FACTORS INFLUENCING FUNDED RESEARCHER PRODUCTIVITY OF EDUCATION FACULTIES: AN EMPIRICAL INVESTIGATION OF THE PUBLICATION PERFORMANCES WITHIN CANADIAN UNIVERSITIES, 2001-2008

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ABSTRACT

Our study seeks to identify the factors that explain the research productivity of education faculties, within seven different universities in Quebec-Canada. The main hypothesis of this study is that productivity in scientific research is significantly influenced by the volume and origin of the funding sources mobilized to support scientific research performance. Based on a sample of 194 researchers and time series data (2001-2008), our research use individual publications in referred journals (number of publications, fractioned publications, citations, impacts) as surrogates for research productivity. Not surprisingly, the findings show that funding is a key input in the scientific production process, and, in turn, in education researcher performance, taken individually. Examining the specific effects of funding sources on productivity, we found that, among the sources for which data were available, only funding from the federal government and the private sector are not statistically significant in its relation to the productivity indicators used. Also not surprisingly, findings show that academic funding from grants and university research funding councils provide the greatest elasticity regarding outputs dealing with the number of publications. Finally, we find that age, gender, size and language (Francophone versus Anglophone) of university instruction, funding councils, grants and provincial government funding significantly affect researcher productivity. Our results raise questions about whether financial incentives boost publication productivity, and whether policy-makers should place greater emphasis on other relevant factors of high productivity among researchers, faculties and departments operating in the education field.

Keywords: Research productivity, research performance, research impact evaluation, education, higher education, Québec-Canada
INTRODUCTION

Thanks to prolific, well-funded and well-inspired researchers, such as Piaget and Heckman (the latter being awarded the Nobel Prize for Economics), great strides have been made in scientific research dealing with education. Considerable advancement in knowledge useful to human capital and the reinforcement of the impact of research in education on the well-being of nations were generated by their research. If Piaget’s research (1972) demystified the key elements of how we learn to improve the instructional effectiveness of the transmission of knowledge, Heckman’s research deciphered the socio-economic performance of human capital training. Heckman’s research demonstrates that the social performance of learning is inversely proportional to the learner’s age (Heckman & Cameron, 2001). In the wake of these illustrious researchers, thousands more, worldwide, have contributed to the advancement of knowledge through their numerous publications, thereby rewarding targeted and expanding public funding for research in the field of education (Edwards, 2000; Mortimore, 1999).

Despite this ongoing funding effort required by research in the education sector, researcher contribution to the advancement of knowledge is rather inconsistent (Carayol & Matt, 2006; Adams & Griliches, 1996-1998; Mortimore, 1999). It raises certain questions about the determinants of researcher productivity and the impact of their scientific publications (Edwards, 2000). This article explores the determinants of the scientific productivity of researchers working in education faculties within universities in the Canadian province of Quebec, using fairly detailed chronological data and dealing with both research inputs (funding, etc.) and outputs, measured by bibliometric indicators. The main hypothesis of this research is that productivity in scientific research is significantly influenced by the volume and origin of the funding sources mobilized to support scientific research performance. It is postulated that the funding sources do not all necessarily have the same effect on researcher productivity and on the impact of the scientific articles produced. Due to the significant amount of funding for university research, funding organizations, like other public organizations, have been exposed to the demands of optimizing resources, leading to adjustments in their allocation strategies and criteria for university research funding based on researcher performance. In this context, the relationship between the inputs and outputs of subsidized research (scientific publications and associated impact) emerges as a strategic issue for public decisions having an impact on innovation and the development of competencies.

Numerous scientific policy evaluators and analysts have shown an interest in researchers’ scientific productivity and have made it performance-measurement parameter of public investment in scientific research (Walberg, Rasher & Mantel 1977; Smith & Caulley, 1981; Walberg, Vukosavich & Tsai, 1981). The analysis of the relationship between research inputs (grants, infrastructure spending, training of researchers, etc.) and research outputs (productivity, citation, impact, etc.) has also been the subject of several explanatory works, mostly done in OECD countries, whether in France (Carayol & Matt, 2006; Turner & Mairesse, 2003), the United States (Bozeman & Gaughan, 2007; Adams & Griliches, 1998), Italy (Abramo, D’Angelo & Caprasecca, 2009), New Zealand (Goldfinch, 2003), the United Kingdom (Elton, 2000), Australia (Marinova & Newman, 2008), or the European Union (Defazio, Lockett & Wright, 2009).

