	RU	13,290,360	15	438	0.07
96	Istanbul	TR	14,429,857	19	220	0.04
97	Bengaluru	IN	11,892,944	28	143	0.04
98	São Paulo	BR	18,446,522	4	204	0.03
99	Delhi	IN	24,285,666	4	138	0.02
100	Mumbai	IN	19,808,326	6	92	0.02

Source: WIPO Statistics Database, March 2020.
Notes: (a) Per capita figures refer to 100,000 of population. (b) Per capita figures refer to 1,000,000 of population.

FIGURE S-1.2

Comparing cluster ranks to S&T intensity ranks



Source: WIPO Statistics Database, March 2020.
Notes: See Table S-1.1 for cluster ranks and Table S-1.2 for S&T intensity ranks.

FIGURE S-1.3

S&T intensity by population

Source: WIPO Statistics Database, March 2020.
Note: Cluster focus defined as any cluster where 60% or more of S&T output is from either academic publications or PCT patents.

Second, S&T intensity is, on average, higher if S&T output is mainly driven by patenting activity. This suggests that agglomeration effects associated with patenting activity may be stronger than those associated with scientific publishing. Again, however, a few outliers challenge this relationship—notably Cambridge in the U.K. and Boston-Cambridge in the U.S.—though, even in these cases, patenting is at least as important as scientific publication.

Conclusion

This chapter presented the latest ranking of the world's top 100 S&T clusters. Year-over-year changes in cluster ranks remain modest, though they are in line with the longer-term trend—namely, faster growth of S&T activity in East Asia and especially in China. Analyzing the S&T intensity of clusters provides a more nuanced perspective of the world's S&T cluster landscape. In particular, it suggests that many European and U.S. clusters show more intense S&T activity than their Asian counterparts, even though they show lower S&T activity in absolute terms.

As in previous years, it is important to point out that the shape of the clusters identified in this chapter and their measured performance depend on certain parameter choices. We have carefully rationalized the parameter values we have adopted and tested the sensitivity of our results to a plausible range of values.[10] While we are confident that the global patterns and trends discussed here would remain the same, it is nonetheless the case that different values may change the shape and output of certain clusters—especially those located in population-dense regions.

Notes:

1 Table SA-1.1 provides an overview of the geocoding results using the latest available data.

2 Bergquist et al., 2018.

3 Technically, the DBSCAN algorithm underlying the identification of clusters still identified Shenzhen-Hong Kong and Guangzhou as separate clusters. However, applying the same criteria for when to merge adjacent clusters as the ones used in the past (see Bergquist et al., 2018) leads—for the first time—to a merging of these two clusters. While this outcome is sensitive to the values of the DBSCAN parameters and merger criteria, the underlying phenomenon is real, in the sense that we observe many new inventor/author points at the periphery of the two previous separate clusters.

4 Note that the calculation of the net change in S&T output keeps the cluster geography constant using this year's geographies. This understates the true net change in S&T output for those clusters that have seen an expanding geography. In the case of Hamamatsu and Kanazawa, the larger cluster size emerged directly from the application of the DBSCAN algorithm to the updated data. The expansion of the Taipei-Hsinshu cluster, in turn, is due to a first-time merger of two previously separate clusters, similar to the Shenzhen-Hong Kong-Guangzhou cluster

5 Indianapolis dropped out of the top 100.

6 Ireland (Dublin) dropped out of the top 100.

7 These figures were taken from the Wikipedia pages of these two metropolitan areas.

8 See table S-1.3 for the full breakdown of the top scientific organizations and patent applicants per cluster.

9 We likely underestimate the current S&T output and intensity of Chinese clusters, because the data underlying our analysis go back to 2014, and the Chinese clusters have seen particularly fast growth since then.

10 Bergquist et al., 2018; Global Innovation Index 2020 (Appendix I).

References:

