Private Sector-Financed Research Activities at Canadian Universities: Distribution and Recent Trends

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ABSTRACT

The mandate of universities includes the pursuit of knowledge, the transmission of knowledge through education and training, and the dissemination of knowledge in the community. To fulfill that mandate, in particular in terms of research activities, they are increasingly relying on partnerships with the private sector, business enterprises and the private non-profit sector being a growing source of research financing. This paper presents an empirical analysis of the evolution of private sector research funding at Canadian universities over the past twelve years. Its objective is to document the profile of the universities which most attract private sector research financing, and to serve as the basis for a study in progress on best practices in university-industry research contracting. Findings confirm the increasing concentration of research in the largest, more research intensive universities in Canada. They also show that although the share of private sector financed research at universities is highest in the largest universities with large graduate programs in the sciences, especially in health and in mathematics and physics, that share seems to be relatively independent of academic excellence. Over time, the private sector orientation of research at the largest universities has grown at a slightly higher rate than at the smaller universities, but the difference is not statistically

significative. When controlling for current private sector research orientations and changes in total sponsored research budgets, changes in private sector orientation seem to favour the smaller universities.

1. Introduction

Studies of national and regional systems of innovation have underlined the role of universities in the knowledge creation process and as a source of highly trained and skilled manpower. Globally, academic research has been shown to have a very good social rate of return and therefore to be an excellent long-term public investment. At the local level, empirical studies are supporting university R&D spillovers and the supply of well qualified science and engineering graduates as solid hypotheses explaining the development of high technology clusters in the vicinity of major university R&D activity (Acs, Fitzroy, and Smith, 1998: 112). University research can be both basic, driven by curiosity and the desire to extend the boundaries of knowledge, and applied, oriented towards innovations and the commercialisation of knowledge. In the USA in 1995, it is estimated that about 67% of total academic R&D was for basic research, 25% for applied research, and 8% for development (NSF-NSB1996: 5-7). The share of basic research in the R&D activities of Canadian universities would be significantly lower, given that a major share of basic research in universities is publicly financed and that, in 1995, only 31% of university R&D in Canada was financed directly by the Federal Government[1]

[1] Estimated from Table 2, Statistics Canada (1998b).

(42% if both federal and provincial governments are accounted for), compared with 60.2% in the USA (NSF-NSB1996: 5-7). Even though there is a strong debate in academic circles on the proper balance of basic and applied research activities at Canadian universities (all publicly funded), questioning even the appropriateness of applied profit-seeking research in academia, the socio-economic potential and importance of applied research and research commercialisation at Canadian Universities has recently been reaffirmed (ACST 1999), provided it is not done to the detriment of basic research. The efficient economic use of higher education R&D is especially important in Canada because of the country s relatively low government and business expenditures on R&D compared with most other large OECD countries, the share of the national gross expenditures on R&D done by higher education is exceptionally high: 21.1% in 1997, compared with 14.3% in the USA, 14.8% in Japan, 17.4% in Germany,19.5% in Great Britain, 16.8 % in France, and 23.8% in Italy (OECD 1998).

Public pressure on universities to increase the short-term relevance of their research activities through innovations, research commercialisation and partnerships with industry, changes in business strategies from in-house research towards the subcontracting of pre-competitive research activities, reductions in the public funding of academic research[2], strong government incentives for university-industry research partnerships (Nimmo and Brennand 1999) have led to increased university-industry linkages in science and technology as well as in

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[2] Since 1990, the combined annual Federal and Provincial funding of higher education research has stood at approximately $1.2 billion in current terms (thus a decrease in real terms), representing a decreasing share of total higher education R&D expenditures, from 49% in 1990-91 to 40% in 1996-97 (Statistics Canada 1998b: Table 2).

education and training. The significant increase in private sector funding of university R&D activities over the past twenty years is a strong example of the growth of those linkages: in 1980-81, 10% of higher education R&D had been financed by the private sector (3.9% by business enterprises (3.9% also in the USA), 6.1% by private non-profit organizations); by 1996-97, that percentage had climbed to 22.9% (11.8% (6.9% in 1995 in the USA) and 11.1% respectively for business and for the non-profit sector)[3].

The main focus of this paper is on the university side of the university-industry collaborative process, and on the impact on the funding of research at large and small universities. Questions which are addressed include the distribution of private sector research funds among universities and its evolution, the type of universities which are attracting such funding and current trends, the impact of private sector research funding on the concentration of academic research activities in larger research institutions, whether private sector support of academic research has been an opportunity for smaller universities. A secondary focus of this paper is to serve as background material for the analysis of the efficiency of the university-industry interface in contract research. Some preliminary results of a research project on the factors and conditions which make for productive university-industry contractual relationships.

After a short review of current knowledge on the economic impact of academic research and a description of recent aggregate trends in private sector financing of research in the higher education sector, this paper presents an analysis of the distribution and trend of private sector research funding in a sample of 24 Canadian universities with active research programs. The

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[3] Canadian data: estimated from Statistics Canada (1998b: Table 2); US data for academic R&D: NSF-NSB (1996: 5-9).

outline of a research project in progress on business-financed research contracts at universities follows with some preliminary results on two case studies. The objective of these case studies is to investigate who drives the process, industry or the university, what are the facilitators, the inhibitors, what is the role of intermediaries, of complementary organizations or programs, what is the impact on the researcher, the university, the firms, the importance of proximity.

2. Aggregate Trends in Private Sector Financing of Research at Canadian universities

There is significant evidence in the literature of the benefits of university-industry cooperation in R&D. In one of the most quoted study on the topic, Mansfield estimated a social rate of return of 28% for academic research in the USA in the late 1970's, and a rate of return of 40% when academic and industrial research were combined (Edwin 1991:11, and 1992: 296). Link and Rees found a rate of return on R&D of 34.5 % for firms with university links, significantly higher than the 13.2% return for the other firms (Link and Rees 1990). In academia, Berman has shown that the .. effect on collaboration on industry research is lagged by about five years.. , which is much shorter than the approximately twelve years needed for the effect of independent academic research (Berman 1990: 353). As noted before, the role of universities in local systems of innovation has also attracted a lot of attention, starting with the observation by David Birch (1987) of the higher than average rate of growth of communities situated around technical universities, the note in 1989 by Jaffe of the effect of university research on the local rate of innovation by inducing industrial R&D spending (but not the reverse) (957), and to a much greater extent, the visibility and success of the high-tech growth

poles which developed around Stanford, MIT, and other leading research universities.

Access to well trained manpower, to leading-edge knowledge, to specialized laboratories and equipment, opportunities for brainstorming with academic researchers are among the benefits listed by industry for their linkages with universities. R&D intensive firms have also started to reduce their in-house basic research as a cost-cutting measure, to contract some of their research to external research organizations and to universities, and to benefit from the synergy associated with pre-competitive joint research with others (Doutriaux and Barker 1995: 4). Subcontracting basic and applied research to universities or doing it in partnership with university research institutes has been made even more attractive by government programs which led to the creation of Centers of Excellence, joint research institutes, industry-supported industrial chairs at universities, and other types of cooperation supported by R&D fiscal incentives or partnership grants (Doutriaux and Barker 1995; Nimmo and Brennand 1999) .

