The Impact of Research Grants on the Productivity and Quality of Scientific Research

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1. Introduction

The evaluation of university research continues to be a subject of much interest among policy-makers, partly because universities produce much valuable knowledge, but also because the intangible character of their output makes it difficult to properly assess the performance of public investments. Despite recent discussions about the transfer and commercialization of university research, however, scientific papers by researchers remain the main output of universities – besides training and producing young graduates. Bibliometrics, then, is still one of the main tools for measuring the performance of university researchers.

The literature on research evaluation has so far addressed four broad types of questions on the relationships between the inputs and outputs of academic research. Firstly, what is the impact of a given amount of money on scientific productivity? Does more money necessarily mean more papers, and what is the nature of the relationship between the two? Second, does funding have an impact on research quality? Are large sums of money a guarantee of publishing in the best papers? Third, what is the impact of the concentration of research funds among a few researchers, i.e.: how do researchers multiply sources of funding; are young researchers penalized by the peer review system? Four, has increased government demand for closer university-industry relations affected research performance with regard to output of papers?

This paper is part of a study conducted for the Natural Sciences and Engineering Research Council of Canada (NSERC) during 2002[1]. For many years, NSERC has been administering a program of grants that is virtually unique in the Western world. Instead of funding specific individual research projects, NSERC's Research Grants Program (recently renamed the Discovery Grants Program) funds Canadian researchers and their general research activities. For this reason, the majority of Canadian researchers in the natural sciences and engineering receive a research grant year in and year out. An annual budget of $240 million is currently allocated for this program.

In order to measure the impact of its grants, NSERC provided the author with the names and institutional affiliations of nearly 15,000 researchers who received funding between 1990 and 1999, plus a sample of unsuccessful (non-funded) researchers. For each researcher, our team calculated his published papers over the period in order to answer the following questions:

1. What is the role of NSERC in Canadian scientific production?
2. What impact does NSERC have on the productivity of researchers?
3. What impact does NSERC have on the quality of their research?

This paper is divided into four parts. The first part examines the contribution of NSERC-funded researchers to Canadian scientific production. It analyzes the proportion of Canadian papers that are written by these researchers, and look at how this proportion has changed over the past ten years. It also presents two indicators that are more qualitative: the proportion of funded researchers' papers written in collaboration with other authors, and the quality of the journals in which the funded researchers' papers appear, as measured by the impact factor. The third part of this paper attempts to determine the impact of NSERC's Research Grants Program in two ways. The first is by analyzing the volume and quality of funded researchers' papers as a function of the dollar amount of the grants they receive. The second is by comparing established researchers (researchers

[1] *A Bibliometric Evaluation of the NSERC Research Grants Program*, NSERC, 2002

who have received funding regularly for 10 years) with researchers who have just come into the system, and with researchers who have never received any grants.

The conclusions of this paper are that researchers funded by NSERC are responsible for the majority of Canadian papers in natural sciences and engineering, and that these papers appear in high-quality journals. The NSERC grants program has a measurable effect on research in Canada: the volume of papers grows with the level of funding. However, the correlation discriminates only those researchers with what are classified as high levels of funding. Our second conclusion is that the level of funding has no impact on the quality of the journals in which the researchers publish. Regardless of the level of funding, the quality of the journals remains the same. Only the number of papers varies.

2. Methodology

Reconstituting Publication Records

The first step in the bibliometric analysis was to construct the database corpus of papers written by researchers who are funded by NSERC. This corpus was identified by tracing the papers published by NSERC-funded researchers in journals that are indexed in the *Science Citation Index* (SCI). The list of funded researchers provided by NSERC comprises 14,837 names of researchers, each of whom received at least one grant from the agency between 1990 and 1999, plus certain other information, such as the researcher's institutional affiliation and department, the years in which grants were awarded, the amounts of these grants, the grant program, etc. Matching was performed manually using a computer interface that allowed us to cross-check this information against the information in the SCI. For each researcher, the interface located all Canadian papers for which one of the authors' names matched that of the funded researcher in question. The matching was performed mainly by cross-checking the name, institution and department, and while relatively easily done, did not allow us to reconstitute these researchers' publication records fully and accurately. This problem, which had two sources, was corrected as described below.

Problems Related to Mobility of Researchers

Though any given researcher generally submits grant applications from only one university and one department, it is still necessary to check whether that researcher has also published under a different institutional affiliation. Some researchers are affiliated with more than one institution. For example, a medical researcher may be affiliated with both a hospital and a university, and may sign some articles with one institution's name and others with the other's, or a visiting researcher may sign under the host institution's name, etc. Thus to complete any one researcher's publication record, we had to check whether, in addition to papers attributed to the right institution and the right department, we ought to include certain papers bearing the address of another institution or department. To perform each such verification, we obtained a precise understanding of the researcher's research topics and career history by searching the Internet, analyzing the titles of the papers, and applying various other triangulation procedures such as cross-checking data from various sources.

Problems Related to Variants of Authors' Names

Sometimes the name that a researcher provided when applying for a grant differed from the name that same researcher used when signing an article (for example, the author may have used initials in one case, but not in the other). In such instances, the computer interface was not able to select the appropriate articles, and automated attribution was impossible. For all cases where no paper was attributed, or where certain elements suggested that the number of papers attributed was too low, an Internet search was performed to find out more about the researcher's exact name.

When this process was completed, the publication records for 12,975 researchers had been reconstructed. For the remaining researchers, however, all efforts to identify papers failed.

3. Place of Funded Research in Scientific Production

With 24,989 papers in 1999, Canada was responsible for 4.3% of world scientific research production, which ranks it in 6th place. This percentage was down slightly from 1990, when it stood at 4.8%. Since 1999, Canada has been slightly surpassed by Italy. [2]

In 1999, the health sciences (biomedical research and clinical medicine) accounted for half of all Canadian scientific papers (49.5%). The other half was accounted for by the scientific disciplines in which NSERC is active: biology (11.6%), physics (9.3%), chemistry (9.1%), earth and space sciences (8.7%), engineering (8.2%), and mathematics (2.1%).

By far the greatest proportion of Canadian papers is produced by universities, which account for 84.0% of all Canadian scientific papers. This percentage has increased since 1990, when it stood at 75.5%. Universities are followed by the federal government, whose researchers account for 14.4% of all Canadian papers, and then by hospitals (11.5%), industry (6.3%), and provincial governments (2.6%).

Each year, an average of 7,000 Canadian researchers receive research grants from NSERC. In total, from 1990 through 1999, nearly 15,000 Canadian researchers have obtained NSERC funding (see Table 1 in the Appendix). The average annual grant, which was $25,552 in 1990, rose to $31,239 by 1999 (see Table 2), an increase of 22.2%.

In 1999, NSERC-funded researchers were responsible for nearly 12,000 scientific papers, or 48% of all Canadian papers, and 57% of all papers by Canadian universities (Figure 1 and Table 3). These percentages have changed very little since 1990. From 1990 to 1999, papers by NSERC-funded researchers grew by 13.3%, slightly less than for the university sector as a whole (15.1%), but more than for Canadian researchers overall (10.1%).

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[2] B. Godin, C. Doré (2003) and V. Larivière, The Production of Knowledge in Canada: Consolidation and Diversification, *Journal of Canadian Studies*, April 2003.