Despite the abundance of empirical works on the question of researcher productivity, there is a paucity of recent studies dealing with the level of research productivity of education
faculties (Clark & Guba, 1976; Eash, 1983; Gordon et al., 1984; Kroc, 1984; Walberg et al., 1977; West, 1978). These studies also seem to be limited to the analysis of citations from some well-known researchers in the field (Walberg et al., 1977), or to a compiling of citations generated by certain articles (Smith & Caulley, 1981; Walberg et al., 1981). Some research has also attempted to measure the impact of education journals (Campbell, 1979; Campanario, Gonzalez & Rodriguez, 2006; Luce & Johnson, 1978; Mayo, Zirkel & Finger, 2006; Orr, 2004; Smart & Elton, 1981; Haas et al., 2007). To our knowledge, no research has focused on the scientific performance of researchers working in education as well as on its determinants.

This research aims at answering two questions. First, what are the determinants of the productivity of university research in the field of education? Second, what is the performance of funding granted to promote producing new knowledge in the field of education? These questions have been examined with regard to researchers affiliated with the education faculties and departments in Quebec (Canada) universities.

In this research, educational researcher productivity has been analysed on validated indicators, taking into account both the quantity of publications (total or fractioned number) and their quality (citations, impacts, etc.). A two-phased approach has been used for empirical analysis. The first is concerned with the origin and size of the effects of total funding on productivity in research. The second looks at the effects attributable to funding from funding grants from the different levels of government and to funding from the private sector (corporations, foundations, etc.). To do so, this research uses empirical data describing the evolution of funding and publications associated with 194 researchers working in the education faculties of Quebec universities from 2001 to 2008. The data used in this work combine various objective databases dealing with inputs (funding) and outputs (in particular, publications, citations, impact factor).

The remainder of the text is in threefold. The first part deals with the analytical framework and the theoretical concepts underlying the measurement of the effects of research funding. It presents the key determinants of the productivity of research updated in scientific literature. The second part presents the data used, the estimation models and the analysis variables. The third part presents the results of the statistical analyses and their interpretation.

CONCEPTUAL FRAMEWORK AND DETERMINANTS OF UNIVERSITY RESEARCH PRODUCTIVITY

An Economic Explanation

Economic theory has greatly inspired the measurement of the productivity of scientific research, especially through econometric models relating, at the macroeconomic level, the outputs of university research to their outcomes on economic growth and the improvement of societal well-being (health, wealth, standard of living, etc.). But in a way more closely related to the concerns of this text, economics has, above all, permitted the formalization of the function of scientific production by equating the microeconomic process of transforming production inputs (funding, competency, organization, etc.) to measurable scientific outputs (knowledge, articles, books, innovation, etc.). Thus, we have taken our inspiration from the works of Adams and Griliches (1996/1998) that equated the productivity of scientific research, using the production functions known in economics and whose logarithmic specification can estimate the elasticity coefficients of the outputs of scientific production, to input variation, in particular, financial capital (grant, funding, etc.), human capital (researcher’s qualifications, age, gender, status, etc.) and any other asset linked to the
attributes of the research disciplines or research organizations (research groups, laboratories, departments, etc.). From linear regression techniques, the evaluators are then also able to estimate the returns to scale of the inputs with regard to the analysed outputs (Adams & Griliches, 1998).

An Evaluative Explanation

From an absolute perspective and from a dynamic perspective, the evaluation of science policies sheds light on the performance, adequacy and value of public support for scientific research and innovation (Marinova & Newman, 2008; Hicks, Tomizawa, Saitoh & Kobayashi, 2004; Abramo et al., 2009; Geuna & Martin, 2003). Using substantiating evidence, several governments have implemented evaluation mechanisms to show the effects and outcomes of publically funded scientific research on the production of knowledge, innovation and diffusion of new technologies. Generally speaking, these evaluations directly link the inputs, outputs and outcomes of research. They very often attempt to measure the impact of research funding and support (merit grant, recurring grant, mixed grant, etc.) on researcher productivity (quantity and quality of research) (Adams & Griliches, 1998). Programme evaluation offers the possibility of formalizing the links between inputs, outputs and impact (or outcomes) within a logic modelling and postulated programme theory framework, and specifying the correlations between inputs and outputs, often formulated in assumptions linking performance to public actions.

This research is also based on the methods and indicators used in bibliometrics to construct and validate its dependent variables (performance of scientific research) (Hicks et al., 2004). The first attempts to classify education faculties did so by polling those knowledgeable in the field with regard to their perceptions of the best departments (Walberg, 1972; Cartter, 1977; Ladd & Lipset, 1979; Blau & Margulies, 1975; Sieber, 1966). Then, the practice evolved toward quantitative (total or fractioned number of publications) and qualitative (impact, citation, etc.) measurement of the publications. The impact factor represents the influence exerted by articles, journals or authors on other articles published subsequently using the number of citations associated with a scientific article or journal. It is the most common and generally the most widely accepted way of measuring a researcher’s or publication’s influence on a field (Brainerd, 2006; Campanario et al., 2006; Glanzel & Moed, 2002). To provide a more complete picture, in addition to considering published articles, presentations made at conferences or professional events, monetary contributions received from non-funding sources, etc., can also be associated with an institution to gage its academic performance in relation to other institutions in the same field (Denton, Tsai & Cloud, 1986; Eash, 1983).

