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Statistics on statistics: measuring research productivity by journal publications between 1985 and 1995

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ABSTRACT

Sixteen international journals publishing statistical theory were surveyed over the 11-year period beginning in 1985. Paper, author and adjusted page counts yield cursory measures of productivity for institutions and countries that contributed to fundamental statistical research during that period. These data clearly identify Canada as one of the main contributors to the development of the discipline in the past decade. They also provide valuable information on the evolution of publication habits, in terms of the volume of research, the length of papers, coauthorship practices, etc.

RÉSUMÉ

Seize revues internationales spécialisées en statistique fondamentale ont été recensées sur une période de 11 ans débutant en 1985. Un décompte des articles publiés dans ces revues, de leur longueur et du nombre de leurs auteurs, permet d'évaluer sommairement la productivité des établissements et des pays ayant contribué à la recherche fondamentale en statistique durant cette période. Ces données mettent en évidence l'importance de la contribution du Canada au développement de la discipline au cours de la dernière décennie. Elles brossent également un portrait de l'évolution des pratiques de publication, notamment en ce qui touche le volume des écrits, leur longueur et le nombre de leurs signataires.

1. INTRODUCTION

Several disciplines have a tradition of periodically assessing the productivity and intellectual influence of their research community through surveys involving publication counts, citation statistics and related indices. Literature concerned with the performance of economics departments is particularly abundant (cf., e.g., Moore 1973, Niemi 1975; Smith and Gold 1976; Graves *et al.* 1982, Hirsch *et al.* 1984, Hall 1987, 1990). In statistics, Phillips *et al.* (1988) appear to have been the first to produce national, institutional and even individual rankings based on a worldwide survey of refereed journals. Despite the interest it generated, their study was never updated.

The present paper aims to fill this gap by comparing the research output of countries and establishments through the publication record of their statisticians between 1985 and 1995. Paper, author and adjusted page counts tallied over a sample of 16 international statistics journals are used to derive national and institutional productivity rankings of various kinds. Section 2 describes the data base, and Section 3 illustrates some of the

current trends in publication practices regarding the length of papers, the frequency of coauthorships and international collaboration. The rankings per se are presented and discussed briefly in Sections 4 and 5. Additional information of interest to the Canadian community is supplied in Section 6, and concluding comments are given in the closing section.

At the national and institutional levels, the evolution over time of productivity rankings may help assess the short- and long-term effects of funding or hiring policies. Periodic benchmarking studies may also assist in setting priorities and attracting clientele or personnel. While the rankings presented here identify the most prolific and productive countries and establishments in the discipline, they should not be regarded as a low-cost proxy for the quality of research output. Measuring productivity is one thing; judging originality, depth, elegance, applicability, relevance, influence or even validity is quite another. Though it may be argued that peer review based on anonymous refereeing induces positive correlation between these characteristics in published work, it is important to stress that the ordinal rankings given herein depend on scores which sometimes afford little separation between successive positions. While this problem is not acute at the aggregate level, it was deemed sufficiently serious to preclude the publication of individual rankings. It should also be emphasized that the results of a study such as this one are totally conditioned by the selection of journals, time period and counting rules.

2. DATA BASE

The data base consists of all research articles published between 1985 and 1995 inclusively in the 16 refereed journals listed in Table 1. This selection is obviously subjective and far from comprehensive, but is felt to provide adequate coverage of the variety of outlets currently available for publishing theoretical and applied statistical research. The sample encompasses the core statistics journals identified by Stigler (1994) as most often cited in the literature; it also makes allowance for general methodology publications with somewhat smaller circulation that are sponsored by national or regional associations. The only glaring omissions in those categories are the *Communications in Statistics* and *Sankhyā* series. While it would have been preferable to include them in the survey, along with more specialized journals in biostatistics, decision sciences, econometrics, psychometrics and time-series analysis, for example, choices were limited by the amount of effort involved in compilation of the data.

Table 1 provides summary statistics for each journal surveyed over the 11-year period extending from 1985 to 1995 inclusively. The variables measured were:

(1) the *number of articles* (ART) published in the journal, including discussions and interviews published in *Statistical Science* but excluding editorials, letters to the editors, book reviews, corrigenda, notices and the like;

(2) the *number of authors* (AUT), summed over all articles;

(3) the *number of distinct authors* (DIS), that is, the number of distinct individuals having authored or coauthored at least one article in the journal;

(4) the *number of pages* (PAG) of the journal devoted to research articles, multiplied by a conversion factor, F, in order to make the printed surface of journal pages comparable to that of *The Annals of Statistics*. Note that these factors are not exactly the same as those given by Phillips *et al.* (1988), who used the average number of characters printed per journal page as their comparison point.

For the purposes of illustration, assume that the study had borne on a single issue of the *Journal of the American Statistical Association* (JASA) comprising 3 articles: a 4-page

TABLE 1: List of journals included in the study, along with the corresponding numbers of articles (ART), authors (AUT), distinct authors (DIS) and adjusted pages (PAG) published between 1985 and 1995; F is the multiplicative factor that was used to convert the nominal number of pages published in each journal into PAG, the equivalent number of pages of *The Annals of Statistics*.

