The Relationship between Ph.D. Students' Excellence Scholarships and their Research Productivity, Scientific Impact and Degree Completion

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Abstract

Drawing on three distinct sources of data (students, excellence scholarships and scientific publications) on the entire population of doctoral students in the province of Québec, this report presents evidence of a relationship between excellence scholarships and research productivity, scientific impact and degree completion. It shows that funded students publish more papers than their unfunded colleagues and that there is only a slight difference between funded and unfunded Ph.D. students in terms of scientific impact. Funded students are also more likely to graduate, and this effect is greater for students funded by the federal government. Finally, although funding is clearly linked to higher degree completion for students who did not publish, this relationship does not hold for those who manage to publish at least one paper during the course of their Ph.D. The paper concludes with a discussion of the implication of the findings for Canadian science policy.

Introduction

Analyses of the relationship between researchers' funding and their research output were typically performed on established researchers (Ali, Bhattacharyya & Olejniczak, 2010; Boyack & Börner, 2002; Campbell & *al.*, 2010). However, they are not the only 'social' group receiving money for research: graduate students, either at the M.A., M.Sc. or Ph.D. level, account, in Canada, for a significant proportion of research funds. More specifically, in 2008-2009, about a third of federal research councils' research funding in the social sciences and humanities, 15% of their funding in the natural sciences and engineering, and 6% of the funding in the medical sciences, goes into fellowships and scholarships.[1] Overall, more than 300 million $CAN were granted by federal research councils in 2008-2009. At the provincial level, about 20% of all research funding goes into scholarships (CNCS-FEUQ, 2008).

Despite the magnitude of this funding as well as the overall importance of graduate programs for the reproduction of the scientific community, no study has yet analyzed, at the Canadian level, the relationship between this funding and students' research productivity, scientific impact and degree completion. This paper aims at providing such analysis at the level of the entire population of Ph.D. students enrolled in Québec universities for the 2000-2007 period. Three dataset are used: 1) all graduate students enrolled in a Ph.D. program in a Quebec university, 2)

[1] These data were compiled with http://www.outil.ost.uqam.ca/CRSH (social sciences and humanities) and, http://www.outil.ost.uqam.ca/CRSNG for the natural sciences and engineering, while the data for the medical sciences comes from an in house database transferred by the Canadian Institutes of Health Research.

the list of 'excellence' scholarships granted by the three federal research councils[2] and the three provincial research councils[3] and 3) the Web of Science-based bibliometric database of papers authored by Québec researchers. Funding analyzed in this study, is, thus, limited to 'excellence' scholarships attributed by these six councils, through peer review, to students directly. Hence, it does not include 'discretionary' scholarships provided by advisors through their own research fund, nor does it include funding coming from teaching or research assistantships.

Graduate scholarships from the six research councils provide a tax free annual salary of 20,000$CAN in the case of the Québec provincial research councils and of 20,000$CAN or 35,000$CAN at the level of the federal Canadian councils, where two kinds of scholarships are available depending on the overall ranking of the student. These scholarships are attributed for a maximum of three years—except the 20,000$CAN scholarship of SSHRC which can be attributed for four years. Although federal and provincial scholarships cannot be cumulated for a specific year—because of a provincial legislation—, students who have the provincial scholarship for the first three years of their doctorate can obtain the federal scholarship for their fourth year. Given that it is mandatory for students who are awarded both scholarships to accept the federal one and reject the provincial, and that the average amount of federal scholarships is greater, we can infer that, generally, students funded at the federal-level did score better in the review process than students funded at the provincial level. These scholarships are generally the main source of income of those who hold them, as their 'paid' working hours, within and outside the university, have to be limited to a strict minimum.

This study cannot measure the 'effect' of these scholarships on Ph.D. students' productivity, impact and degree completion, as they are attributed on a review basis in which publications are taken into account. In other words, the fact that a student has published prior to applying for a scholarship is likely to have a positive influence on its success. Hence, the only question we can answer[4] is whether there is a relationship between having received a scholarship and 1) publication activity, 2) citations and 3) degree completion. If so, we can conclude that research councils were successful in choosing the young researchers with the greatest research potential. On the other hand, this is not exactly true, as some unfunded students could have a research potential as high, but could not fulfill it because they have not received the funding to catalyze it. We could say, thus, that those they funded were *amongst* the students with the most research potential. Actually, the only way—which would not be very ethical—to sort out this impasse would be to 'arbitrary' divide 'fundable' students into two groups, one which we fund and the other which we left unfunded, and then to compare their ulterior research performance.