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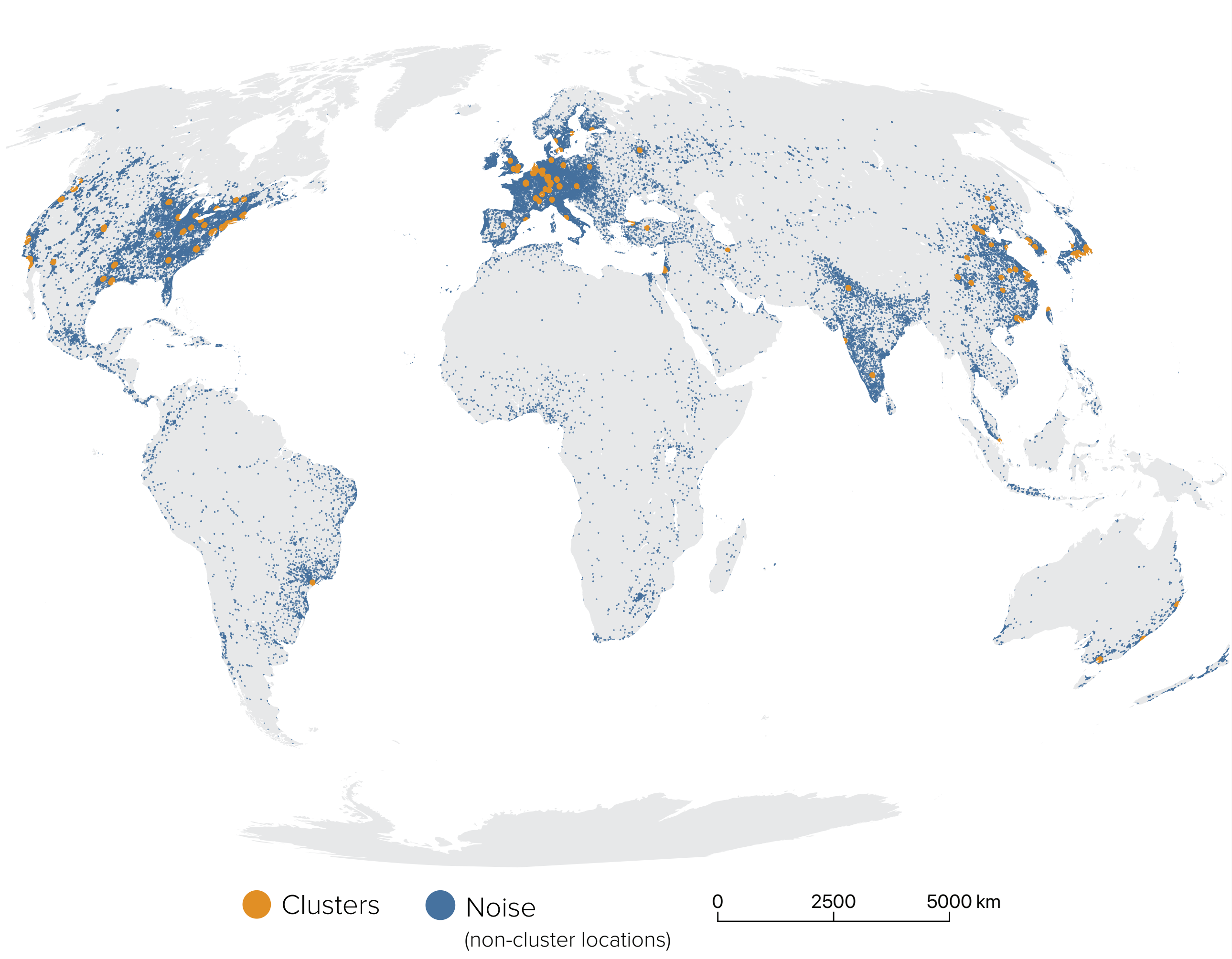
FIGURE S-1.4

Top 100 clusters worldwide



Source: WIPO Statistics Database, March 2020
Note: Noise refers to all inventor/author locations not classified in a cluster.

TABLE S-1.3

Top 100 cluster rankings by publishing and patent performance

			Scientific publishing performance		
Rank	Cluster name	Economy	Top science field	Share, %	Top scientific organization
1	Tokyo-Yokohama	JP	Physics	8.73	University of Tokyo
2	Shenzhen-Hong Kong-Guangzhou	CN/HK	Chemistry	9.42	Sun Yat Sen University
3	Seoul	KR	Engineering	7.56	Seoul National University
4	Beijing	CN	Chemistry	10.09	Chinese Academy of Sciences
5	San Jose-San Francisco, CA	US	Chemistry	6.11	University of California
6	Osaka-Kobe-Kyoto	JP	Chemistry	10.08	Kyoto University
7	Boston-Cambridge, MA	US	Neurosciences & Neurology	5.79	Harvard University
8	New York City, NY	US	Neurosciences & Neurology	6.19	Columbia University
9	Shanghai	CN	Chemistry	12.61	Shanghai Jiao Tong University
10	Paris	FR	Physics	7.26	CNRS
11	San Diego, CA	US	Science & Technology-Other Topics	6.07	University of California
12	Nagoya	JP	Physics	9.38	Nagoya University
13	Washington, DC-Baltimore, MD	US	Neurosciences & Neurology	5.45	Johns Hopkins University
14	Los Angeles, CA	US	Neurosciences & Neurology	5.50	University of California
15	London	GB	General & Internal Medicine	6.58	University of London
16	Houston, TX	US	Oncology	11.29	UTMD Anderson Cancer Center
17	Seattle, WA	US	General & Internal Medicine	4.62	University of Washington
18	Amsterdam-Rotterdam	NL	Cardiovascular System & Cardiology	5.67	University of Utrecht
19	Cologne	DE	Chemistry	7.16	University of Bonn
20	Chicago, IL	US	Chemistry	5.49	Northwestern University
21	Nanjing	CN	Chemistry	11.84	Nanjing University
22	Daejeon	KR	Engineering	13.37	KAIST
23	Munich	DE	Physics	7.59	University of Munich
24	Tel Aviv-Jerusalem	IL	Physics	5.89	Tel Aviv University
25	Hangzhou	CN	Chemistry	12.06	Zhejiang University
26	Stuttgart	DE	Chemistry	7.19	Eberhard Karls University of Tubingen
27	Taipei-Hsinchu	TW	Engineering	9.26	National Taiwan University
28	Singapore	SG	Engineering	10.42	National University of Singapore
29	Wuhan	CN	Chemistry	10.35	Huazhong University of Science & Tech.
30	Minneapolis, MN	US	Chemistry	6.03	University of Minnesota
31	Philadelphia, PA	US	Neurosciences & Neurology	6.31	University of Pennsylvania
32	Moscow	RU	Physics	17.18	Russian Academy of Sciences
33	Stockholm	SE	Science & Technology-Other Topics	5.78	Karolinska Institutet
34	Eindhoven	BE/NL	Engineering	14.64	Eindhoven University of Tech.
35	Melbourne	AU	General & Internal Medicine	5.19	University of Melbourne
36	Raleigh, NC	US	Science & Technology-Other Topics	4.54	University of North Carolina
37	Sydney	AU	General & Internal Medicine	5.17	University of Sydney
38	Frankfurt Am Main	DE	Physics	8.68	Goethe University Frankfurt
39	Toronto, ON	CA	Neurosciences & Neurology	7.20	University of Toronto
40	Xi'an	CN	Engineering	14.64	Xi'an Jiaotong University
41	Brussels	BE	Neurosciences & Neurology	4.73	KU Leuven
42	Portland, OR	US	Neurosciences & Neurology	6.67	Oregon University System
43	Tehran	IR	Engineering	16.01	University of Tehran
44	Berlin	DE	Chemistry	7.23	Free University Of Berlin
45	Madrid	ES	Chemistry	5.61	CSIC
46	Barcelona	ES	Chemistry	5.22	University of Barcelona
47	Chengdu	CN	Engineering	11.69	Sichuan University
48	Milan	IT	Neurosciences & Neurology	8.20	University of Milan
49	Zürich	CH/DE	Chemistry	7.61	ETH Zurich
50	Denver, CO	US	Meteorology & Atmospheric Sciences	4.85	University of Colorado