Higher education research is very important in Canada. It is estimated that, in 1998, the higher education sector will have performed $2.99 billion of R&D, or 21.6% of the country s total, more than the federal and provincial governments combined ($1.86 billion or13.3% of the total), second only to the business sector ($8.88 billion, 64% of the total). The current higher education share of national R&D is down from a high of 26.3 % in 1991 when the federal and provincial governments performed 19.7% of the national R&D and the business sector went through a low of 52.9%. Since that time, the share of R&D performed by the governments has decreased constantly (to 13.3% in 1998), and that of the business sector has increased strongly (to 64%). Since the mid 1980's, the private sector has been the fastest growing source funds for

higher education research, climbing from 10.5% in 1986-87 [4] (4.1% coming from the business sector and 6.4% from the private non-profit sector) to 22.9% in 1996-97 (11.8% from the business sector and 11.1% from the private non-profit sector) (Figure 1).

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[4] Estimated from Estimation of research and development expenditures in the Higher education Sector, 1996-97", Thompson (1998: Table 2).

Figure 1: Private sector share of sponsored higher education research funding
(source, Statistics Canada)

Figure 2: Sponsored Research at Canadian Universities (Source: CAUBO)

And within private sector funding, it is the business funding which has been growing the fastest, from 4.1% to 11.8% between 1986 and 1997, compared with 6.4% to 11.1% for the private non-profit sector. What is also noteworthy is that the $72.5 million given to higher education research by the business sector in 1986-87 represented about 2.25% of its own total R&D expenditures, whereas the $339 million allocated by the business sector to university research in 1996-97 represented 5.7% of its total R&D expenditures.[5] By comparison, in the USA, only about 6.9% of higher education research was financed by industry in 1995, representing only 1.5% of all

[5] Estimated from Thompson (1998), Table 2 for higher education statistics, and Statistics Canada (1998a) for business enterprise statistics.

industry-funded R&D in the country[6]. The relative importance of private sector funding of university R&D in Canada is due in part to the low federal government investment in that field. Robitaille and Gingras (1998) have recently noted that the US federal government had supported 73% of American university research in 1996, compared with 47% by the Canadian federal government for Canadian university research. The average US grant is three time larger than the average Canadian grant. Data on universities alone (rather than the complete higher education sector) confirm those trends: as shown in Figure 2, the *gifts, donations and non-government grants* [7] portion of the sponsored research budgets at Canadian universities, which will be called *private sector* research funding in this study, has grown from $176 million in 1986-87 to $623.4 million in 1996-97 while total sponsored research budgets have gone from $930.5 million to $1,859.3 million during the same period[8], an increase from 18.9 % to 33.5%.

This change in external university research funding is very significant. It reflects the

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6 NSF-NSB (1996: 5-9). In 1980, US industry had financed 3.9% of university research (representing 0.8% of its R&D expenditures).

7 Gifts, Donation and Non-Government grants include receipts from individuals, unincorporated business enterprises, privately controlled corporate enterprises, non-residents, religious organizations, etc., and the equivalent value of services donated by religious organizations; it does not include income from sale of services and product, investment income, and gains on the sale of fixed assets (source: CAUBO 1999).

8 Source: Statistics on Canadian Universities received from Canadian Association of University Business Officers, (CAUBO), Ottawa, Spring and Summer 1999. At $1849 million in 1987, the R&D activity of the whole higher education sector was about double that of the universities alone; at $2,894 million, it was about 50% higher that the universities in 1997 (source: Statistics Canada 1998a).

growing importance of private sector research funding and the relative decrease of peer-reviewed government funding. Whether it affects all universities or only some universities will be analysed in the next section. And whether it shifts the control over research themes and topics away from the research (curiosity driven research), under the control of the private sector sponsor will be addressed indirectly in the next section.

3. Distribution of private sector research financing at universities and recent trends

As noted previously, aggregate data on the share of gross externally-funded higher education research expenditures financed by business enterprises shows a three-fold increase between 1986-87 and 1996-97, from 4.1% to 11.8% (Thompson 1998: Table 2). If we add the non-profit sector, the share of the total domestic private sector research as gone from 10.6% of total external higher education research funding to 22.9%. For universities alone, gifts, donations and non-government funds have gone from 18.9% of total sponsored research to 33.5% in the same time period. In this section, we analyse the distribution of that research funding among Canadian universities and its change over the past twelve years.

In a recent study of industry-financed academic research, Mansfield and Lee (1996) have observed that:

- according to firms in seven major industries, the universities having contributed most to their product and process development are the leading research universities (MIT,

Berkeley, Stanford, Harvard and the like);

- about 40% of the major contributions by academia to product and process innovation came from universities with adequate-to-good and marginal faculties, showing that those universities can do applied R&D of acceptable quality. Mansfield and Lee also note that large science-based firms in our sample have been almost as likely to support applied R&D at a university with adequate-to-good faculty as at one with good-to-distinguished faculty . In fact, at the stage where the firms need to interact with university personnel... less prestigious universities may have a comparative (indeed an absolute) advantage (Mansfield and Lee 1996: 1057).

- physical proximity between a firm s R&D facility and a university is also a major determinant of applied research funding, in particular for universities with faculties of average quality, and that, in spite of advances in telecommunications. And, the more applied the research, the more important proximity is. As written by Mansfield and Lee, only universities with good-to-distinguished faculties seem to have much chance of obtaining support from firms at least 100 miles away (1055).

Based on those findings, we would expect the big Canadian research intensive universities to receive substantial private sector research funding, as well as the universities with faculties of average quality situated in very large urban centres.

In 1996-97, 33.7% of health sciences research funding in higher education came from the private sector (21.1% from the non-profit sector and 12.6% from business); for natural sciences

and engineering research funding, that percentage was 22.7% (5.2% from non-profit, 17.5% from business); and for social sciences and humanities research funding, it was 9.25% (7.25% from non-profit, 2% from business).[9] Given the fact that between 1986-87 and 1996-97, total higher education research spending in health sciences grew by 76% (current dollars), in other natural sciences and engineering by 69% and in the social sciences and humanities by 49%,[10]

> *we would expect universities with active programs in heath-related domains to attract a significant share of private sector research funding, followed by other natural sciences and engineering, social sciences and humanities attracting the least private sector research funding.*

This study of the distribution and recent evolution of university external research funding is based on the gifts, donations and non-government funds share of the external sponsored research income received by the universities (a total of $176 million in 1986-87 for all universities, $623.4 million in 1996-97, and $671.4 million in 1997-98) (CAUBO: various years). Those funds include all the research funding received from the private sector, individuals, unincorporated businesses, corporate business enterprises, foundations and non-profit organizations (see CAUBO 1999). They correspond closely to the sum of the research funding received from the business sector and from the private non-profit sector published by Statistics Canada for the complete higher education sector ($72 million and $113 million respectively in 1986-97, and $339 million and $319 million respectively in 1996-97) (Thompson

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[9] Estimated from Table 1, Statistics Canada (1988).

[10] Estimated from tables 5,6,7, Statistics Canada (1988).