The following section briefly examines the results of related studies on students funding, publication patterns and degree completion, while the methods section describe the dataset, data compilation and indicators used. The third section presents the results obtained and is followed by a discussion and conclusion.

[2] Canadian Institutes of Health Research (CIHR), Natural Sciences and Engineering Research Council of Canada (NSERC) and Social Sciences and Humanities Research Council of Canada (SSHRC).
[3] Fonds de la recherche en santé du Québec (FRSQ), Fonds québécois de recherche sur la société et la culture (FQRSC) and Fonds québécois de la recherche sur la nature et les technologies (FQRNT).
[4] These limitations were also discussed by Bornmann and Daniel (2005).

Related studies

The general literature on students' participation in papers being scarce, only a few direct sources of information on the specific factors influencing such participation were found in the literature. Similarly, although several studies have analyzed the effect of funding on students' graduation, very few have linked their funding with their research productivity.

The main source of information on doctoral education found in the literature is the large-scale survey of doctoral students—more than 9,000 students covering all disciplines—performed by Nettles and Millets (2006). It provides unique results on the effect of funding and supervisors on students' publication records. The authors present the different types of funding offered to students during their doctorate, broken down into three categories: fellowships, research and teaching assistantships. As one could expect, students of the different disciplines are not equal in terms of access to this research funding. The disciplines with the highest proportion of students with fellowships are the humanities (69%), followed by the social sciences (61%), sciences and mathematics (59%), engineering (50%) and in education (46%). Nettles and Millett's study does not provide any indication of the amount received, as smaller fellowships might explain the higher percentage of students funded in the humanities.

In terms of research assistantships, the tendency is quite different: 82 % and 69%, respectively, of students in engineering and in science and mathematics worked as faculty members' assistants, while this percentage was only 49%, 33% and 28% in the social sciences, humanities and education, respectively. Finally, in all disciplines but education, a majority of students received teaching assistantships. These various types of funding were found to have a strong effect on the PhD students' participation in peer-reviewed papers. Students receiving fellowships were more likely to publish in education, science/mathematics and in social sciences. Similarly, in all disciplines but the humanities, students who were research assistants published more papers. Teaching assistantship was positively linked with research productivity only in the humanities. Along the same lines, Buchmueller, Dominitz and Hansen (1999) have also positively linked students' research assistantships with research productivity, using a sample of doctoral students in economics. Unsurprisingly, working with productive faculty members also increased students' research output. Similarly, Larivière (2010) has showed that specialties where the average amount in funding received by professors was higher, the percentage of doctoral students who published at least one paper was also higher. This is not surprising, as research funds received by faculty members are often used to give scholarships or to hire students to work on their research projects which, in turn, increase students' participation to peer-reviewed papers as well as faculty members' probability of being funded again

Although no study has analyzed funding effects on the scientific impact of students' papers, Campbell & *al.* (2010) provides evidence of a clear relationship between the funding of researchers and their citation rates. Similar results were obtained by Peritz (1990), as well as in a number of confidential report made by various bibliometric organizations through the world. Finally, several studies from the higher education community have positively linked students' funding with degree completion (Bowen & Rudenstine, 1992; Ehrenberg & Mavros, 1995; Ethington & Pisani, 1993).

Methods

Students' database

Given that the status of individual authors does not appear in the byline of papers or in bibliographical databases a list of doctoral students is needed to find papers they authored. Although all Quebec universities have their own lists of enrolments, expected differences in format and content, as well as difficulties of access, discouraged their use. Hence, it was decided to use the Quebec's government administrative database of university enrolments in Quebec, the *Gestion des données sur l'effectif universitaire* database (GDEU). This database contains the names—essential information for this study—of all university students in the province of Quebec. In order to find publications authored by doctoral students, the database of scientific papers written by authors from the province of Quebec and the database of students were matched using the name of the student. This database was provided for the 2000-2007 period. More specifically, the dataset analyzed in this study contains PhD students that either 1) enrolled in a PhD program during the period between fall 2000 and fall 2007 or 2) enrolled before fall 2000 but were still registered or graduated at any point after 2000. Hence, students that completed their PhD in 1998 or 1999 are excluded from the dataset, as well as students who joined a PhD after 2007. On the whole, the list of doctoral students contains 27,397 distinct doctoral students, with 2,838 (10.4%) having changed program at least once during the period under study.