	Patent performance			
Share, %	Top patenting field	Share, %	Top applicant	Share, %
10.4	Electrical machinery, apparatus, energy	9.69	Mitsubishi Electric	8.79
11.09	Digital communication	31.37	Huawei	23.46
11.67	Digital communication	17.27	LG Electronics	19.31
16.25	Digital communication	21.64	BOE Technology Group	28.24
28.83	Computer technology	23.28	Google	8.61
16.51	Electrical machinery, apparatus, energy	12.87	Murata Manufacturing	11.13
38.37	Pharmaceuticals	16.57	M.I.T	6.30
9.79	Pharmaceuticals	14.17	Honeywell	5.98
16.58	Digital communication	21.45	ZTE Corp.	22.66
17.03	Transport	11.19	L'Oréal	7.12
38.51	Digital communication	31.94	Qualcomm	59.31
26.37	Electrical machinery, apparatus, energy	18.26	DENSO Corp.	21.78
18.4	Pharmaceuticals	17.79	Johns Hopkins University	12.86
33.36	Medical technology	19.09	University of California	6.29
36.89	Computer technology	12.90	British Telecom	9.21
18.58	Civil engineering	34.54	Halliburton	19.44
48.84	Computer technology	41.04	Microsoft	45.44
11.97	Civil engineering	6.65	Shell	8.43
11.22	Basic materials chemistry	9.77	Henkel	9.54
20.24	Digital communication	7.80	Illinois Tool Works	15.65
12.54	Electrical machinery, apparatus, energy	11.09	Southeast University	9.93
17.84	Electrical machinery, apparatus, energy	21.46	LG Chem	44.06
40.19	Transport	12.18	BMW	16.43
25.13	Computer technology	17.16	Intel	5.54
42.15	Computer technology	29.88	Alibaba Group	42.94
32.84	Electrical machinery, apparatus, energy	12.45	Robert Bosch	45.67
16.35	Computer technology	11.02	MediaTek	14.24
27.5	Computer technology	8.12	A*Star	17.93
21.05	Optics	15.25	Wuhan China Star Optoelectronics Tech.	27.15
52.37	Medical technology	31.29	3M Innovative Properties	36.04
37.54	Pharmaceuticals	21.35	University of Pennsylvania	10.42
27.41	Computer technology	12.28	Yandex Europe	4.06
36.17	Digital communication	40.83	LM Ericsson	46.18
45.62	Medical technology	27.12	Philips Electronics	72.08
17.92	Pharmaceuticals	9.08	Monash University	5.07
37.04	Pharmaceuticals	14.09	Duke University	9.86
29.53	Medical technology	12.24	Cochlear	4.84
17.57	Medical technology	12.91	Merck Patent	9.89
60.06	Medical technology	13.96	Synaptive Medical	5.88
20.43	Digital communication	15.80	Xi'an Zhongxing New Software	11.35
26.02	Basic materials chemistry	8.01	Procter & Gamble Company	5.92
47.25	Computer technology	20.64	Intel	54.34
7.86	Medical technology	14.93	Fanavaran Nano-Meghyas	2.69
27.65	Electrical machinery, apparatus, energy	11.10	Siemens	13.76
11.17	Digital communication	10.59	CSIC	9.24
22.19	Pharmaceuticals	9.83	Hewlett-Packard	24.53
30.2	Pharmaceuticals	11.66	Sichuan University	4.91
18.24	Pharmaceuticals	7.02	Pirelli Tyre	7.63
29.23	Medical technology	8.18	Sika Technology	5.14
41.79	Medical technology	12.84	University of Colorado	7.09