1998) with adjustments for investment income and other special income, and are refereed to as *private sector research funding* in this study. Because of their private non-profit component, they may not fully reflect the research strategies of for-profit business enterprises, but the private non-profit sector funding is very important to capture the private sector support of research in the health sciences. This data is collected annually by Statistics Canada with the assistance of the Canadian Association of University Business Officers (CAUBO). It is published in an annual report of Financial Statistics of Universities and Colleges . Data on 24 universities representing 90.6% of total sponsored research activity at universities in Canada in 1997-98 is used for the analysis (Table I)[11].

The analysis is based on the mean research and operating characteristics of Canadian universities for two six-year periods, 1986 to 1992 and 1992 to 1998, as well as the relative change between those means (ratio of the 1992-98 mean to the 1986-92 mean)[12]. Means are used to reduce the variability of sponsored research accounts and operating characteristics under short term university, regulatory, or industry influences. Ratios are used as an estimate of trend.

4. The evolution of sponsored research at universities, 1986 to 1998 (Table 1).

In 1997-98, the sponsored research income at the 24 universities in the sample went from

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[11] This sample of 24 universities includes all but one of the universities in Canada with 1997-98 sponsored research income above $10 million. The University of Sherbrooke, with 1997-98 sponsored research income of $25.1 million, is the only one missing from the sample.

[12] Student t-tests to compare the means of two small samples have been used for the analysis, with (most of the time) acceptable tests for a common variance.

$282 million at the University of Toronto to $12.1 million at Concordia (Table 1). Mean 1992-98 sponsored research budgets show a regular decrease from the largest (University of Toronto, $249.9 million) to the smallest (Concordia University, $14.1 million) which makes the identification of clearly identifiable subgroups difficult.

Table 1: Sponsored research at Canadian Universities
($1,000,000.00 unless otherwise noted)

	Total Income 1997-98	Mean, Years 1992-98	Mean, Years 1986-92	Growth ratio, 92-98/86-92	Rank, 92-98	Rank, 86-92	Rank, growth ratio	University Type	University Size
University of Toronto	282.0	249.9	122.8	2.03	1	1	1	MD	L
Université de Montréal	139.1	164.9	102.2	1.61	2	2	4	MD	L
U. British Columbia	126.7	135.4	92.3	1.47	3	3	8	MD	L
McGill University	166.1	125.9	91.5	1.38	4	4	13	MD	L
University of Alberta	135.4	108.1	69.3	1.56	5	5	6	MD	L
McMaster University	86.5	85.3	66.1	1.29	6	6	18	MD	L
Université Laval	86.2	82.9	58.3	1.42	7	7	9	MD	L
University of Calgary	104.3	72.4	53.4	1.36	8	9	16	MD	L
University of Guelph	87.7	71.2	55.1	1.29	9	8	17	C	L
Queen's University	56.3	63.4	45.7	1.39	10	10	11	MD	L
University of Ottawa	78.4	59.3	40.3	1.47	11	14	7	MD	L
U. Western Ontario	81.5	57.8	41.6	1.39	12	13	10	MD	L
University of Manitoba	60.7	51.9	43.9	1.18	13	11	21	MD	L
University of Waterloo	42.9	47.9	42.8	1.12	14	12	22	C	L
U. Saskatchewan	46.3	44.7	36.0	1.24	15	15	19	MD	L
Dalhousie	42.1	37.2	31.3	1.19	16	16	20	MD	L
École Polytechnique	25.8	29.1	17.8	1.63	17	19	3	C	M
U. Québec à Montréal	27.2	26.8	16.8	1.59	18	20	5	C	M
Memorial University	27.0	25.9	19.1	1.36	19	17	15	C	M
Carleton University	22.7	22.8	16.7	1.37	20	21	14	C	M
York University	19.5	21.1	19.0	1.11	21	18	23	C	M
Simon Fraser University	23.7	21.0	12.0	1.75	22	24	2	C	M
U. of New Brunswick	19.7	17.8	12.9	1.38	23	23	12	C	M
Université Concordia	12.1	14.1	15.7	0.90	24	22	24	C	M
Subtotal (% of Canada)	1799.8 (90.6%)	1636.7 (89.6%)	1122.5 (88.9%)						
Canada	1985.9	1825.8	1262.2	1.45					

Sources: *Data:* Canadian Association of University Business Officers.

University Type : MD, medical/doctoral : Universities MD, medical/doctoral : Universities with a broad range of MD, medical/d wellwell as a medical school; C, comprehewell as a medical school; C, comprehensivwell as a medical school; C, co graduate and undergraduate programs (MacLeans, special annual November issue on Universities).

UniversityUniversity Size: Large or Medium, according to sponsored research budget, Large or Medium, according to sponsored operatingoperating budget, and number of doctorate programs (Janoperating budget, and number of doctorate program 88F0006XPB N.12, November 1998, list 1, page 27.

Table 2: Selected Operating characteristics at Canadian Universities, mean values 199
and rank of each university in the sample (source: computed from CAUBO financial and operating statistics; see the Not

	Average Sponsored Research Budgets 1992-98		Private sector research orientation 1992-98		University Research Intensity, 1992-98		Total University Operating Budget, 1992-98, ($ million)		Sponsored Research Budget per full time graduate student equivalent ($1000.)		Average Number o granted			
											Agriculture and biological sciences		Enginee and app scienc	
	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean ($1000)	Rank	Mean	Rank	Mean	
University of Toronto	1	37.75	5	25.77	3	962.49	1	29.68	4	47.0	6	155.6	
Université de Montréal	2	41.60	2	31.62	1	520.23	4	30.58	3	30.7	9	10.8	
U. British Columbia	3	34.27	8	19.39	9	702.01	2	22.13	11	56.4	4	101.8	
McGill University	4	24.24	17	24.55	5	511.88	5	19.58	15	56.7	3	115.4	
University of Alberta	5	24.72	16	20.35	7	529.18	3	27.25	6	48.1	5	72.7	
McMaster University	6	40.87	3	25.63	4	332.70	12	39.65	2	15.3	14	55.9	
Université Laval	7	24.86	15	18.14	11	457.46	6	14.73	19	60.6	2	74.7	
University of Calgary	8	32.11	10	19.61	8	366.48	9	25.36	10	15.4	13	40.9	
University of Guelph	9	13.92	23	24.52	6	289.60	15	46.02	1	131.5	1	14.0	
Queen's University	10	33.67	9	17.84	13	356.98	10	25.43	9	22.7	10	51.2	
University of Ottawa	11	44.79	1	19.23	10	307.58	13	18.03	18	9.85	20	38.9	
U. Western Ontario	12	40.17	4	13.71	17	417.56	7	19.67	14	12.5	16	23.9	
University of Manitoba	13	34.37	7	15.49	16	334.44	11	18.32	17	35.3	8	55.0	
University of Waterloo	14	26.67	13	17.02	14	281.34	16	26.97	7	12.9	15	99.6	
U. Saskatchewan	15	25.79	14	15.53	15	290.78	14	26.82	8	43.9	7	31.0	
Dalhousie	16	21.06	19	17.94	12	207.41	21	20.71	13	19.1	12	0.0	
École Polytechnique	17	20.36	21	28.00	2	104.19	24	28.43	5	0.0	24	104.3	
U. Québec à Montréal	18	29.93	11	9.51	21	281.27	17	10.65	21	10.4	19	0.0	
Memorial University	19	20.80	20	11.30	19	229.11	18	20.93	12	11.4	17	11.6	
Carleton University	20	26.99	12	11.06	20	206.15	22	11.51	20	8.7	21	40.1	
York University	21	21.46	18	5.61	24	376.11	8	7.98	23	10.8	18	0.0	
Simon Fraser University	22	19.79	22	9.16	22	228.94	19	10.08	22	20.0	11	7.8	
U. of New Brunswick	23	34.40	6	12.11	18	146.74	23	19.57	16	4.7	22	34.7	
Université Concordia	24	8.38	24	6.18	23	228.12	20	5.77	24	3.0	23	46.9	
Canada		30.58		15.83		11530.9		20.59		747		1322	
Mean, Toronto to Western Ontario		32.75		21.70		479.5		26.52		42.22		63	
Mean, Manitoba to Concordia		24.17		13.24		242.8		17.31		15.08		35.9	
Test on means, student-t		2.66		3.92		4.14		2.76		2.7		1.72	

