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Collaborative research

Impact of collaborative research on academic science

Benoît Godin and Yves Gingras

Over the past 15 years, we have witnessed, according to some analysts, a trend toward greater heterogeneity in scientific research and a growing affiliation of university researchers with extra-university partners. To this end, governments have actively promoted through diverse policy mechanisms greater collaboration and exchange between universities, businesses and governments. This paper assesses the extent to which collaborative research in Canada influences the nature of scientific production and the level of international scientific collaboration. Beliefs that collaborative research is detrimental to academic research do not seem empirically grounded. However the situation must continue to be monitored.

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OVER THE PAST 15 YEARS, we have witnessed, according to some analysts, a trend toward greater heterogeneity in scientific research and a growing affiliation of university researchers with extra-university partners. This is one of the five characteristics that, according to Gibbons *et al* (1994) define today's new modes of knowledge production. Primed by recent science policies, governments do indeed enjoin researchers to increase the relevance of their work. To this end, they have actively promoted through diverse policy mechanisms greater collaboration and exchange between universities, businesses and governments.

The rapid growth of collaborations between universities and industries has raised many questions among academics concerned that the more applied nature of the knowledge produced by such partnerships could be done at the expense of more fundamental research, the traditional objective of university research.

Few studies, however, have sought to measure the effect of collaborations on university research. Yet the studies available paint a more subtle picture: researchers active in collaborations do not necessarily participate in such activity at the expense of more academic pursuits (Blumenthal *et al*, 1996; Godin, 1998).

The object of this paper is to assess the extent to which collaborative research influences the nature of scientific production and the level of international scientific collaboration. More specifically, we seek to answer the following questions. Does collaborative research, because of the demands it imposes on the limited time and resources of researchers, lead to a reduction in the number both of scientific publications in general and of publications arising from international collaboration? Are university publications

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written with industries or government laboratories more applied than those written only with university researchers? Is there a difference in the average impact factor of publications written in collaboration with non university researchers?

Database and methodology

The data used in this paper were compiled from the Canadian bibliometric database produced by the Observatoire des sciences et des technologies (OST) under the patronage of Statistics Canada (Godin *et al*, 1998). They comprise publications by Canadian researchers indexed in the *Science Citation Index* (SCI). The period covered by the database runs from 1980 to 1997. For present purposes, the analysis was restricted to the years 1980, 1985, 1990 and 1995. In each year, Canadian publications were analyzed according to whether they were produced in domestic or in international collaboration.

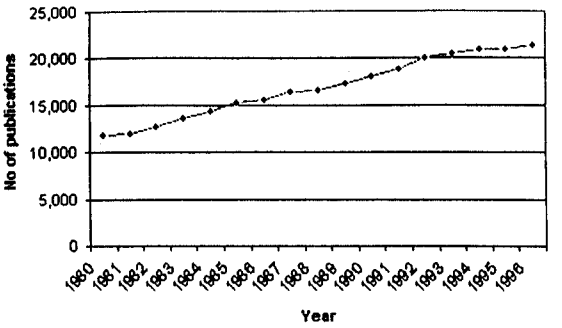

Figure 1. University production in Canada

Each publication was codified according to the discipline of the journal in which it appeared, using CHI classification. Scientific production was measured in 100 specialties, grouped into eight disciplinary sets: biomedical research; clinical medicine; biology; chemistry; earth and space sciences; engineering; physics; and mathematics.

Each address included in a publication was attributed to one of five sectors: universities; business firms; government laboratories (provincial and federal); hospitals; and colleges. Publications written by at least one university author together with at least one author from one of the other sectors are referred to as intersectorial publications.