CONTINUED

TABLE S-1.3

Top 100 cluster rankings by publishing and patent performance, continued

Rank	Cluster name	Economy	Scientific publishing performance: Top science field	Share, %	Top scientific organization
51	Istanbul	TR	Engineering	7.22	Istanbul University
52	Montréal, QC	CA	Engineering	7.29	McGill University
53	Heidelberg-Mannheim	DE	Oncology	9.86	Ruprecht Karl University Heidelberg
54	Copenhagen	DK	Neurosciences & Neurology	5.61	University of Copenhagen
55	Atlanta, GA	US	Public, Environmental & Occupational Health	6.92	Emory University
56	Tianjin	CN	Chemistry	17.49	Tianjin University
57	Cambridge	GB	Science & Technology-Other Topics	7.69	University of Cambridge
58	Rome	IT	Neurosciences & Neurology	6.75	Sapienza University Rome
59	Cincinnati, OH	US	Pediatrics	6.24	University of Cincinnati
60	Bengaluru	IN	Chemistry	12.62	IISC-Bangalore
61	São Paulo	BR	Neurosciences & Neurology	4.21	Universidade de Sao Paulo
62	Dallas, TX	US	Cardiovascular System & Cardiology	6.34	Univ. of Texas Southwestern Med. Center
63	Nuremberg-Erlangen	DE	Chemistry	7.75	University of Erlangen Nuremberg
64	Pittsburgh, PA	US	Neurosciences & Neurology	6.00	PCSHE
65	Ann Arbor, MI	US	Chemistry	4.47	University of Michigan
66	Changsha	CN	Engineering	11.43	Central South University
67	Delhi	IN	Chemistry	7.93	All India Institute of Medical Sciences
68	Helsinki	FI	Science & Technology-Other Topics	5.10	University of Helsinki
69	Qingdao	CN	Chemistry	13.08	Ocean University of China
70	Vienna	AT	Science & Technology-Other Topics	5.14	Medical University of Vienna
71	Oxford	GB	Physics	6.92	University of Oxford
72	Suzhou	CN	Chemistry	16.99	Suzhou University
73	Cleveland, OH	US	Cardiovascular System & Cardiology	7.32	Cleveland Clinic
74	Vancouver, BC	CA	Neurosciences & Neurology	5.18	University of British Columbia
75	Busan	KR	Engineering	9.82	Pusan National University
76	Lyon	FR	Chemistry	6.86	CNRS
77	Chongqing	CN	Chemistry	10.06	Chongqing University
78	Phoenix, AZ	US	Neurosciences & Neurology	7.51	Arizona State University
79	Hefei	CN	Chemistry	14.05	University of Science & Tech. of China
80	Harbin	CN	Engineering	13.04	Harbin Institute of Technology
81	Ottawa, ON	CA	Engineering	5.73	University of Ottawa
82	Jinan	CN	Chemistry	13.85	Shandong University
83	Brisbane	AU	Engineering	5.38	University of Queensland
84	Bridgeport-New Haven, CT	US	Neurosciences & Neurology	6.78	Yale University
85	Hamamatsu	JP	Physics	8.20	Hamamatsu University School of Medicine
86	Austin, TX	US	Chemistry	10.12	University Of Texas Austin
87	Changchun	CN	Chemistry	22.06	Jilin University
88	Ankara	TR	Engineering	5.81	Hacettepe University
89	Lausanne	CH/FR	Chemistry	7.91	EPFL
90	Hamburg	DE	Physics	7.64	University of Hamburg
91	Kanazawa	JP	Chemistry	7.75	Kanazawa University
92	Grenoble	FR	Physics	16.45	CNRS
93	Manchester	GB	Chemistry	6.71	University of Manchester
94	St. Louis, MO	US	Neurosciences & Neurology	6.70	Washington University (WUSTL)
95	Basel	CH/DE/FR	Neurosciences & Neurology	7.53	University of Basel
96	Lund-Malmö	SE	Science & Technology-Other Topics	5.55	Lund University
97	Columbus, OH	US	Oncology	5.23	Ohio State University
98	Mumbai	IN	Chemistry	16.43	Bhabha Atomic Research Center
99	Warsaw	PL	Chemistry	9.35	Polish Academy of Sciences
100	Göteborg	SE	Engineering	7.32	University of Gothenburg

Source: WIPO Statistics Database, March 2020.
Notes: Patent filing and scientific publication shares refer to the 2014–18 period and are based on fractional counts, as explained in the text. We use the location of inventors to associate patent applicants to clusters; note that addresses of applicants may be outside the cluster(s) to which they are associated. The identification of technology fields relies on the WIPO technology concordance table linking International Patent Classification (IPC) symbols with 35 fields of technology (available at http://www.wipo.int/ipstats/en/). The