Notes: *Private sector orientation*: percentage of sponsored research budgets coming from the private sector
Research intensity: sponsored research budget expressed as a percentage of total university operating budget.
SponsoredSponsored Research Budget per fullSponsored Research Budget per full time graduate student equivalent: Sponsor
one third of the part-time students.
Average Number of graduate degrees equivalent : average number of Ph.D degrees plus one third of Master s degrees grante

Not surprisingly, as shown by the data in Table 2,[13] universities with the largest sponsored

[13] Table 2 provides individual 1992-98 university means for each of those measures, as well as the

research budgets also have on the average - the highest *private sector research orientation* (percentage of sponsored research funds coming from the private sector), the highest *research intensity* (sponsored research expressed as a percentage of total university operational income), the highest university operational income,
and award the largest number of Ph.Ds in agriculture and biological sciences, engineering and applied sciences (just significant at a one-sided 5% level of significance), health professions, mathematics and physical sciences. And as expected, the Medical-Doctoral [14] universities also have significantly larger sponsored research budgets than the others (t=4.17 for a comparison of the 1992-98 mean sponsored research for the two groups).

Similarly, the 12 most research intensive universities have a mean 1992-98 sponsored research budget of $101.8 million, significantly larger than that of the other 12 universities at $35.6 million (t=3.8), and the relative increase in sponsored research from 1986-92 to 1992-98 at 48% for the first group is also significantly higher than the 32% of the second group (t=1.83, one sided test).

In 1986-92, the twelve universities with largest sponsored research budgets in Canada accounted for 66.5% of the total sponsored research budget at Canadian universities, the twelve following universities accounted for 22.5 of the total, for a total of 89% for the twenty four universities in our sample. In 1992-98, these numbers had changed to 72%, 18.6% and 90.6%

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average for the group of twelve universities with highest 92-98 sponsored income, the average for the group of the twelve other universities in the sample, and the student-t value for a one sided test on those means (based on hypothesis of equality of variances, supported by the data).

[14] Medical/Doctoral and Comprehensive as defined by MacLean s; complete definitions are given at the bottom of Table 1.

respectively. An analysis of relative changes in sponsored research (current dollars) between 1986-92 and 1992-98 shows increases at all but one university in the sample, up by 103% (an average 13% per year) at the University of Toronto, 75% at Simon Fraser University, 63% at École Polytechnique, 61% at Université de Montréal, and down 10% at Concordia University (Table 1). The average percentage increase of sponsored research budgets between 1986-92 and 1992-98 for the group of the twelve universities with largest mean 1992-98 sponsored research budgets (University of Toronto to University of Western Ontario) has been 47%, compared with 32% for the twelve smallest universities in the sample (University of Manitoba to Concordia University). The mean percentage increase for the first group is barely significantly larger than that for the second group (one sided test, equal variances, t=1.74, p=0.05). For Medical/Doctoral (43% average increase) and Comprehensive (35%) universities, the difference is not significant.

There has been relatively little change in the ranking of universities by sponsored research budgets between 1986-92 and 1992-98 (Table 1). The only significant moves (defined here as three places or more) are for the University of Ottawa (who moved up from 14th to 11th) and for York (who moved down from 18th to 21st). The sample is too small to detect any significant differences[15] between the rate of change of sponsored research at universities in the 5 main regions of Canada (Atlantic Provinces, Québec, Ontario, Prairies and British Columbia).

Sectorally, the mean 1992-98 sponsored budgets of the twelve universities having awarded the largest number of graduate degrees in agriculture and biological sciences from 1992 to 1997 (numbers and ranks, Table 2, columns 11 and 12) are $102,921, $100,148, $96,365, and

[15] Using a one-way ANOVA model and regrouping provinces and regions in groups of similar sizes.

$88,861 respectively, are significantly larger than that of the other universities in the sample. At 44%, 49%, 46% and 39% respectively, their rates of growth since 1986-92 are larger than those of the other universities in health (35%), mathematics (30%) and agriculture (33%), and equal for engineering (40%). The differences between rates of growth of sponsored funding between the universities granting high numbers of graduate degrees in a given field with those of the universities granting a smaller number of degrees in that field, is however significant only for mathematics and physics (one sided p=0.01) and weakly significant for agriculture (p=0.07). As most big universities in Canada grant each year a sizable number of graduate degrees in all the fields considered in this study, it is difficult to conclude that these differences in sponsored research budgets growth are due to a specific discipline or to a large university effect.

To try to correct for the effect of the size of the universities, the *relative* number of graduate degrees granted in a field of study (Table 3) rather than at the actual number has been used, as a proxy for its relative importance in the university,[16] for the level of specialisation of

[16] Approximated here by the ratio of the number of graduate students equivalent (Number of Ph.D.s and one third of the Masters) receiving degrees in a given field to the total number of graduate students equivalent studying at the university.

Table 3 Mean annual 1992-97 number of graduate degrees awarded per 1000 graduate students equivalent registered at the university and rank in sample.								
	Agriculture and biological sciences		Engineering and Applied sciences		Health sciences		Mathematics and physical sciences	
	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank
University of Toronto	5.62	15	18.60	9	19.90	3	3.64	15
Université de Montréal	5.68	14	1.99	21	23.37	1	3.80	14
U. British Columbia	9.23	8	16.63	13	10.64	12	4.12	10
McGill University	8.81	10	17.88	12	16.06	5	3.52	16
University of Alberta	12.02	4	18.25	11	17.18	4	4.89	8
McMaster University	7.11	13	25.95	4	13.55	7	5.40	3
Université Laval	10.76	6	13.25	15	12.87	8	2.52	21
University of Calgary	5.52	16	14.65	14	12.76	9	3.29	17
University of Guelph	84.92	1	9.04	17	0.00	18	4.06	11
Queen's University	9.16	9	20.53	5	10.92	11	5.35	4
University of Ottawa	3.00	22	11.84	16	7.22	13	3.10	18
U. Western Ontario	4.30	19	8.23	19	20.37	2	4.90	7
University of Manitoba	12.45	3	19.47	8	12.24	10	2.53	20
University of Waterloo	7.28	12	56.48	2	2.14	16	15.10	1
U. Saskatchewan	26.43	2	18.53	10	6.13	15	3.85	13
Dalhousie	10.97	5	0.00	22	13.84	6	5.20	5
École Polytechnique	0.00	24	102.50	1	0.00	18	2.15	23
U. Québec à Montréal	4.14	20	0.00	22	0.00	18	2.64	19
Memorial University	8.73	11	8.99	18	6.95	14	3.85	12
Carleton University	4.40	18	20.28	6	0.00	18	4.92	6
York University	4.08	21	0.00	22	0.00	18	1.62	24
Simon Fraser University	9.65	7	3.71	20	0.00	18	4.78	9
U. of New Brunswick	5.11	17	38.29	3	0.00	18	5.86	2
Université Concordia	1.24	23	19.49	7	1.23	17	2.38	22