Following standard bibliometric techniques,

Table 1. Publications according to sectors, 1980, 1985, 1990, 1995

Year	University	Hospital	Federal government	Provincial government	Firms	Colleges	Others	Unknown	Total	N
1980	11,838	1,896	2,453	388	595	105	328	121	17,724	15,774
1981	12,034	1,923	2,327	372	525	99	326	495	18,101	16,027
1982	12,696	2,111	2,406	386	538	93	336	474	19,040	16,781
1983	13,681	2,238	2,764	385	577	87	354	469	20,555	17,986
1984	14,437	2,312	2,847	435	667	129	446	416	21,689	18,972
1985	15,218	2,418	2,970	551	847	161	504	126	22,795	19,850
1986	15,512	2,472	2,922	525	628	192	459	489	23,199	20,090
1987	16,421	2,594	3,080	608	706	190	487	497	24,583	21,127
1988	16,657	2,521	2,965	655	723	209	519	519	24,768	21,254
1989	17,352	2,658	3,186	640	676	205	520	544	25,781	22,041
1990	18,153	2,824	3,216	737	951	247	603	104	26,835	22,774
1991	18,840	2,988	3,165	722	795	257	581	560	27,908	23,453
1992	20,099	3,009	3,250	772	882	153	613	644	29,422	24,673
1993	20,440	3,083	3,203	752	875	166	654	644	29,817	25,078
1994	21,028	3,290	3,361	824	909	305	669	596	30,982	25,812
1995	21,008	3,293	3,357	864	1,191	321	766	85	30,885	25,666
1996	21,336	3,320	3,196	897	1,229	300	772	129	31,179	25,775

Table 2. University publications broken down by collaboration with other sectors, 1980, 1985, 1990, 1995

Year	Biology		Chemistry		Mathematics		Clinical medicine		Physics	
	Publication	Collaboration	Publications	Collaboration	Publications	Collaboration	Publications	Collaboration	Publications	Collaboration
1980	1,599	195	1,328	56	553	8	3,371	1,010	1,339	57
1985	2,020	287	1,602	117	555	7	4,458	1,414	1,603	98
1990	2,348	417	1,669	154	497	7	5,383	1,667	2,027	177
1995	2,159	470	2,001	136	540	14	6,182	2,050	2,335	229

	Biomedical research		Engineering		Earth and space		Unknown		Total	
	Publications	Collaboration	Publications	Collaboration	Publications	Collaboration	Publications	Collaboration	Publications	Collaboration
1980	1,927	199	818	101	728	84	175	22	11,838	1,732
1985	2,584	362	1,237	147	951	151	208	15	15,218	2,598
1990	3,230	579	1,592	234	1,319	245	88	10	18,153	3,490
1995	3,709	759	1,992	322	1,674	338	416	102	21,008	4,420

publications are counted on the basis of addresses and not authors (the SCI does not allow the assignment of a specific address to a particular author). Thus, for a publication in which there are two university researchers from the same institution, one industrial researcher, and two government researchers from two different institutions, the university institution is assigned one publication, the industrial institution one, and the two federal institutions one each.

Results

University production

Publications from the university sector, that is, ones that include at least one university address, represented 82.8% of all Canadian publications in 1996 (Table 1). This share represented 75.0% in 1980. Far from having decreased, university production has thus never ceased to grow in absolute and relative terms, going from 11,838 publications in 1980 to 21,336 publications in 1996 (Figure 1).

The other sectors are present in the following proportions in 1995:[1] hospitals (12.9%), federal laboratories (12.4%), business firms (3.4%), provincial governments (2.5%).

During the period under consideration, university publications grew by 80.2%. There were, however, some fluctuations in this growth rate over time. It dropped from 21.9% in 1980–84, to 15.3% in 1984–88, climbed to 20.6% in 1988–92, and dropped again to 6.1% between 1992–1996.

Over the same period, the growth in university production is surpassed only by two other sectors: provincial governments, which increased their scientific output by 131.2%, and business firms which grew by 106.6%. Lagging slightly behind universities, hospitals and federal laboratories grew by 75.1% and 30.3%, respectively.

