CS-CAN | INFO-CAN Research Report

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Around 10 years ago, in 2013, a Canadian Research Committee collected a wide range of data to assess Research in Computer Science in Canada over the previous decade, and created the report: *Computer Science Research in Canada: Strengths, Challenges and Recommendations*

Since then, the Computer Science (CS) academic and research landscape has drastically changed. Still, many issues that were pointed out 10 years ago remain surprisingly similar. In here, we summarize our main findings focusing on the academic and research sector, show what has happened in the last 10 years in academia and industry in Canada, how it is different or remained similar to the landscape 10 years ago, and present some recommendations of how CS-CAN/Info-Can, the academic research committee at large and industrial partners can further foster excellence in research to the benefit of Canada.

This report is aimed at stakeholders in the CS research community, such as chairs and researchers, to inform them about the status, impact and direction of CS Research in Canada.

Key Developments in Research and Academia

- **Focused Research Funding:** Canada now provides heavy funding for specific areas through large-scale funding initiatives such as CIFAR or CREFS. Some of this funding has gone to CS initiatives
  - Artificial Intelligence (AI) and Machine Learning (ML) have become a driving economic force and Canada has invested heavily into both academic research in core ML as well as industrial R&D for AI and ML across many different domains.
  - A second CS sector with focused government investments has been cybersecurity,
  - Touching on CS expertise, e.g., quantum information processing, there are multiple funding initiatives in the context of quantum computing.

- **Cross-disciplinary Research:** Given the importance of Data Science and ML, many research initiatives in other domains (health, sustainability) seek CS expertise or hire their own domain-specific ML researchers. There do now exist more programs at Canadian funding agencies and universities to foster inter- and cross-disciplinary research, and a considerable part of those have CS as one of their stakeholders. This also holds for participating in international research initiatives. But these funding programs are still somewhat in their development phases.

- **Funding for broad CS Research:** Research funding in CS but outside the focus areas (AI/ML/cybersecurity) has not received any particular funding increases. In particular, average NSERC funding for CS has been continuously below average compared to other disciplines, creating a two-tier system among CS researchers that weakens CS research at large. Furthermore, already the 2013 report indicated problems with CS researchers obtaining NSERC partnership grants. This tendency has not changed much. On the contrary, the relatively new National Security Guidelines for Research Partnerships seem to aggravate the problems.

- **Very large enrollment surge:** From a drought of CS undergraduate students 15-20 years ago, enrollment in CS undergraduate programs across Canada has ballooned. Still, until recently, demand was higher than graduate rates, although this gap seems to be starting to diminishing.

- **Hiring of tenure-track staff**: Hiring of tenure-track and research faculty has increased significantly but not quite at the same rate as the increase in undergraduate enrollment. Instead, teaching is more and more covered by teaching-focused staff. A considerable part of the tenure-track and research faculty new hires are in the area of AI/ML. This not only changes the academic landscape but also creates pressure on funding opportunities for junior and senior researchers outside AI/ML.

- **Needs for HQP at the graduate level:** It has become clear that in many areas of CS, obtaining a graduate degree is becoming more and more important in order to get the deep background knowledge and become aware of the recent advances in research, in particular in the fields of AI/ML. Over the last years, the number of graduate students has continuously increased, but not by a large margin.

What happened in CS in the last 10 years

Most of the information presented here was collected late 2022 and early 2023. At that time, the latest data available was from 2021. A recent check of the resources shows that a considerable part of the statistics have not yet been updated since then. Data that refers to the period before 2012 was taken from the first Computer Science Research Report.

The ICT sector:

The Government of Canada and its departments such as ISED (Innovation, Science and Economic Development), and agencies such as NSERC often use the term "ICT" when referring to computer-related technologies and research, such as in [1]. While ICT includes CS at its core it also covers some closely related areas. Often, information and statistics about ICT best approximate what is happening in CS.

Economy [1]:

The ICT sector in Canada, especially within the software and computer services industry is thriving.

ICT continues to contribute more and more to the Canadian GDP growth.
ICT accounted for 8.9% of Canadian GDP growth in the 10-year period preceding 2012, but an impressive 15.3% in the 5-year period 2016-2021. Still, it counts for a relatively small but increasing part of the overall GDP (from 4.3% in 2014 to 5.3% in 2021).

The number of ICT related companies has been constantly rising from 33,500 in 2011 to 45,000 in 2021. The percentage of ICT companies that lie within the sub-section of the software and computer services industry has risen from 80% to 90% over the last 10 years. Most companies (38,000+) employ less than 10 people, and this is more prevalent in the software and computer services industry. The small size of a majority of the companies in this sector make it difficult for them to directly support university-based research in ICT, and complicates their ability to participate in existing partnership programs. A very recent study of the U.S. Bureau of Labor Statistics indicates a large Canada high-tech **employment growth of 29.4% in 2020/21 with Vancouver, Toronto, Montreal in the North-America top-five for high-tech job growth in 2020/2021** (44.2, 37, and 16%, respectively).

HQP [1]:

Workers are highly educated. More than 65% of employees in the Software and Computing Services Industry have university degrees (compared to 54% in 2011).
Average salaries are very high, with employees in the Software and Computing Services Industry earning 63% more than the Canadian average (compared to 60% in 2011).

Research and Innovation [1,2,3,4]:

We looked at two different factors: R&D investments and patents.

