Evaluating British Columbia's Performance in Health Research:

Technical Report 1999-2006

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Executive Summary

The purpose of this report is to evaluate British Columbia's performance in health research over the past several years. The analysis reveals some very positive trends in health research in BC as well as some opportunities for further improvement. The findings can be summarized as follows:

- BC's success in competing for health research funding has improved significantly across a number of sectors, including national grant funding from the Canadian Institutes of Health Research (CIHR), and funding from private, not-for-profit sources. BC has also registered the largest relative gains in private sector sponsorship of health-related research and development compared to other jurisdictions. Nevertheless, there remains considerable room for further expansion of BC health research funding in all these sectors.

- The increase in funding (from CIHR, private industry, not-for-profit organizations, and foreign sources combined) attributable to BC's increased competitiveness is conservatively estimated to be $577 million from 2000 to 2005 inclusive.

- Measures of the quality of health research also demonstrate very positive trends in BC. Of the four major provinces, BC showed the largest improvement in CIHR Operating Grant success rates (a measure of the overall quality of research submissions), but again much further improvement remains possible. BC currently ranks first among the four large provinces in terms of success rates in CIHR Personnel Awards.

- The Average Relative Impact Factor (ARIF) for BC's health-related scientific researchers — a measure of the quality and impact of their research findings — has shown the strongest growth of any province over the past six years, and now leads the country. Considerable room still remains for BC to improve, however, if it is to compare with U.S. counterparts such as Washington state.

- Indicators of international collaboration, which assess the involvement of health researchers at the international level, have also shown strong growth in BC over the past six years, and BC now significantly leads all other provinces in this area.

- BC's overall health research output, as measured by annual production of health-related scientific publications, has demonstrated exceptional growth in recent years. Despite this, however, the province still lags behind other comparators in terms of *health research output per capita* and *health specialization index*. Some preliminary but inconclusive evidence suggests that this might be due to a lower number of health researchers (per capita) in BC.

This report forms part of MSFHR's commitment to evaluate the return on public investment in health research in BC on a continuing basis. The Foundation will receive and analyze ongoing updates of these and more specific data to allow more precise evaluations of its own funding programs and BC's overall performance in health research in the future.

About this Report

In an effort to evaluate progress in health research in British Columbia over the past several years, the Michael Smith Foundation for Health Research (MSFHR) has generated this compendium of indicators that describe and define sectoral progress. This report represents the first step in an ongoing evaluation of performance indicators of health research in BC, and a continuing assessment of the return on investments in health research.

Information sources for this report are specified where they were utilized, and comprise data supplied by the Canadian Institutes of Health Research (CIHR); Statistics Canada; and a bibliometric analysis commissioned from Science-Metrix (Montreal, Quebec) and the Observatoire des Sciences et des Technologies (OST; Montreal, Quebec).

The report consists of three sections, each taking a slightly different perspective on the evaluation of progress in health research. The first section, ***Funding***, compares health research resources granted to BC researchers from different sources (federal, private sector, not-for-profit foundations, and foreign sources) against those granted to other provinces. The second section, ***Impact and Quality***, uses internationally recognized measures of scientific impact to assess BC's health research activity compared to other provinces. And the final section, ***Output and Capacity***, considers health research output measured in relative quantitative terms across jurisdictions. The Appendix provides detailed descriptions of each of the report's metrics, including explanations of the analytic methodology employed.

Considerable debate continues in the health research community about the relative advantages and disadvantages of various approaches and metrics to evaluate the return on investment of expenditures in health research.[1] Additionally, issues of cost and feasibility must be considered. On the one hand, direct measures focusing specifically on research output and quality within large jurisdictions require large amounts of primary data collection and would be prohibitively expensive. On the other hand, data on funding levels and bibliographic impact are readily available at far lower cost. This report relies on the latter type of data, and it must be recognized that these are only proxy measures of research effectiveness. Reasonable criticisms about the validity and precision of each metric can be raised. In such considerations, the critical question remains whether there are mechanisms by which these metrics would be ***systematically*** different across jurisdictions such as provinces in their ability to reflect, albeit indirectly, the true underlying quality and effectiveness of health research.

[1] See for example, *Medical research: assessing the benefits to society.* A report by the UK Evaluation Forum, supported by the UK Academy of Medical Sciences, Medical Research Council and Wellcome Trust, May 2006.

Funding

This first section evaluates BC's performance in attracting research funding from a number of sectors: national public funding agencies (primarily CIHR), private industry sponsors, not-for-profit organizations and foreign sources. Because CIHR data include information on research themes, this report later provides a more in-depth analysis of CIHR funding in order to better identify opportunities in different areas of health research.

In 1999/2000, analysis of Canadian federal (MRC)[2] funding for health research indicated that investigators in British Columbia were competing successfully for between eight and nine per cent of available national MRC funding. Considering that then (and now) BC is home to just over 13% of the country's population, this level of achievement was cause for concern, and provided the impetus behind efforts (led by the Coalition for Health Research in British Columbia) to gain government support for and investment in efforts to build provincial health research capacity.

Provincial Share of National (CIHR) Funding

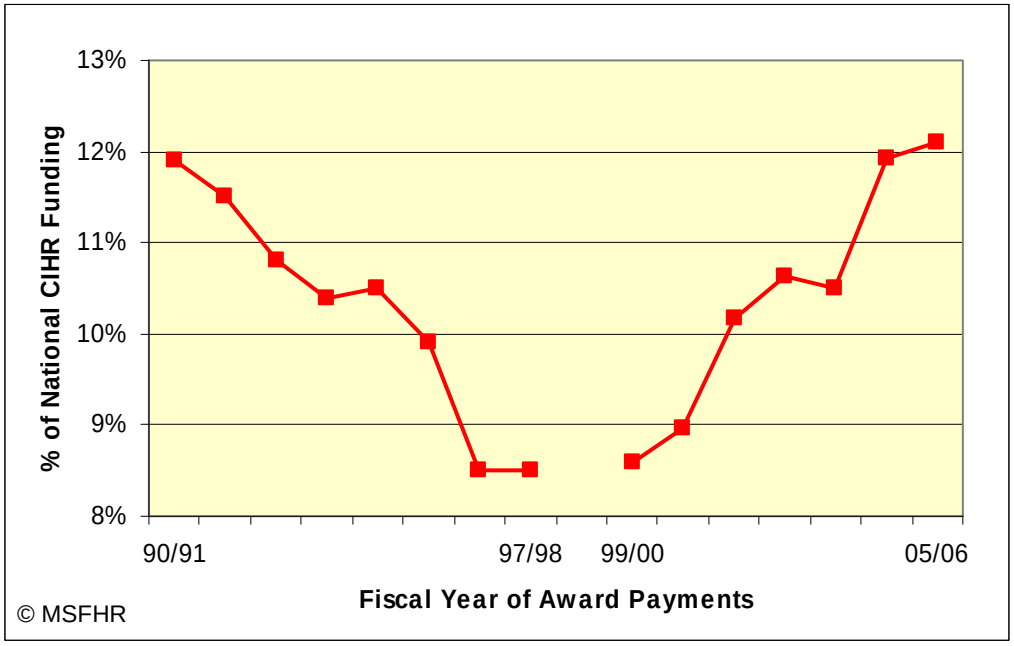

Figure 1: BC Share of MRC/CIHR National Funding 1990/91 - 2005/06

Figure 1 shows that BC's share of MRC/CIHR funding declined over the period 1990/91 to 1999/00, reaching a low of approximately 8.5%. However, over the past six years the province has experienced a complete reversal of this trend.

[2] MRC is the Medical Research Council, which was transformed into the Canadian Institutes of Health Research (CIHR) in 2000/01. MRC/CIHR is Canada's premier health research funding agency.

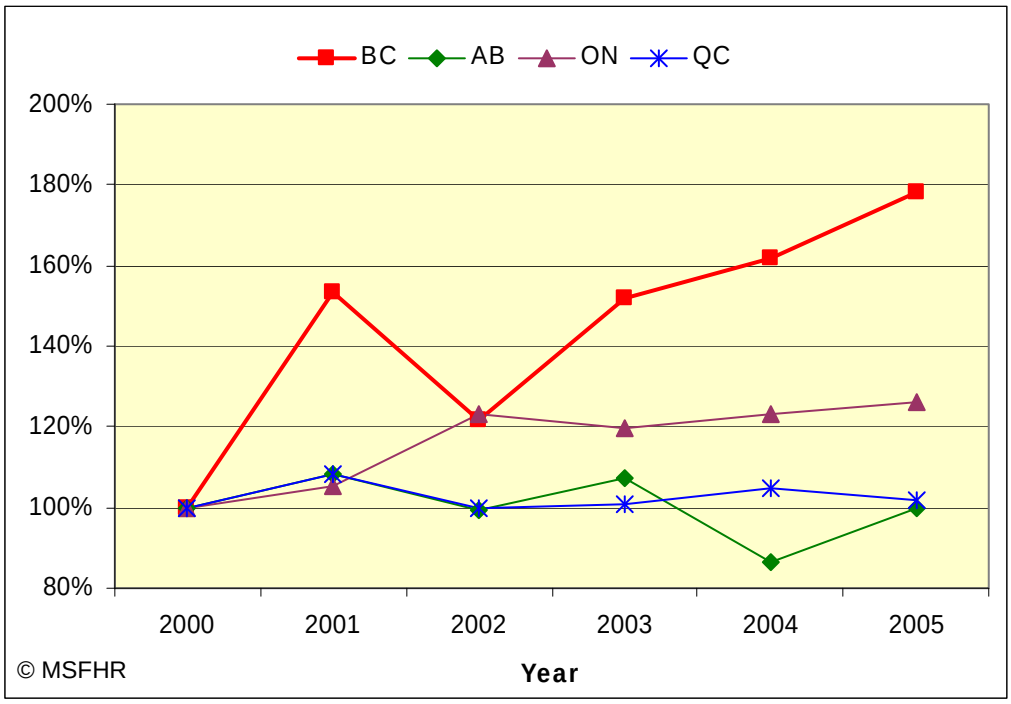

Figure 2: Growth in Number of CIHR Funded Grants, by Province. (Baseline 2000=100%)

The increasing amount of CIHR funding to BC is a direct result of the growth in the number of successful CIHR grants awarded to BC researchers. Figure 2 demonstrates that the growth in numbers of funded grants (measured against the baseline year 2000) has been greater in BC than in the three other large provinces (Alberta, Ontario, Quebec).