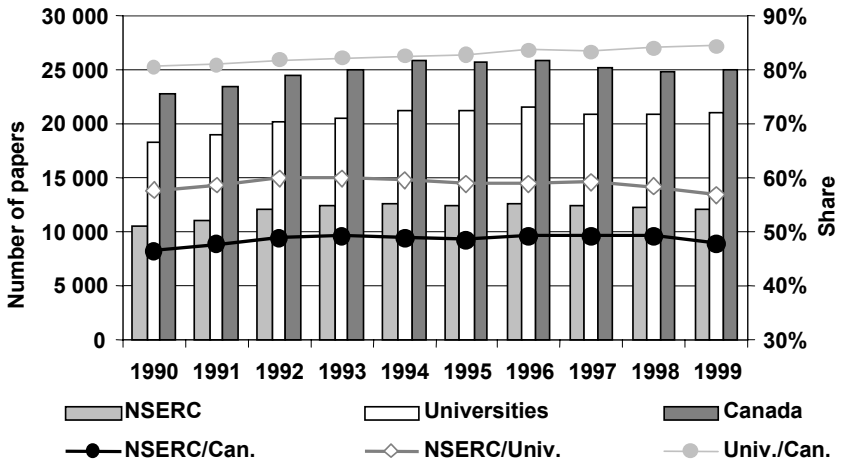


Figure 1. Number of Papers, NSERC and Canada, 1990-1999

Because NSERC's funding specifically targets research in natural sciences and engineering, its contribution to Canadian papers is not equally distributed across the disciplines (Figure 2 and Table 4). In the disciplines that define NSERC's field of activity–natural sciences and engineering–NSERC-funded researchers accounted for 70% of all Canadian papers in 1999 (up from 65% in 1990), and 85% of all papers from Canadian universities (up from 83%) (Figure 3 and Table 5). In absolute numbers, however, the volume of papers has grown very little. It totalled nearly 8,000 in 1990, climbed to over 9,000 in the mid-1990s, then fell back to slightly more than 8,300 in 1999. Overall, however, NSERC-funded researchers are responsible for a growing proportion of Canadian papers.

In 1996-99, NSERC-funded researchers authored three-quarters or more of all Canadian papers in chemistry (80.0%), physics (76.2%), engineering (74.4%), and mathematics (73.6%). Next came the earth and space sciences (63.7%) and biology (61.3%). More unexpectedly, the health science disciplines were also represented, and substantially so in

the case of biomedical research, where 43% of all Canadian papers were written by a researcher funded by NSERC.

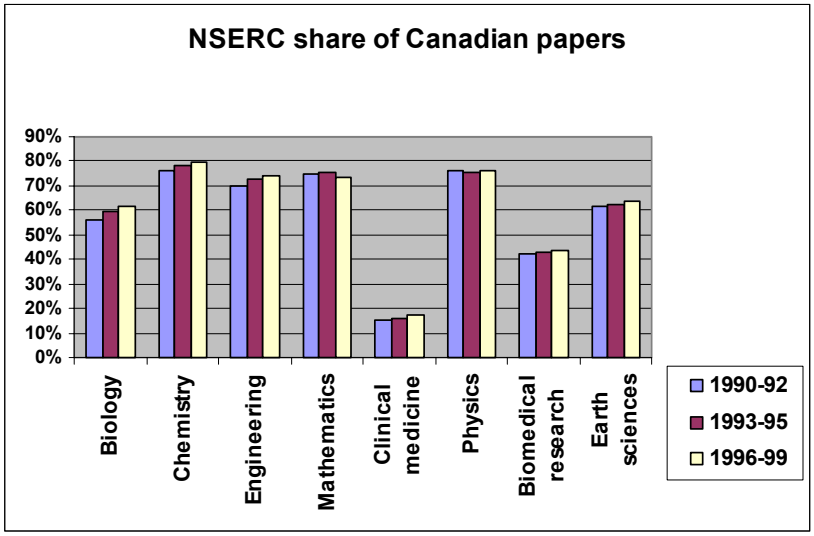


Figure 2. NSERC share of Canadian Papers, 1990-1999

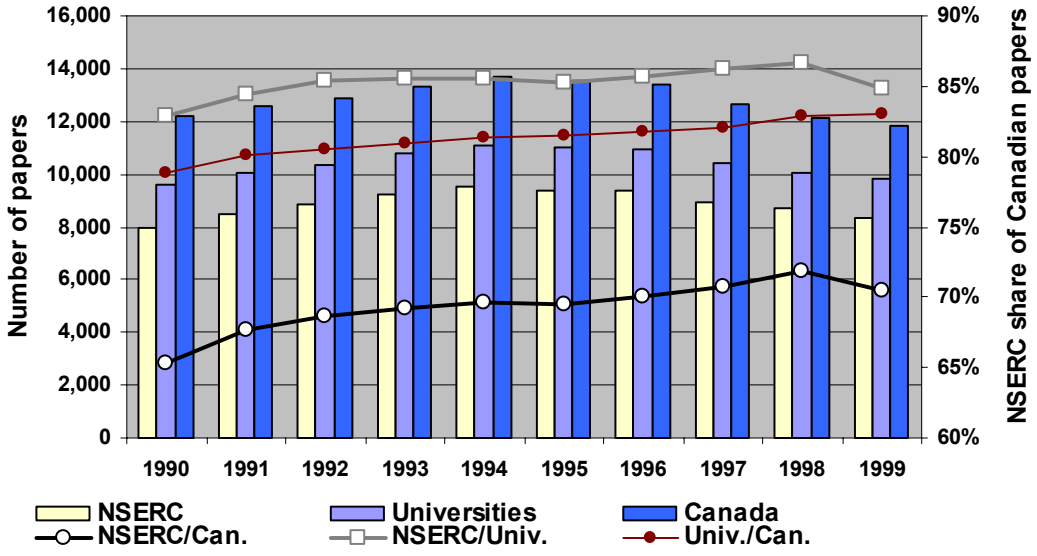


Figure 3. Papers in Natural Sciences and Engineering, NSERC and Canada, 1990-1999

Researchers with NSERC grants also made a substantial contribution to scientific papers in the university sector as a whole. Their contribution covered all science and engineering disciplines, including sub-disciplines. This contribution did vary, however, from one discipline to another, with some areas of strength and others of weakness. In 1996-99, NSERC-funded researchers authored more than three-quarters of Canadian university papers in chemistry (91.2%), physics (85.9%), engineering (90.0%) and earth and space sciences (85.2%). They also accounted for high percentages of papers in biology (81.2%) and mathematics (74.5%). These results are not surprising, since the majority of researchers in natural sciences and engineering do receive NSERC grants. Lastly, NSERC-funded researchers also authored a respectable share of university papers in the health sciences: 49.6% in biomedical research and 21% in clinical research. Figure 4 and Table 6 show trends in the number of papers in the university sector attributable to NSERC-funded researchers from 1990 to 1999.