the university. Except for universities granting a high proportion of degrees in health sciences, there is no significant difference in the total sponsored research budgets and their rates of increase between 1986-92 and 1992-98 for the twelve universities granting the highest relative number of graduate degrees and for the other twelve universities in the sample, in mathematics, in agriculture, and in engineering. In health sciences, a field of study present mostly in the

largest universities, university rankings by number of graduate degrees and by relative numbers of graduate degrees are the same. We therefore have the same result as in the previous paragraph: significantly higher sponsored budgets in the universities with highest health orientation, with a non statistically significantly higher rate of growth since 1986-92 (44% vs. 35%).

In spite of the limited size of the sample, a factor analysis was used to confirm the results of that bivariate analysis. The Universities of Waterloo and Guelph, as well as École Polytechnique were removed from the study for this part of the analysis because their high percentage of graduate degrees awarded in engineering and in agriculture (Table 3) made them outliers , non representative of the rest of the sample. Five factors were obtained through principal factor analysis, explaining 88% of the variance. As shown by the correlations in Table 4, they represent respectively the size of the universities, their research intensity and health sciences orientation (*research oriented large universities,* F1), academic research funding (*academic excellence,* F2), high relative number of graduate degrees in mathematics and physical sciences orientation *(mathematics and physical sciences orientation,* F3), high relative number of graduate degrees in engineering and applied sciences (*engineering and applied sciences orientation,* F4), and high relative number of graduate degrees in agriculture and biological sciences (*agriculture and biological sciences orientation,* F5). The fact that factor F1 includes both research orientation, large size, and health science orientation corresponds is logical, given that most significant health programs in the country are found at large universities. And not surprisingly, as our largest most research intensive universities are located in the biggest cities, the size of the university s metropolitan areas is positively correlated with academic excellence (F2). It is also negatively correlated with mathematics and physical sciences (F3), a

characteristic more difficult to explain. As shown by the regression model results in table 4, sponsored research budgets are strongly correlated with most factors: university size and research intensity (as well as health sciences), agriculture and biological sciences, academic excellence, and engineering and applied sciences. The increase in sponsored research between 1988-92 and 1992-98 is however only correlated with size and research intensity, and academic excellence, confirming a concentration of research activities in a reduced number of large universities.

These brief bivariate and multivariate analyses confirm the increasing concentration of research in the largest, more research intensive universities in Canada, recognized for academic excellence through the peer-reviewed research granting process, and having the highest research budgets. Rates of change between 1986-92 and 1992-98 favour the large/research oriented universities, in particular those with large graduate programs in mathematics and physics, in health and in agriculture.

Table 4 Factor Analysis to study sponsored research budgets and their relative change

Factor Analysis, varimax rotation
- correlations (loadings) between variables (tables 1, 2, 3) and factors -
(all correlations below 0.2(abs. value)removed for ease of interpretation)

Variables	F1	F2	F3	F4	F5
Relative number of graduate degrees (Table 3)in:					
agric-bio.		-0.23244			0.92825
engineer.			0.29052	0.92700	
health sc.	0.89513				
Math-Phys			0.92009		
Average number of graduate degrees (Table 2) awarded in:					
agric-bio.	0.60267	0.23620	-0.22842		0.65145
engineer.	0.58642	0.32539		0.67843	
health sc.	0.91484	0.23326			
math-phys.	0.81096	0.49218			
University (table 2):					
operating budget	0.77901	0.42708	-0.26122		
res.intensity	0.90860		0.24556		
res. funds/stud.	0.69989		0.54396		
Academic research (see Table 6):					
sshrc $	0.59093	0.59967			-0.24142
sshrc #	0.50354	0.68232			-0.27295
nserc-mrc $	0.34339	0.86884			
nserc-mrc #		0.89832			

Regression Model for sponsored research budgets in 1992-98" (R2=0.94, p=0.0000, residuals acceptable)					
coefficients	53.6	16.7	----	10.1-	----
(p-value)	(0.000)	(0.000)	----	(0.011)	---

Regression model for relative change in sponsored research, 86-92 to 92-98, (R2=0.26, p=0.017, residuals acceptable)		
coefficients	0.12	
(p-value)	(0.018)	

The next section of this paper focuses on one specific source of academic research funding, the private sector, to see to which degree its increasing importance is changing the academic research landscape in Canada.

5. Evolution of the private sector research orientation of universities, 1986 to 1998 (Table 3).

As noted earlier, *the private sector research orientation of universities* is defined in this paper as the percentage of sponsored research financing received by universities as gifts, donations and non-government grants. This includes receipts from corporate business enterprises and foundations. Investment income and miscellaneous income such as rentals, library fines, gains or losses from the sale of fixed assets are not included. A high private sector research orientation may be due to a high level of research income received by a university as gifts, grants and contracts from the private sector. As it is a relative measure, it may also reflect a university s weakness in securing research grants from the federal (SSHRC, NSERC, MRC) and provincial research funding agencies. As noted by Mansfield and Lee, in their study of the effect of distance and quality on university-industry research linkages, noted that In 1991, about 62% of industry s support for R&D at the 200 universities with the largest R&D expenditures went to such universities [rated adequate-to-good or below, compared with 50% for the US federal government]... Note too that the [US] federal government has been more inclined to support R&D at universities with good-to-distinguished faculties than industry as a whole... (Mansfield and Lee 1996: 1055).

From 1986-92 to 1992-98, the mean private sector research orientation at all the Canadian universities[17] has increased by 34%, from a six-year average of 22.8% in 1986-92 to a six-year

[17] In addition to traditional universities, CAUBO s list includes academic degree-granting institutes such as the Institut Armand Frappier and the Institut National de la Recherche scientifique (INRS)

average of 30.6% in 1992-98. It is still increasing, reaching an average 33.8% in 1997-98 (Table 5). For the 24 universities in our sample, the average 1992-98 private sector research orientation was 28.5% (32.8% for the 12 universities with highest sponsored research budgets, 24.2% for the twelve following); in 1986-92, it was 22.1% for the twenty four universities (24.6% for the twelve largest (1992-98 ranking), 19.7 % for the twelve following). Individually (Table 5), 1992-98 private sector research orientations ranged from 44.8% at the University of Ottawa to 8.4% at Concordia with largest 1986-92 to1992-98 relative increases at the University of New Brunswick (17.3% to 34.4%), Simon Fraser University (10% to 19.8%), the University of Saskatchewan (15% to 25.8%) and Carleton University (17% to 27%), and largest decreases at Concordia (16% to 8.4%), École Polytechnique (29.6% to 20.4%), and Memorial University (24.1% to 20.8%).