ICT is more than ever innovation driven.
According to [1], while the ICT sector held around 34-35% of all private sector R&D expenditures in the years 2011-2018, its contributions have increased to a 44.1% share in 2021.
Comparing this with the relatively small market share in terms of contribution to GDP of just over 5%, this shows how important R&D is in the context of the ICT sector. For best success, this requires sufficient numbers of well–educated HQP but also optimal connections to academic research in order to guarantee industry to be at the cutting edge of the newest developments.

The world **share of patents** going to Canadian inventors and assignees, overall and for the ICT sector, h**as slightly decreased over the last decade**. In 2012, the vast majority of patents went to industry (90%). While we have no new data, we don't think that this has changed. It is possible that this trend might change soon for AI given the high levels of investment and activity in academia and in industry, but this needs to be further investigated in the next few years.

Academic Research:

Publications [5,6]:

Canada is doing quite well in terms of publications. Considering G7 countries as well as China and South Korea, **Canada has the highest number of papers adjusted for population** throughout the last decade (in the same realm as the previous decade). When **normalized for GDP,Canada is in the middle of the pack**, with China and South Korea considerably higher as are Italy, Spain and the UK.

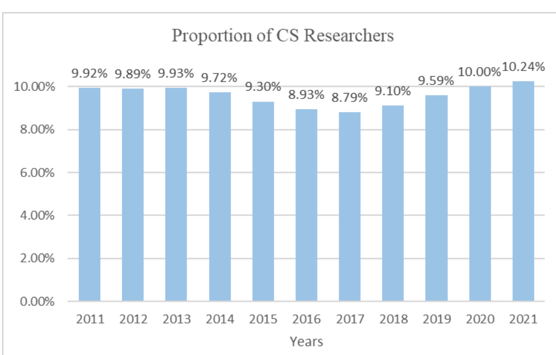
Funding [7,8]:

Funding levels in CS have been a major concern for CS researchers for a long time. Note that in the context of this section a CS researcher is defined as someone who holds a NSERC Discovery Grant from the CS evaluation group.

In this report we mainly focus on NSERC grants. We first provide summary results for most types of NSERC grants for years up to 2021 and then bring more detailed information for the last competition year that we collected through NSERC's public dashboard, with comparison to other evaluation groups.

NSERC Discovery Grants, Summary from the 2013 Report:
The 2013 report noted that the **CS NSERC Discovery Grant levels historically tended to be lower on average** than the other NSERC disciplines. Overall, CS received between 6.2% and 7% of all NSERC-available funds between 2003 and 2010. Additionally, the 2013 report indicated as major concern the partnership programs. **While CS researchers received nearly 10% of all Discovery grant funding, the amount of funding received within the partnership grants was much smaller** (6.3% of Strategic Grants, 6.6% of CRD and 4.6% of Industrial Research Chairs funding). As such, one of the main recommendations of the last report was to rethink partnership grants and find more effective ways to interact with industry while continuing to do first-class research.

NSERC Discovery Grants 2011-2021: A more detailed analysis **shows some improvement** over the **last decade** in this respect but there is still a funding gap. The overall share of NSERC funding assigned to CS researchers is 6-8%. This is slightly higher than in the previous decade, but**the average CS NSERC Discovery grant is still smaller than the average.** While CS researchers made up mainly between 9 and 10% of all Discovery Grant holders over the last decade, their overall share of funds was only 8- 9%, although the gap seems to be closing, with the average CS grant in 2011 being around 18% lower than the average and 7.5% smaller in 2021. Figure 1 illustrates the data. Annother observation is that the overall grant sizes increased by around 20% in the 10-year period following roughly the cumulative inflation rate in this time period.



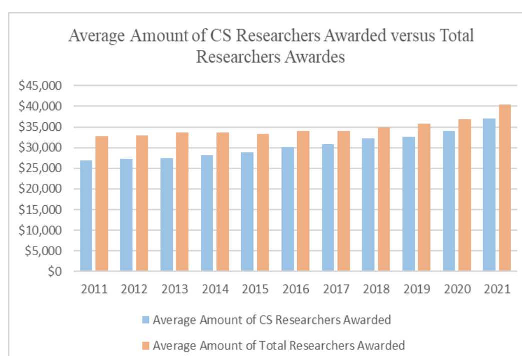


Figure 1: Discovery Grants: Proportion of CS Researchers (CS evaluation group) among all grant holders and the average amount granted to CS Researchers vs. all researchers. Furthermore, CS researchers made up between 11 and 13% of all Accelerator Grant holders. Additionally, in terms of the smaller Discovery Development Grants (15K), CS researchers made up between 12-16% of all grant holders.

NSERC Research Chairs 2011-2021:
A further positive trend is the number of CRCs (Canada Research Chairs) that were given to CS Researchers – these rose from just over 5% in 2012 to nearly 9% in 2021, close but not quite the percentage achieved for Discovery Grants. The average grant size, however, has been significantly smaller for CS Researchers, in particular in the last 5 years (up to 13% smaller). This is illustrated in Figure 2. It should be noted, however, that given that CRC have application rounds within the university, the decision making process here is different than with other NSERC grants.