Several other indicators also help to assess the research effects: the citation rate per publication; the percentage of a researcher’s publications having a high citation rate in a specific field of research; the mean or median impact factor of a researcher’s total number of publications; the average standardized position of the journals in which the researcher has published; the ratio between a researcher’s impact and the mean impact score of the researcher’s field of activity; the ratio between the impact of the journals in which the researcher has published and the mean impact score of the researcher’s field of activity (Costas, van Leeuwen & Bordons, 2010). Other measures have also been developed to correct the weaknesses of certain measures, in particular: e-index, g-index; h-index; age-weighted citation rate (Ouimet, Bédard & Gélineau, 2011).
Determinants of Productivity in University Research

The literature dealing with productivity in research has highlighted many of its determinants. These can be put into at least three categories: researchers’ individual attributes, funding attributes and the organizational attributes of the research context.

Individual Attributes

The relationship between the researcher’s age and productivity has led to several empirical analyses (Gordon et al., 1984; Gingras, Larivièrè, Macaluso & Robitaille, 2008; Lehman, 1953). Although there is general agreement that age, reflecting the experience and the accumulation of a store of knowledge in human capital, exerts an influence on research productivity, the same cannot be said about its nature and extent. Certain authors claim researchers are more prolific in their forties (Lehman, 1953) and fifties (Gingras et al., 2008). Beyond this age, many researchers gradually reduce their activities in research and scientific productivity to take up administrative functions or to emphasize the quality of the publication rather than the quantity of publications. On the other hand, Costas et al. (2010) observe that the most productive researchers are the youngest, when they are seeking an interesting university career and scientific recognition. In this research, we have retained age as a determinant of researcher productivity (Sax, Hagedorn & Dicrisi, 2002; Oster & Hamermesh, 1998).

The gender of researcher has also been identified as another determinant of research productivity. Levin and Stephan (1998) suggest that women publish less than their male counterparts. Various reasons would explain this gap: reasons linked to family responsibilities, to lack of involvement in research networks (often male-dominated) or to under-representation in administrative circles involving several researchers and sizeable research budgets (Davis & Patterson, 2001; Sax et al., 2002; Kyvik, 1990). But, the diversity of contingencies and contexts does not permit the empirical evidence to affirm, beyond all reasonable doubt, that women researchers are less productive than their male counterparts. In this research, we have included the gender variable as a determinant of scientific research productivity.

Organizational attributes

Organizational attributes (Broder, 1993) and working environment are also considered to be explanatory factors of productivity in scientific research, in particular, the size, reputation and structure of the researchers’ university. Researchers from large, prestigious universities benefit from positive externalities that induce them to produce more scientific articles and to be cited more than their colleagues from smaller universities (Davis & Patterson, 2001). This is partially explained by the facility with which they can be part of collaboration networks with renowned researchers, by greater facility to be published and by holding a university position that confers preferences, competencies and incentives (Gordon et al., 1984). Anglophone universities are frequently better positioned than Francophone or Germanophone universities in international classifications of universities and research performance. Such classifications are often biased since they do not sufficiently take into account publications written in languages other than English. The predominance of English in databases indexing scientific publications used is a fact. In this research, we take the university’s official language and size into account, with the assumption that these factors are susceptible to influencing productivity in research.
Funding attributes

Funding attributes are at the core of much empirical research (Carayol & Matt, 2006; Adams & Griliches, 1996-1998). These researches show us that productivity in research would be heavily influenced by strategies and priorities linked to the granting of financial incentives by research funders (Auranen & Nieminen, 2010; Fender, Taylor & Burke, 2006). The type of funding (research funded by grants vs. research sponsored by the public or private sector) would have different effects on researcher productivity. The most productive researchers would be those who implement coincidentally merit-based funded research (through grants) and contracted research sponsored by private and public partners (Bozeman & Gaughan, 2007).