In order to compare the results obtained across the spectrum of disciplines, the 866 distinct doctoral programs of students provided in the GDEU database were categorized into 42 specialties and 9 disciplines. This classification scheme used for categorizing doctoral programs was based on the 2000 revision of the U.S. Classification of Instructional Programs (CIP) developed by the U.S. Department of Education's National Center for Education Statistics (NCES). This classification of programs was recently used in Larivière & *al*. (2010) for Quebec's university-affiliated researchers. A CIP-based discipline could not be attributed to 232 doctoral students (0.8% of the dataset); these were excluded from the analysis.

Funded students' database

The list of all funded students was built by combining the three databases of the federal research councils (CIHR, NSERC and SSHRC) and the two databases of the provincial councils (FQRNT/SC and FRSQ). The information provided by the councils was not of homogeneous 'quality': while the federal data contained information on the *exact* amount received by students for each year during which he or she was funded, Québec research councils did not provide any information on the yearly amount received. These scholarships can either be attributed to students studying in Québec and to students studying in other Canadian provinces or Canada.[5] Although we know that the amount of provincial grants is 20K$ annually, in some cases—such as interruption of studies—some students might have received less than 20K$. Another limitation is that funding from the FQRSC and FQRNT was merged—as the two councils used to be only one entity—which prevents from analyzing the specific effect of each of the provincial research councils. In any case, because of these limitations, this report is limited to the analysis of students funded or unfunded through any of the excellence scholarships and of, for funded students, of the

[5] The only exception are Canada Graduate Scholarships (federal level), which can be only obtained by students enrolled in a Canadian university.

difference between those funded by the federal and the provincial programs taken as a whole. Students who have had provincial and then federal funding were considered in both categories when data was broken down by source of funding.

The matching of the list of funded students with the list of all Québec students from the GDEU database was performed using an in-house software for matching lists. The matching was performed on a surname basis and manually validated. Out of the 7,491 grants that have been attributed, 5,766 were matched to a student in our list, for a total of 4,672 distinct students. Hence, 1,725 grants were attributed to students who have pursued a doctoral degree outside the province or country, as these scholarships can either be attributed to students studying in Québec and to Canadian or Quebec students studying in other Canadian provinces or outside Canada. It is also possible that a small proportion of these unmatched students are actually false negatives—i.e. students who indeed pursued doctoral studies in Québec but could not be matched because the spelling of their surname/given name has changed.

Finally, an important limitation of our analysis is the fact that doctoral students can have other sources of funding: institutional or 'discretionary' scholarships—i.e. scholarships given by the students' supervisor—, teaching assistantships, research assistantships or external jobs. Data compiled on these, however, is not compiled in a consistent manner, and certainly does not exist at the level of the entire population, as it is the case for the funding analyzed in this paper. The funding covered in this paper is, however, the most 'prestigious' available to Ph.D. students and, contrary to what is generally the case for these other sources, is obtained through a very competitive peer review process.

Disambiguation of students' papers

This paper includes the whole population of PhD students enrolled in Quebec's universities between 2000 and 2007 (N=27,393). Papers authored by these students during the 2000-2007 period were retrieved from Thomson Reuters' Web of Science (WoS) by matching the names of all of Quebec's doctoral students with the names of authors of papers with at least one institutional address from Quebec. Given that the WoS does not index the complete first name of the authors, but only their initials, this rough match generates a high number of false positives—papers authored by other researchers having the same name as a doctoral student (homonyms)—which were removed using both manual and automatic validation. More details on the disambiguation process can be found in Larivière (2010). After the disambiguation process, 31,738 author-article combinations were retained (out of the 313,367 originally obtained with the first match) for 25,159 distinct papers and 8,468 doctoral students with at least one paper.