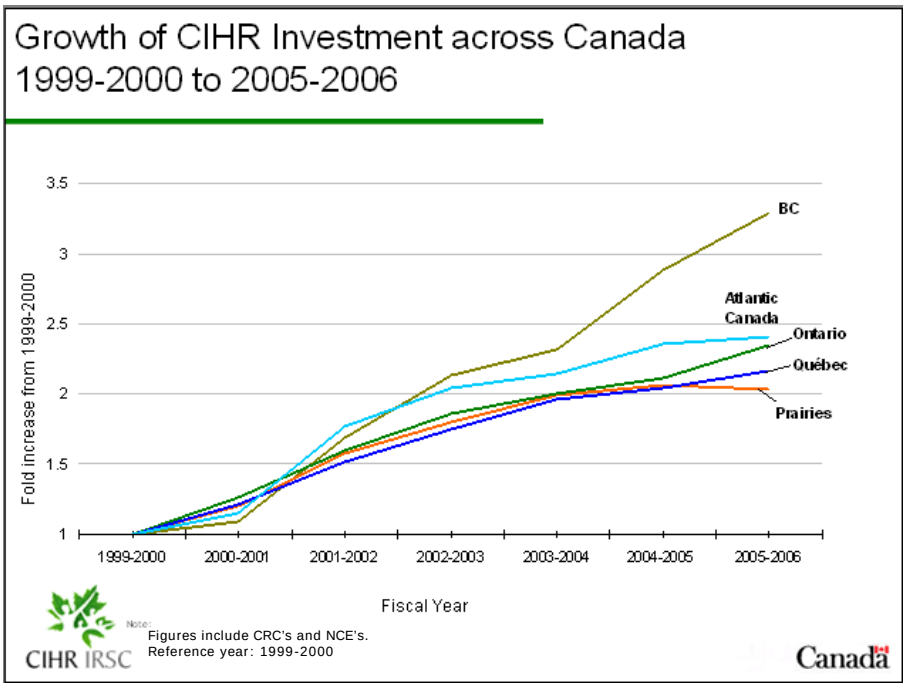

Figure 3: CIHR Graph of Increases in Funding to Regions in Canada (Baseline 1999/00)

This positive funding trend is also seen in Figure 3 (produced by CIHR), which demonstrates that over the period 1999/00 to 2005/06, CIHR funding increased more rapidly in BC than in any other region in Canada. In absolute terms, this represented an increase from $25 million to $82 million annually, a 3.3-fold increase. At the same time, the national CIHR funding envelope grew 2.4-fold, from $275 million in 1999/00 to $657 million in 2005/06.[3]

It should be noted that improvements in BC's relative performance in attracting CIHR funding should also lead to increased revenues from sources which utilize Tri-Council Agency funding levels as a basis for their funding formula. The Federal Indirect Costs of Research program is a prime example (such additional revenues are over and above any amounts included in this report).

This report also does not include funds from the Canada Foundation for Innovation or Genome Canada.

[3] CIHR figures provided by CIHR. National CIHR funding envelope consists of CIHR expenditures for Open Competitions and Strategic Initiatives, not including CIHR's Operating Expenditures.

The ratio of a province's actual share of a funding envelope within a given sector, to its equivalent-to-population share, provides a simple and readily available metric for comparing relative performance. For convenience, this ratio will be referred to as the ***funding index*** for a given envelope (see Appendix for more detailed methodology). To illustrate, in 1999/00 BC received 8.5% of national MRC funding, while its population made up 13.1% of Canada's total. If we divide this funding percentage by the population percentage (8.5%÷13.1%), the result is a funding index of 0.65. By comparison, in the same year, the province of Quebec received 30.4% of MRC funding, compared to a population share of 24.1%, yielding a funding index of 1.26.

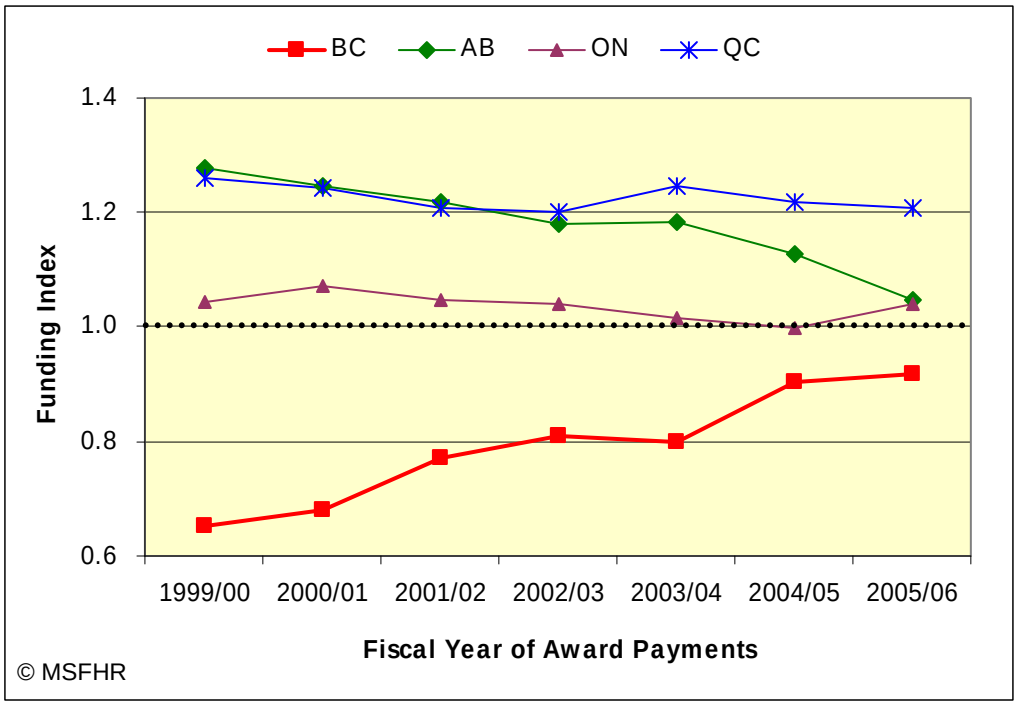

Figure 4: MRC/CIHR Funding by Province - Funding Index based on Population

Use of the funding index allows for standardized comparison with other provinces. Figure 4 presents similar data to Figure 1, but is based on the funding index. As seen before, and now in Figure 4, BC's ability to attract national MRC/CIHR funding has risen steadily since 1999/00, increasing from an initial funding index of 0.65 to the most recent available figure of 0.96 (for 2005/06). At the same time, the funding indices for the other large provinces have not increased.

A funding index of 1.0 indicates that a jurisdiction is performing on par with Canada as a whole, and reflects average performance. This is stated as a benchmark, not a goal. The aspiration of BC should be to achieve and maintain the highest funding indices possible; i.e. well above 1.0. Identifying sectors, themes, and disciplines where funding indices may be relatively low is not about detecting underperformance, but exploring for opportunities where the greatest gains might be achieved. While the recent growth in BC is very encouraging, at the same time, it is important to note that considerable opportunity remains for further improvement.

In terms of available funding, the total national annual funding (Open Competitions and Strategic Initiatives) in the CIHR budget for fiscal year 2005-06 was $657 million. Each further increase of 0.1 in BC's funding index would represent an additional $8.6 million in annual CIHR funding, not including increases if the size of the envelope were to grow.

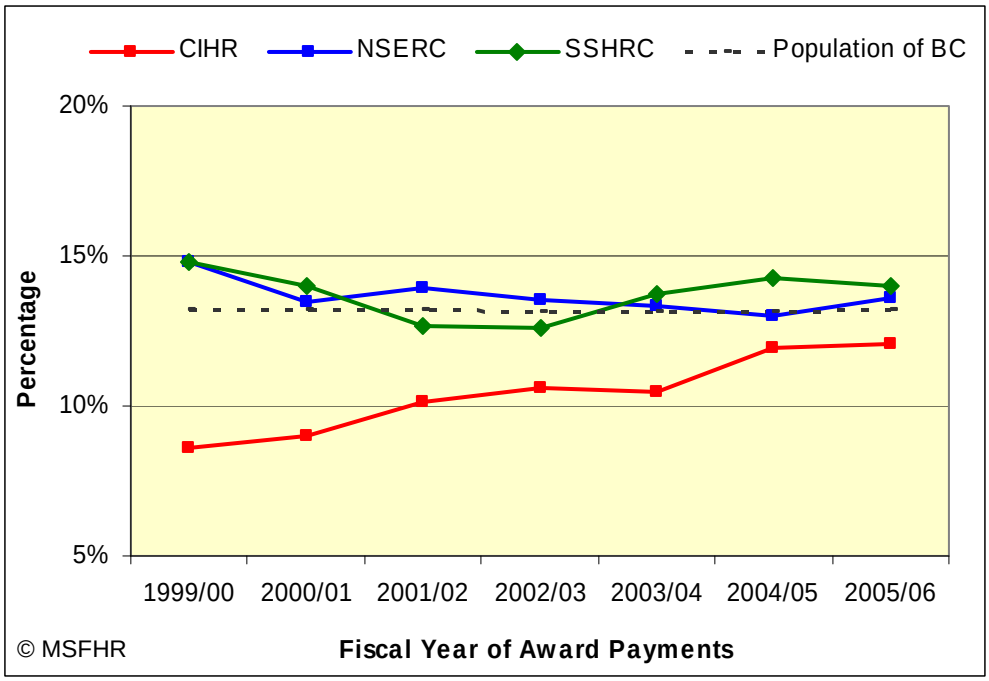

Figure 5: BC Share of National Tri-Council Agency Funding 1999/00 - 2005/06

To see whether the increased share of CIHR funding awarded to health researchers in BC may have been part of a larger trend of increased research funding in other areas of study, funding levels from the Social Sciences and Humanities Research Council (SSHRC) and the Natural Sciences and Engineering Research Council (NSERC) were also considered. As seen in Figure 5, during the period 1999/00 to 2005/06 the BC shares of NSERC and SSHRC funding were relatively constant: at or slightly above proportional population share.

Provincial Share of Spending on Health R&D from the Private Sector

Statistics Canada collects data on gross domestic expenditures on research and development (GERD) within a number of sectors. In particular, information is available on investments in health-related research and development in each province by private industry sponsors. These include, for example, pharmaceutical companies, medical device manufacturers, and biotechnology firms.