Journal	ART	AUT	DIS	PAG	F
Ann. Inst. Statist. Math.	596	958	672	7417	0.94
Ann. Statist.	1222	1945	1070	20941	1.00
Austral. J. Statist.	385	634	453	5007	1.14
Biometrics	1160	2290	1534	14772	1.19
Biometrika	1066	1824	1174	10487	1.18
Canad. J. Statist.	428	738	628	4906	1.06
Internat. Statist. Rev.	234	385	341	4454	1.21
J. Amer. Statist. Assoc.	1487	2716	1745	24130	1.96
J. Multivariate Anal.	833	1338	868	11463	0.84
J. Royal Statist. Soc. Ser. B	460	777	555	6700	1.15
J. Statist. Plann. Inf.	1151	1911	1258	13884	0.94
Scand. J. Statist.	280	438	348	3918	1.06
Statist. Sci.	682	869	648	7379	1.66
Statist. Sinica	205	379	309	3481	1.07
Statist. Neerlandica	227	382	299	2973	1.02
Technometrics	381	700	517	5712	1.54

paper by A, an 8-page joint contribution by A and C, and a 12-page text coauthored by B, C, $\mathcal{D}$ and $\mathcal{E}$. This would have yielded ART = 3, AUT = 7, DIS = 5 and PAG = $(4 + 8 + 12) \times 1.96 = 47$. With these conventions, the database is found to encompass 10,797 articles, 147,624 (adjusted) pages and 18,284 authors, including 6920 distinct authors affiliated with 1897 institutions from 75 countries worldwide. For the purpose of this study, Czechoslovakia, Yugoslavia and the USSR were considered as undivided entities, and the two Germany were counted as one.

The data in Table 1 make it plain that the sample is dominated by *Biometrics*, *Biometrika*, *JASA* and *The Annals of Statistics*, four highly respected journals which together account for 70,330 pages or 47.6% of the total. Adding the *Journal of Multivariate Analysis* (JMA), the *Journal of Statistical Planning and Inference* and *Technometrics* brings the proportion to 68.7% (101,389 pages). The percentages in terms of papers published are roughly the same (45.7% and 67.6%). It seems unlikely, therefore, that the inclusion in the sample of journals sponsored by national or regional statistical societies other than the ASA would have any significant effect on the rankings presented in Sections 4 to 6.

The seven nationally based journals included in the study are listed in Table 2, along with a percentage breakdown of total volume of publication originating from the corresponding countries, with Scandinavia standing for Denmark, Finland, Norway, and Sweden. These proportions were computed from the variable PAG*, defined as the sum over all articles of their number of pages times their number of authors; the numerator of PAG*(country)/PAG* was obtained by restricting the sum to those authors whose affiliation, as listed in the paper, was in the appropriate country. Contents of national origin, which correspond to the diagonal entries, varied from 27.3% in the Japanese journal to 75.4% in *JASA*; except in the latter case, the proportion of papers from the United States is usually second highest, for reasons which will become apparent in the next section. Another measure of the journals' scientific diversity is given by the ratio DIS/AUT, which is a rough indicator of the heterogeneity of its pool of contributors. This quotient varies from 55% in *The Annals of Statistics* to 89% in *International Statistical Review*.

TABLE 2: Journals sponsored by statistical societies of national or regional character included in the study, and percentage breakdown of total publications contents by nation(s), measured in pages authored by individuals whose affiliation was listed in the appropriate country(ies). In case of multiple authorship, the number of pages was multiplied by the number of authors. Scandinavia stands for Denmark, Finland, Norway, and Sweden.

Journal	Japan	Aus.	Can.	USA	U.K.	Scand.	Neth.
Ann. Inst. Statist. Math.	27.3	2.7	7.8	33.7	1.6	1.9	0.4
Austral. J. Statist.	2.1	54.6	3.3	17.5	5.6	0.5	0.3
Canad. J. Statist.	0.8	0.6	56.5	28.2	1.5	1.1	0.7
J. Amer. Statist. Assoc.	0.6	2.9	5.8	75.4	3.2	1.7	0.8
J. Royal Statist. Soc. Ser. B	1.0	8.3	4.9	38.2	29.2	3.8	0.4
Scand. J. Statist.	0.0	1.6	3.2	24.8	3.3	38.5	4.9
Statist. Neerlandica	0.1	1.2	1.6	10.3	3.1	1.3	64.4

3. GENERAL TRENDS

Before rankings are considered, it may be worthwhile highlighting some of the current trends in publication habits that are apparent from the survey. One can easily see from Table 1 that between 1985 and 1995, papers averaged 13 pages in length in most journals, ranging from 9.8 in *Biometrika* to approximately 19 in *International Statistical Review*, which regularly publishes long survey articles. What the table does not show is that the average length of papers has been increasing slowly over that period, as illustrated in Figure 1. Given the ever rising costs of publication and space pressure caused by the expanding community of statistical researchers, this trend seems somewhat surprising at first. It is nevertheless real and affects most journals, including *Biometrika*, *JASA*, *The Canadian Journal of Statistics*, and *The Annals of Statistics*. However, it is most striking in *Statistical Science*, where the expected length of papers has more than doubled (from 11 in 1986 to 24 approximately) in a decade.

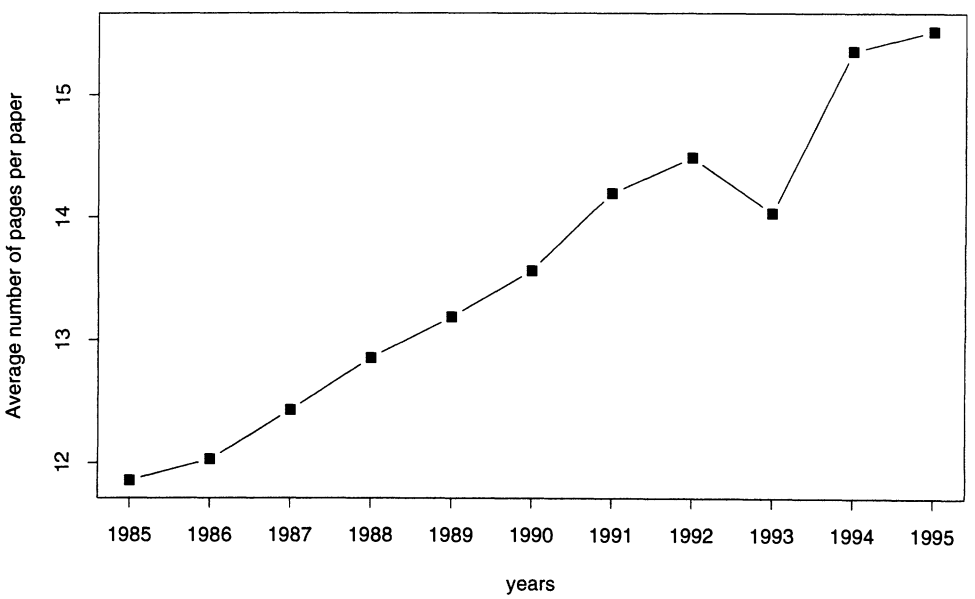

FIGURE 1: Evolution of the average number of pages per paper from 1985 to 1995, as estimated from a survey of the 16 refereed statistics journals listed in Table 1.