Bibliometric database and indicators

Publication counts presented in this paper are based on the number of articles, notes and review articles to which authors from Québec contributed during the 2000-2007 period. Hence, editorials, book reviews, letters to the editor or meeting-abstracts are excluded from the analysis, as they are not generally considered as original contributions to scholarly knowledge and are not peer-reviewed (Moed, 1996). These numbers are based on full counting of papers, as opposed to fractional counting sometimes used in bibliometrics. Hence, each individual or organization contributing to a paper is assigned one 'full' contribution, instead of a fraction of a contribution, irrespective of their rank in the author order. Papers are considered as being authored by doctoral

students when at least one of the authors is enrolled in a PhD program in one of Quebec's universities during the publication year of the paper or has been enrolled during the year prior to the publication of the paper. In other words, in line with Lee (2000), doctoral students' papers are still considered as such until one year after they graduate or leave the program. Note that this practice is also found in the large teams of particle physics, where researchers get to sign the papers coming out of the experiment until one year after they leave the team (Biagioli, 2003).

Citations measures are made over the full period, which means that the total number of citations received since publication by a given paper are counted. In order to compare data between different specialties, each article's number of citation is divided by the average number of citations received by papers of the same discipline published the same year (Moed, De Bruin & van Leeuwen, 1995; Schubert & Braun, 1986). Self-citations are excluded and impact measures are normalized so that when the average of relative citations (ARC) is above 1, the articles of the group of researchers in a given field are, on average, cited above the world average for the same field. Conversely, an ARC below 1 means that the number of citations received is below the world average. Finally, the well known limitations of bibliometrics apply to this analysis. Indeed, the measures presented here do not include all documents likely to have been published by doctoral students, as no bibliometric database indexes all of the scholarly literature published worldwide. This limitation is more important in the social sciences and the humanities, where the application of article counting methods poses two main problems: 1) no coverage of research output in media other than journal articles (Larivière & *al.*, 2006) and 2) very limited coverage of research output in the form of articles written in languages other than English (Archambault & *al.*, 2006).

Results

Table 1 presents the percentage of doctoral students who have received a scholarship from the three federal, three provincial, or from any of the six research councils. Globally, it shows that about 17% of doctoral students in our population have received one of these scholarships, and that most of these scholarships were obtained from federal government. The only areas where the main sources of student's scholarships are the provincial councils is business and management and education. We clearly see that students in medical sciences and health are more likely to be funded, followed by students in the humanities, sciences and social sciences. A smaller proportion of Ph.D. students in applied or professional fields such as engineering, education and business hold scholarships, which is likely a reflection of industry funding and part time studies. These differences can also be explained by the number of applications made, but also by differences in success rates of applications. At the federal level, 64%, 32% and 22% of the applications reviewed by NSERC, CIHR and SSHRC, respectively, got funded while, at the provincial level, 42%, 34% and 33% of the applications made to FRQNT, FRSQ and FQRSC were successful. (CSE, 2010)

Although not shown, a larger proportion of students who enrolled at the beginning of the period studied than those enrolled at the end have obtained a scholarship. This can be explained by the fact that the former group of students 1) had more time to improve their research record and 2) probably applied on a yearly basis which, from a strictly probabilistic point of view, increases their chances of landing a scholarship.

Table 1. Percentage of Ph.D. students who have received a scholarship from the federal or provincial research councils, by source and discipline, 2000-2007.

Research Area	Federal		Provincial		Federal or provincial		All Students
	N.	%	N.	%	N.	%	
Basic Medical Sciences	620	16,2%	443	11,6%	970	25,3%	3 833
Business & Management	59	3,8%	85	5,5%	128	8,3%	1 536
Education	72	4,0%	102	5,7%	157	8,7%	1 801
Engineering	370	7,4%	241	4,8%	498	10,0%	4 973
Health Sciences	89	12,6%	68	9,6%	140	19,9%	705
Humanities	521	12,2%	308	7,2%	727	17,1%	4 261
Non-Health Professional	158	9,2%	112	6,5%	240	14,0%	1 714
Sciences	698	13,1%	360	6,8%	875	16,4%	5 331
Social Sciences	737	11,0%	500	7,4%	1 046	15,6%	6 717
All Areas	3 267	11,9%	2 146	7,8%	4 672	17,1%	27 397

Research productivity

Two measures of research productivity are presented in Figure 1: the percentage of students with at least one paper (A) and the average number of papers (B). Both measures converge and show that, when all disciplines are combined, funded students are more than twice as productive, in terms of papers, than their colleagues who did not receive such funding. This is observed in each of the disciplines, although the difference between funded and unfunded Ph.D. students is smaller for the disciplines of basic medical sciences and sciences. This is likely a reflection of the fact that professors of these disciplines receive more funding than their colleagues of the social sciences and humanities (Larivière, 2010), which in turn, is used to fund students. In other words, students of medical and natural sciences who received no scholarship are more likely than their colleagues of the social sciences and humanities to obtain 'discretionary' funding through their advisors, not to mention the existence of various other sources of funding through the various foundations dealing with specific illnesses.