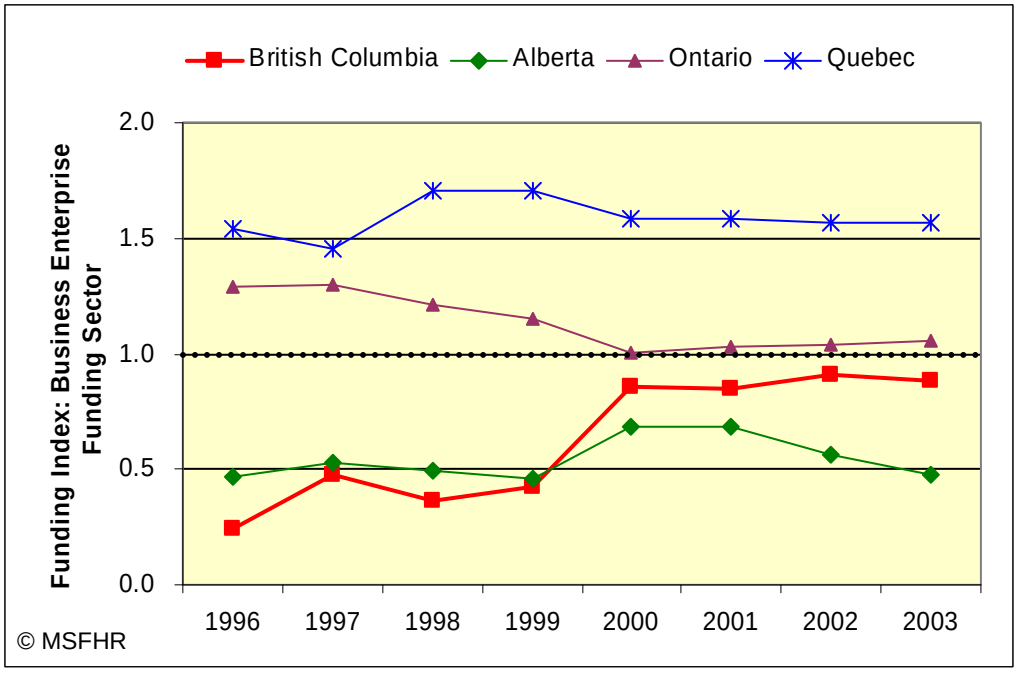

Figure 6: Gross domestic expenditures on R&D in the health field - Funding Index for Sector: Business Enterprise

Figure 6 demonstrates that BC's success in attracting private sector[4] R&D funding in health research (as reported by Statistics Canada) has increased during the period 1996 to 2003[5]. During this period, the funding index for BC more than tripled in this sector, from 0.24 to 0.88. At the same time, considerable opportunity remains for further growth in BC, as it still ranks third among the four provinces analyzed.

In absolute terms, the tripling of BC's funding index in annual private sector health research funding between the years 1996 and 2003 represented an increase from $20.0 million to $170.6 million per year. In 2003 (the most recent year for which data were available), Statistics Canada reported total national private sector R&D funding in health of $1,466 million; thus, each further increment of 0.1 in BC's funding index would represent an additional $19 million in annual funding, based on the 2003 figure. The actual amount will also rise as the total envelope increases.

[4] In this section, "Private Sector" is defined by Statistics Canada as the sector "Business Enterprise."
[5] Note: this earlier interval was utilized because Statistics Canada reports are current to only 2003.

Provincial Share of Spending on Health Research from the Private Not-For-Profit Sector

Statistics Canada also provides data on health research funding from private not-for-profit foundations. Organizations such as the Heart and Stroke Foundation, the Lung Association, and the National Cancer Institute of Canada are examples of charities that fund health research.

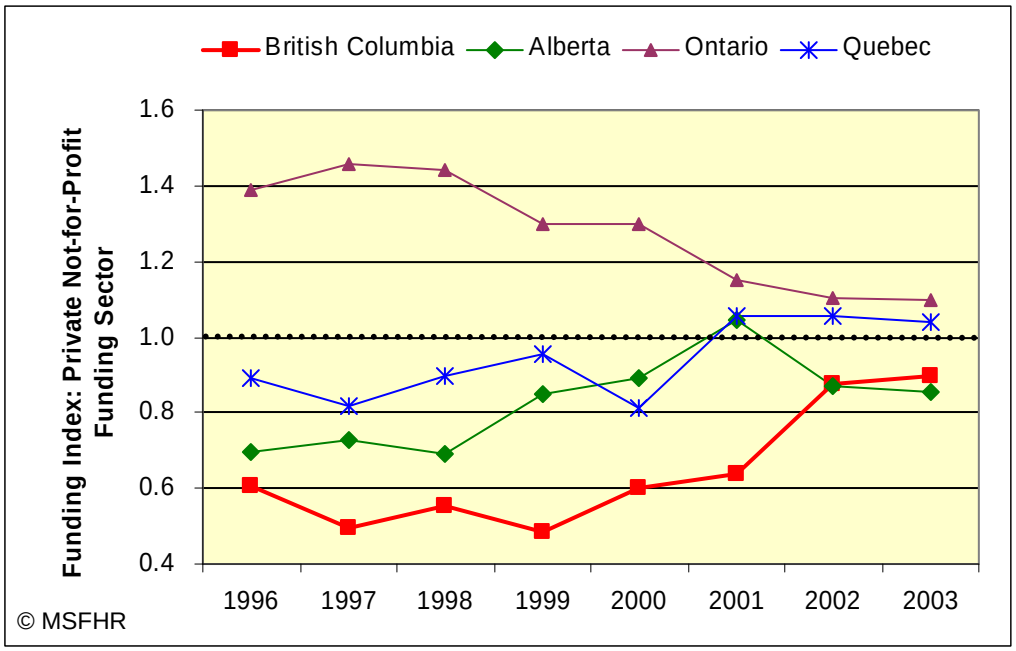

Figure 7: Gross domestic expenditures on R&D in the health field - Funding Index for Sector: Private Not-for-Profit

Figure 7 demonstrates a similar pattern of increased funding to BC, this time within the private, not-for-profit sector. BC's success in attracting funding in this sector has increased since 1996, and has shown the largest growth of the four provinces analysed. However, as the funding index for BC was still below 1.0 in 2003, much further growth remains possible. In 2003, the total size of this envelope in Canada was $391 million.

Provincial Share of Spending on Health Research from Foreign Sources

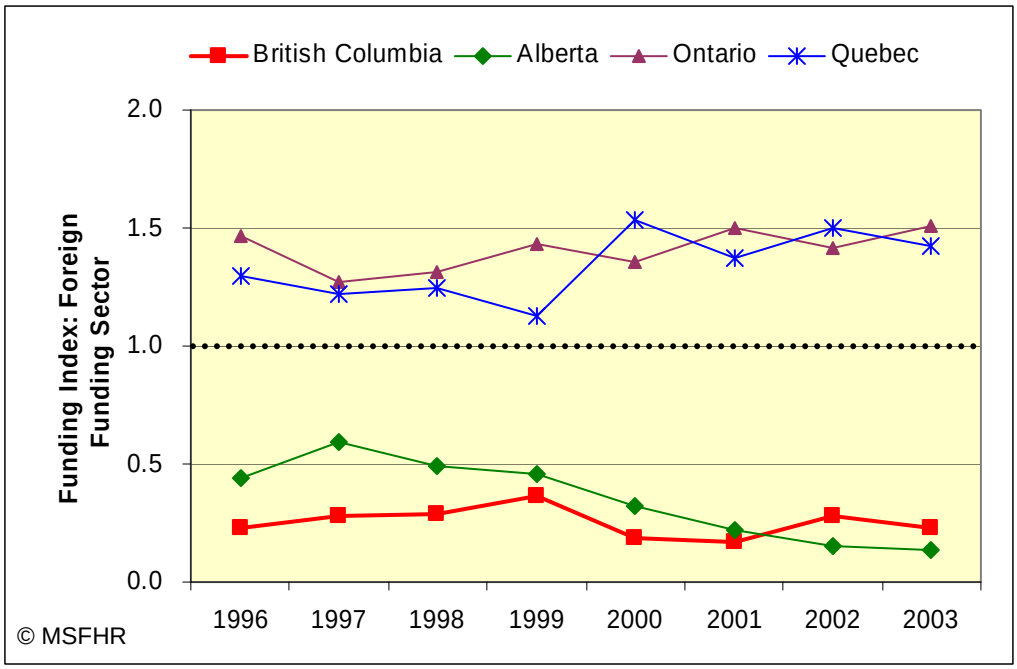

Figure 8: Gross domestic expenditures on R&D in the health field - Funding Index for Sector: Foreign

Foreign funding for health research remains the one sector in which BC's funding index has not shown growth over time. As can be seen in Figure 8, the funding index for BC has remained relatively low, while Ontario and Quebec have consistently high indices in this sector. The reasons for BC's performance are unclear and will be subject to further study.

Overall Funding Impact

To summarize, the previous analyses suggest a positive trend in BC's success in attracting health research funding in a number of sectors. The fact that this trend is present not only for CIHR grants but also for private sector and private not-for-profit health research funding suggests that this finding is not incidental. Only foreign support for health research in BC has not shown recent growth.

What do these trends mean in overall financial terms? One way to approach this is to model a no-improvement scenario in which BC's performance, as measured by the funding index in each of the four sectors (CIHR, private industry, not-for-profit, and foreign), is assumed to have remained constant at its 1999/00 index. This scenario can then be compared to the observed funding received by BC researchers.