Share, %	Top patenting field	Share, %	Top applicant	Share, %
	Patent performance			
14.63	Other consumer goods	18.69	Arcelik	47.68
31.61	Digital communication	16.41	LM Ericsson	8.77
44.55	Basic materials chemistry	13.42	BASF	42.23
53.92	Biotechnology	14.95	Novozymes	10.76
27.34	Medical technology	13.58	Georgia Tech	7.70
20.57	Computer technology	10.47	Tianjin University	12.48
54.77	Computer technology	16.20	ARM	11.54
23.85	Pharmaceuticals	10.31	Bridgestone	7.58
32.76	Medical technology	33.82	Procter & Gamble Company	41.62
21.75	Computer technology	20.99	Hewlett-Packard	10.10
35.24	Medical technology	8.77	Natura Cosmeticos	4.01
36.11	Civil engineering	16.52	Halliburton	15.92
49.35	Electrical machinery, apparatus, energy	17.10	Siemens	35.26
50.15	Medical technology	12.69	University of Pittsburgh	14.15
65.63	Pharmaceuticals	10.22	University of Michigan	29.52
30.20	Electrical machinery, apparatus, energy	9.48	Zoomlion	7.97
10.26	Pharmaceuticals	12.02	Sun Pharmaceutical Industries	4.36
41.98	Digital communication	30.04	Nokia	11.79
15.45	Other consumer goods	43.01	Qingdao Haier Washing Machine	27.04
21.09	Electrical machinery, apparatus, energy	8.63	Technische Universitat Wien	4.28
57.83	Biotechnology	13.74	Oxford University	12.90
48.73	Digital communication	10.37	Fujitsu	11.76
35.07	Medical technology	17.22	Case Western Reserve University	10.71
52.55	Medical technology	9.44	University of British Columbia	5.99
27.37	Medical technology	7.68	Pusan National University	5.59
22.91	Basic materials chemistry	10.26	IFP Energies Nouvelles	11.29
18.59	Optics	16.58	HKC Corp.	36.69
37.63	Semiconductors	16.25	Intel	24.71
29.14	Other consumer goods	14.76	Hefei Hualing	15.29
30.20	Measurement	14.32	Harbin Institute of Technology	36.35
43.04	Digital communication	48.28	Huawei	42.98
42.47	Computer technology	17.85	Shandong University	18.35
36.87	Civil engineering	12.37	University of Queensland	8.18
63.11	Pharmaceuticals	15.69	Yale University	11.15
21.75	Mechanical elements	14.92	NTN Corp.	26.17
62.24	Computer technology	20.83	University Of Texas	13.94
41.61	Measurement	15.58	Changchun Institute Of Applied Chemistry	14.38
13.18	Medical technology	15.12	Aselsan	18.01
34.89	Food chemistry	8.86	NESTEC	25.83
42.84	Organic fine chemistry	14.60	Beiersdorf	8.75
52.62	Computer technology	8.89	Fujifilm Corp.	31.04
31.57	Electrical machinery, apparatus, energy	13.77	CEA	39.44
49.75	Electrical machinery, apparatus, energy	15.46	Micromass	13.54
51.25	Biotechnology	16.00	Monsanto Technology	17.65
45.41	Pharmaceuticals	18.98	F. Hoffmann-La Roche	13.56
64.26	Digital communication	25.61	LM Ericsson	24.18
66.73	Pharmaceuticals	12.87	Ohio State Innovation Foundation	18.96
17.00	Organic fine chemistry	17.71	Reliance Industries	4.90
14.59	Medical technology	8.43	General Electric	4.49
33.00	Digital communication	13.89	LM Ericsson	22.63

top scientific field is based on SCIE's Extended Ascatype subject field. An article can be assigned to more than one subject field. Fractional counting was used when more than one subject was assigned to an article. Codes refer to the ISO-2 codes. See chapter 1 for a full list, with the following addition: TW = Taiwan, Province of China. CNRS = Centre National De La Recherche Scientifique, KAIST = Korea Advanced Institute Of Science & Technology, CSIC = Consejo Superior De Investigaciones Cientificas, IISC - Bangalore = Indian Institute Of Science - Bangalore, PCSHE = Pennsylvania Commonwealth System Of Higher Education, EPFL = Ecole Polytechnique Federale De Lausanne, and CEA = Commissariat A L'Energie Atomique Et Aux Energies Alternatives.