Intersectorial collaboration

In 1995, 21% of university publications were the result of collaborations with other sectors (Table 2). In 1980, they represented 14,6%.[2] During the period under study, the proportion of intersectorial collaboration grew by 155.2%, from 1,732 to 4,420 publications. However, like the trend of university publications, the growth of collaborative publications fluctuated and, ih this case, dwindled over the 15-year period. It went from 50% during 1980–85, to 34.3% in 1986–90, and to 26.6% in 1991–1995.

The greatest growth in intersectorial collaboration between 1980 and 1995 is in earth and space sciences (302.4%) and physics (301.8%), followed by biomedical research (281.4%), engineering (218.8%), chemistry (142.9%), biology (141.0%), clinical medicine (103.0%), and mathematics (75.0%).

Intersectorial collaboration is unequally distributed among the disciplines (Table 3). Clinical medicine is the most active, with 33.2% of its publications

Table 3. Intersectorial collaboration of universities, 1980, 1985, 1990 1995

	1980										1985									
	Biology	Chemistry	Mathematics	Clinical medicine	Physics	Biomedical research	Engineering	Earth and space	Unknown	Total	Biology	Chemistry	Mathematics	Clinical medicine	Physics	Biomedical research	Engineering	Earth and space	Unknown	Total
Hospital	4	11		818	1	125	2		17	978	2	16		1,153	1	239		1	3	1,415
Federal government	133	29	3	36	39	46	24	52	2	364	194	54	2	50	69	57	42	94	5	567
Provincial government	24			84	2	6	8	10		134	41	3		103	4	16	12	21	2	202
Firm	12	5	4	15	10	6	57	17	3	129	18	24	3	27	16	16	87	29	3	223
College	6			11	1	1	1	1		21	7	1		19	2	3				32
Others	24	11		77	3	22	11	6	1	155	28	19	2	130	10	32	13	7	2	243
Unknown	5		1	24	1	2	1	1		35	8	1		19		8	4	8		48
Total	208	56	8	1,065	57	208	104	87	23	1,816	298	118	7	1,501	102	371	158	160	15	2,730

	1990										1995									
	Biology	Chemistry	Mathematics	Clinical medicine	Physics	Biomedical research	Engineering	Earth and space	Unknown	Total	Biology	Chemistry	Mathematics	Clinical medicine	Physics	Biomedical research	Engineering	Earth and space	Unknown	Total
Hospital	5	5		1,320	1	372	1	2	3	1,709	12	12	3	1,567	5	503	3	1	61	2,167
Federal government	271	86	3	67	89	112	80	159	1	868	320	68	2	120	122	138	92	234		1,117
Provincial government	49	16	2	184	8	38	28	32	1	358	75	7	1	238	4	50	26	33	5	439
Firm	47	32		55	50	34	112	49	4	383	38	34	2	79	63	57	172	49	13	507
College	23	6		29	3	7	2	4		74	22	2	2	32	6	14	4	11	1	94
Others	50	13	3	137	28	44	25	20	1	321	47	17	4	201	36	45	41	35	7	433
Unknown	7	4		19	1	2	7	3		43	2			17	1	5	2	7	1	35
Total	452	162	8	1,811	180	609	255	269	10	3,756	516	140	14	2,254	237	812	340	370	109	4,792

produced collaboratively in 1995 (Figure 2). This of course is due to the strong links between universities and affiliated hospitals. This strong interaction between hospitals and university also explains the fact that nearly half (46.4%) of all intersectorial collaboration in 1995 originates from the field of clinical medicine. It is followed by biology (21.8%), biomedical research (20.5%), earth and space sciences (20.2%),

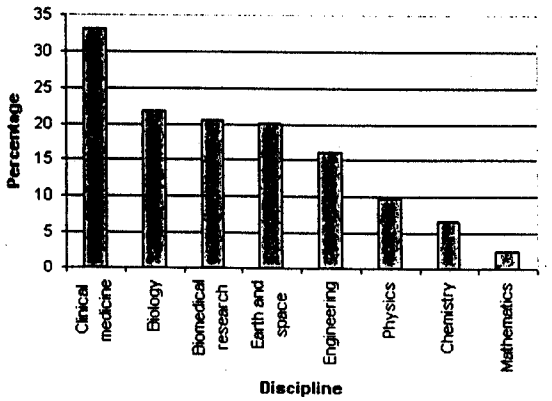

Figure 2. Intersectorial collaboration by discipline in 1995

University researchers in clinical medicine and biomedical research tend to pair up mainly with hospitals; in biology, earth and space sciences, physics and chemistry with federal laboratories; and in engineering with business firms