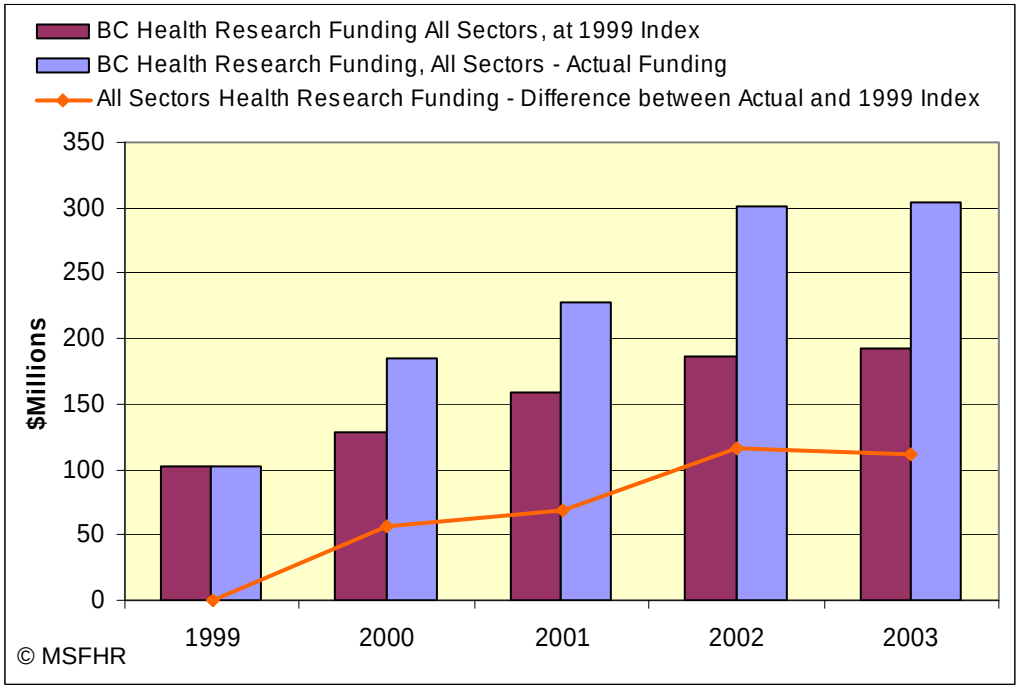

Figure 9: BC Funding Growth in Four Sectors – Actual Funding Compared to 1999 Index

Figure 9 shows the results of this analysis. The red (left) columns represent the total combined funding from the four sectors (CIHR, private industry, not-for-profit, foreign) which would have occurred each year if the funding index in each sector had remained at its 1999 index level. The reason for the increase in these amounts over time is that the combined funding envelope grew each year. The blue (right) columns show the total combined funding actually received by BC in each year, and the differences between the two bars (shown by the orange line) reflect the gains in funding in BC due to improved performance. Over the four years 2000 to 2003 inclusive, this incremental funding totalled $353 million and reached an annual rate of $112 million in the last year of analysis. Even if one assumes no further growth in the subsequent two years (2004 and 2005), a conservative estimate for the incremental funding in BC for the six years from 2000 to 2005, inclusive, would be $577 million.

BC Provincial Share of National (CIHR) Funding By Research Theme

While available Statistics Canada data do not allow any analyses into different areas or sub-fields of health research, the CIHR data do provide this level of detail. The CIHR's four research themes, by which the majority of the awarded grants are categorized, are: (1) biomedical research; (2) clinical research; (3) health services research; and (4) population health research. This more detailed level of analysis allows for examination of performance and opportunity within the different health research themes, albeit restricted to the single sector of CIHR funding.

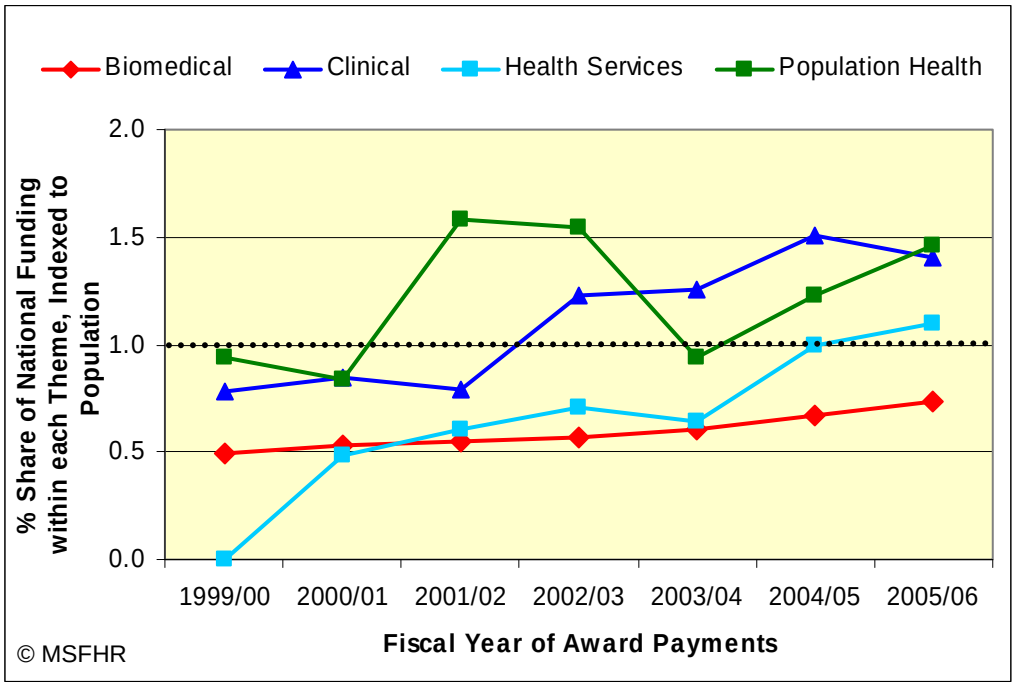

Figure 10: BC Funding Index for MRC/CIHR Funding by Research Theme

Figure 10 depicts the MRC/CIHR funding indices for BC for each of the four health research themes, over the period 1999/00 to 2005/06. In themes 2, 3, and 4, the funding indices have grown and are now at or in excess of 1.0. Theme 1 (biomedical) has seen steady growth in funding index, from 0.49 to 0.74. Room for further growth clearly exists in all four themes, but particularly in biomedical research. Given that the total available funding within the biomedical theme exceeds those of the other three themes combined, this presents an opportunity for a considerable increase in funding to BC researchers.

BC Provincial Share of National (CIHR) Funding By CIHR Institute

Analysis of data from CIHR also provides information about the funding associated with each of its 13 scientific Institutes. This information is derived from applicants, who designate the topic area of their grant proposal to the Institute most closely aligned with their research.

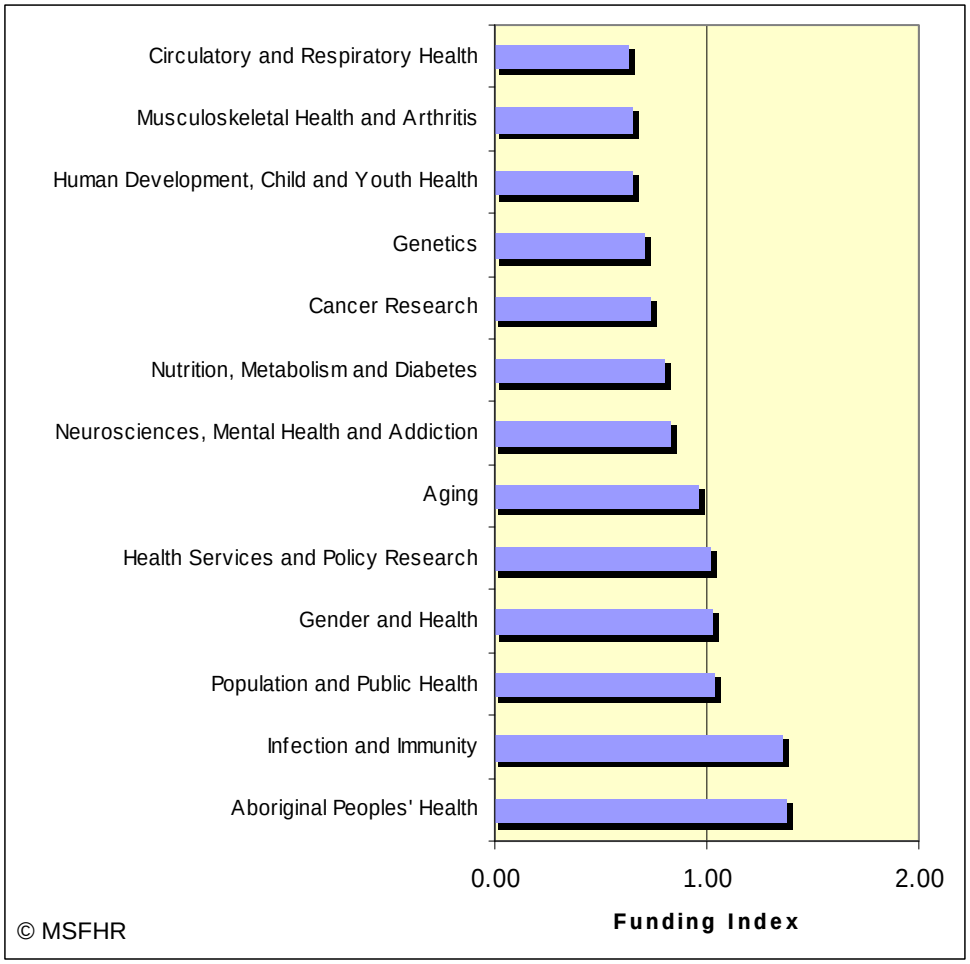

Figure 11: BC Funding Indices for CIHR Funding by Institute for Awards 1999/2000 and later.

Figure 11 displays the results of the analysis by CIHR institute[6]. Note that data in the figure represent combined funding for the entire period 1999/00 to 2005/06, and may not accurately represent relative performance in the most recent period. However, for the entire period, BC achieved funding indices below 1.0 for the first seven Institutes; at or near 1.0 for the next four Institutes; and above 1.0 for the final two Institutes. This is consistent with the observation in Figure 10, since the first seven Institutes are among those with the largest biomedical components.

[6] Source of 'Institute' field in data: applicants are asked to select a CIHR Institute by matching the research areas of their proposal to the most appropriate Institute. The Figure includes funding from strategic and open competitions.

Before jumping to conclusions about BC's relative performance in different themes and topic areas, it is important to recognize the role of capacity as a key determinant. Put simply, the CIHR funding awarded to researchers in BC in a given theme or topic is a function of the following:

- the number of researchers actively working in the theme/topic;
- the average number of proposals each researcher submits;
- the success rate of the proposals;
- the average duration of the successful grants; and
- the average size of the successful grants (in dollars).

Low funding indices in a given theme (e.g. biomedical) or topic area (e.g. genetics) could simply be a reflection of relatively lower numbers of BC researchers per capita in the given theme or topic, relative to other provinces. Capacity will be discussed in the final section of this report, keeping in mind that data regarding relative capacity in different themes are not readily available.

Impact and Quality

This section presents three common, high-level measures of research quality: **grant success rates**, reflecting the overall quality of grant submissions; **research impact**, or the relative impact of research as described by a quantitative impact rating of scientific publications reporting research findings; and **international collaborations**, which reflect the extent to which research activities in a given jurisdiction are operating on the international level.

Grant Success Rates

Grant success rates are defined as the proportion of all proposals submitted within a jurisdiction (e.g. province) that were successful in terms of receiving funding. CIHR uses national panels to adjudicate submissions equitably from all jurisdictions in Canada, and successful grants are determined by these panels, based on the panels' evaluation of the quality of the submissions. Thus, grant success rates provide a simple and effective measure of the overall quality of research proposals from different jurisdictions. Note that these rates are a measure of the *quality* and not the *volume* of research proposals.