Figure 2 presents the same indicators for students funded by federal or provincial scholarships. As mentioned previously in this paper, federal scholarships are, on average, of a greater amount than their provincial counterpart. Surprisingly, there is no noticeable difference, at the level of all disciplines, in terms of research productivity, between students funded by the federal government and those funded by the provincial government of Québec. Although in most disciplines, provincial funding is linked to higher productivity, these differences are quite small, and the opposite is true in some others. All in all, this suggests that the amount Ph.D. students' scholarships, as well as their 'rank' in the evaluation, has little effect on their publication output. Being funded is what counts, whatever the amount.

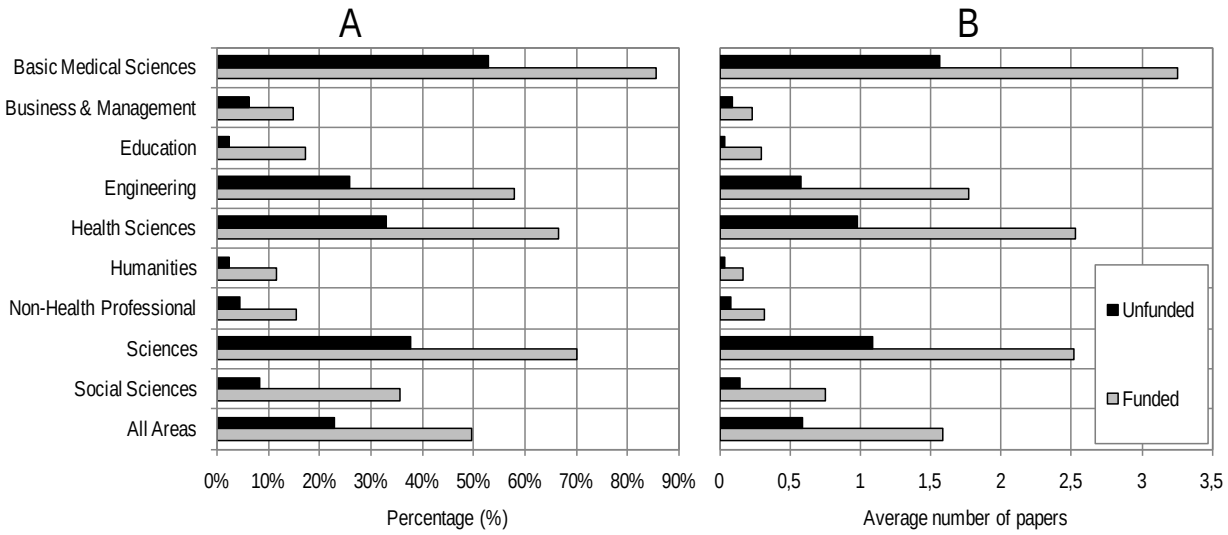

Figure 1. For funded and unfunded Ph.D. students: A) Percentage of students with at least a paper and B) Average number of papers of students, 2000-2007.