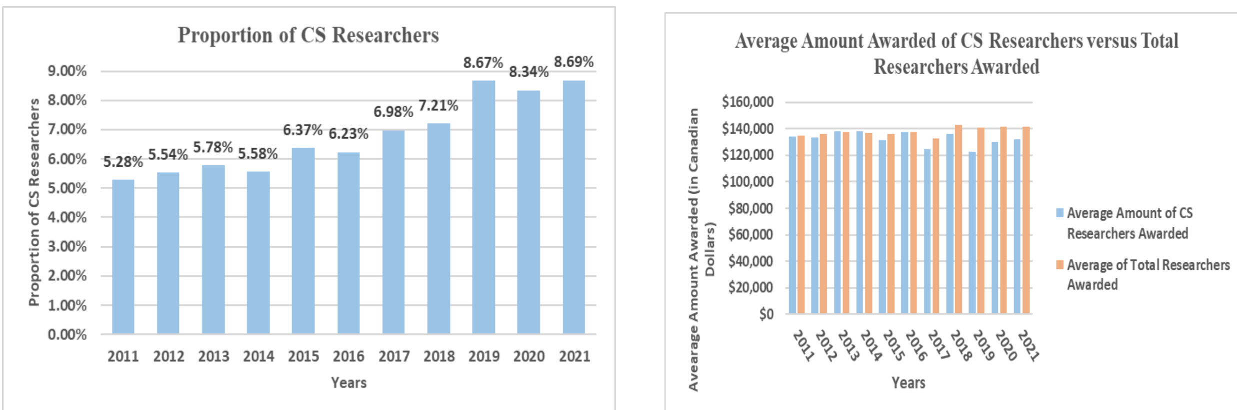


Figure 2: CRCs: Proportion of CS Researchers (having an NSERC Discovery grant from the CS evaluation group) among all CRCs and the average amount granted to CS Researchers vs. all researchers.

As shown in Figure 3, the number of **Industrial Research Chairs** (IRCs) varied a lot over the last ten years, from a low of 2% to a high of 10%. Again, the average grant sizes are significantly below the average. The variation might be affected by the relatively small number of industrial research chairs.

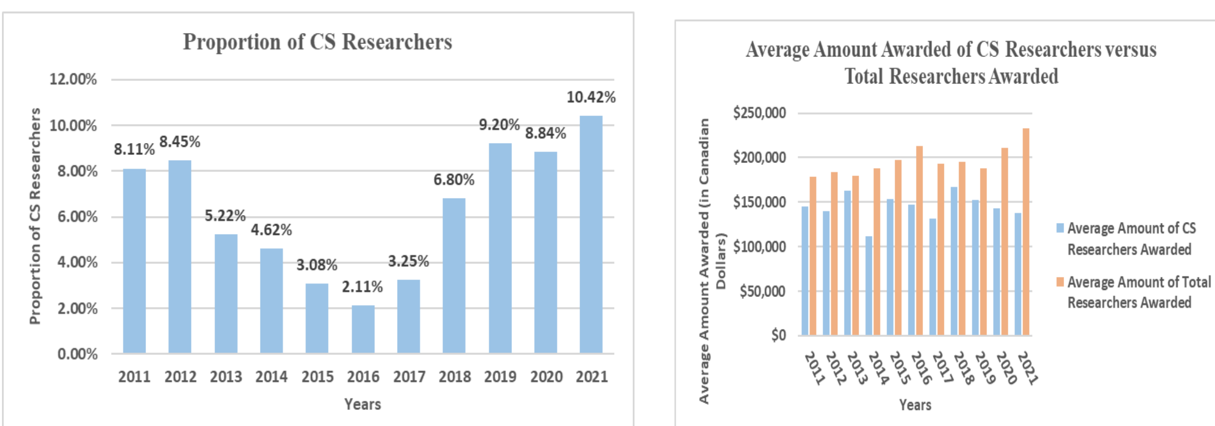


Figure 3: IRCs: Proportion of CS Researchers (having an NSERC Discovery grant from the CS evaluation group) among all IRCs and the average amount granted to CS Researchers vs. all researchers.

NSERC partnership grants 2011-2021:

In regards to **Strategic Grants** (Figure 3), the percentage of CS researchers among all researchers with a Strategic Grant oscillated between 5% and 7% but the average amount awarded to each Strategic Grant with at least one CS researcher is significant higher, regularly 20% (we consider a CS strategic grant to be any grant that has a CS NSERC discovery holder, even if this researcher is not the main PI). Therefore, it could be that CS researchers participate in interdisciplinary grants that have higher funding levels. This needs to be further investigated.