Any analysis of trends in success rates for a jurisdiction must take into account background trends in the overall success rate which vary from year to year and across research themes. CIHR success rates have generally been declining due for the most part to rapid increases in the number of applications the agency is receiving.

One way to control for this is to utilize a **success rate index**, not dissimilar to the funding index used in the previous section. The success rate index for a jurisdiction is defined as the jurisdiction's success rate in a given category/theme/time period divided by the overall national success rate in that same category/theme/time period. For example, over the two-year period 2000-01, BC's success rate in CIHR competitions was 28.8%, compared to a national success rate of 32.8%. This yields a success rate index of (28.8%÷32.8%) = 0.88.

As with the funding index, a success rate index of 1.0 indicates that a jurisdiction is performing on par with Canada as a whole, and reflects average performance. Higher (lower) indices reflect submission of grant proposals that are of higher (lower) quality than the national average.

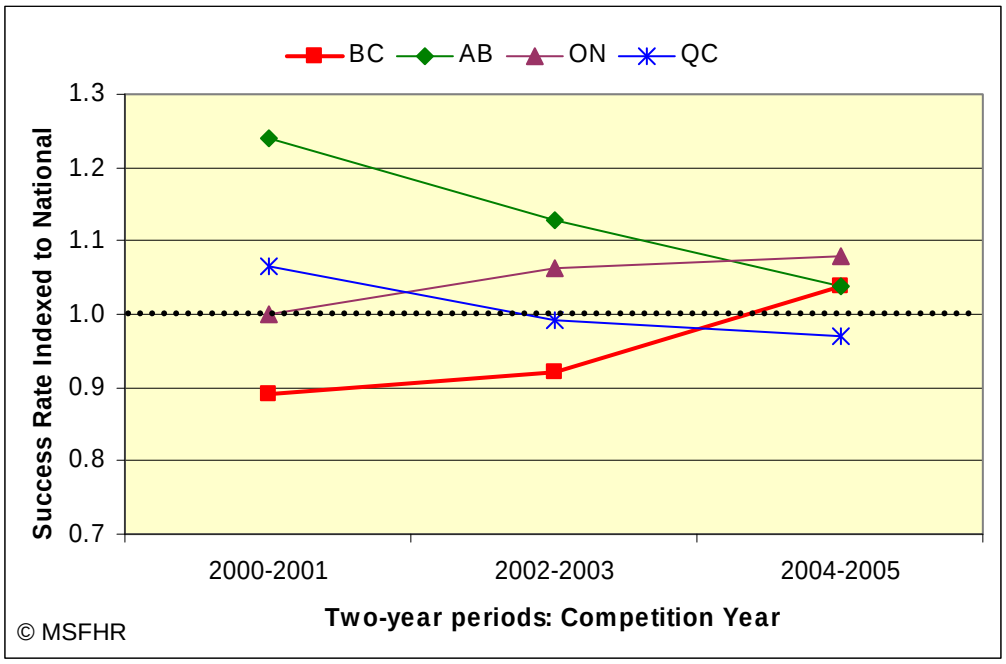

Figure 12: Success Rate Indices for CIHR Operating Grants (Provincial Success Rate/National Success Rate)

Figure 12 displays the success rate indices of the four provinces analyzed, for Operating Grant competitions at CIHR. Two-year time periods were utilized in order to improve the stability of the estimates. For Operating Grants, in the first time period (2000-01) BC had the lowest performance, with an index of 0.88. By 2004-05, this had risen to second amongst the four provinces, at 1.03.

It is important to consider that the increase in quality of BC submissions occurred during an interval of significant growth in quantity. During this interval, the growth in number of Operating Grant submissions was the most rapid in BC (not shown) as was the growth in number of funded grants (see Figure 2). It is often the case that rapid increases in quantity come at the expense of overall quality; what is noteworthy in this analysis is that during the period of study, BC demonstrated not only the strongest growth in numbers of Operating Grant submissions, but also the largest increase in their overall quality.

However, with the most recent index only reaching 1.03, much further improvement in BC remains possible.

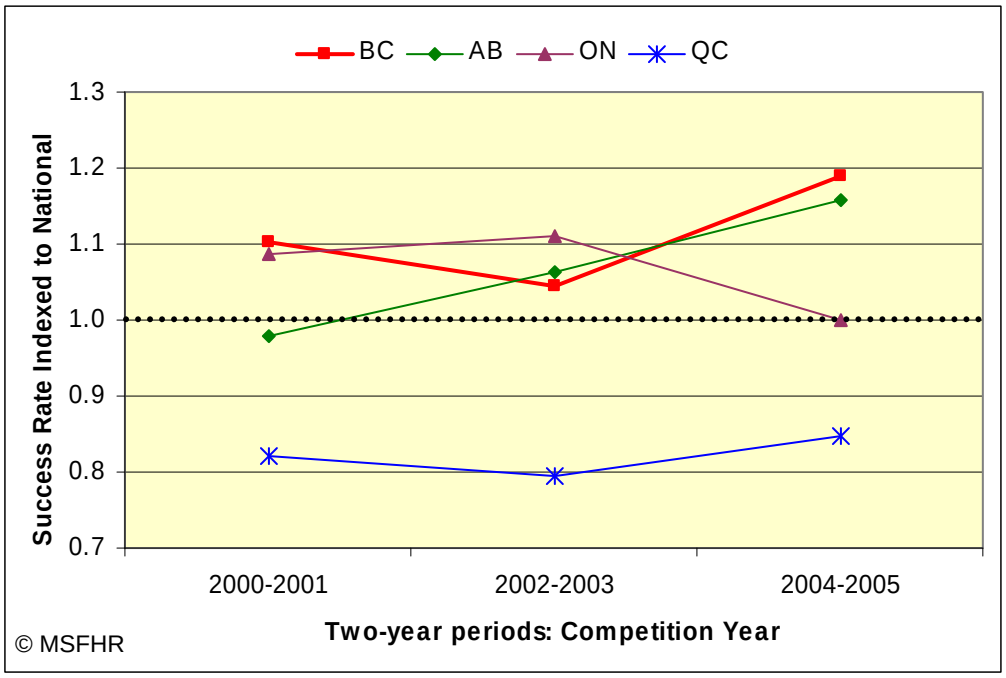

**Figure 13: Success Rate Indices for CIHR Personnel Awards[7]
(Provincial Success Rate/National Success Rate)**

Figure 13 displays the recent success rate indices for the four large provinces for Personnel Award competitions at CIHR. Personnel Awards support the salaries of graduate students, post-doctoral fellows, and researchers at various career stages (see footnote for full details). In this instance, BC began and ended in first position among the four provinces analyzed, and demonstrated overall improvement during the time frame.

[7] Programs included are: Graduate (CGM,CGD,MDR), Postdoctoral Fellowship (MFE,MC1), New Investigator (MSH,MC2), Investigator (MSC), Senior Investigator (MSS).
Province is that of the Institution Paid, as entered by the applicant

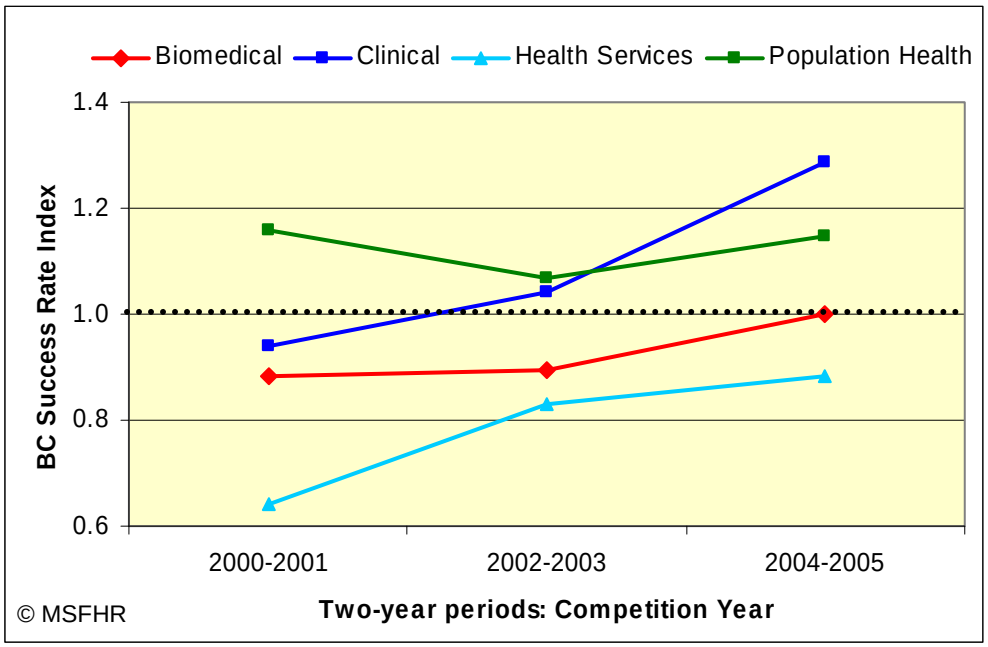

Figure 14: BC Success Rate Index for CIHR Operating Grants, by Theme (BC Success Rate/Canada Success Rate)

In considering BC's recent improvement, it is useful to investigate the trends by research theme. Figure 14 displays the recent Operating Grant success rate indices in BC across health research themes. There has been improvement in all themes with the exception of population health, where success rate indices have been relatively stable above 1.0. There has been a marked increase in clinical research success rates, and room for improvement exists for all themes, but particularly for biomedical and health services research.

Average Relative Impact Factor (ARIF)

The Average Relative Impact Factor (ARIF) is one of a group of evaluation tools known as *bibliometrics*. "The science of bibliometrics, involving analysis of publications and citations, is based on the premise that a researcher's work has value when it is judged by peers to have merit, and is therefore made available in a peer-reviewed journal. Bibliometric approaches describe outputs in and across research areas by assessing the volume and estimating the quality of publications. Its quantitative and systematic methodology allows for comparative and repeated analyses. Bibliometric approaches have mainly been used to assess the contribution of scientific research to knowledge creation, rather than to determine socio-economic benefit."[8]

The ARIF indicator is a proxy for the *quality* of the journals in which a researcher or group of scientists publishes. Each journal has an impact factor (IF), calculated annually by the publishing company Thomson Scientific, and is based on the number of citations a journal receives relative to the number of papers it publishes. The IF of articles is calculated by ascribing to them the IF of the journals in which they are published.