Even if the twelve universities with largest 1992-98 mean sponsored research budgets (University of Toronto to University of Western Ontario)[18] tend to have a significantly higher average private sector orientation than the twelve which follow (University of Manitoba to Concordia University), 32.8% compared with 24.2% (t=2.66, one sided p=0.008), the rate of change of the average private sector orientation of the two groups over the 1986-92 to 1992-98 periods is practically the same (an average 32% for the individual increases for the universities of the first group compared with an average 30% for the individual increases in the second group). The fact that group means increased by 33.3% (from 24.6% to 32.8%) and by 22.8% (from 19.7% to 24.2%) respectively for each group indicates that universities with a higher private

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in Québec.

[18] The twelve first universities listed in any table, as all the tables present the universities by decreasing 1992-98 mean sponsored research budgets.

sector orientation in the first group had a private sector orientation that grew at a faster rate than the others in their group while the reverse occurred in the second group of universities.

When one compares the group of the twelve universities with highest private-sector orientations in 1992-98 (University of Ottawa to Carleton University, Table 5, mean 35.9%) with the twelve following (Waterloo to Concordia, mean 21%), the rate of increase of the private sector research orientation of the first group since 1986-92 (up 43% from a mean value of 25.7%) is only weakly statistically larger than the rate of increase of the second group (up 21% from a mean value of 18.5% in 1986-92; $t=1.72$, $p=0.05$ (one sided)).

Table 5: Private sector research orientation of Canadian universities
(Ratio of gifts, donations and non govt. grants to total sponsored research, %)

	Mean sponsored research 92-98: Rank	Private sector research orientation						
		Year 1997-98	Mean, Years 1992-98	Mean, Years 1986-92	Ratio, 92-98/86-92	Rank, 92-98	Rank 86-92	Rank Ratio
University of Toronto	1	46.15	37.75	25.31	1.49	5	8	6
Université de Montréal	2	34.05	41.60	28.59	1.46	2	5	7
U. British Columbia	3	40.44	34.27	21.87	1.57	8	13	5
McGill University	4	29.72	24.24	22.62	1.07	17	11	21
University of Alberta	5	22.45	24.72	20.25	1.22	16	15	16
McMaster University	6	31.68	40.87	34.02	1.20	3	1	18
Université Laval	7	23.42	24.86	19.76	1.26	15	16	13
University of Calgary	8	31.65	32.11	22.58	1.42	10	12	8
University of Guelph	9	16.71	13.92	10.40	1.34	23	23	12
Queen's University	10	41.10	33.67	28.40	1.19	9	6	20
University of Ottawa	11	68.47	44.79	32.43	1.38	1	2	11
U. Western Ontario	12	57.53	40.17	28.87	1.39	4	4	10
University of Manitoba	13	40.78	34.37	27.41	1.25	7	7	14
University of Waterloo	14	32.63	26.67	21.57	1.24	13	14	15
U. Saskatchewan	15	28.93	25.79	15.04	1.71	14	21	3
Dalhousie	16	25.56	21.06	14.87	1.42	19	22	9
École Polytechnique*	17	2.27	20.36	29.62	0.69	21	3	23
U. Québec à Montréal	18	40.34	29.93	24.80	1.21	11	9	17
Memorial University	19	25.03	20.80	24.10	0.86	20	10	22
Carleton University	20	38.24	26.99	17.05	1.58	12	19	4
York University	21	19.59	21.46	18.03	1.19	18	17	19
Simon Fraser University	22	20.59	19.79	10.03	1.97	22	24	2
U. of New Brunswick	23	35.15	34.40	17.28	1.99	6	18	1
Université Concordia	24	10.34	8.38	16.03	0.52	24	20	24
Canada		33.81	30.58	22.79	1.34			

Source: Estimated from data from the Canadian Association of University Business Officers (CAUBO), and table 1.
Note * : **At École Polytechnique,** drop in gifts, donations.. from over $13 million in 1994-95 to about $0.6 million for 1995-96, 1996-97, 1997-98 according to CAUBO data (with only a slight reduction in total sponsored research budgets). For consistency purpose, the CAUBO data was used. A telephone conversation with Jean Choquette at École Polytechnique (Nov. 29th, 1999) seems to indicate that numbers close to $14.5 million, $13.3 million and $12.6 million respectively for 1995-96, 1996-97, 1997-98 would probably be more appropriate for the institution s gifts, donations.. . Total sponsored research budgets seem to be exact.

When, however, one compares the group of the twelve universities with highest private-sector orientations in 1986-92 (McMaster to Calgary, mean 27.4% in 1986-92, 33.4% in 1992,98) with the twelve following (UBC to Simon Fraser University, mean 16.8% in 1986-92, 23.5% in 1992-98 (still significantly lower than that of then other group)), it is the rate of growth of the mean

private research orientation of the second group which, at 42%, is weakly larger than that of the first group (at 22%, t=1.55, one sided p=0.07). Universities with a lower private sector research orientation have therefore increased that orientation at a slightly higher rate than the others.

When the universities are placed in two groups by mean 1992-98 *research orientations* (ratio of sponsored research income to total university operating income; Table 2, columns 5 and 6), one group with the twelve highest, from University of Montreal (research orientation of 31.6%) to Dalhousie University (research orientation of 17.9%) and the other group with the twelve lower research orientations (Queens (17.8%) to York (5.61%), the resulting group mean private sector research orientations of 30.1% and 26.9% respectively for the two groups are not statistically different. At 29% and 34% respectively, the mean rates of increase of those private sector research orientations between the two time periods in the study are also non significantly different.

In relative terms, universities with the largest mean total operating budgets receive significantly more research funding from the private sector than the other universities in the sample, an average 32.5% for the 1982-98 mean private sector research orientations for the twelve largest in 1992-98 (University of Toronto with a mean 1992-98 operating budget of $962.5 million to McMaster at $332.7 million, Table 2, columns 7 and 8)), compared with 24.4% for the twelve others in the sample (Ottawa at $307.6 million to École Polytechnique at $104.2 million; t=2.47, p=0.01 for the comparison of mean private sector research orientations). The rate of change from 1986-92 to 1992-98 for both groups is however identical, both funding shares having increased by an average of 30%.

No difference in private sector research funding orientation is observed when universities are regrouped by mean sponsored research funding per graduate students equivalent[19]: in 1992-98, the mean sponsored research budget per graduate students at all Canadian universities had been 20.6 thousand dollars (Table 2, columns 9 and 10). The mean value for the twelve universities in the sample with highest budgets per students have been 29.2 thousand dollars, compared with 14.7 thousand dollars for the other twelve in the sample, the first group having a mean private research orientation of 29.4% compared with 27.5% for the other group, which is not significantly different. And the rate of change of that private sector orientation from 1986-92 to 1992-98, at 28% and 35% respectively, is higher for the second group, but not significantly from a statistical point of view.