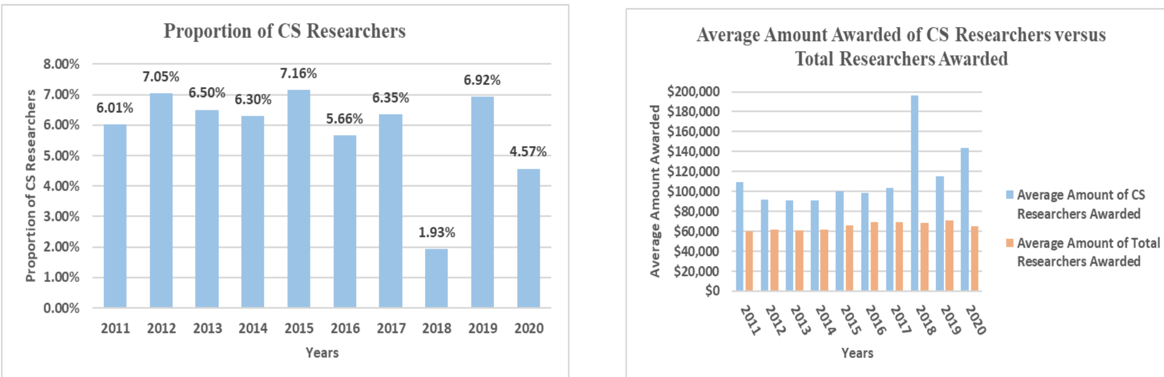


Figure 3:: Strategic Grants: Proportion of Strategic grants with at least one CS Researcher among all Strategic Grants and the average amount of a Strategic Grant with at least one CS Researcher vs. all Strategic Grants.

In regards to CRDs (Collaborative Research Grants), the percentage of CS researchers among all with a CRD is between 10 and 13%, thus higher than the share within Discovery grants. However, the amount awarded is significant lower in every year, oscillating mainly between 8 and 12%. See Figure 4.

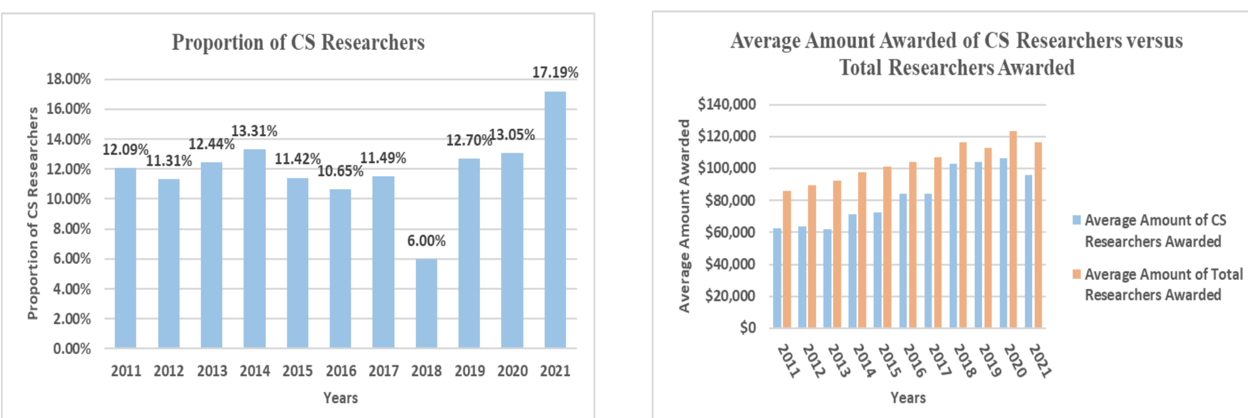


Figure 4: CRDs: Proportion of CRD grants with at least one CS Researcher among all CRDs and the average amount of a CRD Grant with at least one CS Researcher vs. all CRD Grants.

The Alliance Grants replaced the Strategic and CRDs and there is only data available for 3 years. The proportion has been above average, from 12% to a high of 27% in the first year, but average grant sizes are again smaller.

The underrepresentation in larger Strategic Grants and overrepresentation in the smaller CRDs might be correlated with the fact that companies in the ICT sector are generally smaller and thus could have been more interested in the shorter-term and smaller in scope CRDs.

Finally, the very large NCE network grants have also had very bad performance, from a low of 0.5% CS researchers to a high of 7% over the last decade. The funding amount is hard to judge given the large number of researchers per grant.

As a summary, it appears that the proportion of CS researchers among the various grants has increased and for some grant types, it isall higher than the proportion within the Discovery grants. However, the average grant size remains to be significantly lower for most grant types.

NSERC Discovery Grant Details 2023

In 2023 the funding scheme for NSERC Discovery Grants was radically changed. Grant applicants are put into bins (A to P) depending on their performance in three categories (excellence of the (i) researcher, (ii) proposal, (iii) HQP). Until 2022 it was sufficient for established researchers (ER) to be in bin J and have an evaluation of at least “Strong” in each of these categories. In 2023, ERs needed at least one “Very Strong” to qualify for funding (bin I). Note that the funding scheme did not change for early career researchers (ECR) – they needed to be at least in bin K (or even L). This shift was made to provide funded researchers with a larger grant amount so that they can handle the increased costs of research, in particular, funding PhD students at the appropriate level. This led to the situation where a noticiable number of researchers were not funded, while those that were funded did not receive significantly more funding. This caused, presumably unintended, consequences, e.g., a large number of students could no longer be funded since their supervisors, unexpectedly, lost their Discovery Grants. Thus, by trying to solve a problem, another one was created.

Given this radical change and also to better understand how other evaluation groups work and are funded, we performed a more detailed evaluation of the 2023 competition using the NSERC Result Dashboard. We note that the data only represents around 20% of all researchers as it is only data from the year 2023.

1. Success Rates:

Figure 5 on the left side shows the funding rates for the different evaluation groups sorted by overall funding rate. Given the overall funding rate of 56%, it appears the CS Evaluation Group ratings are harsher than other groups.. Deeper analysis reveals that this appears to be due to the funding rate for Early Career Researchers (ECR) being the lowest among all evaluation groups at 50%, while it is somewhat in the midrange for established researchers (ER) at 59%. However, as CS has the highest rate of ECRs at 40% the low success rate for ECR pushes CS down in regard to overall funding rate. Figure 6 shows the percentage of ECR applicants in each evaluation group (sorted).