Figure 2 displays the progression in coauthorship practices between 1985 and 1995. During that period, the average number of authors per paper varied from 1.5 to 1.9 across the journals surveyed; *Biometrics*, *Biometrika* and *JASA* were on the higher side, while *Statistical Science* was markedly on the lower side. Overall, the percentage of single-authored articles decreased from 50.9% in 1985 to 34.9% in 1995, while two-author papers rose from 38% to 46.8%, and three-author papers from 9% to 14.5%, in the same period. This phenomenon may be partly responsible for the observed growth in the length of papers: over the study period, single-authored papers averaged 12.8 pages, while two- and three-author articles averaged 14.3 and 14.6 pages, respectively.

Finally, it is instructive to look at Figure 3, which shows the yearly variation in the level of international collaboration, as measured by the fraction of coauthored papers that include researchers from different countries. This proportion was of the order of 19% between 1985 and 1995 and appears to increase at a slow pace, with significant fluctuations. Given the enormous volume of statistical research conducted in the United States, as documented in the following section, a ratio of 1:5 for transnational production seems fairly impressive. It is in the *Journal of the Royal Statistical Society, Series B* that this ratio was the highest over the study period, standing at the 30% mark. *ISI Review*, *JMA* and *Statistica Sinica* also scored high on this variable, while *Statistica Neerlandica* was lowest.

4. NATIONAL RANKINGS

This section is concerned with what might be called the "statistical wealth of nations," to paraphrase May (1997). As with economic activity, national production in statistical research can be measured in different ways. If determining the overall contribution of countries to statistical science is of prime concern, then total output is probably all that matters. But for other purposes, such as judging national productivity or vitality in the discipline, performance relative to the size of the country or its publishing community may be more relevant. This is why three different national rankings will be examined in turn.

Information on the geographic distribution of researchers having published between 1985 and 1995 in the 16 journals surveyed is given in Table 3 by country of job affiliation in terms of variables ART, PAG, ART* and PAG*. While the first two of these counts assign a weight of $1/n$ of the publication credit to each one of the $n \geq 1$ joint authors of a paper, the variables ART* and PAG* give full credit to each person in case of multiple authorship. To clarify the counting procedure, consider once again the example of Section 2 and assume that A and B are American, while C, $\mathcal{D}$ and $\mathcal{E}$ are Canadian, say. In this case variables ART, ART*, PAG and PAG* would take the values 1.5, 2, 8, 12 for author A; 0.75, 2, 7, 20 for author C; and 0.25, 1, 3, 12 for authors B, $\mathcal{D}$ and $\mathcal{E}$, respectively. Country totals would then equal 1.75, 3, 11, 24 for the USA and 1.25, 2, 13, 44 for Canada, respectively.

Table 3 ranks the world's top 25 countries by what might be termed "gross national publication" (GNP) in statistical sciences. The ranks are those induced by variable PAG*, whose discriminating power is the largest of all considered, in terms of variance. Rankings based on the other variables differ slightly, but the conclusions are unaltered. In terms of sheer research output, the data confirm the overwhelming advantage of the USA and the strong leadership of predominantly English-speaking countries in general, which together were responsible for over 71.8% of all articles published between 1985 and 1995 in the 16 journals surveyed. It is possible that this dominance is somewhat overestimated, given that only 3 of the 16 journals included in the study publish papers in languages other than

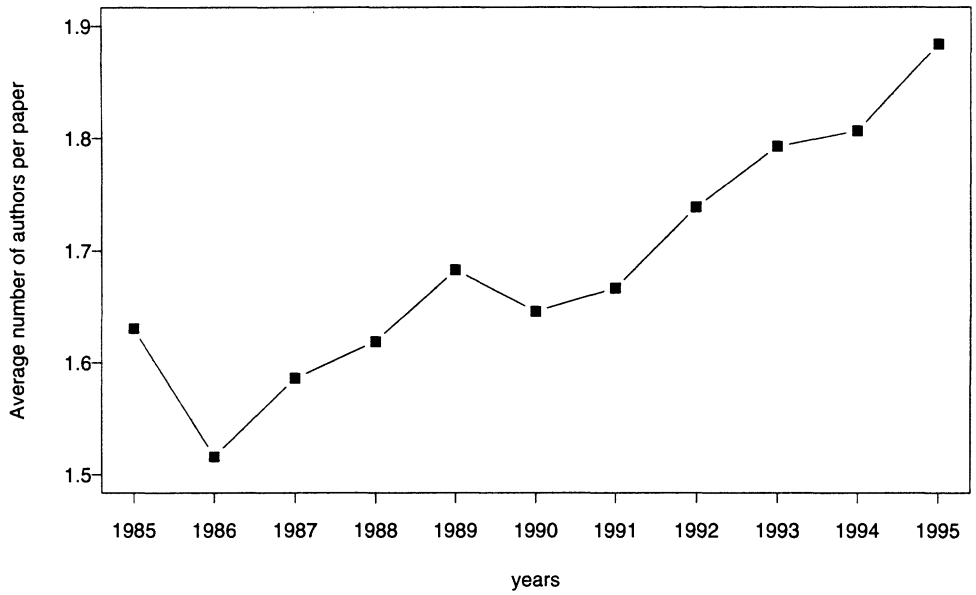

FIGURE 2: Evolution of the average number of authors per paper from 1985 to 1995, as estimated from a survey of the 16 refereed statistics journals listed in Table 1.