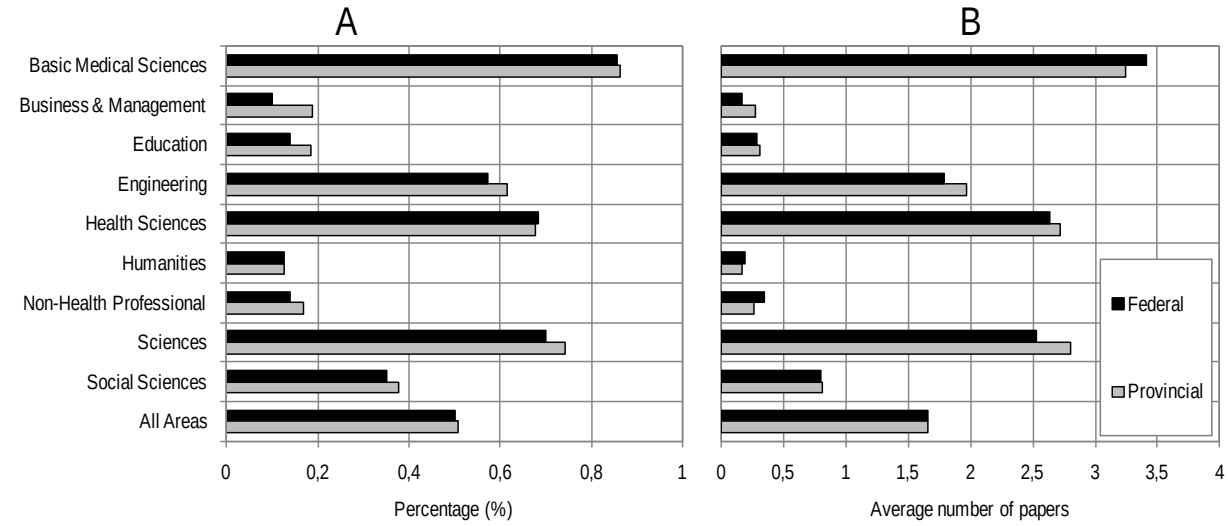

Figure 2. For students funded by federal or provincial councils: A) Percentage of students with at least a paper and B) Average number of papers of students, 2000-2007.

Scientific Impact

Figure 3 presents the field normalized citation rate of papers to which funded and unfunded students contributed (A) and of papers authored by students funded by federal or provincial research councils (B). Figure 3.A shows that funded students' papers obtain, on average, slightly higher citation rates than those of their unfunded colleagues (1.32 vs. 1.29), and that the difference between the two groups' scores varies greatly among disciplines. In more 'basic' disciplines, funded students' papers have more impact, while the opposite is true for more applied disciplines such as business, education and non-health professions (law, etc.). The exception here is engineering, where funded students' papers have more scientific impact.

The difference between federally- and provincially-funded students' research impact is greater: while federally-funded students' papers obtain an ARC score of 1.43—43% greater than the world average of their specialty—those funded by provincial councils obtain an ARC of 1.14—14% greater than the world average. This is not true, however, in disciplines such as business and management, education, engineering and health sciences. Despite the different patterns observed for these four areas, it does seem that federal councils have managed, in the five disciplines that account for 80% of all Ph.D. students in the province, to fund students who contributed to papers obtaining a greater scientific impact. This can be explained by the fact that students who get both scholarships—and are thus probably the best students—have to accept the federal one and, thus, liberate a provincial grant, which can then be attributed to the next student on the list.