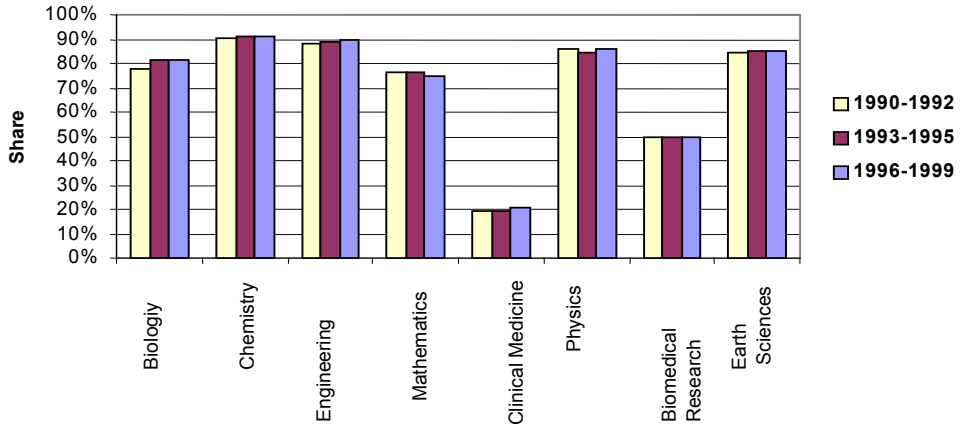


Figure 4. NSERC Share of Canadian University Research Papers, 1990-1999

On a number of more qualitative dimensions, NSERC-funded researchers also contribute, to varying extents, to Canadian performance as a whole. First of all, the international collaboration rate for NSERC-funded researchers rose from 25% in 1990 to 35.6% in 1999; in other words, one-third of all papers by NSERC-funded researchers are now

written in collaboration with foreign partners. This percentage is equal to that for the university sector (excluding NSERC-funded researchers), but slightly lower than that for Canada as a whole (ex-NSERC) (Figure 5 and Table 7). For the entire period considered in this study, the disciplines in which NSERC-funded researchers engaged in the most international collaboration were mathematics (52%)–the only discipline where NSERC-funded researchers surpass the university sector–followed by physics (42%) and earth sciences (37%) (Figure 6 and Table 8). As of 1999, the highest proportion of foreign co-authors (41.6%) came from the United States, followed by the United Kingdom (10.9%), Germany (9.8%), France (9.3%), and Japan (6.8%).

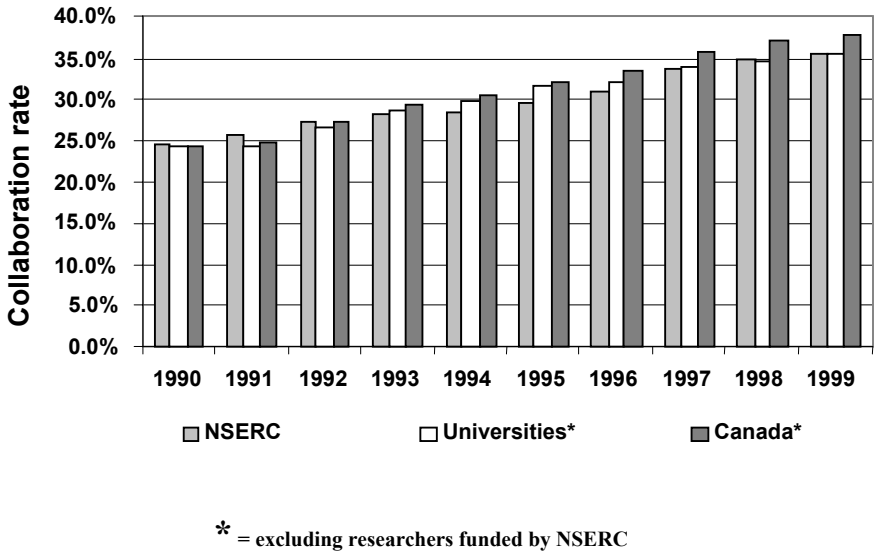


Figure 5. International Collaboration Rate for NSERC-funded Researchers, Other University Researchers, and Other Canadian Researchers, All Disciplines, 1990-1999.

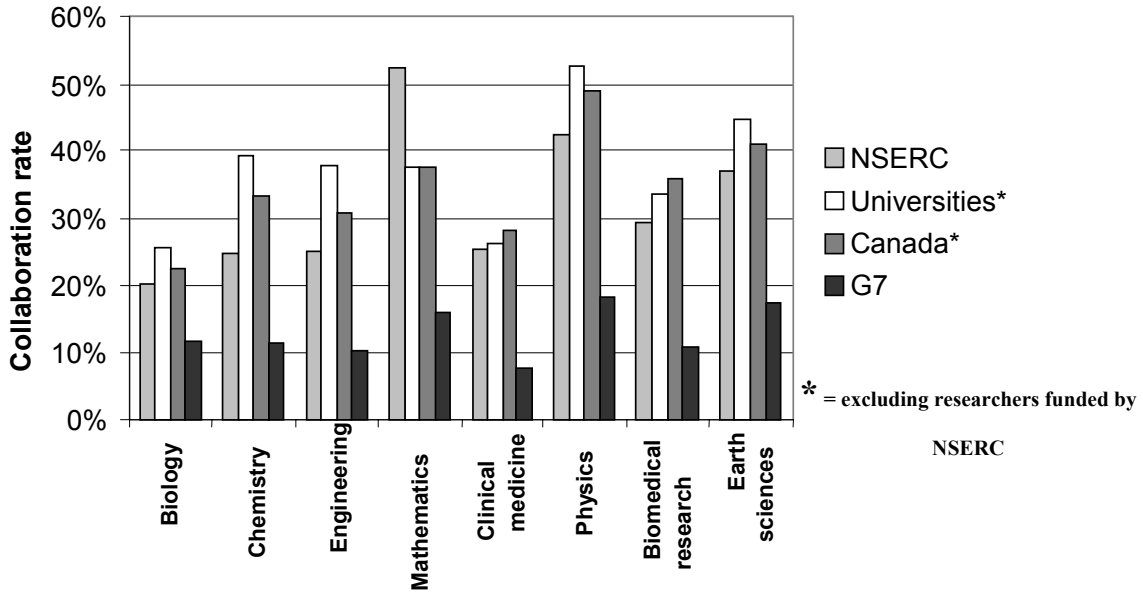


Figure 6. International Collaboration Rate for NSERC-funded Researchers, Other University Researchers, and Other Canadian Researchers, by Discipline, 1990-1999

In another form of collaboration, NSERC-funded researchers collaborate on slightly over 20% of their papers with researchers from other sectors (government and industry). This rate was 15.3% in 1990. Government researchers are the main co-authors (52.4%), while researchers in industry account for 16.0% of collaborations. This form of collaboration is most common in biology (30.9% of papers) and the earth and space sciences (27.3%). These figures are comparable in all respects with those for the Canadian university sector as a whole, which would seem to indicate that NSERC funding has no specific effect on collaboration rates.