Table 4. Intersectorial collaboration, 1980, 1985, 1990, 1995

	1980									1985								
	University	Hospitals	Federal government	Provincial government	Firm	Colleges	Others	Unknown	Total	University	Hospital	Federal government	Provincial government	Firm	Colleges	Others	Unknown	Total
University		978	364	134	129	21	155	35	1,816		1,415	567	202	223	32	243	48	2,730
Hospital	978		7	31	14	5	18	13	1,066	1,415		17	36	18	15	41	10	1,552
Federal government	364	7		27	42	6	9	8	463	567	17		41	71	13	14	14	737
Provincial government	134	31	27		7	2	7	8	216	202	36	41		16	3	17	8	323
Firm	129	14	42	7		2	12	5	211	223	18	71	16		3	12	10	353
Colleges	21	5	6	2	2		3	1	40	32	15	13	3	3		2	1	69
Others	155	18	9	7	12	3		5	209	243	41	14	17	12	2		3	332
Unknown	35	13	8	8	5	1	5		75	48	10	14	8	10	1	3		94
Total	1,816	1,066	463	216	211	40	209	75	4,096	2,730	1,552	737	323	353	69	332	94	6,190

	1990									1995								
	University	Hospital	Federal government	Provincial government	Firm	Colleges	Others	Unknown	Total	University	Hospital	Federal government	Provincial government	Firm	Colleges	Others	Unknown	Total
University		1,709	868	358	383	74	321	43	3,756		2,167	1,117	439	507	94	433	35	4,792
Hospital	1,709		33	72	33	16	62	9	1,934	2,167		40	105	53	17	94	14	2,490
Federal government	868	33		81	123	32	30	7	1,174	1,117	40		98	134	67	54	12	1,522
Provincial government	358	72	81		31	9	26	3	580	439	105	98		50	12	53	9	766
Firm	383	33	123	31		2	16	7	595	507	53	134	50		10	35	3	792
Colleges	74	16	32	9	2		6		139	94	17	67	12	10		8	3	211
Others	321	62	30	26	16	6		3	464	433	94	54	53	35	8		10	687
Unknown	43	9	7	3	7		3		72	35	14	12	9	3	3	10		86
Total	3,756	1,934	1,174	580	595	139	464	72	8,714	4,792	2,490	1,522	766	792	211	687	86	11,346

engineering (16.2%), physics (9.8%), chemistry (6.8%), and mathematics (2.6%).

Not surprisingly, the principal partner of university researchers in 1995 was the hospital sector (Table 4 and Figure 3), representing 45.2% of the intersectorial collaboration of universities. Then follows federal laboratories (23.3%), business firms (10.6%), provincial governments (9.2%), and various other partners (9.0%). Clinical medicine and biomedical research tend to pair up mainly with hospitals; biology, earth and space sciences, physics and chemistry with federal laboratories; and engineering with business firms.

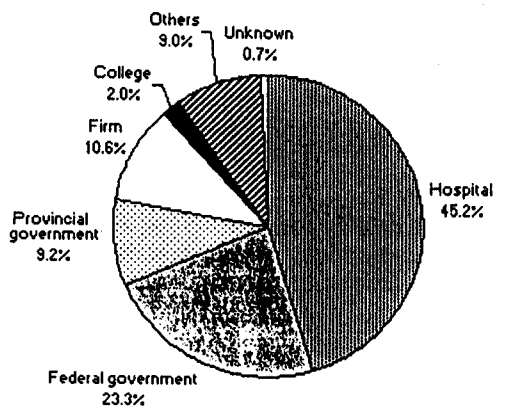

Figure 3. University collaboration by sector – 1995

International collaborations

In 1995, 30.4% of university publications were produced with foreign partners (Table 5). In 1980, the level of international collaboration was only half as high, at 16.0%. This percentage is twice that found at world level. In fact, small countries are known to collaborate more than bigger ones (Gingras *et al*, 1999).