A major difficulty with impact factors *per se* is that they differ across subfields of health research. For example, more citations are given within biomedical research than in social science, and thus journals in the former subfield have higher impact factors than those in the latter. Therefore without adjustment, simple comparisons of impact factors across such subfields would be misleading. In order to account for these different citation patterns across fields and subfields of science, each paper's IF can be divided by the average IF of the papers in its particular subfield in order to obtain a Relative Impact Factor (RIF). The ARIF of a given entity (scientist, research unit, province, etc.) is calculated using the average RIF of all articles produced by the entity. When the ARIF is above 1.0, it means that the entity scores better than the world average in terms of impact factor (after taking the distribution of subfields into account). When it is below 1.0, it means that the entity publishes in journals that are of lesser impact than the world average.

A number of concerns have been raised regarding the general validity of impact factors. The first, namely the differing impact factors across subfields, has been discussed above and the ARIF is a method that attempts to adjust for this. Other issues, such as the effect of self-citation on impact factors and the manipulation of impact factors by some editors and journals, are outside the scope of this report.[9] It is important to note, however, that these issues affect all jurisdictions (e.g. provinces) equally. The pertinent question in the present context is whether any systematic bias in the validity of impact factors creates an uneven playing field when comparing provinces, given that the calculation of ARIF is applied equally to all of them. Whether such a bias exists is unclear.

It is important to note that ARIF is a measure of *quality*, not of *volume*. Since it is an average, it does not measure the output of an entity in terms of *number* of publications, but rather the *average quality* or *impact* of each publication. Capacity and volume issues will be discussed in the final section.

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8 *Medical research: assessing the benefits to society.* A report by the UK Evaluation Forum, supported by the UK Academy of Medical Sciences, Medical Research Council and Wellcome Trust, May 2006, p.15.

9 For a critical discussion of impact factors, see *The Impact Factor Game*, PLoS Medicine, June 2006, vol.3, no.6; and *Impact Factor: The Numbers Game*, AJR: 178, March 2002.

In August 2006, the Michael Smith Foundation for Health Research contracted with the firm of Science-Metrix[10] and their partner, L'Observatoire des Sciences et des Technologies (OST), to undertake a comparative bibliometric analysis of BC health research activity. This included identification of all health-related research publications with one or more authors from a given province, and an impact analysis of these publications over the time period of this report.

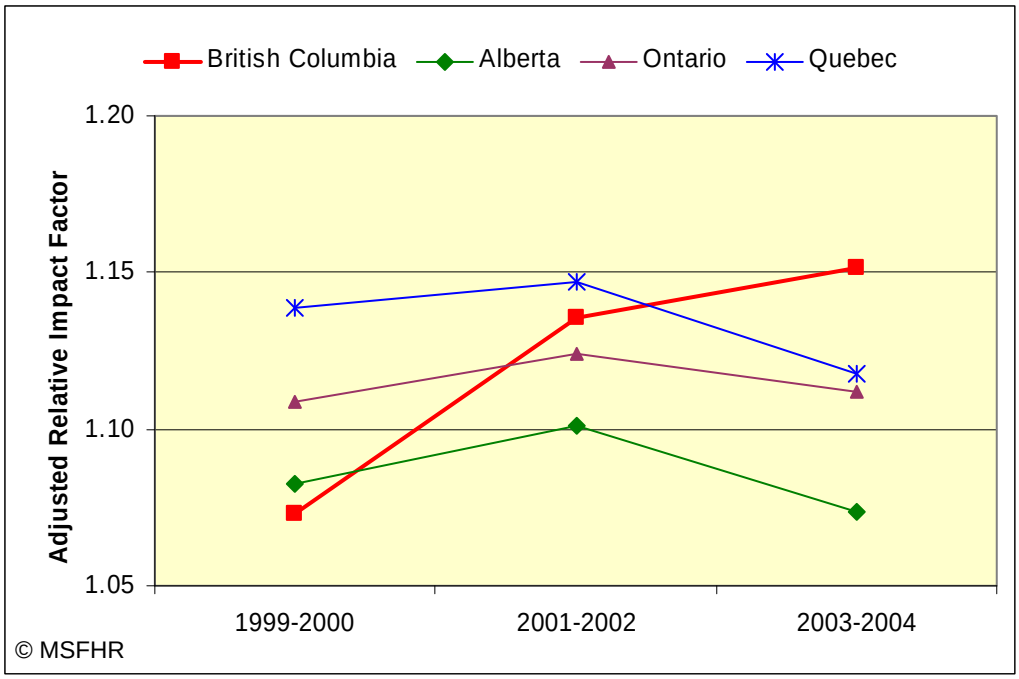

Figure 15: Adjusted relative impact factor (ARIF) for Health Research over 3 periods

As seen in Figure 15, the adjusted relative impact factor (ARIF) of BC health research increased steadily over the three, two-year time periods analyzed. While the ARIFs of the other provinces remained roughly constant over this interval, the ARIF of health research in BC rose from 1.07 to 1.15 and became the highest of any province.

As a point of comparison, however, the ARIF for the state of Washington in 2003-04 was 1.32, illustrating that considerable room for improvement exists in BC and across Canada.

[10] Science-Metrix website : http://www.science-metrix.com/index2.htm
OST website: http://www.ost.qc.ca/

International Collaboration

The international collaboration rate is an indicator of the relative intensity of scientific collaboration of a jurisdiction at the international level. The rate is calculated as the proportion of all health research publications by authors within an entity (e.g. country, state, province) that have at least one other author whose institution is in a foreign country. This is a proxy measure for international collaboration, reflecting the extent to which research activities in a given jurisdiction are operating on the international level. Research has shown that collaborations with scientists from foreign institutions have a positive effect on the publication impact.[11] According to unpublished data from Science-Metrix, research involving collaborations between high income countries is generally of higher quality and impact than research conducted within any of the single countries involved.

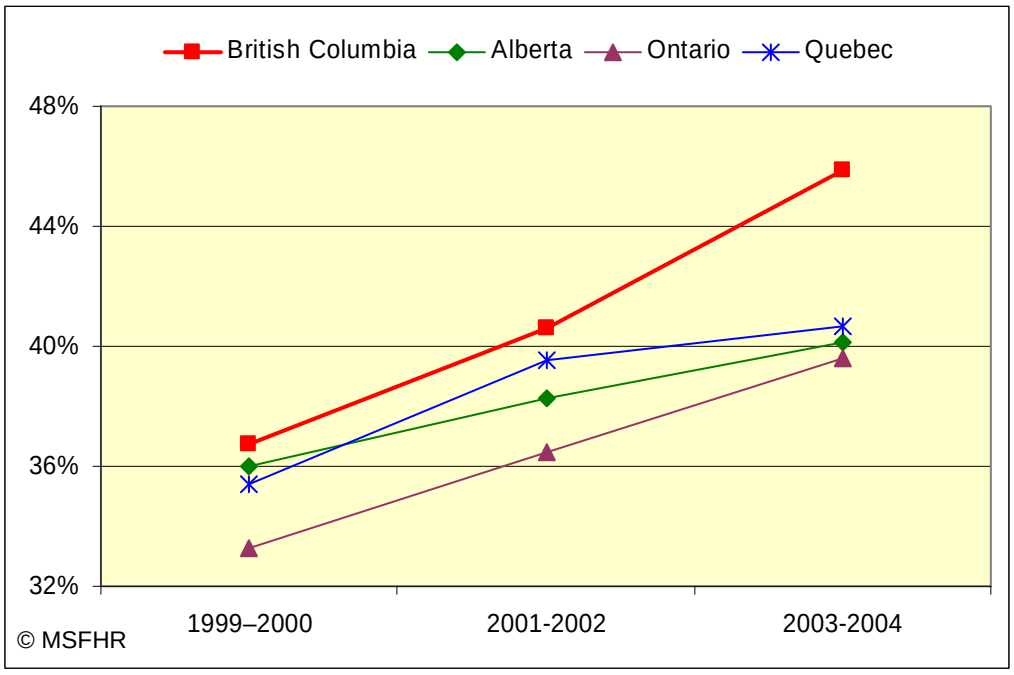

Figure 16: Proportion of International papers over 3 time periods.

Figure 16 shows the rates of international collaboration across the three time periods; BC has remained in first position among all ten provinces, and has shown the largest growth.

[11] Katz J.S. and Hicks D. 1997. How much is a collaboration worth? A calibrated bibliometric model. *Scientometrics*. 40 (3): 541-554. For further discussion of bibliometric indicators and scientific collaboration see for example:
Calero C., Buter R., Valdes C.C., and Noyons E. 2006. How to identify research groups using publication analysis: an example in the field of nanotechnology. *Scientometrics*. 66 (2): 365-376
Glanzel W. and Schubert A. 2001. Double effort = Double impact? A critical view at international co-authorship in chemistry. *Scientometrics*. 50 (2): 199-214.

Output and Capacity

The third section of this report presents evidence of scientific productivity, i.e. quantitative measures of scientific output and specialization relative to population size.

Growth in Health Research Publications

This analysis evaluates growth in the number of health-related scientific articles associated with authors within given geographic areas (e.g. provinces, states or countries). For the purpose of this analysis, the number of articles produced in the year 1999 is set as the baseline of 100%.

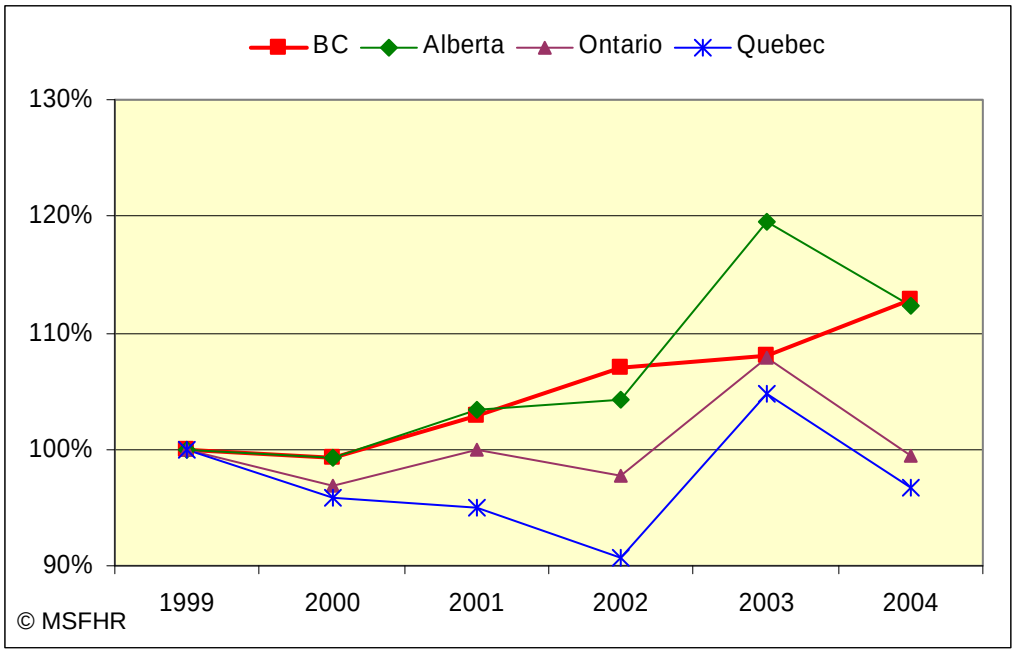

Figure 17: Annual increases in production of health-related scientific articles (Baseline 1999=100%).