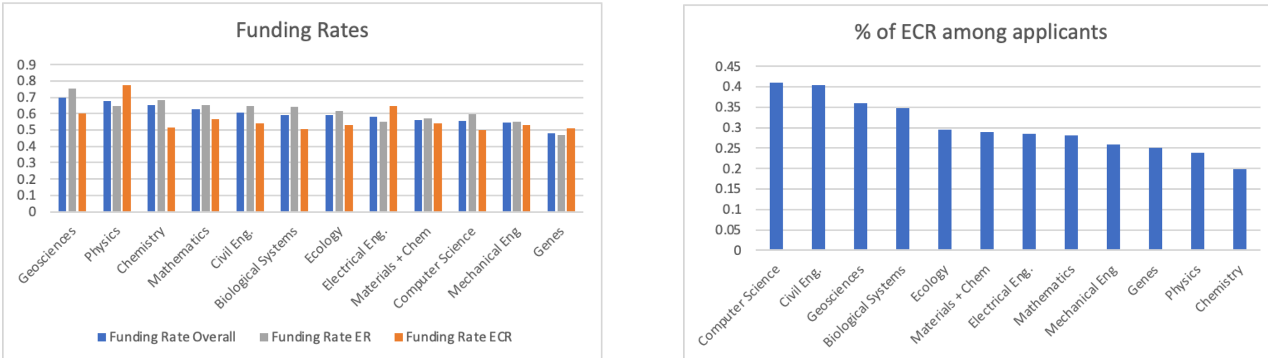


Figure 5: Funding rates and % of ECR among applicants

A closer look at how reviewers of the different evaluation groups assign ERs to bins is shown in Figure 6. Taking all applicants in bins A-J (which the reviewers assumed to be funded when they evaluated them) as 100%, it gives the percentage of applicants in each of the respective bins. The bars for each of the bins are sorted by name of the evaluation group. CS is the yellow bar in the middle. One can observe that except Biology, most evaluation groups had a similar percentage of applicants in bin J – the bin that was considered to still be funded. Differently, Chemistry and Physics generally put researchers in higher bins while CS distributes them more equally.

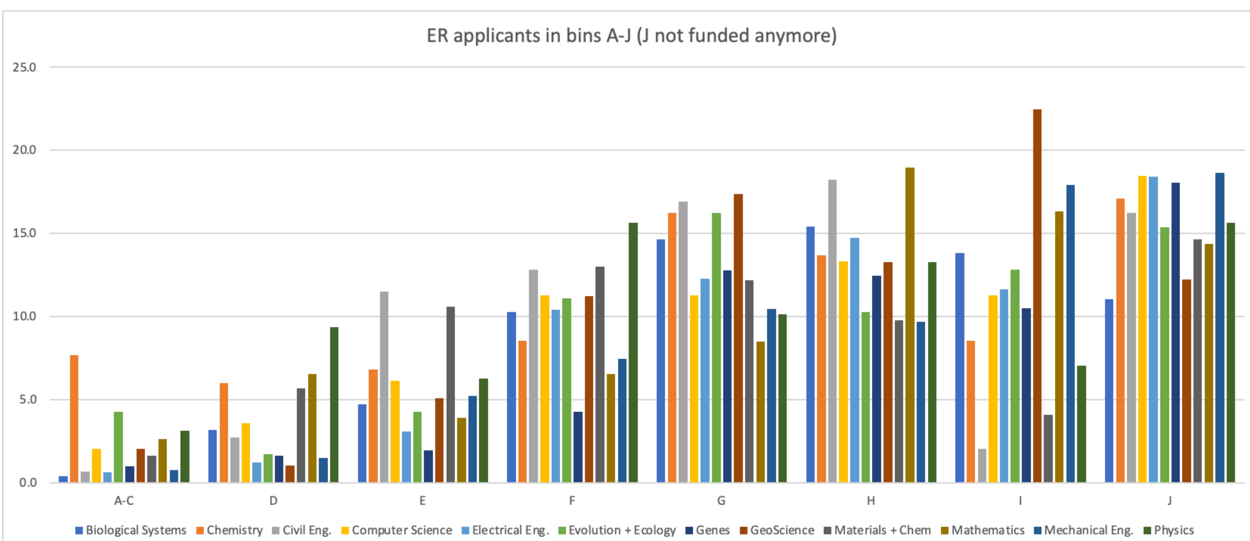


Figure 6: Percentage of applicants in each bin (applicants in bin A-J represent 100%)

One can observe that evaluation groups appear to have very different behavior. The biggest outliers are Chemistry and Physics which put many researchers in very high bins. Civil Engineering concentrates the applicants into the middle bins, while CS appears to distribute them more evenly.