As compared to intersectorial papers, these publications have a higher rate of growth. Over the period

Table 5. International collaboration of universities, 1980, 1985, 1990, 1995

	Biology		Chemistry		Mathematics		Clinical medicine		Physics	
	Publications	Collaboration	Publications	Collaboration	Publications	Collaboration	Publications	Collaboration	Publications	Collaboration
1980	1,599	162	1,328	199	553	170	3,371	376	1,339	281
1985	2,020	231	1,602	328	555	218	4,458	648	1,603	411
1990	2,348	424	1,669	373	497	218	5,383	1,081	2,027	766
1995	2,159	474	2,001	514	540	247	6,182	1,668	2,335	1,037

	Biomedical research		Engineering		Earth and space		Unknown		Total	
	Publications	Collaboration	Publications	Collaboration	Publications	Collaboration	Publications	Collaboration	Publications	Collaboration
1980	1,927	331	818	170	728	177	175	29	11,838	1,895
1985	2,584	530	1,237	255	951	226	208	46	15,218	2,893
1990	3,230	772	1,592	366	1,319	430	88	17	18,153	4,447
1995	3,709	1,147	1,992	544	1,674	611	416	148	21,008	6,390

1980–1995, publications written in international collaborations grew by 237.2%. It is also this type of publication that had the most stable growth rate over the 15-year period, going from 52.7% (1980–1985), to 53.7% (1986–1990), and to 43.7% (1991–1995).

The relationship between Canadian researchers and their collaborators in foreign countries have changed over the course of the period studied. The United States stood for 48.7% of Canadian international collaborations in 1980, against 38.0% in 1995. The space left by the US has not been filled, however, by other large European countries. Collaboration with the United Kingdom dropped from 11.0% to 7.4%, while collaboration with France stayed at 7.2%. Only Germany grew from 3.7% to 5.5%. Asian countries, notably Japan (which grew from 2.5% to 4.8%), and small countries, such as the Netherlands, have taken up the room left by the decline of US collaboration with Canada.

To sum up, university production has increased over the last 15 years. Its collaboration has also increased, but international collaboration has grown more than intersectorial collaboration.

Highly productive researchers

To check whether collaborative research has a negative influence on the publication level of researchers, we have drawn up two samples. The first is composed of the 37 researchers[3] who publish the most frequently with other sectors. In 1995, these researchers produced 43.0% of their publications in collaboration with non-university partners — twice the national average. Their share was 25.9% in 1980. The average number of publications per researcher was 3.7 articles in 1980 against 7.1 in 1995. International collaborations also grew from 13.6% of publications in 1980 to 30.0% in 1995, in step, therefore, with the national trend.

The second sample is composed of the 100 most productive Canadian researchers. In this group, interestingly, nearly half the researchers (49) collaborate with industry. In 1995, 4.7% of their publications involve an industrial partner (as compared to less than 1% in 1980). Moreover, this sub-group publishes more than the sub-group of those who do not collaborate. In 1995, they produced 682 papers compared to 593 for non-collaborators. Over the period 1980–1995, their production increased 101.2% while the growth for those who do not collaborate was 81.3%. Finally, the international collaboration is 32.1% for those who collaborate with industry compared to 37.6% for those who do not have such collaboration.

These data suggest that: the most productive scientists are also those who tend to form partnerships with other sectors; and that this tendency affects only slightly their level of international collaborations.