Is there a sectoral effect, some fields of research and study attracting more private sector interest (and funding) than others? The total number of graduate degrees equivalent awarded by each institution in each of the four main categories of science, applied science, and engineering, has been used as a proxy for the sectoral research orientation of the university: agriculture and biological sciences, engineering and applied sciences, health professions, and mathematics and physical sciences. The number of graduate degrees equivalent awarded in a given field is being used as an approximation of the absolute importance of that program; the number of graduate degrees equivalent has been estimated as the sum of the Ph.Ds degrees awarded by each institution, plus one third of the number of Master s degrees awarded in the same field. Individual university results are listed in table 2, columns 11 to 18. As in the previous analyses,

[19] Estimated here as the sum of the number of full time graduate students and of one third of the number of part-time graduate students.

universities in the sample have been placed in two groups: the twelve universities with the largest number of graduate degrees awarded in a given field of studies between 1992 and 1998, and the twelve other universities (some with no degrees awarded in that field). A comparison of the two resulting groups in each fields yields the following results:

Agriculture and biological sciences: no significant difference in private sector research orientation between the two groups of universities in 1992-98 (28.0% vs. 28.9%); noteworthy, however is that the universities with more agriculture and biological sciences degrees in 1992-98 had a lower private sector orientation than the others in 1986-92 (20.4% vs.23.9%, t=1.4, one sided p=0.08) and therefore experienced a higher private sector funding growth from 1986-92 to 1992-98 than the others (up 41% compared with 22%, t=1.5, one sided p=0.07).

Engineering and applied sciences: no significant difference in private sector research orientation between the two groups of universities in 1992-98 (28.5% vs. 28.4%); noteworthy, however is that the universities with less engineering and applied sciences graduates in 1992-98 started with a significantly lower private sector research orientation in 1986-92 (20.1% compared with 24.1% , t=1.61, p=0.06) but experienced a significantly higher rate of growth of the relative share of private sector research funding between the two time periods (46% vs. 18%, t=2.31, p=0.016).

Health professions: The universities with a larger number of graduate degrees in health in 1992-98 had a significantly higher private sector research orientation in 1992-98 (32.5%

vs. 24.4%; t=2.5) as well as in 1986-92 (24.6% vs. 19.6%, t=2.0). The rate of change of that private sector research orientation from one time period to the next has however been about the same for both groups (33% for the Health professions ` universities, 30% for the others).

Mathematics and physical sciences: The universities with a larger number of graduate mathematics and physical sciences degrees in 1992-98 had a significantly higher private sector research orientation in 1992-98 (32.8% vs. 24.1%; t=2.7) as well as in 1986-92 (24.5% vs. 19.8%, t=2.0). The rate of change from 1986-92 to 1992-98 of that private sector research orientation from one time period to the next has been slightly higher for universities granting a high number of degrees in mathematics and physical sciences (37%) than for the others (27%), but the difference is not statistically significative.

When, instead of the absolute number of graduates degrees awarded in a field of study, the relative number of degrees awarded in a field per graduate students equivalent is used as a measure of the relative importance of that field of study/research at a university (Table 3), no significant difference is observed between the mean private sector orientation and its 1986-92 to 1992-98 rate of increase in engineering and applied sciences and in mathematics and physical sciences between the group of the twelve universities with the highest relative number of graduates and the group of other universities in the sample. In health sciences, the twelve universities with the highest proportion of graduates in health sciences have a significantly higher private sector research orientation (32.5%) than the other universities (24.5%), but there is no difference in the rate of increase of the private sector orientation of the two groups between

1986-92 and 1992-98. In agriculture, it is just the opposite, with a significantly lower private sector research orientation (25.4%) for the universities with a high relative number of graduates in agriculture and biological sciences compared with the other universities (31.6%), and again with no difference in the rate of increase of the private sector orientation of the two groups over the period under analysis. Results for the relative aggregate number of graduate degrees awarded in science, health, agriculture and engineering per graduate student equivalent are similar:

Table 6 SSHRC, NSERC and MRC grants, mean value and number of grants per 100 eligible professors								
	Social Sciences and Humanities Research Council grants				Natural Sciences and Engineering Research Council and Medical Research Council grants			
	Mean value ($1000)	Rank	Number per 100 eligible professors	Rank	Mean value ($1000)	Rank	Number per 100 eligible professor	Rank
University of Toronto	6478	3	32.23	1	63438	5	136.76	4
Université de Montréal	5750	4	23.17	8	52009	8	113.6	13
U. British Columbia	7175	2	30.56	2	56523	7	125.75	6
McGill University	5586	5	28.13	3	69313	1	124.97	7
University of Alberta	5294	6	20.52	11	67969	2	153.75	2
McMaster University	7376	1	26.39	5	46638	11	97.31	14
Université Laval	4541	9	18.76	13	39525	15	91.24	16
University of Calgary	2766	17	16.96	16	42329	14	93.52	15
University of Guelph	3247	14	18.89	12	45352	12	121.91	8
Queen's University	3874	11	27.35	4	66457	3	118.88	10
University of Ottawa	4661	8	17.18	15	38866	16	89.29	17
U. Western Ontario	3122	15	24.76	7	49772	10	115.03	11
University of Manitoba	1961	20	10.22	20	36047	17	83.64	18
University of Waterloo	2161	19	14.98	19	51685	9	131.98	5
U. Saskatchewan	508	23	5.82	22	21005	21	53.71	22
Dalhousie	2954	16	18.68	14	29941	19	76.19	19
École Polytechnique	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
U. Québec à Montréal	4437	10	20.69	10	27301	20	73.85	20
Memorial University	733	22	5.76	23	16770	23	45.1	23
Carleton University	2682	18	16.48	17	63900	4	141.36	3
York University	3551	12	15.75	18	56525	6	212.51	1
Simon Fraser University	4864	7	25.63	6	44201	13	120.09	9
U. of New Brunswick	1014	21	7.69	21	18799	22	64.75	21
Université Concordia	**3305**	**13**	**22.46**	**9**	**30711**	**18**	**113.88**	**12**
Source: Maclean's, November 15, 1999, page 78								

significantly higher private research orientation for the 12 universities with the highest science orientation compared with the 12 other universities (31.4% vs 25.5%, t=1.71, one sided p=0.05), but with exactly the same mean growth rates of that orientation between 1986-92 and 1992-98 (average increases of 31% and 33% respectively).

To analyse the relationship between private sector research orientation and a university s academic quality, data on relative research funding[20] received by each university has been used as a proxy for the academic research quality (Table 6).[21] Although the private sector research orientation of the group of twelve universities with largest average SSHRC and NSERC-MRC grants is higher that that of the other universities (31.5% vs 25.9% for SSHRC, and 30.5% vs. 26.9% for NSERC-MRC), the difference is barely significant for SSHRC (one sided p=0.06) and is not significant for NSERC-MRC. And the rates of increase of the universities private sector orientation during the period under study are similar for both groups. For the percentage of grants received by eligible professors, we observe no difference in private sector orientation between universities with high percentage of SSHRC scholars and the others. For NSERC-MRC, on the other hand, the twelve universities with a lower percentage of NSERC-MRC scholars have a weakly higher private sector orientation (31.9% compared with 26.0% for the group of twelve universities with a high percentage of NSERC-MRC scholars (one sided p=0.05). This does support weakly Mansfield and Lees findings of the appeal of good-to-average universities for industry (Mansfield and Lee 1996).

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[20] For Social Sciences and Humanities Research Council grants, and jointly for Natural Sciences and Engineering Research Council and Medical Research Council grants, average size of the grants received, and percentage of eligible professors with grants (Data prepared and published by Maclean s magazine, November 15, 1999 issue on Universities in Canada).