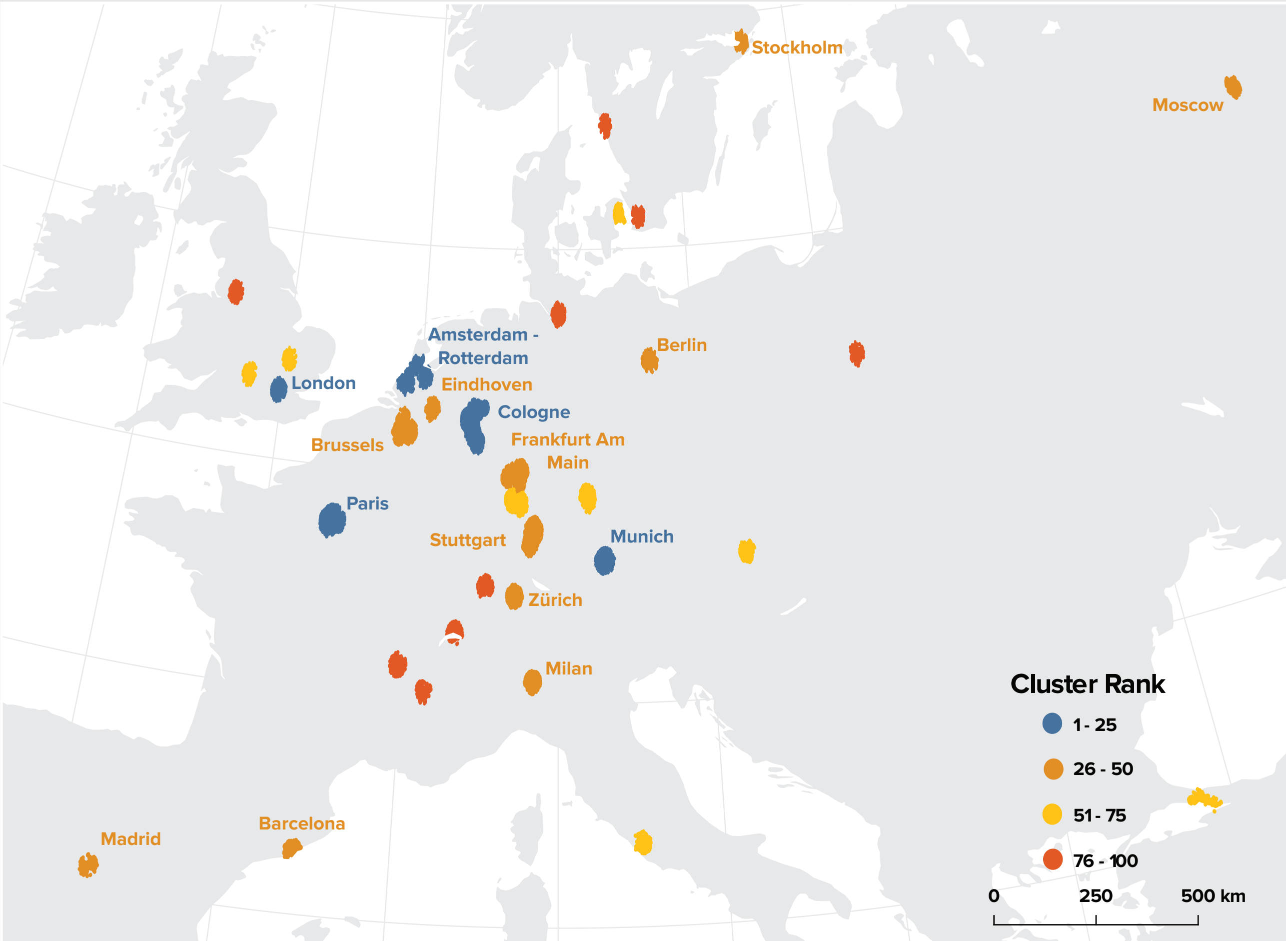
FIGURE S-1.5

Regional clusters: Asia

Source: WIPO Statistics Database, March 2020.
Note: Cluster rank is based on total share in patent filing and scientific publication using fractional counting and the publication period of 2014-2018, as explained in the text.

FIGURE S-1.6

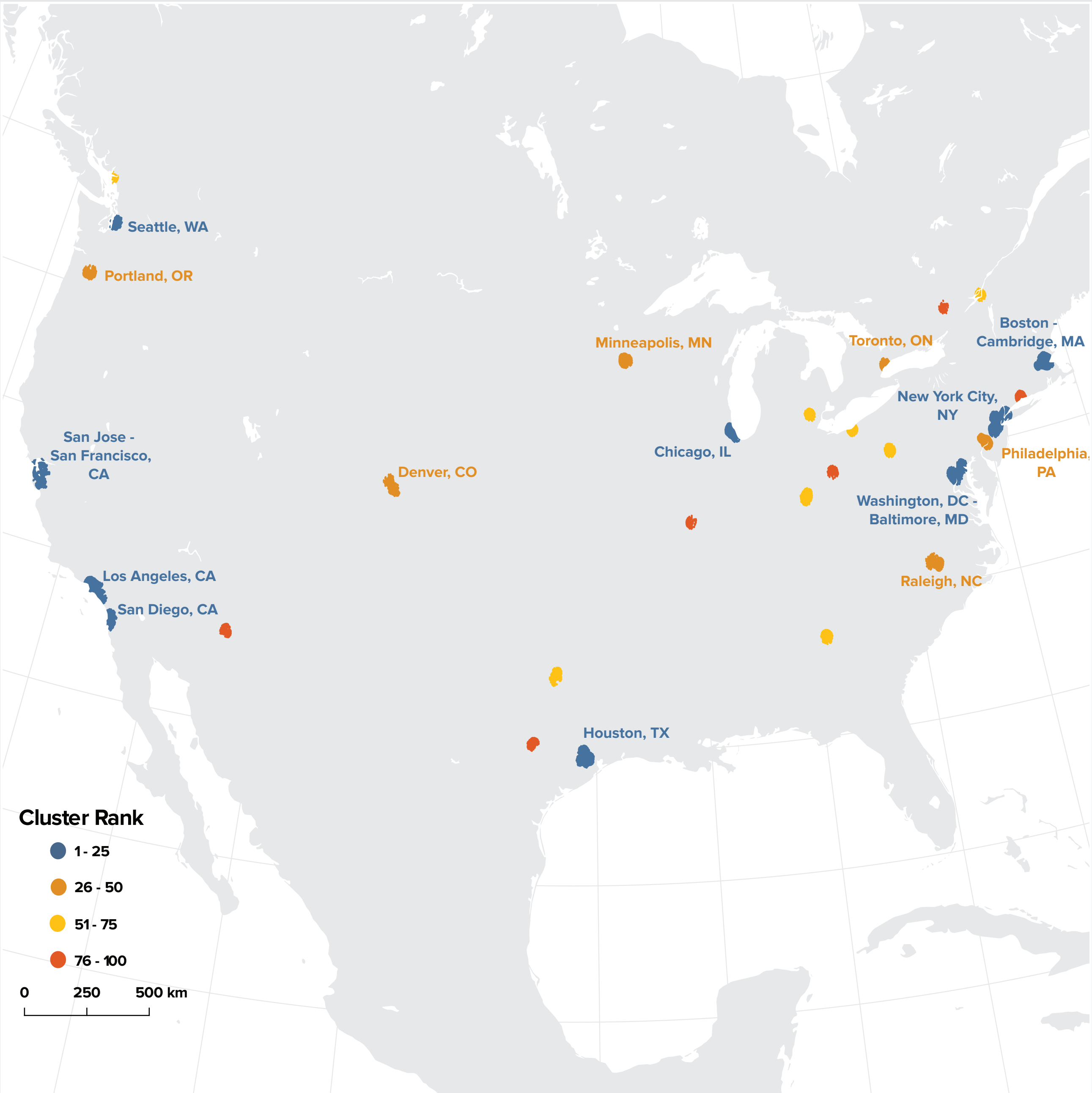
Regional clusters: Europe



Source: WIPO Statistics Database, March 2020.
Note: Cluster rank is based on total share in patent filing and scientific publication using fractional counting and the publication period of 2014-2018, as explained in the text.