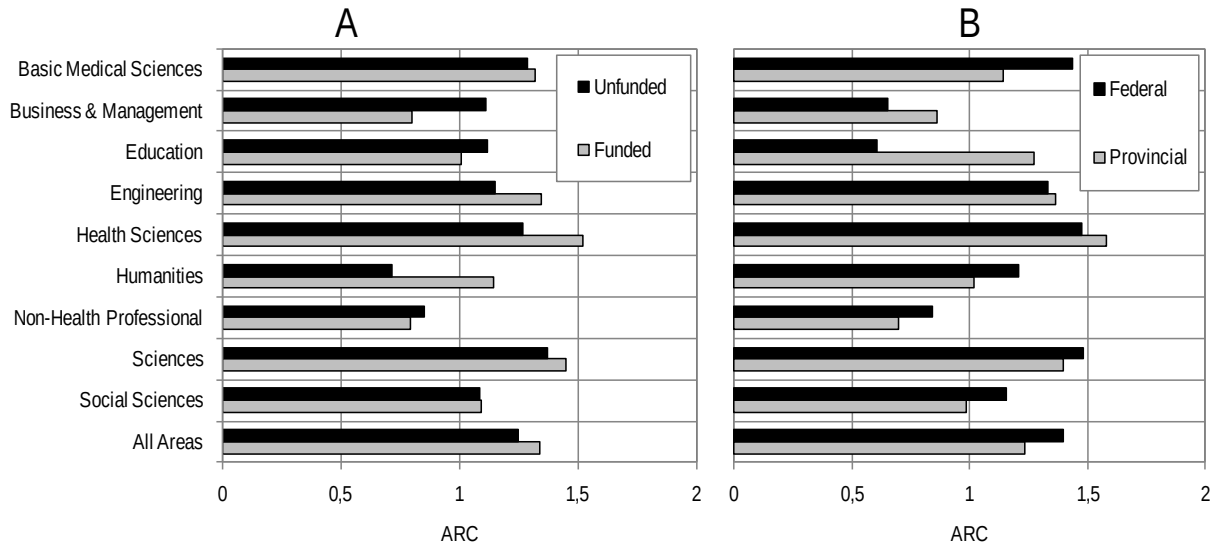

Figure 3. A) Average of relative citations of papers to which funded and unfunded students contributed, B) Average of relative citations of papers to which federally—and provincially—funded students contributed, 2000-2007.

Degree Completion

The funding of doctoral students has been previously linked to degree completion (Bowen & Rudenstine, 1992; Ehrenberg & Mavros, 1995; Ethington & Pisani, 1993).. Data presented in Figure 4.A points in the same direction: in all disciplines, we clearly see that funded students of the 2000-2002 cohorts (6,596 distinct students) were more likely to have graduated as of the end of 2007 than their unfunded colleagues of the same cohorts. More specifically, while slightly more than 50% of the funded students of these cohorts have graduated, this percentage drops at 34% for those who were not funded by any of the six research councils. Although this doesn't mean that those who have not graduated as of the end of 2007 have not graduated since then, it does mean that, if they did so, it took them longer than the five years usually allocated for the completion of a Ph.D.

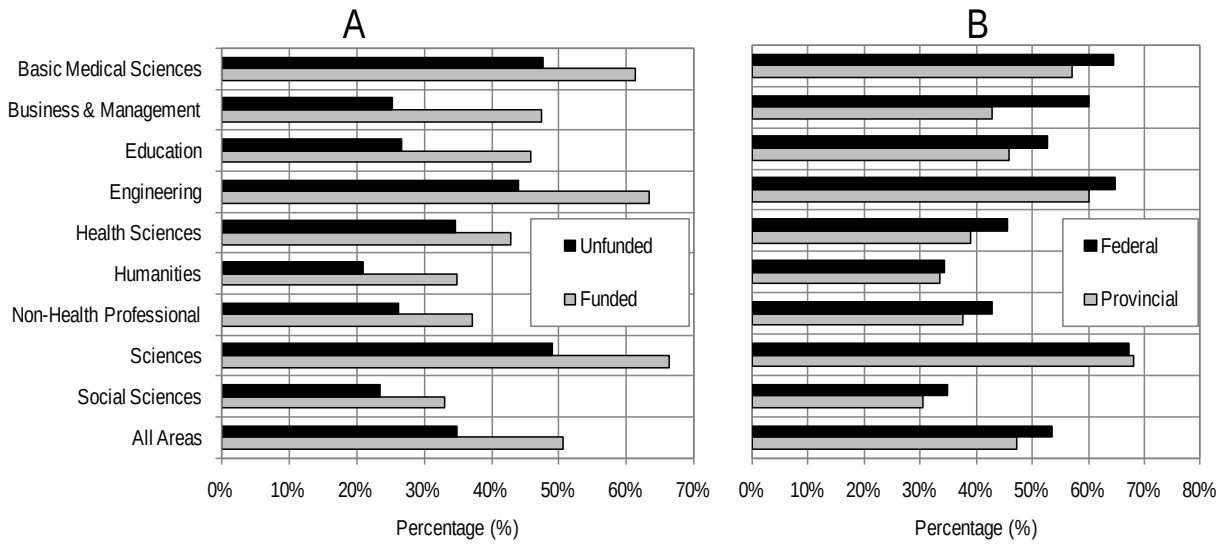

Figure 4. As of the end of 2007 A) Percentage of funded and unfunded students of the 2000-2002 cohorts who completed their degree, B) Percentage of federally—and provincially-funded students of the 2000—2002 cohorts who completed their degree.

Figure 4.B presents completion rates of students funded by the federal and by provincial councils. Although the difference in the research productivity and impact between federally- and provincially-funded Ph.D. students was somewhat mitigated—those funded by the federal government were not always the most productive nor had the highest impact—we see a clear trend toward degree completion for students funded by federal research councils.