2. Funding Amounts:

Figure 7 shows the amounts paid in each bin for the different evaluation groups as well as the overall averages for ERs and ECRs. The major observations are that the traditional natural sciences have the highest average amounts with chemistry having by far the highest grant amounts overall, followed by physics, evolution and biological sciences. Given the overall average grant and the average ER grant, Computer Science ranks 9th out of 12 evaluation groups, but for ECR it is ranked 5th. Chemistry provides very large grants to researchers in the highest bins but very little to ECRs. Mathematics is an outlier as it provides very small grants across all bins. We note, however, that NSERC directly funds foundational research in mathematics through specific research institutes such as … PIMS and MITACS, which probably explains this outlier.

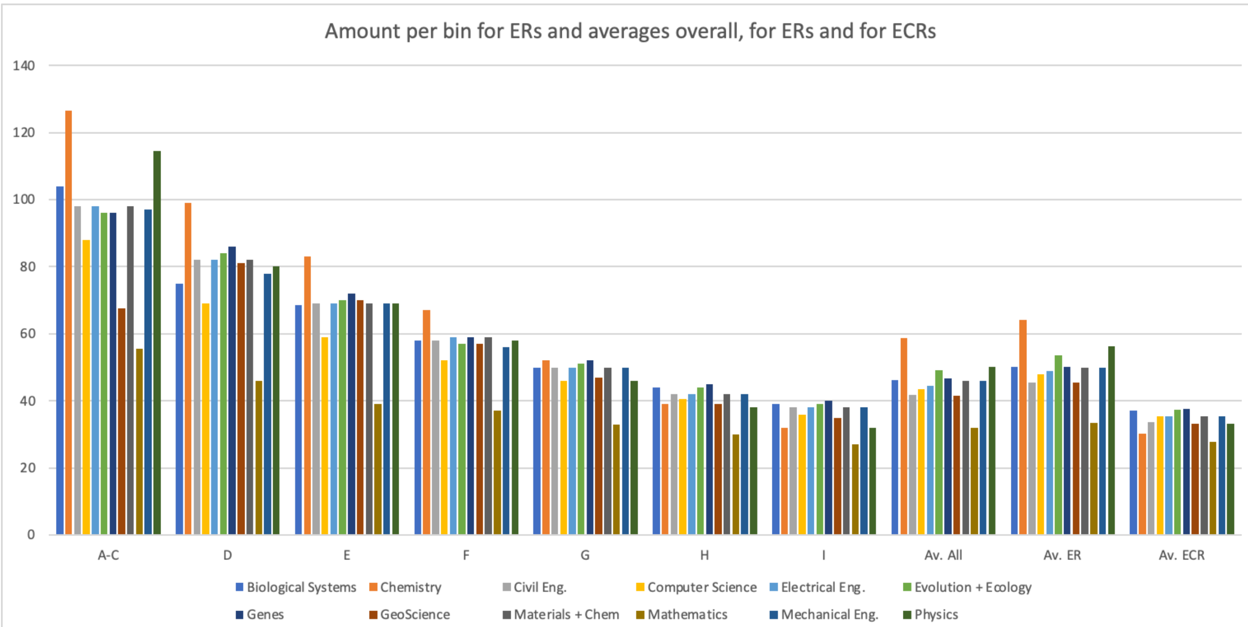


Figure 7: Grant Amounts in $1000 per bin and evaluation group (for ERs) plus averages.

General Comments:
We inquired of NSERC regarding the operational principles governing the distribution of funding across evaluation groups. Although no clear response was obtained, NSERC's response seems to suggest that funds are allocated globally and there are no specific amounts allocated to evaluation groups. If this is the case, one would expect that researchers in the same bin would get similar amounts across evaluation groups, but this is not the case. To compare overall averages is somewhat dangerous as different evaluation groups have different percentages of ECRs which generally get less funding. However when the outlier Mathematics is removed, the averages for ER range from 45.5K to 64K and for ECRs (who are not as spread across bins)from 30K to 37.5K$. Overall, it is fair to say that the overall budget allocated to NSERC discovery grants is too low to provide adequate support for any discipline. Nevertheless, there are some significant funding differences between evaluation groups, providing generally more funding for the "older" disciplines compared to newer ones and Engineering disciplines.

We do not have data regarding CREATE funding – a potentially very powerful funding source. In recent years, a considerable number of interdisciplinary CREATE proposals have been funded, with AI and data science being important aspects that might involve a considerable number of CS researchers and supervisors.

We also lack data on RTI and CFI funding. But generally, the landscape in this direction hasn't changed since the last report. RTI is generally underfunded and it is extremely hard to get funding while CFI (apart of new researcher CFI) is not well suited for CS. Furthermore, there is a distinct lack of funding to support development and maintenance of software tools that are used in CS research. This makes it harder to achieve impact.

Finally, there are **MITACS Accelerate** (short-term graduate student internships) and Elevate (post-doc level) grants for applied research. Note that MITACS spans different areas than NSERC with some areas being very broad (Engineering, Earth sciences, Business, Life sciences, Social sciences and humanities, mathematical sciences, computer science, physical sciences). **14% of Accelerate and 4% of Elevate grants go to CS.** 30% of both types of grants go to Engineering, while Life Sciences are tilted, having only 15% of Accelerate but 41% of Elevate grants. That means, **MITACS grants heavily favor Engineering compared to Computer Science. MITACS grants are typically also very industry focused.** It would be interesting to know how many result in peer-reviewed publications, a measure that is very important for academic performance. Nevertheless, they seem an interesting and important entray point for industry collaboration. Close to 3500 academics overall were involved in MITACs grants.