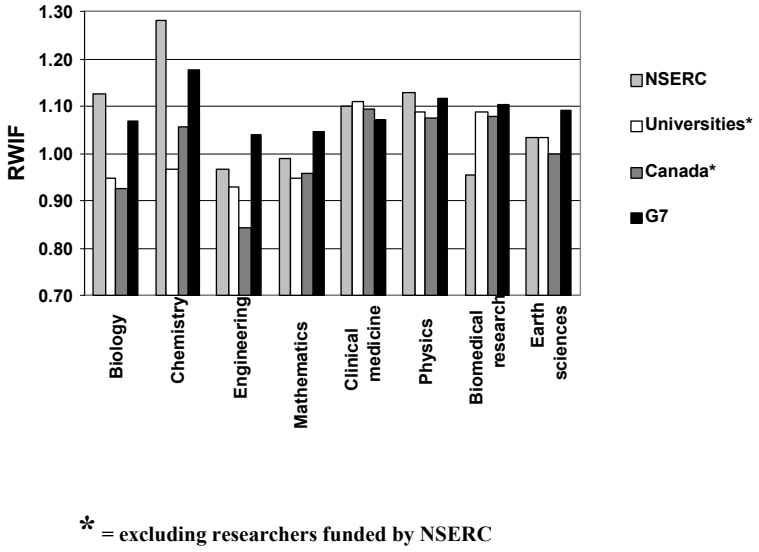


Figure 7. Relative Weighted Impact Factor (RWIF) for NSERC, Universities, Canada, and G7 Countries

To measure the "quality" of the scientific papers published by NSERC-funded researchers, we constructed a relative weighted impact factor (RWIF). The relative weighted impact factor is used to summarize, in a single value, the relative impact factors scored by a group of researchers in their various specialties, while taking into account the relative proportion of this group's production in each of the specialties. [3] In the following example, the basis for comparison is the set of all Canadian researchers, and the relative weighted impact factor for a group of researchers X is calculated as:

[3] For discussions on relative measurements, see: H.F. Moed et al. (1995), New Bibliometric Tools for the Assessment of National Research Performance: Database Description, Overview of Indicators and First Application, *Scientometrics*, 33: 381-422; A. Schubert and T. Braun (1986), Relative Indicators and Relational Charts for Comparative Assessment of Publication Output and Citation Impact, *Scientometrics*, 9: 281-291.

$$\sum\left(\frac{\text{Impact factor for group X in sub-discipline Y}}{\text{Impact factor for Canada in sub-discipline Y}} \times \frac{\text{Number of papers by group X in sub-discipline Y}}{\text{Total number of papers by group X}}\right)$$

A relative weighted impact factor greater than 1 means that the mean of the impact factors for the group in question is greater by the corresponding number of percentage points than that of the basis for comparison. Conversely, a relative weighted impact factor less than 1 means that the mean of the impact factors for the group in question is less than that of the basis for comparison.

Overall, the RWIF of the journals in which NSERC papers appear is generally greater than or equal to that for the university sector and for the rest of Canada (Figure 7 and Table 9). In comparison with the RWIF for other university researchers, for example, the RWIF for NSERC-funded researchers is 31% higher in chemistry and 18% higher in biology. Next come physics, where the advantage is slighter (5%), engineering and mathematics (4% each), and earth sciences (2%).

4. Impact of Funded Research on Scientific Production

Researchers who receive grants through the NSERC Research Grants Program produce an average of 6,000 papers annually, or about half of all papers by funded researchers for all grant programs combined. In order to look at the relationship between funding and papers, we constructed quartiles that divide the data in a rank distribution into four equal sets, each comprising one quarter of the population: Q1 = ¼ (25 %); Q2 = ½ (50% or median); Q3 = ¾ (75%); Q4 = 1 (100 %). In this paper the quartiles for funding amounts were calculated for each grant selection committee. The table below shows the intervals

for each quartile for each committee, where Q1 is the lowest amount in the distribution, and Q4 is the highest.

Average Annual Funding Quartiles for Established Researchers Receiving Grants from the Research Grants Program, by Grant Selection Committee

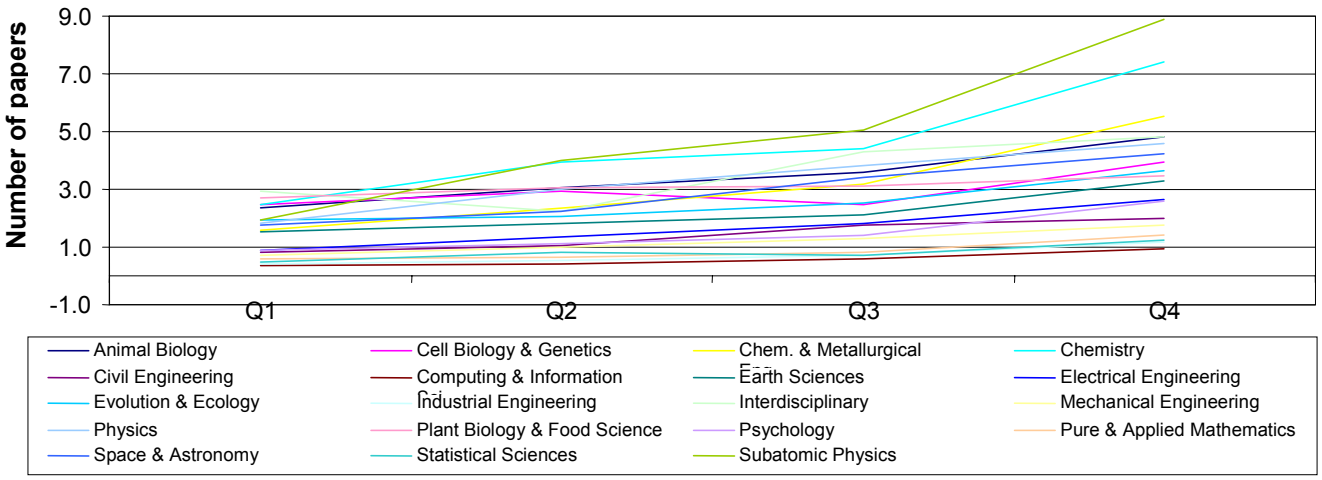
(all figures in dollars)

Committee	[Q1	] Q2	] Q3	] Q4]
Animal Biology	3 400 to 22 940	to 31 386	to 42 063	to 157 913
Cell Biology and Genetics	3 833 27 496	35 901	50 496	80 738
Chem. & Metallurgical Eng.	3 890 22 631	28 152	36 983	86 542
Chemistry	3 985 29 485	39 161	59 022	161 756
Civil Engineering	4 250 19 178	23 856	29 892	97 977
Computing and Information Science	3 190 16 593	22 677	33 826	80 259
Earth Sciences	7 051 19 576	28 081	39 122	129 272
Electrical Engineering	3 932 17 900	22 181	28 314	70 083
Evolution and ecology	4 879 21 242	30 186	42 324	104 833
Industrial Engineering	7 900 15 145	20 530	29 012	61 171
Interdisciplinary	7 051 17 157	25 021	40 987	64 549
Mechanical Engineering	9 226 19 181	23 812	30 726	71 486
Physics	5 754 20 081	28 587	37 786	97 873
Plant Biology and Food Science	10 319 21 791	32 707	44 927	118 343
Psychology	11 338 20 306	27 903	40 049	86 111
Pure and Applied Mathematics	5 338 10 355	14 420	20 963	97 873
Space and Astronomy	5 233 19 373	27 343	46 837	118 014
Statistical Sciences	3 234 9 055	12 978	17 909	135 614
Subatomic Physics	3 054 26 377	36 479	55 403	357 494

We also constructed a publication window where a paper was considered the result of funding from NSERC if it had been published by a funded researcher between the second year following the start of the grant and the second year after the end of the grant.