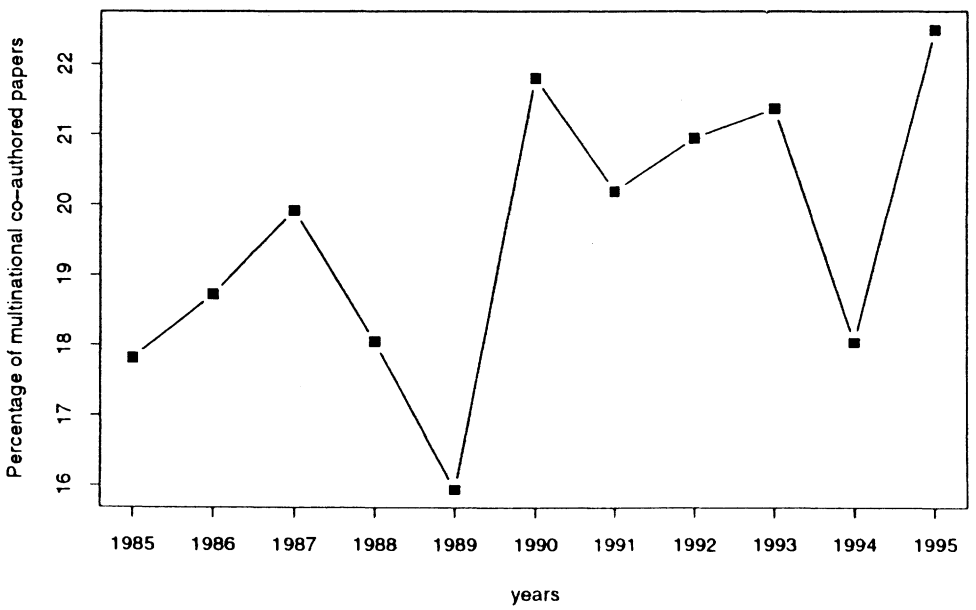

FIGURE 3: Evolution of the proportion of internationally coauthored papers from 1985 to 1995, as estimated from a survey of the 16 refereed statistics journals listed in Table 1.

TABLE 3: Top 25 countries for gross national publication (GNP) of statistical research; the ranks are based on variable PAG*.

Rank	Country	PAG*	PAG	ART*	ART
1	USA	138544	77974	9484	5493
2	Canada	20933	11805	1588	925
3	United Kingdom	16296	9949	1178	749
4	Australia	13891	7782	991	578
5	Germany	8868	5917	622	419
6	Netherlands	6939	4063	468	282
7	Japan	6813	4570	554	379
8	France	5034	2595	351	177
9	India	4252	2322	456	250
10	Denmark	3416	2105	211	135
11	Israel	2589	1450	190	109
12	Taiwan	2489	1433	182	110
13	Norway	2014	1303	126	81
14	Spain	1952	931	138	70
15	Belgium	1947	932	116	55
16	Poland	1784	1050	163	98
17	Sweden	1723	1128	121	83
18	Italy	1428	823	105	62
19	New Zealand	1401	929	115	73
20	Switzerland	1358	754	91	54
21	Finland	1340	702	96	51
22	China	1287	709	101	58
23	Brazil	967	448	72	35
24	South Africa	945	572	76	45
25	Greece	841	548	78	53

English; they are *Biometrics*, *ISI Review* and *The Canadian Journal of Statistics*, which accept French-language papers. It should also be borne in mind that leading nations in statistical sciences have a strong power of attraction for foreign researchers, to the detriment of their countries of origin. India is a prime example of a nation that long suffered from this "brain drain"; China and the ex-USSR provide more recent illustrations of the same phenomenon.

Table 4 lists the top 25 world countries, ranked by GNP per capita. The population figures used to this end were excerpted from Kidron and Segal (1992) and expressed in millions (POP). Taking the United States as the reference point, the results suggest that Australia, Canada, Denmark and Israel have comparatively larger pools of contributors to published statistical research than the USA, enough so to pull them ahead of it in the ranking. As for countries like Japan, France or Germany that did not fare so well in Table 4 compared to Table 3, they happened to be much less well represented in the 16 journals used for the study than might have been predicted from their population size in the period considered.

Finally, the top 25 world countries as ranked by PAG*/DIS are identified in Table 5. This measure factors into the statistical GNP the number DIS of "active production units." What comes out, therefore, is less a ranking of nations than an indicator of the relative productivity of the pool of distinct authors of research papers in statistics, country by country. Argentina and Tanzania, for example, are by no means large producers of statistical research, and their numbers of contributors to the 16 journals surveyed were modest between 1985 and 1995, but those groups turned out to be quite competitive. While one might anticipate that talented individuals or groups of statisticians in small

TABLE 4: Top 25 countries for statistical GNP per capita; the ranks are based on variable PAG*/POP.

Rank	Country	PAG*/POP	PAG/POP	ART*/POP	ART/POP
1	Australia	812	455	58	34
2	Canada	787	444	60	35
3	Denmark	670	413	41	26
4	Israel	563	315	41	24
5	USA	551	310	38	22
6	Norway	479	310	30	19
7	Netherlands	466	273	31	19
8	New Zealand	424	282	35	22
9	United Kingdom	284	173	21	13
10	Finland	268	140	19	10
11	Sweden	203	133	14	10
12	Switzerland	203	112	14	8
13	Belgium	197	94	12	6
14	Iceland	152	107	7	4
15	Singapore	146	83	10	6
16	Ireland	129	76	9	6
17	Hong Kong	124	76	11	7
18	Taiwan	123	71	9	5
19	Germany	112	74	8	5
20	France	89	46	6	3
21	Greece	83	54	8	5
22	Austria	77	49	6	4
23	Hungary	60	37	4	3
24	South Africa	59	36	5	3
25	Japan	55	37	4	3

countries could outperform relatively easily the mass of researchers in the leading nations, it is noteworthy that many of the countries with large statistical GNP (USA, Canada, Australia, Germany, Japan, etc.) continue to do very well, even under that criterion. The high productivity of Danish and Belgian statisticians seems all the more remarkable and, in the latter case, confirms earlier findings reported by Hallin (1996).