In order to take into account the relative importance of both publishing papers and receiving a scholarship on completion rate, we compiled, for both funded and unfunded Ph.D. students, the percentage of students who graduated as a function of their number of publications (Figure 5). Although for students with no paper—which account for the majority of students—those who were funded are more likely to graduate, there is no difference, for a given number of papers, between funded and unfunded students in terms of completion rates. Moreover, when limited to students who published between 1 and 5 papers, unfunded students, obtain higher completion rates than funded students! The figure also shows that there is a linear relationship between the number of papers published and completion rates, and that this stabilizes between 70% and 80% for those who published more than five papers.

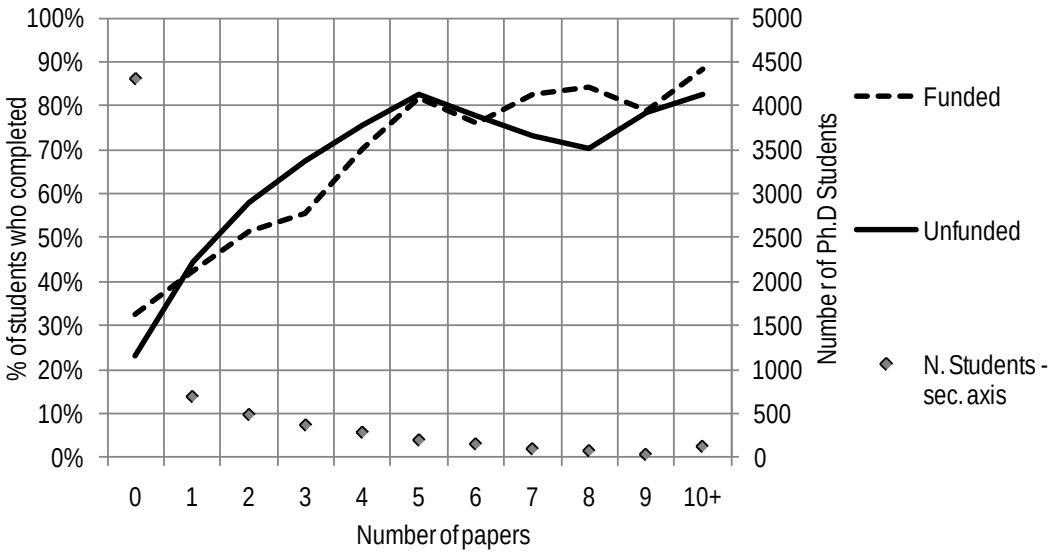

Figure 5. Percentage of funded and unfunded students of the 2000-2002 cohorts who graduated as of the end of 2007, as a function of their number of papers.

Discussion and Conclusion

Drawing on three heterogeneous sources of data (student data, funding data and publication data) related to the entire population of doctoral students in the province of Québec, this paper presented evidence of a relationship between research funding and research productivity, scientific impact and degree completion. It has showed that funded students publish more papers than their unfunded colleagues, although there is no meaningful difference between those funded by federal scholarships and those funded by provincial scholarships. In terms of scientific impact, there is only a slight difference between funded and unfunded Ph.D. students, but students funded by federal scholarships obtain significantly greater impact scores than those funded by the provincial government. It cannot be assessed, however, whether this is due to their higher rank within the councils' ranking—and hence, 'pre-doctoral' record or 'excellence'—or if it is an effect of the scholarship *per se*. Funded students were also more likely to graduate, and this relationship was greater for students funded by the federal government. Finally, although funding has a clear effect on the graduation rates of students who did not publish, it has virtually no effect on students who have managed to publish at least one paper during the course of their Ph.D.

On the whole, these data call for a reflection on the 'hierarchy' of scholarship programs in Canada. Our data show that, despite their more important funding, federally-funded students do not publish more than their provincially-funded colleagues. Productivity depends on the number of researchers (Abt, 2007), and for doctoral students, being funded is probably the only manner they can devote all their time to their research. Hence, instead of concentrating the funds on an elite of doctoral students receiving a greater scholarship, funding programs should offer only one kind of scholarship and use the supplementary funds to fund more students.

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