As can be seen from Figure 8 (and from Table 10), there is a positive correlation between funding level and number of papers, regardless of grant selection committee. The correlation does vary, however, from committee to committee. It is stronger in the case of chemical engineering and metallurgy, space and astronomy, physics, and electrical engineering, but far weaker (virtually non-existent) in biology and interdisciplinary

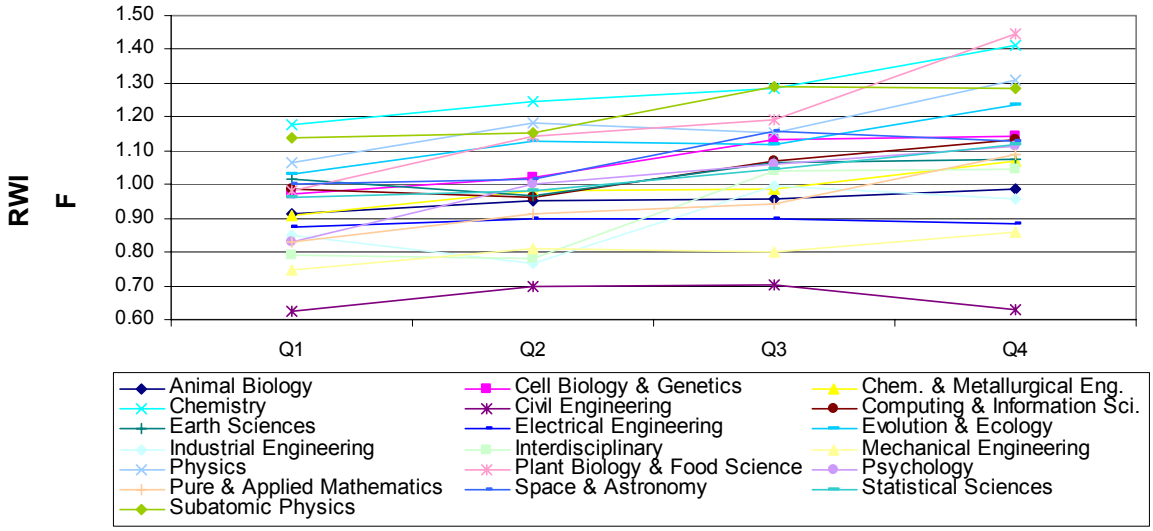
research. It should be noted, however, that the differences in scientific production by funding level are not always significant. In general, it is only when funding is relatively high (quartiles 3 and 4), that the number of papers differentiates the researchers.



Q1 = $3,190 – $19,017 Q2 = $19,018 – $26,820 Q3 = $26,821 – $38,850 Q4 = $38,851 – $357 494$

Figure 8. Average Annual Number of Papers by Established Researchers, by Funding Quartile and by Committee

There is also a very weak statistical relationship between funding level and RWIF, and a significant difference by funding level for a limited number of committees only, such as chemistry, plant biology, physics, and mathematics (Figure 9 and Table 11). From these results, we must conclude that regardless of the level of funding that researchers receive, they publish in journals of similar quality, and this quality is relatively high.



Q1 = $3,190 - $19,017 Q2 = $19,018 – $26,820 Q3 = $26,821 – $38,850 Q4 = $38,851 – $357 494$

Figure 9. Relative Weighted Impact Factor (RWIF) for Established Researchers, by Funding Quartile and by Committee

To analyze these results more closely and to measure the impact of funding from a different angle, we have constructed four groups of researchers, as follows:

Group 1. Established Researchers

This group consists of researchers who received funding every year for the entire period from 1990 to 1999.

Group 2. New Researchers Funded Since 1993

This group consists of researchers who made their first grant applications in 1993. This group, along with group 3, gives us a control group so that we can perform a quasi-experimental analysis to measure the effect of the program on new researchers.

Group 3. New Researchers not Funded in 1993

This group consists of researchers who made their first grant applications in 1993, but never received funding from the agency during the period covered by this study.

Group 4. Researchers whose Funding Terminated in 1992

This group consists of researchers who received annual funding between 1988 and 1992, but never received any more funding from 1993 to 1999.

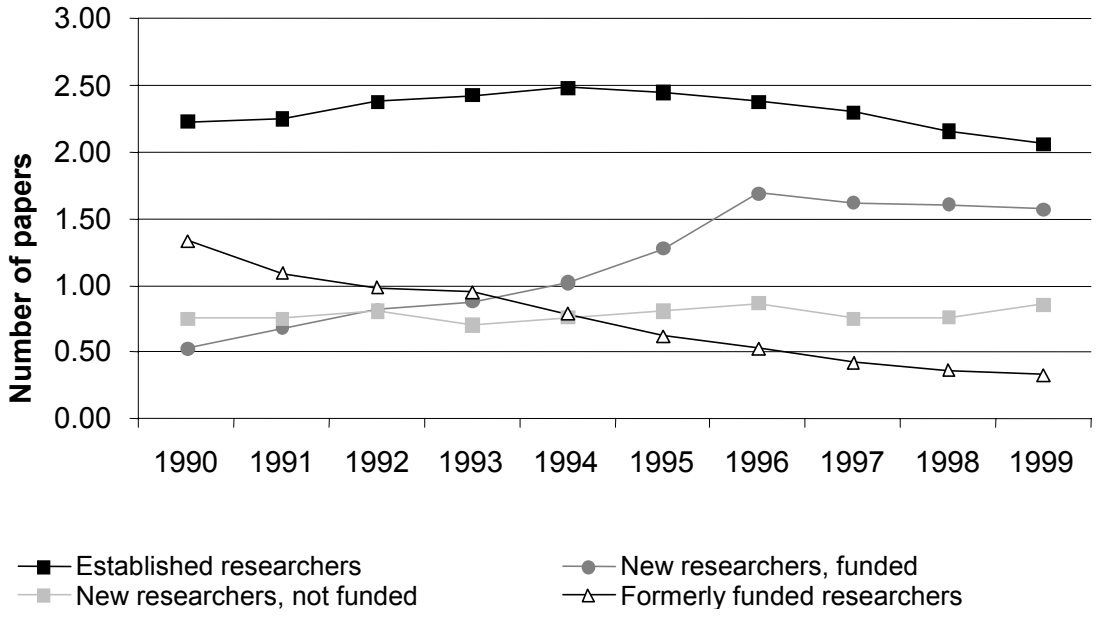


Figure 10. Productivity (average number of papers per year) for Researchers with Different Funding Histories

Figure 10 (and Table 12) reveal three facts. First, the established researchers (Group 1) produce the most papers: over 2 per year throughout the period. Their productivity has decreased slightly, however, since 1994. Perhaps some of them are slowly joining the ranks of older researchers who are winding up their careers. Second, the productivity of newly funded researchers (Group 2) has increased steadily: these went from less than one paper per year in 1993 to 1.5 in 1999, and so almost doubled (their productivity had already begun to climb before 1993). At this rate, they should catch up with the established researchers within a few years. Lastly, new researchers who did not receive funding (Group 3) have seen their productivity languish below one paper per year. In short, the data show that the funding has a definite impact on researchers' productivity,

and on the productivity of new researchers in particular. In about ten years, a young funded researcher reaches a high productivity level, whereas if not funded, that researcher stagnates.

Regarding the RWIF for researchers in the four groups, we see the same trends as before: funding has no impact on the quality of the journals in which authors publish (Figure 11 and Table 13). Apart from those researchers who have not received any funding since 1992 (Group 4), all the researchers, including those who were unsuccessful in the 1993 competition and never received any NSERC funding subsequently (Group 3), publish in journals of about the same quality.