Many more rankings could be envisaged that were not considered here for lack of space or reliable data. Of particular interest would be those that take into account economic variables such as gross domestic product or percentage thereof invested in research and development, particularly in the statistical sciences. This could be the object of future work.

5. INSTITUTIONAL RANKINGS

Table 6 identifies the 25 most prolific institutions in statistics, ranked by the variable PAG*, which measures the volume of publication by their researchers in the journals listed in Table 1 over the period 1985–1995. This information is supplemented in the appendix, where 125 additional establishments are listed. These data confirm the huge disparity in activity already documented by Phillips *et al.* (1988). Based on the first 150 institutions, the mean (median) count for PAG* is 1104 (742), with a standard deviation of 870. In this population, Stanford University ranks first, some 4.2 standard deviations above the mean.

Predictably, universities and particularly U.S. schools totally dominate the rankings: 21

TABLE 5: Top 25 countries for statistical GNP per national contributor; the ranks are based on variable PAG*/DIS, where DIS is the number of distinct authors whose listed affiliation is from a given country.

Rank	Country	PAG* / DIS	PAG / DIS	ART* / DIS	ART / DIS	DIS
1	Argentina	95	45	5	3	7
2	Denmark	46	28	3	2	74
3	Belgium	43	21	3	1	45
4	USA	41	23	3	2	3410
5	Australia	39	22	3	2	358
6	Canada	37	21	3	2	567
7	United Kingdom	34	21	2	2	483
8	Germany	33	22	2	2	266
9	Israel	32	18	2	1	80
10	Ireland	32	19	2	1	14
11	Norway	31	20	2	1	65
12	Japan	31	20	2	2	223
13	Czechoslovakia	30	16	2	1	10
14	Hungary	30	18	2	1	21
15	Finland	29	15	2	1	46
16	Taiwan	29	17	2	1	86
17	Netherlands	29	17	2	1	243
18	Tanzania	27	13	2	1	2
19	New Zealand	26	17	2	1	54
20	Sweden	26	17	2	1	67
21	Switzerland	26	14	2	1	53
22	France	26	13	2	1	196
23	South Africa	26	15	2	1	37
24	Nigeria	24	19	2	2	5
25	Senegal	24	6	1	0	1

of the top 25 institutions are American, and of the other 4, 2 are Australian (Australian National University, 3rd; C.S.I.R.O., 22nd) and 2 are Canadian (University of Waterloo, 9th; University of Toronto, 19th). Within the USA, centers of excellence in statistics seem to be fairly well spread out: there are 5 in the west (4 of them in California), 5 in the midwest, 9 in the northeast, and 2 in the south (specifically in North Carolina). With Stanford University and the University of California at Berkeley in first and second positions, it is clear that the San Francisco Bay area remains a pinnacle of statistical research, both in the United States and worldwide (Phillips *et al.* 1988). It should be observed, however, that Harvard University would in fact rank first by a fair margin if Harvard School of Public Health, Harvard Medical School and Dana Faber Cancer Institute had not been counted separately. Likewise, the University of Washington would rank higher than 8th, should it include the data for the Fred Hutchinson Cancer Research Center. Further associations of this sort are possible; the list provided in the appendix may be used to that end. For convenience, Table 7 also identifies the top 10 nonacademic institutions, along with their ranks.

As was the case with countries, it is plain that the rankings displayed in Table 6 and in the appendix favor large institutions in which the pool of researchers in statistics is important. This is illustrated by the rightmost column of that table, where the number of distinct authors is given for each establishment. This figure, which represents the number of authors who contributed to the 16 journals surveyed between 1985 and 1995, includes people who were on the faculty in mathematics, statistics or other departments, but also

TABLE 6: Top 25 world institutions, ranked by publication output in statistics, as measured by the variable PAG*.

Rank	Institution	PAG*	PAG	ART*	ART	DIS
1	Stanford U.	4783	2953	268	162	67
2	U. of California at Berkeley	4478	2694	252	156	70
3	Australian National U.	4111	2338	266	153	60
4	U. of Wisconsin at Madison	3717	1985	264	146	87
5	Harvard School of Public Health	3335	1510	230	108	66
6	AT&T Bell Laboratories	3177	1650	173	100	78
7	U. of Chicago	3150	2148	190	133	53
8	U. of Washington	3096	1657	189	109	68
9	U. of Waterloo	2960	1600	222	127	56
10	U. of North Carolina at Chapel Hill	2882	1618	192	110	50
11	Cornell U.	2792	1445	180	96	47
12	Carnegie Mellon U.	2545	1562	159	101	43
13	Purdue U.	2440	1396	162	100	55
14	Pennsylvania State U.	2392	1385	171	99	46
15	U. of California at Los Angeles	2312	1279	145	85	48
16	North Carolina State U.	2211	1050	140	69	49
17	Johns Hopkins U.	2153	1208	156	87	49
18	U. of Michigan	2111	1337	142	91	82
19	U. of Toronto	2100	1179	154	86	50
20	Texas A&M U.	2025	1067	138	76	38
21	U. of California at Davis	2024	1209	137	82	32
22	C.S.I.R.O.	2012	1146	155	90	57
23	Rutgers U.	1996	1084	153	83	35
24	U. of Pittsburgh	1965	955	142	70	56
25	Harvard U.	1952	1086	124	73	47

TABLE 7: Top 10 nonacademic institutions in the world, ranked by publication output in statistics, as measured by variable PAG*. The ranks are those in the overall ranking of Table 6, continued in the appendix.