DATA AND EXPLANATORY MODEL

Data

The statistical analyses conducted in this research use two categories of indicators and data: data on research funding and bibliometric data. The data on funding come from administrative and statistical files declared by the universities (university research funding, whatever its source) at the request of the Quebec Ministry of Education, Recreation and Sports (Ministère de l’Éducation, du Loisir et du Sport) and integrated into the Information System for University Research (Système d’information de la recherche universitaire (SIRU)). This system is updated annually and its data are validated and updated in collaboration with the administrations that are responsible for research in all Quebec universities. The bibliometric data are extracted from Web of Science (WoS -Thomson Reuter) that indexes the articles from more than 11,000 scientific journals dealing with a variety of scientific disciplines: social sciences and humanities, pure and applied sciences and health sciences. Such data are more reliable than declarative data from a survey (non-verifiable responses) to which researchers would have the choice of responding.

Funding and bibliometric data are compiled and supplied by Expertise recherche Québec (www.erq.gouv.qc.ca). They are integrated into a database including the university research of more than 13,000 Quebec university researchers.

As in similar research (Carayol & Matt, 2006; Adams & Griliches, 1996-1998), the researchers selected for the purposes of our analyses had to respond to three criteria: to be employed in an education faculty or department in a Quebec university, to have received research funding (granted or sponsored), and to have published, over a certain period of time, publications listed by the databases indexing recognized scientific journals. More specifically, the researchers had to have received funding from one of the sources recognized in SIRU: grants, corporations, governments, community organizations, foundations, etc., between 2001 and 2007, and to have published or participated in at least one scientific publication indexed in WoS -Thomson Reuter, between 2002 and 2008. Thus, for analytical purposes, we have inserted a one-year lag between the funding and publication periods. This better permits taking into account the periods of time between granting the funds and beginning to produce a publication (Adams & Griliches, 1998).

In all, the 194 university professors-researchers selected come from sixteen Quebec universities. Researchers in one of the following situations have been excluded: a) to have published indexed articles without having been funded by grants, or b) to have had their research funded or sponsored without having produced an article indexed in the database consulted. The population of researchers used includes only holders of a doctoral degree (Ph.D or equivalent) and 54% of them are women (46% men). The average age is 53. One
A researcher out of four (26%) is affiliated with an Anglophone university and two researchers out of three (66%) come from a large university (having a Faculty of Medicine). The study population used is representative of the target population of Quebec researchers as described by the University and College Academic Staff Survey (UCASS) administered by the Conference of Rectors and Principals of Quebec Universities (CRÉPUQ), according to age, gender and affiliated educational institutions.

The variables available in the database for the purposes of our study and with an analytical interest describe two individual attributes (age and gender), two institutional attributes (dominant language of instruction and size of the university) and funding attributes, according to source (total funding, funding from academic foundations and councils, funding from provincial government departments and agencies, funding from federal departments and agencies, funding from corporations). Bibliometric data dealing with scientific publications (number of publications, number of fractioned publications, number of citations, impact factor, h-index). The publications used for constructing these indicators are articles, research notes and reviews (Moed, 1996). The variables used are presented in Table 1. The data obtained show that each of the researchers contributed, on the average, 4.47 publications during the period of the study (standard deviation = 7.864). Considering the relative share of the researchers in these publications, their mean fractioned number is 1.75 publications (standard deviation = 2.319). Each published article was cited 0.734 times, on the average (standard deviation = 1.99); the mean impact factor is 0.66 (standard deviation of 0.67) and the mean h-index, 1.56 (standard deviation of 1.673).

[Table 1 near here]

Regarding the total funding obtained during the period from 2001 to 2007, the researchers from our sample obtained $465,151, on the average, with a standard deviation of $801,139 and a maximum in the neighbourhood of $7.8 million (for one researcher). Funding from the Quebec provincial government between 2001 and 2007 was an average of $186,001, with a standard deviation of $598,021 and a maximum of $7.2 million; federal government funding was an average of $181,371, with a standard deviation of $263,702; the average funding received from corporations during the same period was $8,686, with a standard deviation of $32,992.

Model

The explanatory model is operationalized using a linear equation that enables the explanation of the performance variables using variables measuring the mobilized inputs in the knowledge production process. Such a model has been used in different research dealing with the effects of funding on research productivity (Adams & Griliches, 1998; Bozeman & Gaughan, 2007; Carayol & Matt; 2006; Feldman & Lichtenberg, 1998). The works consulted track logarithmic transformations of key variables that permit the interpretation of the regression coefficients such as returns-to-scale indicators or elasticities linking research inputs to outputs. Our results can be thus interpreted each time the dependent and independent variables are transformed into a logarithm.