Figure 17 shows that BC has exhibited consistent and strong growth in health research productivity, as measured by annual publication of health-related scientific articles relative to the baseline year of 1999. BC and Alberta have demonstrated the highest rates of growth.

Data from OST indicate that during the most recent two-year period (2003-04), BC produced 3,953 health-related scientific publications. The corresponding totals for the other provinces analyzed were: Alberta: 4,124; Ontario: 14,171; and Quebec: 7,813. In order to adjust for population size, these were converted to rates of publication per 10,000 population in the following figure.

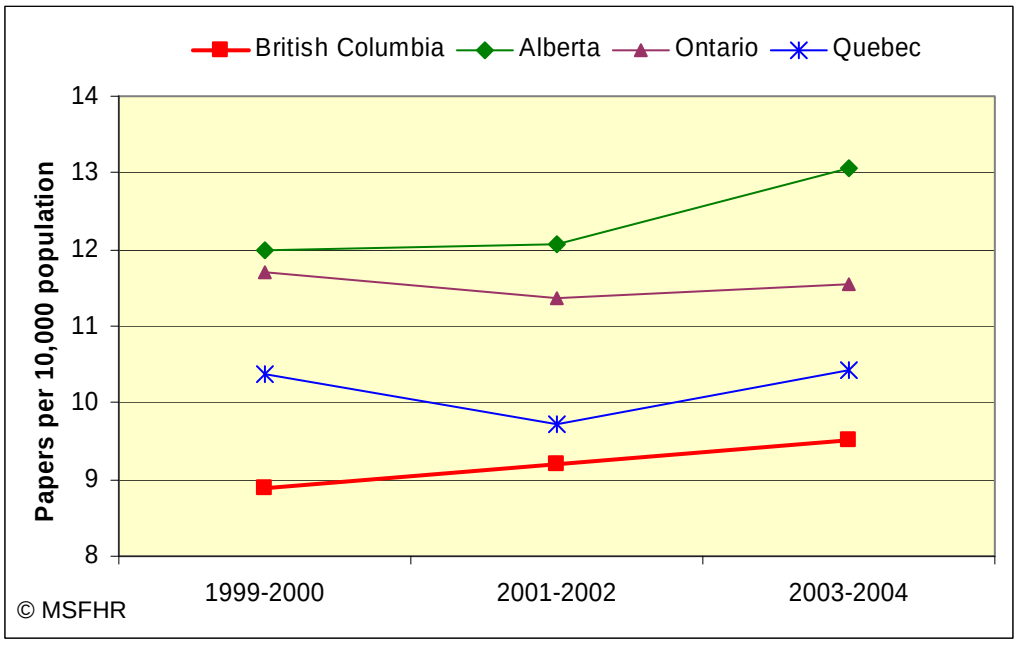

Figure 18: Comparison of health-research related publications per capita over three time periods

Despite the stronger growth in BC shown in Figure 17, the province still lags behind Alberta, Ontario, and Quebec in terms of health-related scientific publications per capita (Figure 18). Although the rate of health related publications in BC grew from 8.9 to 9.5 per 10,000 population over the three time periods, it remains well below those of the other provinces analyzed.

Trends in Health Research Specialization

The *specialization index* of a specific field (e.g. health, mathematics) measures the research intensity within that field of a jurisdiction relative to world levels (see Appendix for details). For a jurisdiction with a specialization index of greater (less) than 1.0 in a field, this indicates that the proportion of its scientific publications that are within that field is higher (lower) than the corresponding proportion of the world literature.

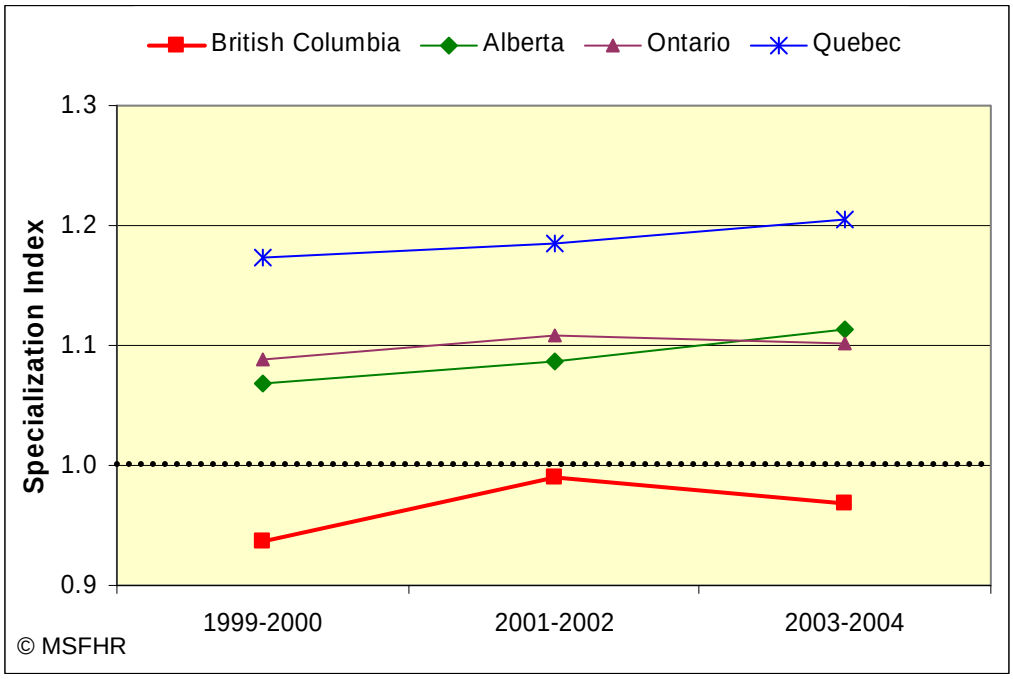

Figure 19: National Comparison of Specialization Index in Health Research

Figure 19 demonstrates that BC has the lowest health specialization index of the four provinces analyzed. The index in BC in 2003/04 was 0.97, indicating that specialization within health was just below the world average of 1.0.

Health Research Capacity in British Columbia

The previous sections demonstrate that BC's health research output has seen the highest growth rate in the recent past compared to Alberta, Ontario, and Quebec, but that BC continues to lag behind these provinces in terms of both *health research publications per capita* and *health specialization index*. These observations warrant additional consideration.

The indicator of health related scientific publications per capita is essentially a function of two key parameters: the number of actively publishing health researchers per capita in a jurisdiction, and the average productivity of each active researcher in terms of scientific publications. MSFHR has commissioned a direct analysis of the latter; however, measures in this report — such as grant success rates, relative impact factors, and international collaboration — do not point to any deficiencies in the effectiveness of health researchers in BC. If anything, these data suggest that BC ranks among the highest in terms of individual quality, and moreover, that this trend is continuing to improve even further.

The aforementioned naturally begs the question: Could the observation of the lower output per capita in BC be driven largely by the fact that BC might have a lower number of health researchers per capita than other provinces? The latter would explain the lower rate of publications per 10,000 population. Similarly, if health researchers are proportionately less represented among the scientific community in BC than in other provinces, this would lower the province's health specialization index as well.

So how does the number of health researchers per capita in BC compare to other provinces and jurisdictions? The answer is not so simple to obtain. No real census of health researchers is readily available from the appropriate institutions. This is partly because, as of yet, no common definition exists as to what constitutes a health researcher — the field encompasses disciplines beyond those of traditional medical research. The BC Directory of Health Researchers and Trainees, launched in September 2006 by MSFHR, aims to address this gap, as it captures all researchers that have an academic affiliation in BC and who carry out health research. Furthermore, as previously mentioned, MSFHR will be conducting regular analyses of BC's performance in health research to address this question and provide an ongoing assessment of the return on investments in health research in the province.

In the interim, one source of information in this area may be provided by the Canadian Common CV (CCV). Since July 2002, all Canadian researchers submitting a grant to CIHR have had to complete and use the latest version of the Canadian Common CV for their application.

MSFHR requested data from CIHR on the numbers of CVs submitted to CIHR through the Canadian Common CV process, according to province of residence. These data appear in Table 1 below. According to this information, a total of 5,556 distinct CVs have been submitted (cumulatively) to CIHR through the Canadian Common CV by individuals with residence in BC. Corresponding numbers from other provinces range from 220 in New Brunswick to 17,378 in Ontario. It should be noted at the outset that these totals are certainly overestimates of the number of actively publishing health researchers in some of the provinces; the main reason for this is that the totals below include Master's and PhD students, as well as postdoctoral fellows who have completed a CCV in the course of a grant or fellowship application to CIHR. This would lead to significant overestimation. On the other hand, not all health researchers would be captured in this way because not all health researchers apply to CIHR for funding; this leads to

a degree of underestimation. Moreover, we do not know if the net of these effects is the same across provinces.

Province	Number of CVs Submitted to CIHR	Population (2003)	CVs per 1000
Québec	13,702	7,623,870	1.80
Nova Scotia	1,549	936,988	1.65
Ontario	17,378	12,599,364	1.38
Manitoba	1,568	1,178,348	1.33
British Columbia	**5,556**	**4,279,462**	**1.30**
Alberta	4,043	3,306,359	1.22
Saskatchewan	1,076	990,930	1.09
Prince Edward Island	148	138,157	1.07
Newfoundland	344	514,409	0.67
New Brunswick	220	751,111	0.29
All Provinces	**45,584**	**32,318,998**	**1.41**

Table 1: Comparison of absolute number of CVs submitted to CIHR and rates per 1,000 population across 10 provinces

With these caveats, one can make indirect comparisons, as shown in Table 1, where per capita rates of CVs by province are presented. Based on the Common CV data, BC ranked fifth of ten provinces in terms of the rate of CVs per 1,000 population. Of the four large provinces compared throughout this report, only Alberta appeared to have a lower rate. Under the assumption that the number of CVs reported by CIHR is proportional to the number of actively publishing health researchers, this provides some evidence of relative under-representation of health researchers in BC, at least in comparison to Ontario and Quebec. Again, while we reiterate that the validity of this assumption is unclear, it can be argued that this analysis is none the less worth considering, for the reasons discussed below and illustrated in Figure 20.