Rank	Institution	PAG*	PAG	ART*	ART	DIS
6	AT&T Bell Laboratories	3177	1650	173	100	78
22	C.S.I.R.O.	2012	1146	155	90	57
31	Indian Statistical Institute	1550	844	151	83	56
33	Fred Hutchinson Cancer Research Center	1544	739	110	54	32
39	National Cancer Institute	1288	634	108	58	37
43	Academia Sinica	1218	724	91	57	42
45	Institute of Statistical Mathematics	1188	840	85	60	30
62	Natl Institute of Environ. Health Sci.	890	506	71	41	26
64	I.N.R.A., France	851	392	63	29	29
71	Statistics Canada	793	397	57	31	37

staff, graduate students and perhaps even visitors who may have listed that institution as their professional affiliation. Note that when multiple addresses were mentioned for an author, only the first one was recorded in the data base.

To help identify highly productive establishments independently of their size, a ranking was prepared using the ratio PAG*/DIS. As illustrated by Table 8, however, this scheme tends to put forward very small research groups (typically teams of one or two people)

TABLE 8: Top 10 most productive world institutions in statistical research, ranked by PAG*/DIS, irrespective of size.

Rank	Institution	PAG*/DIS	PAG/DIS	ART*/DIS	ART/DIS	DIS
1	U. of Essen	150	137	7	5	2
2	CUNY Queens College	128	99	9	7	1
3	U. de Buenos Aires	122	60	8	4	3
4	U. de Pernambuco	102	48	7	4	1
5	U. of Aarhus	101	69	7	5	12
6	Kagawa University	92	80	7	6	1
7	I.U.T. de Limoges	86	56	5	3	2
8	Technical U. of Dresden	83	51	5	3	1
9	U. libre de Bruxelles	82	35	4	2	6
10	Katholische U. Eichstatt	81	59	5	3	2

that can easily be more productive on average than larger institutions. This is the same phenomenon that put Argentina on top of the ranking of world countries given in Table 5; only it is much more pervasive at the institutional level. As the intent was to spot fertile research environments, as opposed to prolific isolated individuals, the ranking was thus limited (arbitrarily) to those institutions with at least 9 contributors to the 16 journals listed over the study period. The top 25 institutions are ranked in Table 9. The list is once again dominated by American universities, which take up 17 of the 25 top positions. The United Kingdom is second, with 3 institutions (University College London, 9th; University of Glasgow and University of Bath, respectively 18th and 19th). Canada is third with 3 representatives (Carleton University, 4th; University of Ottawa, 5th; University of Waterloo, 22nd), while Australia (Australian National University, 7th) and Denmark (University of Aarhus, 1st) each hold one position. The fact that the Danish institution leads the pack is all the more impressive. The strong productivity of the Ottawa statistical research community is also worth highlighting.

6. CANADIAN RANKINGS

This section supplies additional information that might be of particular interest to a Canadian audience. The focus is on provincial and institutional performance within the country. Table 10 provides a breakdown of the statistics GNP of Canada in terms of the variables ART, ART*, PAG, PAG*, and DIS. Three rankings are also provided, which are the provincial analogues of the national rankings presented in Tables 3 to 5. They are based on the variables PAG*, PAG*/POP and PAG*/DIS, respectively. By all indicators, it is plain that Ontario was responsible for more than 50% of Canada's contribution to statistical research in the study period. Of course, that province is also the largest in population, and in fact, ranking I is in general agreement with provincial population figures, except for Newfoundland, Nova Scotia and Saskatchewan, which are shuffled. Clearly, therefore, the discipline is not equally well developed throughout the country. Judging from ranking II, which measures "gross provincial publication" statistics per capita, it appears that Newfoundland and Nova Scotia are larger producers of statistical research than might have been expected from their size, while Québec, Saskatchewan and Alberta are comparatively underrepresented in the 16 journals surveyed between 1985 and 1995. A look at the ratio DIS/POP also shows that the proportion of authors from New Brunswick, Prince Edward Island and Saskatchewan is much lower than in the seven other provinces. Finally, ranking III shows that research productivity, as measured by

TABLE 9: Top 25 most productive world institutions in statistical research, ranked by PAG*/DIS, conditional on DIS $\geq$ 9. The ranks are those in the unconditional ranking by the variable PAG*/DIS.

Rank	Institution	PAG*/DIS	PAG/DIS	ART*/DIS	ART/DIS	DIS
5	U. of Aarhus	101	69	7	5	12
11	U. of Minnesota at St. Paul	80	52	5	3	13
17	Stanford U.	72	44	4	2	67
18	Carleton U.	71	36	5	3	16
20	U. of Ottawa	70	46	4	3	9
22	Northwestern U.	69	48	4	3	13
24	Australian National U.	69	39	4	3	60
28	U. of California at Berkeley	64	38	4	2	70
30	U. College London	63	38	4	2	13
31	U. of California at Davis	63	38	4	3	32
37	U. of Chicago	59	41	4	3	53
38	Cornell U.	59	31	4	2	47
39	Carnegie Mellon U.	59	36	4	2	43
42	U. of North Carolina Chapel Hill	58	32	4	2	50
43	Rutgers U.	57	31	4	2	35
46	U. of Maryland, Baltimore County	57	31	4	2	14
47	U. of Illinois Urbana-Champaign	59	34	4	2	33
48	U. of Glasgow	57	28	4	2	13
50	U. of Bath	57	30	3	2	14
54	Indiana U.	54	30	3	2	27
56	Texas A&M U.	53	28	4	2	38
59	U. of Waterloo	53	29	4	2	56
61	Washington State U.	52	35	4	3	11
62	Florida State U.	52	28	3	2	21
63	Iowa State U.	52	30	4	2	32

TABLE 10: Canadian provinces, ranked by production in statistical research, as measured by PAG* (rank I), by PAG*/POP (rank II), and by PAG*/DIS (rank III).