FIGURE S-1.7

Regional clusters: Northern America



Source: WIPO Statistics Database, March 2020.
Note: Cluster rank is based on total share in patent filing and scientific publication using fractional counting and the publication period of 2014-2018, as explained in the text.

MATCHING S&T CLUSTERS TO POPULATION

Utilizing population data to enhance our cluster comparisons provides substantial improvement to our analysis. Unfortunately, aligning our "bottom up" clusters with typical population statistics is less than ideal. Our identified clusters almost never conform to standard administration boundaries with which we could find population statistics (for example, census blocks in the U.S. or NUTS—2/3 regions in the European Union). In addition, finding consistent administrative population data across multiple countries proved difficult.

To address these issues, we turned to the European Commission's Global Human Settlement population distribution data. This data provides an estimation of population for every 250–300 square meters. By disaggregating census population data based on satellite imagery, we are able to plot population based on where people actually live, rather than just on arbitrary political boundaries. Having the population distribution at such a high level of detail allows us to reaggregate population into custom geographies (i.e., our clusters). Thus, just like our inventor/author geocoded locations, this population data allows us to define total population from the bottom up.

Matching the population data with our clusters is done geographically by capturing all pixels that are contained within a cluster's area. For the purposes of aggregating population, we defined a cluster's area as all space within 0.05 degrees of each inventor's location.[1] Once the buffer radius was applied, we combined all areas of a cluster into one final polygon. We achieved the final total population by summing the values of all the population pixels that are contained in the final cluster polygon.[2]

The use of a buffer was preferred to possible alternative methods, due to its ability to capture nearby population pockets. For example, if we had limited our cluster area to edges defined only by our cluster points, we may have missed dense population areas that were just next to one of our points. This would have caused an underestimation of the population. As can be seen in Figure SA-1.1, if we had used only our cluster points to define the edges of San Jose-San Francisco, we would have missed the dense urban area of Concord, California. The use of buffers also minimizes errors that could occur from overreliance on imprecise geolocation. For example, our scientific publication data is only geocoded at the city level (see Table SA-1.1 for a full breakdown of our geocoding results). Thus, the use of a buffer for these points more appropriately reflects the lack of precision that some of our geolocated points have.

Buffers require a choice of radius size or how much area around the point should be included. Similar to choosing the radius and density parameters used for DBSCAN, we chose a buffer radius that minimizes the potential for false negatives (not capturing population areas that should be included in the cluster) and false positives (capturing areas that should not be included). Increasing the buffer radius decreases the risk of underestimating the population but increases the risk of overestimating it. This can be seen in Figure SA-1.1. If we had used 0.01 degrees as the radius, we would not have captured Concord, causing an underestimation. However, if we had chosen 0.10 degrees, we would have captured the city of Antioch, California, which is in the next valley over from Concord. This would have caused an overestimation of the

TABLE SA-1.1

Summary of geocoding results

Country	Scientific publications: Number of addresses	Scientific publications: City-level address accuracy (%)	Scientific publications: Publications covered (%)	PCT applications: Number of addresses	PCT applications: Block-level address accuracy (%)	PCT applications: Sub-City-level address accuracy (%)	PCT applications: City-level address accuracy (%)	PCT applications: Applications covered (%)
United States of America	5,925,624	97.55	98.64	861,743	94.25	5.40	0.15	99.86
China	3,454,935	99.04	99.47	451,848	92.35	0.05	4.90	97.38
Japan	1,117,078	94.96	97.02	548,970	32.50	28.20	37.73	98.76
Germany	1,262,920	97.36	98.18	258,816	97.47	0.41	1.68	99.74
United Kingdom	1,276,213	96.61	97.70	79,335	74.06	13.89	10.03	98.22
France	1,040,275	92.91	95.08	106,503	86.34	1.50	6.72	95.79
Italy	990,376	95.54	96.98	40,780	87.60	5.08	6.26	99.09
Republic of Korea	734,697	94.12	96.75	215,692	0.12	0.69	79.91	87.77
Canada	813,125	98.36	98.94	41,886	96.84	2.32	0.59	99.69
Australia	761,695	81.77	87.84	20,505	92.17	4.77	2.18	99.31
Spain	747,705	96.75	97.98	26,508	73.21	10.03	15.67	99.21
India	632,809	94.77	96.71	38,193	33.14	44.63	19.06	97.24
Brazil	572,348	98.65	99.54	9,304	80.48	12.25	6.30	99.45
Netherlands	471,728	97.38	98.48	50,790	87.47	0.38	11.79	99.66
Turkey	365,592	96.66	97.11	12,579	32.12	51.74	12.98	97.11
Iran (Islamic Republic of)	356,585	97.09	98.34	529	0.57	2.84	89.22	91.13
Russian Federation	341,968	99.00	99.26	14,542	85.57	5.35	7.35	99.26
Switzerland	300,307	90.67	92.37	35,888	89.74	3.71	4.34	98.55
Sweden	274,192	97.63	98.22	41,828	94.52	0.86	4.15	99.60
Israel	145,890	90.55	94.78	28,497	54.09	3.91	32.16	94.85