Impact of collaboration on university research

Among the critiques often raised against collaborations of universities with industry and government laboratories is that such partnerships would push

Table 6. Appliedness of university papers, 1980, 1985, 1990, 1995

	1980	1985	1990	1995
Biology	3.1	3.2	3.2	3.2
international collaboration	3.2	3.3	3.4	3.3
with sectors	3.1	2.9	3.3	3.0
without sectors	3.3	3.4	3.4	3.4
national collaboration	3.1	3.2	3.1	3.1
with sectors	2.7	2.9	2.8	2.9
without sectors	3.2	3.2	3.2	3.2
Chemistry	3.7	3.7	3.6	3.6
international collaboration	3.7	3.8	3.7	3.7
with sectors	3.0	3.4	3.7	3.5
without sectors	3.7	3.8	3.7	3.7
national collaboration	3.7	3.7	3.6	3.6
with sectors	3.6	3.4	3.4	3.3
without sectors	3.7	3.7	3.6	3.6
Mathematics	3.3	3.4	3.3	3.3
international collaboration	3.4	3.4	3.3	3.3
with sectors	2.0	3.7	4.0	3.7
without sectors	3.4	3.4	3.3	3.3
national collaboration	3.3	3.4	3.3	3.2
with sectors	2.4	2.3	2.3	3.0
without sectors	3.3	3.4	3.3	3.2
Clinical medicine	2.4	2.5	2.5	2.5
international collaboration	2.5	2.6	2.6	2.5
with sectors	2.2	2.3	2.3	2.3
without sectors	2.6	2.7	2.7	2.6
national collaboration	2.4	2.4	2.5	2.5
with sectors	2.0	2.1	2.2	2.3
without sectors	2.6	2.6	2.6	2.6
Physics	3.7	3.6	3.6	3.6
international collaboration	3.8	3.8	3.8	3.7
with sectors	3.6	3.9	3.8	3.5
without sectors	3.8	3.7	3.8	3.7
national collaboration	3.6	3.6	3.5	3.5
with sectors	3.5	3.4	3.3	3.2
without sectors	3.6	3.6	3.6	3.6
Biomedical research	3.8	3.8	3.8	3.8
international collaboration	3.8	3.9	3.8	3.8
with sectors	3.3	3.6	3.7	3.7
without sectors	3.9	3.9	3.8	3.8
national collaboration	3.8	3.8	3.8	3.8
with sectors	3.7	3.6	3.7	3.7
without sectors	3.8	3.9	3.9	3.8
Engineering	1.8	1.7	1.7	1.7
international collaboration	1.8	1.7	1.7	1.9
with sectors	1.3	1.5	1.5	1.7
without sectors	1.8	1.7	1.8	1.9
national collaboration	1.8	1.7	1.7	1.7
with sectors	1.5	1.5	1.5	1.6
without sectors	1.8	1.8	1.7	1.7
Earth and space	3.2	3.2	3.2	3.2
international collaboration	3.4	3.4	3.4	3.5
with sectors	3.4	3.5	3.2	3.4
without sectors	3.4	3.4	3.5	3.5
national collaboration	3.1	3.1	3.1	3.1
with sectors	2.7	3.0	3.0	3.0
without sectors	3.1	3.2	3.2	3.1
Total	3.1	3.1	3.1	3.1
international collaboration	3.2	3.2	3.2	3.2
with sectors	2.6	2.9	2.9	2.8
without sectors	3.3	3.3	3.3	3.3
national collaboration	3.1	3.0	3.0	3.0
with sectors	2.4	2.5	2.6	2.7
without sectors	3.2	3.2	3.1	3.1

toward more applied research and that it would have less scientific impact.

To test these assertions, we have used the classification scheme for determining the degree of application of science journals constructed by CHI Inc which produces statistics for the National Science Foundation (NSF). Journals are classified by experts according to the degree to which they contain applied or basic research on a scale from 1 (very applied) to 4 (very fundamental).

Table 6 clearly shows that research undertaken in collaboration is more applied than research undertaken solely between university researchers, and this conclusion applies to all disciplines. It should also be noted that the average level of application is not significantly different for national and international publications. Although this should not come as a surprise, these data thus confirm the hypothesis that university work done in intersectorial collaboration tends to be more applied.