The 2013 Research report had as further recommendations a request for more funding support in regard to international collaboration and interdisciplinary research. Since then, NSERC has created the New Frontier Research Fund that tackles exactly those two aspects. Given that this has now been in place since 2018 it will be important to find a way to collect information regarding these larger grants to see their impact and whether they fit the CS landscape.

Research and Research Support in AI [9]

Canada has invested heavily in the sub-field of AI within Computer Science in the last few years, with the main, more academic, focus coming through CIFAR and industrial R&D funding via superclusters. With an overall envelope of **$120 million in its first round that targeted a 5-7 year spa**n, 100 AI researchers have been supported so far with CIFAR chairs, and a second round has started.

The Pan-Canadian AI strategy has an interesting approach as it funds both fundamental research and combines it with support for start-up and knowledge mobilization through the AI institutes. According to the CIFAR webpage, the AI strategy has brought a significant amount of venture capital for Canadian AI resulting in doubling start-ups since 2018 (to 1200), and 10x increase in AI related patent applications since 2017. The impact on fundamental research remains to be analyzed but it appears that this funding will allow Canada to keep up with research achievements of peer countries.

Additionally, there have been **two AI-based CFREFs** (Canada First Research Excellence Fund), both to Université de Montreal as lead, with a total of **over $200 million for a period of 12 years**. So far there has not been any further CS-based CFREF (a total of 31 6-year CFREF have been granted since 2015).

The overall funding for AI needs to be considered in the context of overall CS funding. For instance, there is around $20 million CIFAR funding per year for the AI research centers compared to $35.6 million in NSERC Discovery Grants (for 2023) for CS researchers (many of them AI researchers). While targeted funding in AI is extremely important and supported by the CS community at large, the underfunding of non-AI areas in CS might be counter-productive given that the ICT sector is growing not only in AI.

HQP Training

Enrollment [10]:

The landscape has changed extremely in the last decade.

The 2013 Research report recorded relatively low enrollment numbers in the preceding decade. Furthermore, while undergraduate numbers were high at around the year 2000, they decreased throughout the next decade and then stagnated around 2009. For graduate degrees the numbers slightly increased over the same period (Undergraduate degrees decreased from 8,000 to 5,000 in MCIS (math/cs) with enrollment between 37,000 and 23,000, graduate degrees increased from 600 to 1000 in CS). **With this, as of 2008, Canada ranked 23rd out of 24 countries in the number of undergraduate/graduate degrees awarded per 100,000 population in CS.**

Since then enrollment and graduation increased greatly. Undergraduate degrees in MCIS increased back to 9,000 in 2019, and the number of enrolled students increased to 55,000. Graduate degrees increased to 3,000. It is noteworthy that **the increase for graduate students is exclusively at M.Sc. level** (less than 300 PhD degrees in CS per year). **With this, Canada ranked 14th out of 24 countries in number of undergraduate/graduate degrees awarded per 100,000 population in CS in 2020** (considering the same list of countries as in 2008, where it ranked 23rd out of 24). In a larger list Canada ranks 20 of 36 countries in the number of graduates per 100,000 in 2020. It is also interesting to note that the variation between countries has shrunk over the years.

We do not have exact numbers of how the number of university professors, university faculty lecturers and support staff has changed over that period. The only indicator is the number NSERC Discovery grant applications that have risen by nearly 25% between 2016 and 2020, but then decreased and were 10% less in 2023 compared to its height in 2020, although this might be related to COVID pandemic and NSERC's decision to extend funding duration for those requesting it. Nevertheless, growth in advertised tenure-track positions is far behind the growth in undergraduate population. But clearly, this increase in students has put a lot of extra teaching obligations on professors that often have to handle very large classes. The fact that the number of PhD students has not significantly increased might indicate that not a significant number of new university professors were hired. But it might also be an indication that research funding is not sufficient to increase the PhD pool.

HQP Funding:

The 2013 Research Report was very concerned about the funding level for graduate students. The very high number of international students shows that **it is very hard to recruit Canadian students** as the funding that can be provided is not competitive with salaries in industry after a Bachelor's degree.

As such, one of the major recommendations of the 2013 report was to provide the means that enable larger funding for graduate and post-doctoral students.

The situation now is unchanged at best, but may be even worse. A huge effort was put in the last years by the Canadian Consortium for Research to lobby the government for larger federal scholarships for M.Sc./PhD students. NSERC/CIHR/SSHRC were very happy about this lobbying approach and it appeared that the government heard the message. However, the latest government budget did not increase NSERC's funding pool and NSERC scholarship levels remained unchanged – they have remained the same for nearly 2 decades; given inflation, this means considerably lower funding levels. As such NSERC made this year the decision to fund fewer researchers in order to provide higher funding levels to researchers with funding so that they can provide higher scholarships to their students, but as mentioned above this led to less students being funded. This is an understandable decision given the funding levels NSERC has to operate in, but it is a decision that has considerable adverse impact on the CS academic scene and will result in adverse impacts on the entire ICT sector. .