Source: WIPO Statistics Database, March 2020.
Note: This list includes the top 20 countries that account for the highest combined shares of patents and scientific articles. PCT inventor addresses were geocoded to the highest level of detail. Due to the much larger volume, scientific author addresses were geocoded to the city level only.

population. Therefore, we calculated population using a number of different radiuses for the buffer and looked at the changes in the population estimations, preferring the one that minimized large shifts. When compared to other distances, a radius of 0.05 degrees minimized large shifts in the total population calculated across all clusters as well as minimized the maximum population shift of any one cluster.

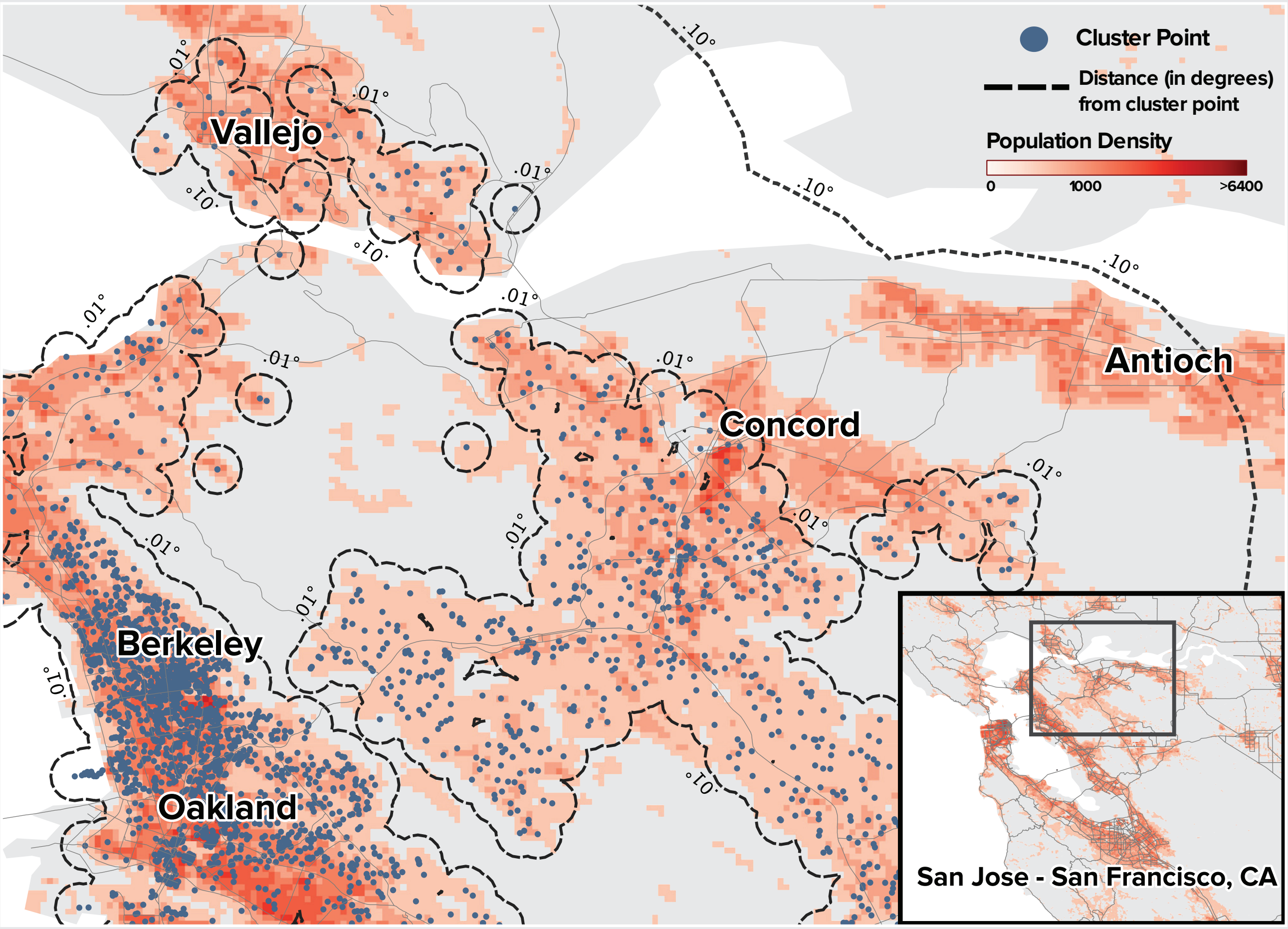
Notes:

1. When using degrees to define the radius, the actual distance will vary depending on the latitude of the center point. In this case, 0.05 degrees translates to between 4–5 kilometers for the vast majority of our points.

2. We utilized QGIS's Raster Analysis Zonal Statistics tool to perform the aggregation. A pixel was included in a polygon if at least its center point was included. Given the size of our clusters and the large number of population pixels typically contained, this binary in or out selection is acceptable.

FIGURE SA-1.1

Comparing buffer radius



Source: WIPO Statistics Database, March 2020; Schiavina et. al., 2019.