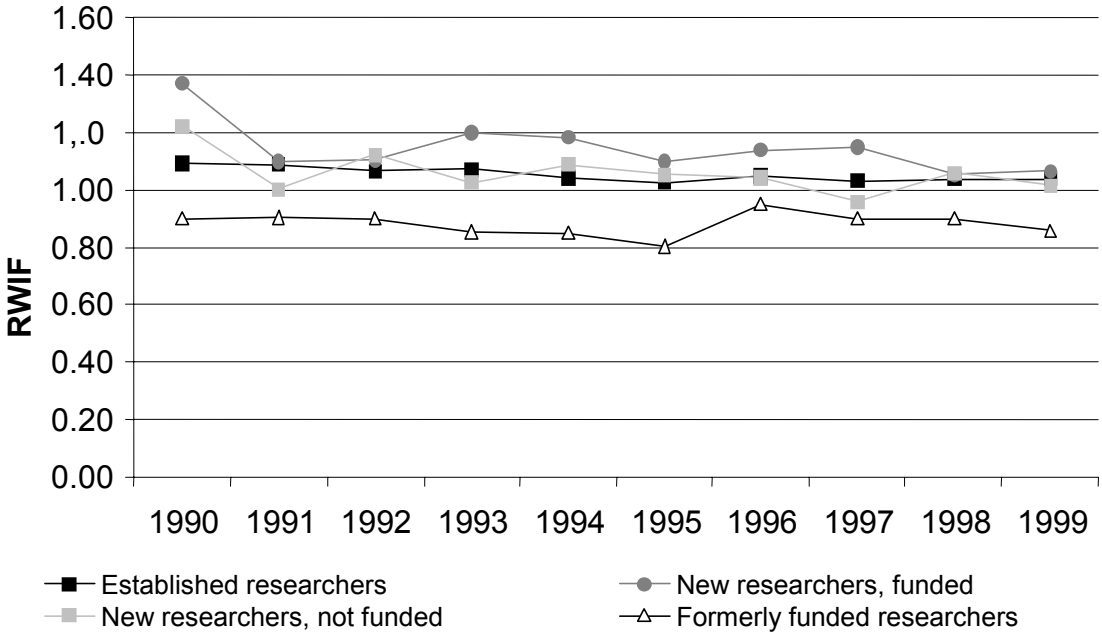


Figure 11. Relative Weighted Impact Factor (RWIF) for Researchers with Different Funding Histories

A final confirmation of these results is provided in figures 12 and 13 (and Table 14), which show the level of scientific production and the RWIF according to whether the researchers receive funding from more than one program. Researchers funded through the Research Grants Program (RGP) publish an average of 1.44 papers per year. When they

receive additional funding from another program, they publish an average of 2.12 papers per year. This figure rises to 2.29 in the case of the university/industry program, and 2.7 for the strategic grants program. Again, however, the RWIF changes only a few percentage points, regardless of whether a researcher participates in more than one program.

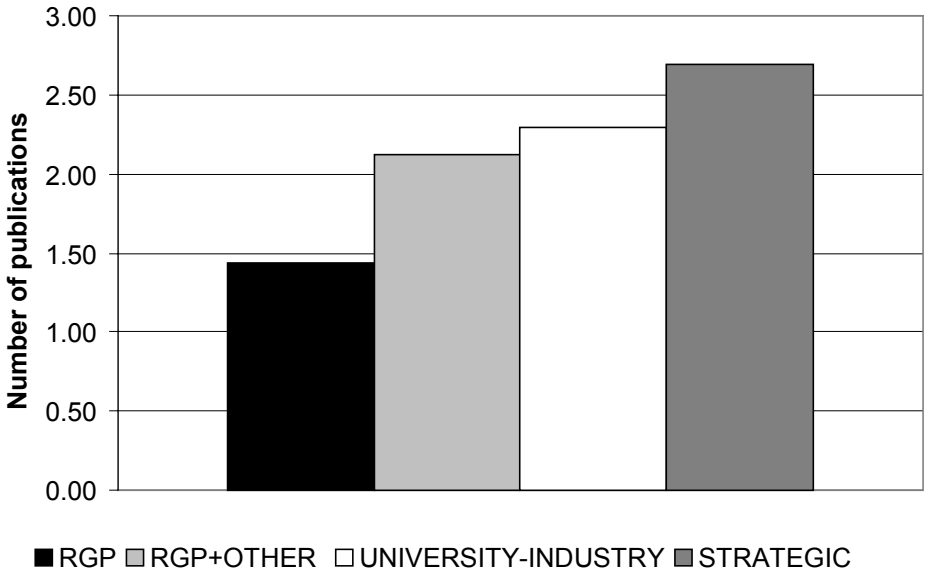


Figure 12. Average Number of Papers per Researcher by Program

4. Conclusion

The conclusions that emerge from the present analysis allow us to assess the impact of funding in two ways. First, the analysis illustrates the place of funded researchers in Canadian scientific production as a whole, and in the scientific production of Canadian universities specifically. Second, the analysis assesses funding's contribution to the productivity of the researchers whom it funds, and to the impact of their papers:

I. NSERC's place in Canadian scientific production

- Researchers funded by NSERC produce a total of about 12 000 papers annually, or 70% of all Canadian papers in natural sciences and engineering, and 85% of papers in natural sciences and engineering from Canadian universities.
- NSERC-funded researchers produce 35.6% of their papers in collaboration with foreign co-authors, and 20% in collaboration with Canadian researchers from industry and government.
- The impact factor (RWIF) of the journals in which NSERC-funded researchers publish is, overall, greater than or equal to that for researchers in the university sector and in the rest of Canada.

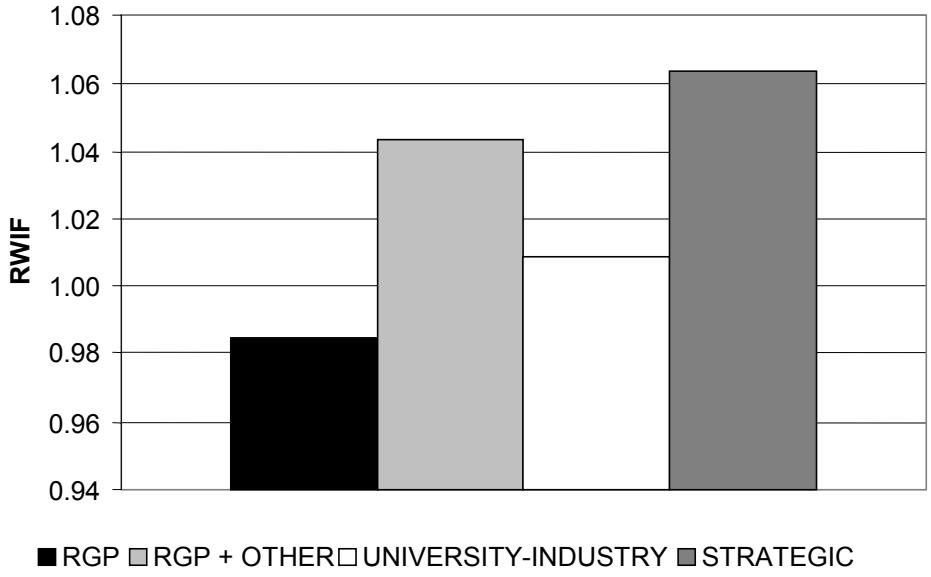


Figure 13. Relative Weighted Impact Factor (RWIF) for Researchers by Program

II. NSERC's contribution to the productivity of researchers and the impact of their research

- The funding that researchers obtain from NSERC is correlated with increased scientific productivity, and more strongly correlated when the level of this funding is high (with high defined as "above the median").
- The absence of NSERC funding and the level of funding have no impact on the quality of the journals in which the researchers publish.
- Young researchers' productivity increases steadily as soon as they obtain a research grant and, over time, tends to compare favourably with that of established researchers. Conversely, the productivity of researchers whose grant applications are rejected tends to stagnate subsequently.