Rank I	Rank II	Rank III	Province	PAG*	PAG	ART*	ART	DIS
1	1	1	Ontario	11987	6569	892	499	301
2	6	3	Québec	3604	2050	274	164	113
3	2	2	British Columbia	2363	1423	184	114	69
4	7	4	Alberta	1242	760	100	63	45
5	5	8	Manitoba	582	323	49	28	22
6	3	6	Nova Scotia	513	308	39	25	19
7	4	7	Newfoundland	312	203	26	18	12
8	8	9	New Brunswick	205	104	16	9	8
9	9	5	Saskatchewan	111	58	7	4	4
10	10	10	Prince Edward Island	14	7	1	1	1

PAG*/DIS, is highest in Ontario (40), British Columbia (34) and Québec (32); it appears to be roughly the same in all other provinces (around 27), except in Prince Edward Island (14).

Using Table 6 and the appendix, it is possible to find the ranking of the leading Canadian research establishments in statistics. This information is conveniently summarized in Table 11, where all Canadian schools with at least nine distinct contributors are iden-

TABLE 11: Top 25 Canadian research establishments, ranked by production in statistical research, as measured by PAG*, conditional on DIS $\geq$ 9. The ranks are those in the overall ranking of Table 6, continued in the appendix. For those institutions with DIS $\geq$ 9, the world ranking by the variable PAG*/DIS is provided in the rightmost column, identified as Rank_{pr}.

Rank	Institution	PAG*	PAG	ART*	ART	DIS	Rank_{pr}
9	U. of Waterloo	2960	1600	222	127	56	22
19	U. of Toronto	2100	1179	154	86	50	49
32	U. of British Columbia	1546	951	110	70	39	59
47	Carleton University	1139	570	76	38	16	4
48	U. de Montréal	1120	632	83	51	28	57
54	McGill U.	977	549	69	40	22	40
59	U. of Alberta	917	566	73	46	29	112
63	U. of Western Ontario	875	577	72	46	25	89
71	Statistics Canada	793	397	57	31	37	194
85	York U.	666	408	52	32	17	61
89	U. of Guelph	642	307	50	25	21	121
90	U. of Ottawa	632	412	38	26	9	5
102	Simon Fraser U.	572	328	54	32	16	77
103	U. of Manitoba	568	311	47	26	20	143
121	U. Laval	492	261	39	22	13	69
123	McMaster U.	489	268	43	23	19	159
128	U. of Windsor	461	211	35	17	16	139
150	Queen's U.	400	249	29	19	18	187
157	Dalhousie U.	377	229	30	19	14	150
160	Health and Welfare Canada	370	134	29	11	12	118
171	Concordia U.	349	215	30	19	19	217
208	Memorial U.	280	187	23	16	9	115
210	U. of Calgary	277	173	23	15	13	195
224	U. du Québec à Montréal	258	150	22	14	13	206
296	U. of New Brunswick	178	93	14	8	6	—

tified, ranked by the value of PAG*/DIS. From a national perspective, it is pleasing to see that a dozen or so of the top 100 world institutions are Canadian, both in terms of total output (PAG*) and in terms of productivity (PAG*/DIS). A majority of these (8 or 6) are in Ontario, Québec ranking second with 2 or 3, and British Columbia third with 1 or 2 establishments, depending on the criterion.

7. CONCLUSION

The main purpose of this paper was to identify countries and institutions that held a comparative advantage in theoretical and applied statistical research between 1985 and 1995. The data provide a rudimentary measure of national and institutional scientific productivity, but not of the quality and influence of statistical writings, which would require an in-depth analysis of citation patterns, among other things.

Of course, this study is subject to the same criticisms as previous work of this type: the criteria used for journal and article selection are subjective by nature, and there is no doubt that other choices would have produced somewhat different results. In fact, it was already pointed out that the rankings based on variables ART, ART*, PAG and PAG* differ, not so much for the leaders but certainly for those ranked in the lower portions of the tables. The findings should thus be interpreted with caution.

To end on a statistical note, it is noteworthy that in principal-component analyses of standardized variables ART, ART*, PAG and PAG* measured on countries and research establishments, the first principal component typically accounted for well over 95% of the variability and had essentially equal loadings, whether in the case of national or institutional data.

APPENDIX

This appendix is a continuation of Table 6: the top 150 world institutions, ranked by publication output in statistics, as measured by the variable PAG*

Rank	Institution	PAG*	PAG	ART*	ART	DIS
26	U. of Illinois, Urbana-Champaign	1876	1123	121	75	33
27	Ohio State U.	1707	946	118	67	50
28	U. of Minnesota, Minneapolis	1668	1033	121	78	33
29	Iowa State U.	1665	945	113	65	32
30	U. of Iowa	1559	771	113	57	45
31	Indian Statistical Institute	1550	844	151	83	56
32	U. of British Columbia	1546	951	110	70	39
33	Fred Hutchinson Cancer Research Center	1544	739	110	54	32
34	U. of Florida	1499	903	106	64	32
35	Indiana U.	1455	809	87	50	27
36	George Washington U.	1392	779	104	60	34
37	Hebrew U.	1361	836	97	61	27
38	University of Georgia	1310	678	100	52	34
39	National Cancer Institute	1288	634	108	58	37
40	Duke U.	1284	707	76	47	34
41	Yale U.	1237	762	74	48	28
42	Imperial College, London	1237	743	91	59	35
43	Academia Sinica	1218	724	91	57	42
44	U. of Aarhus	1212	826	81	57	12
45	Institute of Statistical Mathematics	1188	840	85	60	30
46	Colorado State U.	1147	574	79	42	30
47	Carleton University	1139	570	76	38	16
48	U. de Montréal	1120	632	83	51	28
49	Florida State U.	1093	594	72	39	21
50	U. of Southern California	1082	501	60	31	28
51	U. of Minnesota at St. Paul	1038	673	70	45	13
52	Temple U.	1031	594	80	49	30
53	U. of Pennsylvania	997	696	75	56	26
54	McGill U.	977	549	69	40	22
55	U. of New South Wales	971	438	75	36	32
56	La Trobe U.	967	607	67	45	23
57	U. of Copenhagen	942	550	58	34	32
58	Virginia Polytechnic Institute	937	496	62	33	26
59	U. of Alberta	917	566	73	46	29
60	U. of Illinois at Chicago	893	459	68	35	25
61	Northwestern U.	893	622	50	36	13
62	Natl. Institute of Environ. Health Sci.	890	506	71	41	26
63	U. of Western Ontario	875	577	72	46	25
64	I.N.R.A., France	851	392	63	29	29
65	U. of Connecticut	838	450	67	38	21