To test the statement concerning the impact of intersectorial publications, we have used the journal impact factor calculated by ISI (International Statistical Institute). The impact factor is defined as the average number of citations received in a given year (here 1995) by articles published by a specific journal during the preceding two years. Every article is assigned the impact factor of the journal in which it is published.

Table 7. Impact factor of university papers, 1980, 1985, 1990, 1995

	1980	1985	1990	1995
Biology	0.8	1.0	1.0	1.2
international collaboration	0.9	1.1	1.2	1.3
with sectors	0.8	0.9	1.1	1.1
without sectors	0.9	1.1	1.2	1.4
national collaboration	0.8	1.0	1.0	1.1
with sectors	0.7	0.9	0.9	1.0
without sectors	0.9	1.0	1.0	1.2
Chemistry	1.8	1.8	1.8	2.1
international collaboration	1.9	1.8	1.8	2.1
with sectors	1.2	1.8	1.4	1.8
without sectors	1.9	1.8	1.8	2.1
national collaboration	1.8	1.8	1.7	2.1
with sectors	1.7	1.6	1.6	1.7
without sectors	1.8	1.8	1.8	2.2
Mathematics	0.4	0.5	0.5	0.6
international collaboration	0.4	0.5	0.5	0.6
with sectors	0.8	0.6	1.0	0.7
without sectors	0.4	0.5	0.5	0.6
national collaboration	0.4	0.4	0.5	0.6
with sectors	0.7	0.6	0.9	0.8
without sectors	0.4	0.4	0.5	0.6
Clinical medicine	2.0	2.2	2.3	2.8
international collaboration	2.6	2.7	2.9	3.3
with sectors	2.6	3.0	2.8	3.7
without sectors	2.6	2.7	2.8	3.2
national collaboration	1.9	2.2	2.1	2.6
with sectors	1.8	2.2	2.2	2.6
without sectors	1.9	2.1	2.1	2.6
Physics	1.9	2.1	2.1	2.1
international collaboration	2.1	2.4	2.3	2.4
with sectors	2.6	3.2	3.1	2.1
without sectors	2.1	2.4	2.3	2.4
national collaboration	1.8	2.0	1.9	1.9
with sectors	1.9	1.9	2.0	1.7
without sectors	1.8	2.0	1.9	2.0
Biomedical research	2.4	2.9	3.1	4.2
international collaboration	2.9	3.6	4.0	5.3
with sectors	1.7	3.6	5.1	6.5
without sectors	3.0	3.6	3.9	5.0
national collaboration	2.3	2.7	2.8	3.6
with sectors	2.5	2.9	3.2	4.0
without sectors	2.3	2.6	2.7	3.5
Engineering	0.6	0.7	0.6	0.7
international collaboration	0.6	0.7	0.6	0.7
with sectors	0.5	0.5	0.4	0.7
without sectors	0.6	0.7	0.6	0.7
national collaboration	0.6	0.7	0.6	0.6
with sectors	0.6	0.7	0.4	0.7
without sectors	0.6	0.7	0.6	0.6
Earth and space	1.5	1.4	1.5	1.7
international collaboration	1.8	1.7	1.7	2.1
with sectors	2.0	2.0	1.4	2.1
without sectors	1.8	1.7	1.7	2.1
national collaboration	1.4	1.3	1.3	1.5
with sectors	1.2	1.3	1.2	1.5
without sectors	1.4	1.3	1.4	1.6
Total	1.7	1.9	1.9	2.4
international collaboration	1.9	2.2	2.3	2.8
with sectors	2.1	2.7	3.0	3.6
without sectors	1.9	2.1	2.2	2.6
national collaboration	1.6	1.8	1.8	2.2
with sectors	1.6	2.0	2.0	2.3
without sectors	1.6	1.7	1.8	2.1

Table 7 shows that, contrary to expectation, the average impact of intersectorial collaborative research is not significantly different from that of university research. Only chemistry and physics have a statistically significant lower impact factor. This means that, on average, papers originating from a collaboration between a university and other sectors does not end up in a less visible journal than a paper written only by university researchers.