One limitations of the present study deserves mention. We attributed all papers coming from funded researchers to NSERC grants. In fact, several researchers hold grants and funding from other sources as well. The only source of multiple funding we looked at was within NSERC itself. We confirmed an interesting result, however, namely that it is the high-caliber researchers (as measured by the volume of papers) who apply for university-industry funding. This result is in line with other recent studies. [4]

There is a question that the present study cannot answer, and it deals with the policy or philosophy behind the distribution of grants. The highest productivity in this study was found among those researchers who had what were classified as high levels of funding. A policy designed to participate in and influence this productivity even further could, on the one hand, offer greater funding to all researchers. In this case, NSERC would need far greater financial resources than are currently available to it for the Research Grants Program. Conversely, and on the other hand, NSERC could decide to concentrate its resources on the most productive researchers, and fund only those who performed the best. However, this would represent a complete change in the program's orientation. It would also mean betting on the notion that the "less productive" researchers are not

[4] Godin, B., Y. Gingras, The Impact of Collaborative Research on Academic Science, *Science and Public Policy*, 27 (1), 2000: 65-73.

essential to the research system. The validity of such an assumption is not obvious, given that these researchers still publish quality research, at least if the quality of the journals in which they publish is any indication.

Appendix

Table 1. Number of Researchers Funded Annually (RGP), 1990-1999

Year	Est. Researchers	Other	TOTAL
1990	3 740	3 403	7 143
1991	3 750	3 594	7 344
1992	3 756	3 686	7 442
1993	3 766	3 715	7 481
1994	3 768	3 676	7 444
1995	3 781	3 670	7 451
1996	3 786	3 716	7 502
1997	3 784	3 762	7 546
1998	3 767	3 843	7 610
1999	3 759	3 917	7 676

*: funded throughout the period

Table 2. Average Annual Grant (RGP), 1990-1999 (all figures in dollars)

Year	Est. Researchers	Other	TOTAL
1990	30 160	20 487	25 552
1991	31 281	20 654	26 080
1992	32 137	21 054	26 648
1993	32 615	20 905	26 800
1994	32 469	20 884	26 748
1995	32 694	20 373	26 625
1996	32 774	20 548	26 718
1997	32 864	20 709	26 804
1998	36 035	23 000	29 452
1999	38 206	24 553	31 239

Table 3. Number of Papers, NSERC and Canada, All Disciplines, 1990-1999

Year	NSERC	Universities	Canada	NSERC/Univ.	Univ./Can.	NSERC/Can.
1990	10 559	18 261	22 701	58%	80%	47%
1991	11 132	18 940	23 384	59%	81%	48%
1992	12 027	20 142	24 593	60%	82%	49%
1993	12 300	20 516	25 024	60%	82%	49%
1994	12 626	21 231	25 764	59%	82%	49%
1995	12 483	21 193	25 619	59%	83%	49%
1996	12 657	21 529	25 768	59%	84%	49%
1997	12 369	20 911	25 108	59%	83%	49%
1998	12 152	20 790	24 770	58%	84%	49%
1999	11 962	21 012	24 989	57%	84%	48%

Table 4. NSERC Share of Canadian Papers, 1990-1999

	1990-92	1993-95	1996-99
Biology	55.8%	59.3%	61.3%
Chemistry	76.0%	78.3%	80.0%
Engineering	70.0%	72.4%	74.4%
Mathematics	74.9%	75.3%	73.6%
Clinical Medicine	15.5%	16.0%	17.6%
Physics	75.8%	75.3%	76.2%
Biomedical Research	42.5%	42.9%	43.7%
Earth Sciences	61.6%	62.5%	63.7%

Table 5. Papers in Natural Sciences and Engineering, NSERC and Canada, 1990-1999

Year	NSERC	Universities	Canada	NSERC/Univ.	Univ./Can.	NSERC/Can.
1990	7 970	9 620	12 199	83%	79%	65%
1991	8 480	10 037	12 540	84%	80%	68%
1992	8 851	10 365	12 881	85%	80%	69%
1993	9 206	10 760	13 299	86%	81%	69%
1994	9 519	11 124	13 679	86%	81%	70%
1995	9 406	11 033	13 548	85%	81%	69%
1996	9 401	10 974	13 425	86%	82%	70%
1997	8 966	10 401	12 669	86%	82%	71%
1998	8 700	10 034	12 113	87%	83%	72%
1999	8 336	9 823	11 829	85%	83%	70%

Table 6. NSERC Share of Canadian University Research Papers, 1990-1999

	1990-1992	1993-1995	1996-1999
Biology	77.6%	81.3%	81.2%
Chemistry	90.2%	91.0%	91.2%
Engineering	88.1%	89.1%	90.0%
Mathematics	76.0%	76.1%	74.5%
Clinical Medicine	19.2%	19.6%	21.1%
Physics	85.7%	84.4%	85.9%
Biomedical Research	49.7%	49.5%	49.6%
Earth Sciences	84.5%	85.0%	85.2%

Table 7. International Collaboration Rate for NSERC-funded Researchers, and for University Researchers and Other Canadian Researchers Excluding NSERC-funded Researchers, All Disciplines, 1990-1999

Year	NSERC	Universities	Canada
1990	24.6%	24.4%	24.4%
1991	25.8%	24.3%	24.8%
1992	27.1%	26.6%	27.2%
1993	28.2%	28.6%	29.3%
1994	28.5%	29.9%	30.5%
1995	29.6%	31.6%	32.1%
1996	30.9%	32.0%	33.5%
1997	33.7%	33.9%	35.7%
1998	34.8%	34.8%	37.1%
1999	35.6%	35.5%	37.8%

Table 8. International Collaboration Rate by Discipline, 1990-99*

	NSERC	Universities	Canada	G7
Biology	20%	26%	23%	12%
Chemistry	25%	39%	33%	11%
Engineering	25%	38%	31%	10%
Mathematics	52%	38%	38%	16%
Clinical Medicine	25%	26%	28%	8%
Physics	42%	53%	49%	18%
Biomedical Research	29%	33%	36%	11%
Earth Sciences	37%	45%	41%	17%

***: excluding NSERC-funded researchers**

Table 9. Relative Weighted Impact Factor (RWIF) for NSERC, Universities*, Canada, G7

	NSERC	Universities	Canada	G7
Biology	1.13	0.95	0.93	1.07
Chemistry	1.28	0.97	1.05	1.18
Engineering	0.97	0.93	0.84	1.04
Mathematics	0.99	0.95	0.96	1.05
Clinical Medicine	1.10	1.11	1.09	1.07
Physics	1.13	1.08	1.08	1.12
Biomedical Research	0.95	1.09	1.08	1.10
Earth Sciences	1.03	1.03	1.00	1.09