Summary:

Since the last report in 2013, some things in which Canada is doing well have stayed the same or got slightly better – the research excellence, ICT economy and employment, and more recently industry R&D. However, many of the issues that were of concern 10 years ago remain unresolved. While industry/academia relationships and collaborations have started to emerge in AI, primarily due to the particular funding schemes provided through CIFAR and CFREFs, it is still extremely difficult for academic researchers outside of AI to perform cutting-edge research in collaboration with industry. Furthermore, grant sizes and student support have failed to keep up with inflation, not to talk about any actual support growth that would match the growth the ICT economy has experienced.Of course, the entire AI initiative is a big boost to CS, both at academia and in industry, and highly welcome, but one needs to be acutely aware that it must not unintentionally and negatively affect non-AI areas in CS. Moreover,he huge CS enrollment has put a considerable burden but also opportunity to CS researchers.

Where do we go from here?

In terms of recommendation, there are some concrete low-level recommendations that don't appear to be so different to what was proposed 10 years ago:

- It is important to support ALL of CS and with sufficient funding that allows researchers to provide attractive funding to the best of our students. Narrow funding for AI alone is not likely to generate the positive impact and outcomes the governments intend; the entire CS ecosystem needs appropriate funding. In particular:
    - NSERC student and post-doc scholarships need to be considerably increased and regularly adjusted for inflation. The number of scholarships need to be adjusted with respect to increasing student population and should accommodate the planned growth in the number of academic faculty members.
    - NSERC Discovery grants need to increase to allow researchers to undertake high risk/high return research projects that are now common in CS and to offer students who are funded through those grants appropriate funding levels. This should not come at the cost of funding fewer researchers but through increased funding for NSERC.
    - NSERC Discovery grants to CS researchers need to be better adjusted to the increasing number of researchers and HQP within the CS area.
- There should be the possibility for the CS community to provide input to NSERC in possible alternative ways that the available funding hould be distributed. NSERC's decision this year to fund fewer researchers (higher cut-off) came as a complete surprise to the research community. A

consulting process would allow NSERC to benefit from the views of the research community. This can be achieved through CS-Can/Info-Can that can facilitate consultations with the larger community.

- As already indicated in the 2013 Research Report, RTI funds are important for CS as CFI funding often does not reflect well the needs (and diversity) of CS researchers.
- Better collaboration with all areas of ICT related industry will boost both the performance of academia and industry. How to find the best way to make such collaboration more easily happen is still an outstanding issue. But the initiatives put forward for AI might help as a guidance.

In a broader context, the research committee has discussed several issues that should be further explored.

A push for more and different research support and training at graduate level:

- The pan-Canadian AI strategy funds research quite differently and connects research in that field with industry using a different model. What lessons can be learned from that experience? Can some parts of the funding model also be applied to CS at large?
    - The successes in this direction are starting to be visible. Canada is now a major player in AI. The synergy of fundamental research through Amii, MILA, Vector with more applied branches is interesting and appears **beneficial to BOTH large-scale companies and SMEs.**
    - **Industry appreciates that AI needs HQP at graduate level and is aware that it needs fundamental research.** Even SMEs believe that the fundamental research performed in MILA/Amii/Vector is beneficial even if not directly put in practice in SMEs. **The AI institutes have many industrial membership partners**. They benefit from the vibe, energy, access to HQP, transfer knowledge through HQP etc.
    - This concentration of AI research in several Canadian locations also helps in bringing R&D centers of multi-nationals companies to Canada (Samsung, Facebook, Google, Microsoft, Deepmind, etc) and the creation of R&D centers of larger national corporations (e.g., RBC).
    - AI funding is done extensively through CIFAR and two local CFREFs. This is relatively direct funding with less competition and a less stringent review process. But NSERC/CIHRC plays also an important part with many Alliance, NCE, and CREATE grants in the AI area. It helps here especially with the interdisciplinary aspect. But so far little has been done to get the smaller companies involved and engaged. Can there be other models included into the granting agency process to connect with these smaller IT companies (ideally also considering a broader reach, i.e., CS as a whole rather than mostly AI)?

- Are there lessons learned for other domains?
    - Canada is currently also investing heavily in health and sustainability at the academic level. This is relevant for CS researchers, not only in AI but also in other fields such as computer infrastructure, software platforms, programming languages and data science. How can this interdisciplinarity of CS with applied domains be best fostered and how can CS research help move forward these domains?
    - In light of the pandemic, Canada has realized that there are several domains where it might be too dependent on international partners (e.g., vaccines, but also production pipelines). The fact that Canada has only around 100 large ICT companies also clearly shows a dependency on multinationals. Many Asian and middle-eastern countries are heavily investing not only in AI, but the entire high-tech market, with incredible force also in fundamental research in this area (e.g., China, Taiwan, Singapore, Hong Kong, United Arab

Emirates, Qatar, etc). Both in the US and Germany, two countries that have many large-scale IT companies, these companies work successfully with researchers of the best universities in many different CS domains. Thus, the question arises whether Canada should thus not only push the AI agenda but high-tech as a whole with the aim of developing high-tech corporations locally. This will have two main advantages: (a) immediate GDP and revenue growth as IT companies often bring in a lot of revenue and provide high-paying jobs, (b) becoming more independent from other countries.

- Already in the report 10 years ago, it was indicated that the partnership programs do not seem to work that well for the CS sector. As our numbers show, this has not really changed. How could this be improved? Push for larger funding amounts for NSERC directly targeted to CS (such as the Quantum initiatives or the Math institutes). Or bolder approaches such as a broader CIFAR-like approach? What exactly is the role of MITACS?

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