The equation of the explanatory model can be expressed as follows:

$$Q = F(K, L, C)$$

(1)

where Q represents the measurement of measured outputs (articles, impacts, etc.), K constitutes a funding-input vector, L, an input vector measuring the human-capital attributes and C, a vector measuring the contextual organizational attributes of the research (university
The equation (1) is expressed as follows after logarithmic transformation:

\[
\ln F(K, L, C) = \beta \ln K + \alpha \ln L + \omega \ln C + \varepsilon
\]  

(2)

where the parameters \(\beta\), \(\alpha\) and \(\omega\) are regression coefficients to be estimated, and \(\varepsilon\) is the error term. The parameters \(\beta\), \(\alpha\) and \(\omega\) can be interpreted in terms of elasticity, that is, the relative variation of the outputs (in %) following a relative variation of the input concerned (in %). These coefficients are estimated with the help of available empirical data. The regression technique of least ordinary squares is used to estimate the regression coefficients.

Five regressions (least ordinary squares type) have been done to explain productivity, measured by production indicators: the real number of publications, h-index, the fractioned number of publications (relative weighting of articles written in collaboration), the number of citations per researcher and the impact factor. We prefer to use different measures rather than only one, each of them with its own strengths and weaknesses. The five indicators used as dependent variables do not measure exactly the same outputs; regardless of this, they can be correlated. However, this situation in no way influences the validity of the findings from the analyses conducted in this research.

**Findings and Interpretations**

The results of the statistical analyses are presented with commentary below, following a two-phased approach. First, the effects of total aggregate funding are examined, and then the effects of funding from each of the sources studied (research funding councils, federal or provincial government, private sector). But, before proceeding any further, Table 2 presents a factor analysis of the dependent variables used in our analyses. The goal of such an analysis is to structure the explanatory variables in sub-sets of correlates in the measurement of productivity. From this analysis, two distinct factors emerged, explaining 85% of the score variance of these variables. The first factor groups the number of publications, the fractioned number of publications and the h-index, suggesting that more than 50% of the researchers’ observed performance is explained by measures linked to the quantity of publications. The second factor deals with the quality of publications, measured by the citations and impact of the scientific journals in which the research was published. This factor explains one-third of the score variance of the researchers’ performance. These results suggest that the volume of articles produced does not guarantee success with regard to citations and scientific impact. It is to be noted that these results are consistent with those obtained by Costas et al. (2010), who conducted a similar factor analysis that separated the quality of publications from their quantity, even if the h-index combines quality and quantity indicators in its metrics.

Table 3 presents the results of a simplified explanatory model, aggregating the total funding received in a single variable, while Table 4 presents the results of an explanatory model decomposing the funding received according to its source and volume. These analyses were preceded by treatment to reduce the potential of several impediments to the statistical validity of the analyses and regressions explaining the determinant relationship between the explained and explanatory variables. The first treatment had to do with outliers. We spotted and verified the observations that fell outside ±3.3 standard deviations in relation to the observations for each variable. Following this verification, certain observations were corrected and a few were excluded. Furthermore, special attention was given to the normality of the distributions of the variables studied. Skewness and kurtosis tests were conducted, giving very acceptable results for all the variables. The logarithmic transformations, already
planned (for the purposes of interpreting the elasticity regression coefficients and correcting the skewness of the data), reinforced the quality of the distributions of the variables studied. The $F$ statistic, reported in the different regression tables, indicates that the explanatory variables used are relevant in explaining the dependent variables studied. To detect the possibility of multi-collinearity between the variables, we have examined the correlation coefficients between the different explanatory variables and the results are conclusive: no coefficient exceeds 0.7. Finally, the VIF (variance inflation factor) test was conducted for the different regressions and none of the explanatory variables had a VIF above 3, thus there is no risk of multi-collinearity.

The Effects of Aggregate Funding

Table 3 presents the results of the regressions integrating aggregate funding as a determinant of research productivity indicators of researchers in education. These regressions present an overall performance judged to be good to fair ($R^2$ varying from 23% to 29%), with the $Fs$ statistically significant, thus providing reassurance for the relevance of the empirical model used. The regression coefficients appearing in the tables are not standardized. [Table 3 near here]

The regression coefficients linked to the variable measuring overall funding per researcher are all positive and statistically significant, therefore confirming the importance of the effects of funding on research productivity. The regression coefficient varies from 0.17 to 0.32. This coefficient constitutes a measure of elasticity (relative variation of outputs following a relative variation of inputs). Our results suggest, for example, that a 10% increase in funding to researchers generates a 3% increase in the volume of publications produced, an approximate 2% increase in the mean h-index, in the fractioned number of publications and in the number of citations, and finally a 1% increase in the mean impact factor. These elasticities are, on the whole, comparable to those established by evaluative research having exploited similar data in the United States (Adams & Griliches, 1998), indicating a decreasing returns to scale for funding granted to promote scientific research.