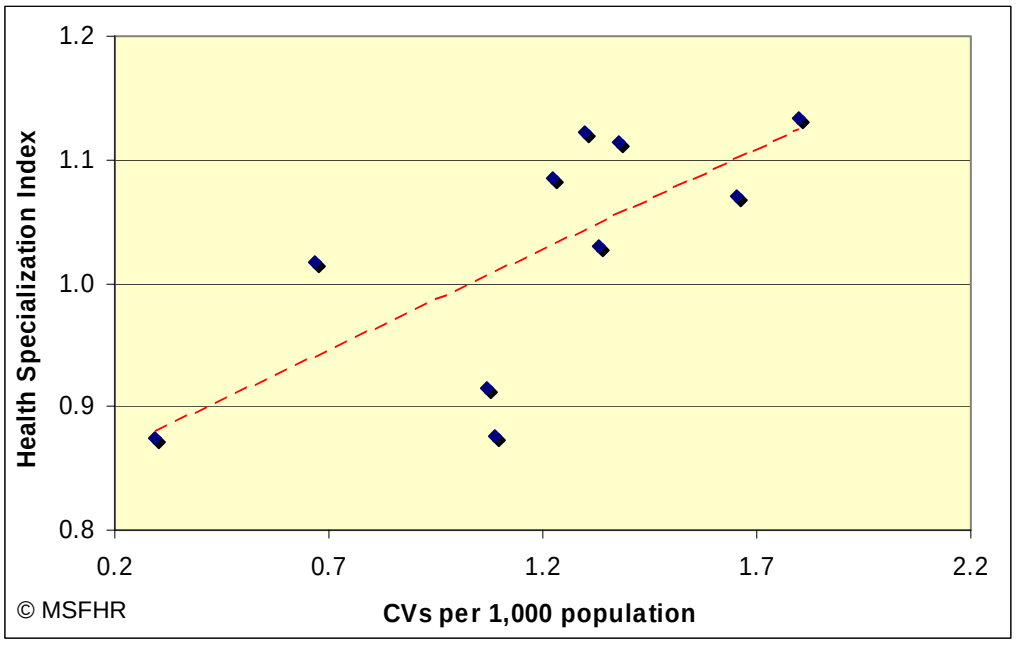

Figure 20: Correlation between Rate of Common CVs in a Province and Health Specialization Index

To test whether this indirect measure of health research capacity correlates with the health specialization index of a jurisdiction, the ten provinces were plotted in Figure 20, with the health specialization index on the vertical axis and the rate of CVs per 1,000 population from Table 1 on the horizontal axis. As seen in the Figure, a reasonably strong correlation (r=0.73) exists between the two parameters. This supports the argument that a lower health specialization index in BC might be driven to some extent by a lower health research capacity per capita.

Appendix: Methodology and Definitions

Statistics Canada data were complete to 2003, while bibliometric data were provided up to 2004. CIHR data were reported to us current to May 2006. As a result, the time periods vary to some extent in different analyses in this report, but we attempted to keep these as similar as possible. For some analyses with lower sample numbers, two-year time periods were used to improve stability.

Funding Data

MSFHR Analysis of CIHR Data

Twice annually, the Canadian Institutes for Health Research (CIHR) provides to the Michael Smith Foundation for Health Research a download of data detailing all health research funding awarded by CIHR, since its inception in 2000. Analysis of this data allows MSFHR to analyze funding received by investigators in each province, and, in combination with Statistics Canada data, compare provincial per-capita funding levels and trends. MRC data for the period prior to CIHR's inception were derived from the *MRC Report of the President 1998-1999*.

Data provided by the CIHR included awards announced up to May 19, 2006. Provincial assignment was based on the Institution Paid of the principal investigator. Provincial percentages were calculated as a proportion of all awards to researchers located in Canada, including those where province could not be assigned.

Population data (for per capita and index calculations) were sourced from Statistics Canada.

Funding Index for an entity (e.g. province) is calculated as:

$$FI = \frac{\text{Entity's share of all Canadian funding}}{\text{Entity's share of Canadian population}}$$

Success rate index for an entity (e.g. province) was calculated as:

$$SRI = \frac{\text{Entity's success rate in a given category/theme}}{\text{National success rate in same category/theme}}$$

MSFHR Analysis of Statistics Canada Health (Gross Domestic Expenditure on Research and Development (GERD) Data

Calculation of gross domestic expenditures on R&D in the health field by funding sector was based on data provided by Statistics Canada as part of a client request made in February 2006 (request completed in July 2006). The most current available data were for 2003.

Bibliometric Data

In August 2006, the Michael Smith Foundation for Health Research contracted with the firm of Science-Metrix to undertake an analysis of BC health research activity. This analysis benchmarked British Columbia's scientific output in health research against that of national and international comparators, and examined the characteristics of the province's scientific output in health research. In contrast to other metrics examining at research *funding*, this analysis was a review of bibliometric data – that is, it analysed patterns relating to scientific publications.

The Science-Metrix analysis was based on publication databases provided by Thomson Scientific. These databases included the addresses of all authors listed in scientific papers for a given jurisdiction. Access to these data enables a precise calculation of a number of statistics and bibliometric indicators that would otherwise be difficult or, in some cases, impossible to perform. In particular, national and international collaboration rates can only be analysed when databases provide a record of all authors' addresses. Two Thomson databases were used in the analysis cited in this report: the Science Citation Index (SCI) and the Social Sciences Citation Index (SSCI). For the present study, statistics were based on the following indicators:

- *Number of papers:* The number of scientific papers with authors associated with geographic areas (based on author addresses; e.g. countries, states, provinces).
- *Growth:* Calculated as the number of scientific papers from a geographic area, expressed as a percentage with respect to the baseline year of 1999.
- *International collaboration rate:* This is an indicator of the relative intensity of scientific collaboration between countries. The rate was calculated by dividing the number of papers with at least one author with a foreign country address, by the entity's (e.g. country, state, province) total number of papers.
- *Average relative impact factor (ARIF):* This indicator is a proxy for the quality of the journals in which an entity publishes. Each journal has an impact factor (IF) which is calculated annually by Thomson Scientific, based on the number of citations it receives relative to the number of papers it publishes. The IF of papers was calculated by ascribing to them the IF of the journals in which they were published for that year. In order to account for different citation patterns across fields and subfields of science (e.g. there are more citations in biomedical research than social science), each paper's IF was then divided by the average IF of the papers in its particular subfield in order to obtain a Relative Impact Factor (RIF). The ARIF of a given entity was computed using the average RIF of each paper belonging to it. When the ARIF is above 1.0, it means that an entity scores better than the world average; when it is below 1.0, an entity publishes in journals that are not cited as often as the world average.
- *Specialization index (SI):* Specialization index is an indicator of the intensity of research of a given geographic or organizational entity (e.g. a country) in a given research area (domain, field) relative to the intensity of the reference entity (e.g. the world) in the same research area. The SI can be formulated as follows:

$$SI = \frac{(C_s / C_t)}{(W_s / W_t)}$$

  C_s = Papers from entity X in a given research area (e.g. Canada in agriculture)

  C_t = Papers from entity X in a reference set of papers (e.g. Canada in the whole database)

  W_s = Papers from the reference entity N in a given research area (e.g. the world in agriculture)

  W_t = Papers from the reference entity N in a reference set of papers (e.g. the world in the whole database).

An index value above 1.0 means that a given entity is specialized in the field relative to the reference entity, while an index value below 1.0 means the opposite.

About MSFHR

The Michael Smith Foundation for Health Research (MSFHR) was established by the provincial government to improve the health and well-being of British Columbians through the support of health research excellence.

MSFHR provides an arm's length mechanism for the fair, transparent distribution of provincial funds to support health research across BC's health research institutions and communities. The Foundation offers a multi-million dollar suite of competitive, peer reviewed awards, including:

- salary awards to train, recruit, and retain the best health researchers;
- infrastructure awards to link and build a critical mass of expertise through the creation of research teams and networks; and
- strategic awards to develop leading edge health research technologies as shared resources for the province.

MSFHR works independently across academic, health and government systems, ensuring provincial input, due process, and accountability in the development and implementation of provincial strategies to advance health research and its application for improved health and new economic opportunity. MSFHR also networks and partners with peer agencies inter-provincially and nationally to leverage knowledge and resources for the benefit of health research in BC.

Background

MSFHR was created in 2001 with an initial five-year, $110 million grant from the Province of British Columbia. The Foundation's mandate was to implement a consensus plan for restoring BC's flagging ability to compete nationally for health research funding and talent – a downward trend that was damaging BC's health system and economy.

Developed and endorsed by a diverse group of health research stakeholders – representing BC's health, education, business, government and non-profit sectors – the plan set out a clear strategy for building health research capacity throughout the province: to help universities, health authorities and research institutions attract, retain, and train the best health researchers, and to help build a research environment in BC that supports individuals and groups of health researchers to do their best work.

MSFHR is named to honour the late Dr. Michael Smith, a renowned BC researcher, teacher, and mentor who was awarded the Nobel Prize in Chemistry in 1993 for his groundbreaking work in genetic research.

Results

MSFHR's programs and activities have spurred significant and profound changes for health research in BC. In 2000, BC researchers successfully competed for only 8% ($25 million) of overall funding from the Canadian Institutes of Health Research, Canada's federal health research funding agency. Since then, CIHR funding to BC has tripled, with BC researchers now successfully competing for a 12% share of CIHR national funding – translating to $82 million annually coming to our province from this source alone.

In 2005, the provincial government endorsed MSFHR's achievements, providing an additional $100 million to sustain and augment activities through 2009.

Since 2001, MSFHR has committed more than $130 million to increase BC's research capacity through support of research trainees, researchers, teams, institutions and networks of researchers throughout the province. With the support of its community, MSFHR has also progressively strengthened its role as a provincial facilitator and catalyst, working across BC's academic institutions, health authorities, non-profit organizations and government to lead joint planning and collaboration for mutual benefit.

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