[21] Bibliometric data on each university could have been another relevant measure, using, for example, the data bank of the Observatoire des sciences et technologies of the Centre Interuniversitaire de Recherche sur la Science et la Technologie (CIRST) in Montreal; see Godin, Gingras, and Davignon (1998).

As for the total sponsored research budgets analysed in the previous section, a factor analysis has been performed to take into account the relationships existing between the various operating characteristics of the universities considered in this study. As was summarized in table 4, five factors summarizing 88% of the variance of the explanatory variables were retained. They represented the research orientation, size, and health sciences orientation of the universities (F1), their academic excellence (F2), their mathematics and physical sciences orientation (F3), their engineering and applied sciences orientation (F4), and their agriculture and biological sciences orientation (F5). As summarized in Table 7, the universities private sector research orientations are significantly correlated with *F1*, and somewhat correlated with *F3*, thus confirming their links with university size and research orientation as well as health sciences and mathematics and physics orientations. They are not correlated with the level of sponsored research at the university (*spon.res.*) or the change in that sponsored research (*ch.sp.re.*). Noteworthy is the lack of a direct link between academic excellence (*F2*) and the percentage of sponsored research budgets coming from the private sector. Mansfield and Lee s US findings could have led to an expectation of a negative relationship. The change in private sector orientation of university research over the 1986-92 to 1992-98 period is positively related with the change in sponsored research funding over the past decade (*ch.sp.re.*; this is logical if increased research funding is received at least in part from the private sector) and with the current private sector orientation of the research (*priv.sect.or.*), and negatively correlated with size, research orientation, and health sciences (*F1*). That negative relationship between the change in private sector orientation and university size and research orientation *when controlling for the effects of the change in sponsored research budget funding and of current private sector orientation* supports the

hypothesis that the private sector may be a source of research funding increasingly used by the smaller universities.

In their US study, Mansfield and Lee (1996) observed that the amount of business research sponsorship received by universities was decreasing rapidly with distance, in particular for universities of average quality.

Table 7 Study of private sector research orientations and their relative change over the period 1982-92 to 1992-98 through regression analysis.

Regression Model for private sector orientation of university research in 1992-98" (R2=0.38, p=0.014)

Independent variables: Principal factors (From Table 4) and other variables								
	F1	F2	F3	F4	F5	F6	spon.res.	ch.sp.re.
coefficients	4.78	---	2.79	---	---	---	---	---
(p-values)	(0.011)		(0.11)					

Regression model for relative change in private sector orientation, 86-92 to 92-98, (R2=0.44, p=0.017)

Independent variables: Principal factors (From Table 4) and other variables								
	F1	F2	F3	F4	F5	F6	spons.res	ch.sp.re. Priv sect or.
coefficients	-0.18	---	---	---	---	---	---	+0.81 +0.015

Assuming that the proximity of a large number of businesses, as in a large metropolitan area, would increase the likelihood of industrial research sponsorship, an analysis of the relationship between private sector orientation, academic quality, and the size of the metropolitat area where the university is located, was performed. An ANOVA model was used with binary variables representing the size of the university s metropolitan area (larger or smaller than 800,000 inhabitants), and the size of the average SSHRC grants (above and below the median of $3,800) and NSERC-MRC grants (above and below the median of $46,000) received by university staff.

ANOVA models, Scheffe paired tests, and multiple regressions models (to reduce the effect of the small number of observations in some cells), with and without interactions, were used to model the sponsored research budgets, the private sector orientations of the research, and their changes over time. The only statistically significant effects observed were the higher sponsored research budgets of universities above median for both SSHRC and NSERC-MRC grants compared with the universities above median for only one type of grant and those below median, and the higher rate of increase of sponsored research budgets between 1986-92 and 1992-98 for the universities above median for both SSHRC and NSERC-MRC compared with the below median universities, thus confirming an increasing concentration of sponsored research in the best academic universities, and consistent with what had been concluded in the first part of this paper. It is noteworthy that it is the interaction of SSHRC and NSERC-MRC which leads to the most significant models rather than simply data on NSERC-MRC and on SSHRC, an outcome not completely surprizing as our analysis is based on the total research funding received by universities and on mean values rather than on case by case analyses. Models dealing with the private sector research orientation of universities and on the change in that private sector orientation were non significant, as were all the effects and interactions related to the size of the metropolitan area. The hypothesis on the expected private research orientation of universities of average quality in large cities is therefore not supported. This lack of significance may be due more to the small size of the sample and to the fact that most of the Canadian research universities are located in the country s largest metropolitan areas, than to the absence of actual effects and interactions.

These various analyses lead to a consistent set of general conclusions on private sector research funding at Canadian universities. They describe average characteristics and trends and may not be representative of individual universities. Because of the limited size of the population and of the sample, some important effects or trends may not have been retained for lack of statistical significance:

- Private sector research orientation (proportion of the sponsored research budgets coming from the private sector) are higher in universities with large sponsored research budgets than in the others; this is also true for universities with large operating budgets (in Canada, these are sensibly the same universities);

- Private sector research orientations and their rates of change tend to be independent of the academic excellence of the universities and of their research orientations; they seem to be also independent from their universities sponsored research budgets per full time graduate student equivalent (an indirect measure of research funding per graduate student);

- Private sector research orientations are consistently higher in the universities with the largest graduate programs in health sciences and mathematics and physics; they used to be lower in universities with large agriculture and biological programs and higher in universities with large engineering and applied science programs, but faster growth in private sector funding in agriculture and biology and lower growth in engineering has eliminated the difference; they are also higher in universities with a large combined

science, health, agriculture and engineering orientation than in the other universities;

- Private sector research orientation tends to be a function of size (size of the university, size of sponsored research budgets, size of graduate programs in a given field) rather than of the sectoral orientation of a university: it seems to be independent of the relative number of graduate students in a given field, a construct used as a measure of a university s degree of specialisation in that field.

- in universities with large agriculture and biological science programs, and with large engineering and applied science programs, the rate of change of the private research orientation of universities has been slightly higher for the universities with a lower private research orientation, thus reducing differences between universities; Globally, however, the rate of change of the private sector orientation of research has been observed to be positively related to the university s private research orientation and to the rate of change of its sponsored research budgets, and negatively correlated with university size and research orientation.

6. Conclusion

The two main conclusions of this analysis are that during the past twelve years, we have observed an increasing concentration of academic research in Canada s largest universities, the universities that are leading in academic excellence and research intensity, and that, although the

private sector funding of academic research is highest in relative terms (as a percentage of total sponsored research) at the largest universities, its rate of change seems to be positively related to its current level at a university as well as to the rate of change of the sponsored research budget at that university, and negatively correlated with the university s size and research orientation. This seems to support Mansfield and Lee s findings in the USA of the special role of business as a source of funds supporting applied research at smaller average universities.

As noted in this paper, the private sector financing of academic research has increased very significantly over the past two decades. This increase leads to two major questions for future research, a question of process and a question of outcome: what makes for successful private sector-university research linkages, and what are the results in terms of new knowledge and innovations and improved training of that privately financed research. A series of cases studies at six Canadian universities are currently in progress to attempt to answer the first question. Their focus is on the process which led to research and training contracts at these universities, the identification of the factors which facilitated or inhibited that process, the evaluation of the impact of such contracts on the researcher, the sponsoring firms, and the region.

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