Certain individual attributes used also influence researchers’ productivity. Our analyses suggest that productivity tends to decrease with age. In other words, other things being equal, the younger the researchers, the more they produce. Furthermore, the gender of researcher does not seem to significantly influence the productivity variables. The results obtained also suggest that university institutional attributes influence productivity in educational research. Other things being equal, researchers working in Anglophone universities (McGill, Concordia, Bishop’s) tend to produce more articles (indexed in the databases used), to be cited more often and to benefit from a higher impact factor. These results are not very surprising, considering the journals catalogued in the WoS database (the source of our bibliometric data) are English-language publications for the most part. Along the same lines, the researchers from large universities (measured by the presence of a Faculty of Medecine) tend to publish more (in real or fractioned numbers) than their counterparts from small universities. University size is therefore an explanatory factor taking into account the positive externalities created by the organization. It was woth noting that universities with a faculty of medecine are more prestigious, and might hire the most promising young researchers. This is a possible explanation for this good performance. The size-related variable, however, does not offer statistically significant regression coefficients for the h-index, the number of citations and the impact factor, leading us to believe the quality of publications is not necessarily influenced by the size of the researcher’s university.
The Specific Effects of Funding Sources on Productivity

Wishing to analyse further the effects of funding on research productivity, we have decomposed the total funding by using four funding categories: academic funding from funding councils, sponsored research funded by the federal government, sponsored research funded by the provincial government, and funding from corporations and not-for-profit organizations (sponsorship, in particular). Table 4 presents the results of the estimations carried out to this effect.

Table 4 near here

The models presented in Table 4 show positive and statistically significant regression coefficients for certain funding sources and not for others. Our results suggest that only academic funding from funding councils and grants exercises a positive and statistically significant impact on almost all researcher productivity indicators. Not surprisingly, the researchers funded by grants and funding councils are more productive, a 10% funding increase leading to, other things being equal, a similarly proportioned increase in the number of publications. This result is not very surprising since researchers receiving funds from funding organizations are usually obliged to disseminate their findings in scientific publications. Incidentally, it is quite normal that research funding from this source also has a significant effect on the h-index, the fractioned number of publications and the number of citations.

Regarding other funding sources, our results suggest that the volume of funding from the Government of Quebec’s sponsored research exercises a positive and statistically significant impact on the number of publications (real or fractioned). That is to say that funding associated with research sponsored by the federal government or the private sector, other things being equal, does not seem to be a vector of researcher productivity in education. This situation is perhaps attributable to the fact that, in Quebec, education comes under provincial jurisdiction (rather than federal), meaning the province is the main decision-maker in choosing the researchers to fund and in defining the research issues to be treated. This result is worth being confirmed by future research.

The results related to the other control variables are essentially identical to those in Table 3. Age once again is a significant determinant of researcher productivity, a negative and statistically significant relationship being observable with regard to publications, the h-index and the impact factor. Again, researchers from Anglophone universities are more likely to publish (total and fractioned number of publications), to be cited more often and to be associated with greater impact factors and h-index. University size (once again measured by the presence of a Faculty of Medicine) also positively influences the real and fractioned number of publications. Universities with a faculty of medicine are more prestigious. Prestigious universities hire the most promising young researchers. It is to be noted that, other things being equal, the model suggests that, in general, women are less likely to publish than their male colleagues. They are also less likely to have a high h-index. Looking first at assistant professors only (table 5), we find that a higher number articles published (with the logarithmic transformation) is associated with being male rather than female, having more children, taking less time to complete the doctoral degree, teaching fewer undergraduate courses, having more resources, working in a private institution, and attending more conferences. This result is consistent with Hesli & Lee (2011), who found that a higher number of articles published is associated with being male rather than female.
CONCLUSION

In this study, we have examined the determinants of university researcher productivity in the education sector, with a specific interest in the effects of the different funding sources. We have also examined the effects of funding sources on productivity using a two-phased approach. The first phase deals with the nature and size of the effects of total funding on university research productivity. The second examines the specific effects of funding sources on productivity. In each of the phases, the specific influence of other determinant factors used has been estimated (age and gender, as well as language of instruction and institutional size). The findings show, not surprisingly, that funding is a key input in the scientific production process, and, in turn, in education researcher performance, taken individually. Generally speaking, our findings support a positive association between research funding intensity and the volume of articles produced by the researcher. This association is supported by regression coefficients below 1, thus demonstrating decreasing returns to scale. The study’s findings estimate research output elasticity in relation to funding at approximately 0.32 for productivity measured in publications. In other words, for an average 10% funding increase, an output increase of 3% can be expected, other things being equal. If we examine the other measurements of researcher productivity, the observed elasticity is weaker, varying between 0.11 and 0.21. Therefore, according to the indicator used, the effect of funding on productivity can be more or less significant. If it is fair to say that research inputs provide significant leverage on the number of publications (real and fractioned), this leverage being less significant when the performance indicators taking into account the benefits of these publications for academic circles (H-Index, citations, impact factors) are considered. This aspect should motivate programme evaluators who assess the benefits of public funding and intervention to support academic research. It is essential that evaluators do not only see these benefits in terms of volume (i.e. the number of publications produced), but also in terms of publication quality (citations and outcomes generated). In this way, those designing interventions to support research will benefit from the information necessary to improve programme effectiveness with regard to production of publications and influence and benefits going beyond the number of publications produced.