APPENDIX (*Continued*).

Rank	Institution	PAG*	PAG	ART*	ART	DIS
66	U. College London	825	499	50	32	13
67	U. of Rochester	823	440	74	39	33
68	U. of Tokyo	823	508	55	35	19
69	U. of Texas at Austin	811	453	58	34	27
70	U. of Maryland, Baltimore County	797	435	62	34	14
71	Statistics Canada	793	397	57	31	37
72	U. of Bath	792	420	39	22	14
73	Columbia U.	778	421	60	35	30
74	U.S. Bureau of the Census	774	395	44	24	30
75	U. of Oslo	746	474	49	32	21
76	U. of Glasgow	739	359	48	23	13
77	New York U.	710	410	50	29	19
78	M.I.T.	708	441	42	29	28
79	U. of Leiden	697	422	53	32	25
80	U. of California at San Francisco	687	295	41	20	14
81	Hiroshima U.	683	451	66	44	20
82	U. of Maryland at College Park	678	443	43	27	15
83	U. of Kent	674	394	41	24	15
84	U. of Southampton	669	346	52	28	16
85	York U.	666	408	52	32	17
86	Bowling Green State U.	664	378	49	28	17
87	U. of Heidelberg	654	492	41	30	22
88	U. de Paris VI	646	325	42	22	19
89	U. of Guelph	642	307	50	25	21
90	U. of Ottawa	632	412	38	26	9
91	U. of South Carolina	628	329	55	29	32
92	Natl. Heart, Lung & Blood Inst.	626	333	47	26	14
93	U. of California at San Diego	619	353	38	23	19
94	U. of Missouri at Columbia	616	365	45	26	19
95	Princeton U.	611	389	35	24	19
96	U. of Sydney	600	393	55	36	26
97	Oak Ridge National Lab.	599	316	35	20	12
98	U. Paul-Sabatier	596	323	41	22	26
99	U. of Cambridge	588	414	41	28	17
100	Washington State U.	576	385	42	29	11
101	Oregon State U.	575	328	41	24	19
102	Simon Fraser U.	572	328	54	32	16
103	U. of Manitoba	568	311	47	26	20
104	Virgina Commonwealth U.	564	248	37	17	16
105	Michigan State U.	564	343	41	25	23
106	National Tsing Hua U.	560	293	38	20	17
107	U. of Auckland	558	358	38	23	13
108	Northern Illinois U.	548	367	51	36	18
109	U. of Oxford	545	331	39	25	19
110	Southern Methodist U.	539	339	41	25	16

APPENDIX (*Concluded*).

Rank	Institution	PAG*	PAG	ART*	ART	DIS
111	U. of Surrey	538	404	37	29	8
112	U. of Western Australia	532	323	37	23	14
113	Osaka U.	525	378	41	29	17
114	Memorial Sloan Kettering Cancer Center	518	203	33	14	18
115	I.B.M.	513	373	29	20	14
116	U. of California at Riverside	506	269	40	21	15
117	U. of Melbourne	504	353	36	25	21
118	U. of Adelaide	500	260	34	19	14
119	U. of Lund	499	280	25	15	14
120	U. of Virginia	495	289	32	20	12
121	U. Laval	492	261	39	22	13
122	Erasmus U.	489	291	29	17	16
123	McMaster U.	489	268	43	23	19
124	U. libre de Bruxelles	488	213	23	10	6
125	U. of Groningen	481	222	35	17	20
126	U. of Kentucky	472	286	37	22	13
127	Free U. of Amsterdam	468	335	32	22	16
128	U. of Windsor	461	211	35	17	16
129	Brown U.	460	257	27	15	12
130	U. of London	458	323	35	25	15
131	U. of Warwick	447	279	32	22	14
132	U. of Amsterdam	443	227	30	16	23
133	SUNY Buffalo	438	267	35	22	16
134	Los Alamos National Lab.	437	206	30	15	15
135	U. of Delaware	437	222	28	15	7
136	U. of Utrecht	437	279	24	16	12
137	London School of Economics	435	317	28	20	13
138	U. of Dortmund	434	269	37	24	15
139	U. of Oulu	434	230	26	13	7
140	U. of Arizona	433	243	31	18	15
141	Monash U.	425	263	38	26	23
142	RAND Corporation	423	280	20	14	12
143	U. of Sheffield	421	253	30	18	12
144	U. of Gottingen	412	260	28	19	10
145	Texas Tech U.	409	270	28	20	11
146	SUNY Stony Brook	406	246	37	23	14
147	Free U. Berlin	405	276	30	22	13
148	U. de Sao Paulo	402	157	30	12	19
149	U. of Lancaster	401	205	30	16	16
150	Queen's U.	400	249	29	19	18

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