What about the impact of university–industry collaboration? The average impact factor is much lower than strictly university papers: 1.4 versus 2.4 (Table 8). However, this is mainly because more than a third of the papers (1995) come from a discipline with a small impact factor — engineering. If we look specifically at the impact factor of engineering papers written in collaboration with industry, it is almost equal (0.6) to university papers in that field (0.7). We can conclude that even for strictly industrial collaboration the impact of research is not adversely affected.

Conclusion

Comments concerning the effects of collaboration on university research are mostly inspired by current trends in R&D financing. R&D funding has in fact become more diversified: the relative share of industrial funding has increased steadily, at the expense of

Table 8. Impact factor of university–industry collaboration

	1980	1985	1990	1995
Biology	0.8	1.0	1.0	1.2
U–I collaboration	0.6	0.8	0.7	1.1
Chemistry	1.8	1.8	1.8	2.1
U–I collaboration	0.9	1.4	1.6	1.6
Mathematics	0.4	0.5	0.5	0.6
U–I collaboration	0.8	1.3		0.6
Clinical medicine	2.0	2.2	2.3	2.8
U–I collaboration	1.3	2.9	2.1	2.5
Physics	1.9	2.1	2.1	2.1
U–I collaboration	1.3	1.1	1.9	1.4
Biomedical research	2.4	2.9	3.1	4.2
U–I collaboration	2.5	2.5	2.0	3.7
Engineering	0.6	0.7	0.6	0.7
U–I collaboration	0.5	0.6	0.5	0.6
Earth and space	1.5	1.0	1.5	1.7
U–I collaboration	0.9	1.0	0.9	1.0
Total	1.7	1.9	1.9	2.4
U–I collaboration	0.9	1.2	1.2	1.4

public funding which has declined from 40.9% to 34.5% between 1986 and 1995 in OECD (Organization for Economic Cooperation and Development) countries (Godin and Gingras, 2000). An increase in the number of university research activities involved in intersectorial collaborations has also been observed: it is estimated that two thirds of the most active researchers are currently engaged in such collaborative work (Godin, 1998).

Still, up to the present, this phenomenon does not seem to have had any major deleterious effects on the scientific output (number of papers) and impact of Canadian researchers. For instance, the scientific production of universities rose 77.5% between 1980 and 1995.[4] At the heart of this activity, collaborations with partners increased by 155.2%, reaching 21% of current publications, while collaborations with foreign countries jumped by 237.2%, reaching 30.4% of current publications.

All these data suggest that university research done in collaboration with industry, hospitals or government laboratories, is not incompatible with quality. More generally recent work has shown that there is no hard-and-fast dichotomy between researchers who conduct strictly applied or collaborative research (or divert their activities in the interest of this type of research), and others who only conduct basic research. As could be expected from Lotka's law, it is generally the same researchers who engage in both types of research activity.

Second, researchers invest in collaborative research because of the advantages they can get, such as access to new areas of research, instruments, unpublished data or additional sources of funding (Meyer-Kramer and Schmoch, 1998, pages 841–842).

In summary, beliefs that collaborative research is detrimental to academic research do not seem empirically grounded. The situation must continue to be monitored to see whether it changes in the future.

Notes

1. The figures are not mutually exclusive, the same publication may include the presence of more than one sector.
2. If we include the hospital sector in the university sector (given that the majority of hospitals are university based), the figures vary little. Collaborative production goes from 11.8% in 1980 to 18.1% in 1995 rather than from 14.6% to 21%.
3. The initial sample included 50 researchers. Upon verification, 13 of them proved not to be university researchers.
4. During the same period, publications in the world as a whole grew by 44.2%. Fluctuations and downswings match those observed in Canada: 13.7% (1980–1984), 5.6% (1984–1988), 10.8% (1988–1992), 8.2% (1992–1995).

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