This research also examined the specific effects of funding sources on productivity. Among the sources for which data were available, only funding from the federal government and the private sector are not statistically significant in its relation to the productivity indicators used. It is also not surprising to notice that academic funding from grants and university research funding councils provide the greatest elasticity regarding outputs dealing with the number of publications (0.13). Funding from the provincial government is positively associated with the productivity of researchers in the education sector. This is due to the fact that education comes under provincial jurisdiction, giving more scope and value added to funding from the provincial government. Once again, leveraging tends to diminish (less than 1% for a 10% input increase) if this effect is examined using indicators that are not limited to the number of publications produced.

Throughout the analysis, our findings have confirmed the influence of other research determinants. Therefore, the researcher’s age, the language of instruction and university size are key determinants in explaining research productivity. Generally speaking, productivity seems more significant among young researchers. Researchers from Anglophone universities appear to be more likely to publish. With regard to variables measuring the possible effects of a Faculty of Medicine (size of researcher’s affiliated university), the findings suggest that
researchers from large universities tend to produce more articles than their colleagues from small universities.

REFERENCES

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</tr>
<tr>
<td>Impact factor</td>
<td>Measurement of the importance of the scientific journals in which the sample group of researchers have been published. The impact factor is calculated each year by the Institute for Scientific Information (ISI).</td>
<td>0</td>
<td>3.6</td>
<td>0.6</td>
<td>0.673</td>
</tr>
<tr>
<td>H-index</td>
<td>Index reflecting both the number of publications and the number of citations per publication. It is measured by the maximum number of articles published by a researcher, with each of the articles having been cited as many times (Hirsh 2005)</td>
<td>0</td>
<td>11</td>
<td>1.56</td>
<td>1.672</td>
</tr>
<tr>
<td><strong>Independent Variables</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total funding (2001-2007)¹</td>
<td>Total amount of research grants received by each researcher in Canadian $</td>
<td>50,449</td>
<td>7,796,584</td>
<td>465,151</td>
<td>801,139.48</td>
</tr>
<tr>
<td>Funding from provincial government (2001-2007)¹</td>
<td>Total amount of research grants received by each researcher from the provincial government in Canadian $</td>
<td>0</td>
<td>7,241,456</td>
<td>186,001</td>
<td>598,021</td>
</tr>
<tr>
<td>Funding from federal government (2001-2007)¹</td>
<td>Total amount of research grants received by each researcher from the federal government in Canadian dollars</td>
<td>0</td>
<td>1,909,208</td>
<td>181,371</td>
<td>263,702</td>
</tr>
<tr>
<td>Corporate funding (2001-2007)¹</td>
<td>Total amount of corporate research grants received by each researcher in Canadian $</td>
<td>0</td>
<td>263,767</td>
<td>8,686</td>
<td>32,992</td>
</tr>
<tr>
<td>Funding from funding councils and grants for research (2001-2008)¹</td>
<td>Total amount from funding councils or grants for research (2001-2008)</td>
<td>0</td>
<td>1,513,752</td>
<td>219,387</td>
<td>224,937</td>
</tr>
<tr>
<td>Researchers’ age</td>
<td>Age of researchers in number of years, in 2008</td>
<td>43</td>
<td>72</td>
<td>53.24</td>
<td>9.82</td>
</tr>
<tr>
<td>Researchers’ gender</td>
<td>Researchers’ gender. Dichotomous variable: Male=0, Female=1.</td>
<td>0</td>
<td>1</td>
<td>0.54</td>
<td>0.5</td>
</tr>
<tr>
<td>Researcher affiliated with an English-language university (language)</td>
<td>Dichotomous variable: French=0 and English=1</td>
<td>0</td>
<td>1</td>
<td>0.26</td>
<td>0.439</td>
</tr>
<tr>
<td>Researcher affiliated with a large university (having a Faculty of Medicine)</td>
<td>Dichotomous variable: No=0 and Yes=1</td>
<td>0</td>
<td>1</td>
<td>0.66</td>
<td>0.474</td>
</tr>
</tbody>
</table>

¹ The different variables with this exponential have been transformed into a natural logarithm before being included in the regression model.
Table 2: Factorial analysis for the dependant variables (with varimax rotation and Kaiser Normalization)