***: excluding NSERC-funded researchers**

Table 10. Average Annual Number of Papers for Established Researchers (RGP), by Funding Quartile

	Avg. Papers per Year by Quartile of Avg. Grant				Spearman Correlation	Significance* at p < 0.05	Significance* of Mann-Whithney U Test at p < 0.05					
Committee	**Q1**	**Q2**	**Q3**	**Q4**			**Q1 - Q2**	**Q2 - Q3**	**Q3 - Q4**	**Q1 - Q3**	**Q2 - Q4**	**Q1 - Q4**
Animal Biology	2.35	3.07	3.56	4.80	0.36	S	N	N	N	**S**	**S**	**S**
Cell Biology & Genetics	2.49	2.95	2.46	3.94	0.20	S	N	N	**S**	N	N	**S**
Chem. & Metallurgical Eng.	1.61	2.33	3.18	5.52	0.62	S	**S**	**S**	**S**	**S**	**S**	**S**
Chemistry	2.49	3.95	4.42	7.38	0.60	S	**S**	N	**S**	**S**	**S**	**S**
Civil Engineering	0.84	1.06	1.74	2.02	0.39	S	N	**S**	N	**S**	**S**	**S**
Computing & Information Sci.	0.33	0.41	0.59	0.97	0.40	S	N	N	**S**	**S**	**S**	**S**
Earth Sciences	1.51	1.81	2.13	3.30	0.40	S	N	N	**S**	**S**	**S**	**S**
Electrical Engineering	0.89	1.35	1.83	2.65	0.48	S	N	N	N	**S**	**S**	**S**
Evolution & Ecology	1.94	2.05	2.56	3.65	0.43	S	N	N	**S**	N	**S**	**S**
Industrial Engineering	0.39	0.53	0.69	1.16	0.44	S	N	N	N	N	**S**	**S**
Interdisciplinary	2.95	2.26	4.30	4.85	0.38	S	N	N	N	N	N	N
Mechanical Engineering	0.73	0.97	1.28	1.79	0.45	S	N	N	N	N	**S**	**S**
Physics	1.84	3.00	3.84	4.59	0.49	S	**S**	N	N	**S**	**S**	**S**
Plant Biology & Food Science	2.70	3.07	3.13	3.50	0.18	S	N	N	N	N	N	N
Psychology	0.91	1.13	1.39	2.58	0.35	S	N	N	N	N	**S**	**S**
Pure & Applied Mathematics	0.62	0.67	0.84	1.38	0.41	S	N	N	**S**	N	**S**	**S**
Space & Astronomy	1.76	2.22	3.40	4.21	0.54	S	N	**S**	N	**S**	**S**	**S**
Statistical Sciences	0.48	0.80	0.73	1.25	0.41	S	N	N	N	N	N	**S**
Subatomic Physics	1.94	3.98	5.05	8.91	0.42	S	**S**	N	N	**S**	**S**	**S**
Note: S = Significant N = Non-Significant												

* S = Significant ; N = Non-Significant

Table 11. Relative Weighted Impact Factor (RWIF) for Established Researchers (RGP), by Funding Quartile

	Weighed Impact Factor by Quartile of Avg. Grant				Spearman Correlation	Significance* at p < 0,05	Significance* of Mann-Whithney U Test at p < 0,05					
Committee	**Q1**	**Q2**	**Q3**	**Q4**			**Q1 - Q2**	**Q2 - Q3**	**Q3 - Q4**	**Q1 - Q3**	**Q2 - Q4**	**Q1 - Q4**
Animal Biology	0,91	0,95	0,96	0,99	0,16	S	N	N	N	N	N	N
Cell Biology & Genetics	0,97	1,02	1,14	1,14	0,26	S	N	N	N	N	**S**	**S**
Chem. & Metallurgical Eng.	0,91	0,98	0,98	1,07	0,23	S	N	N	N	N	N	**S**
Chemistry	1,18	1,25	1,28	1,41	0,29	S	N	N	N	N	**S**	**S**
Civil Engineering	0,63	0,70	0,70	0,63	*-0,01*	*N*	N	N	N	N	N	N
Computing & Information Sci.	0,98	0,96	1,07	1,13	0,18	S	N	N	N	N	**S**	**S**
Earth Sciences	1,02	0,97	1,06	1,08	0,17	S	N	N	N	N	N	N
Electrical Engineering	0,88	0,90	0,90	0,89	*0,08*	*N*	N	N	N	N	N	N
Evolution & Ecology	1,03	1,13	1,12	1,24	0,23	S	N	N	N	N	N	**S**
Industrial Engineering	0,85	0,77	0,99	0,95	0,27	S	N	N	N	N	**S**	N
Interdisciplinary	0,79	0,78	1,04	1,05	0,34	S	N	N	N	N	N	N
Mechanical Engineering	0,75	0,81	0,80	0,86	0,26	S	N	N	N	N	N	**S**
Physics	1,06	1,18	1,15	1,31	0,29	S	N	N	**S**	N	N	**S**
Plant Biology & Food Science	0,98	1,14	1,19	1,44	0,39	S	N	N	N	**S**	**S**	**S**
Psychology	0,83	1,00	1,06	1,11	0,34	S	N	N	N	N	**S**	**S**
Pure & Applied Mathematics	0,83	0,91	0,94	1,09	0,35	S	N	N	N	N	**S**	**S**
Space & Astronomy	1,00	1,02	1,16	1,13	0,28	S	N	N	N	N	N	N
Statistical Sciences	0,96	0,98	1,05	1,12	0,21	S	N	N	N	N	N	N
Subatomic Physics	1,14	1,15	1,29	1,28	*0,15*	*N*	N	N	N	N	N	N

* S = Significant; N = Non-Significant

Table 12. Productivity (average number of papers per year) of Researchers (RGP), by Funding History

Year	Established Researchers	New Funded	New Not Funded	Formerly Funded Researchers
1990	2.22	0.53	0.75	1.34
1991	2.25	0.68	0.75	1.09
1992	2.38	0.81	0.81	0.98
1993	2.42	0.88	0.70	0.95
1994	2.48	1.02	0.76	0.79
1995	2.44	1.28	0.81	0.62
1996	2.38	1.69	0.87	0.53
1997	2.29	1.62	0.75	0.42
1998	2.16	1.61	0.76	0.36
1999	2.07	1.57	0.85	0.33

Table 13. Relative Weighted Impact Factor for Researchers (RGP) by Funding History, 1990-1999

Year	Esatblished Researchers	New Funded	New Not Funded	Formerly Funded Researchers
1990	1.09	1.37	1.22	0.90
1991	1.09	1.10	1.00	0.91
1992	1.06	1.10	1.12	0.90
1993	1.07	1.20	1.03	0.85
1994	1.04	1.18	1.09	0.85
1995	1.03	1.10	1.05	0.80
1996	1.05	1.14	1.05	0.95
1997	1.03	1.15	0.96	0.90
1998	1.04	1.06	1.06	0.90
1999	1.04	1.06	1.01	0.86

Table 14. Average Annual Number of Papers and RWIF by Researcher and Program

	No. of Papers	RWIF
RGP	1,44	0,98
RGP+OTHER	2,12	1,04
UNIVERSITY-INDUSTRY	2,29	1,01
STRATEGIC	2,70	1,06