<table>
<thead>
<tr>
<th>Factors (explaining 85% of variance)</th>
<th>Quantity of publications (53% of variance)</th>
<th>Quality of publications (32% of variance)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Publication number (2002-2008)</td>
<td>.973</td>
<td></td>
</tr>
<tr>
<td>Fractionned publication (2002-2008)</td>
<td>.963</td>
<td></td>
</tr>
<tr>
<td>H-index (2002-2008)</td>
<td>.885</td>
<td></td>
</tr>
<tr>
<td>Citation number (2002-2008)</td>
<td>.889</td>
<td></td>
</tr>
<tr>
<td>Impact factor (2002-2008)</td>
<td>.870</td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Productivity determinants: Reduced model (OLS Regression)

*** p< 0.01; ** p<0.05, * p<0.1

SE= Standard error

<table>
<thead>
<tr>
<th>Independent variables</th>
<th>Publications (ln)</th>
<th>H-Index (ln)</th>
<th>Fractionned publication (ln)</th>
<th>Citations (ln)</th>
<th>Impact factor (ln)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-1.98*** (.744)</td>
<td>-0.411 (.76)</td>
<td>-1.6*** (.51)</td>
<td>-0.83 (0.648)</td>
<td>0.40 (0.38)</td>
</tr>
<tr>
<td>Individual factors</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>-0.015*** (.005)</td>
<td>-0.019*** (.05)</td>
<td>-0.11*** (.04)</td>
<td>-0.15*** (.005)</td>
<td>-0.006* (.003)</td>
</tr>
<tr>
<td>Gender (w=1; m=0)</td>
<td>-0.15 (.106)</td>
<td>-0.17 (.09)</td>
<td>-0.06 (.74)</td>
<td>-0.26 (.09)</td>
<td>-0.07 (.054)</td>
</tr>
<tr>
<td>Organizationnal factors</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>English=1 (French=0)</td>
<td>0.492*** (.126)</td>
<td>0.395*** (.102)</td>
<td>0.343*** (.088)</td>
<td>0.61*** (.11)</td>
<td>0.153*** (.05)</td>
</tr>
<tr>
<td>Big university=1 (small=0)</td>
<td>0.202* (.107)</td>
<td>0.096 (.10)</td>
<td>0.157** (.074)</td>
<td>0.02 (.09)</td>
<td>0.045 (.55)</td>
</tr>
<tr>
<td>Financial factors (grants $)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total grants 2001-07 (ln)</td>
<td>0.315*** (.52)</td>
<td>0.169*** (.051)</td>
<td>0.21*** (.03)</td>
<td>0.15*** (.04)</td>
<td>0.11*** (.027)</td>
</tr>
</tbody>
</table>

R² .29 .28 .26 .23 .27

Statistical signifiencay .000*** .000*** .000*** .000*** .000***

F 13.5 8.62 12.16 9.8 3.22

N 187 167 185 174 112
**Table 4:** Productivity determinants: extensive model (OLS Regression)

*** p< 0.01; ** p<0.05, * p<0.1

SE= Standard error

<table>
<thead>
<tr>
<th>Independent variables</th>
<th>Publications (ln) B (SE)</th>
<th>H-Index (ln) B (SE)</th>
<th>Fractionned publication (ln) B (SE)</th>
<th>Citations (ln) B (SE)</th>
<th>Impact factor (ln) B (SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Constant</strong></td>
<td>-0.48 (0.58)</td>
<td>-0.53 (0.54)</td>
<td>-0.55 (0.4)</td>
<td>-0.29 (0.49)</td>
<td>0.78** (0.3)</td>
</tr>
<tr>
<td><strong>Individual factors</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>-0.01*** (0.006)</td>
<td>0.017*** (0.006)</td>
<td>-0.003 (0.004)</td>
<td>-0.011 (0.005)</td>
<td>-0.07* (0.03)</td>
</tr>
<tr>
<td>Gender (w=1; m=0)</td>
<td>-0.18* (0.1)</td>
<td>-0.19** (0.09)</td>
<td>-0.07 (0.07)</td>
<td>-0.044 (0.092)</td>
<td>-0.08 (0.053)</td>
</tr>
<tr>
<td><strong>Organizational factors</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>English (vs French)</td>
<td>0.49*** (0.132)</td>
<td>0.369*** (0.104)</td>
<td>0.351** (0.091)</td>
<td>0.59** (0.11)</td>
<td>0.159** (0.057)</td>
</tr>
<tr>
<td>Big university=1 (small=0)</td>
<td>0.24** (0.1)</td>
<td>0.13 (0.097)</td>
<td>0.18** (0.076)</td>
<td>0.043 (0.094)</td>
<td>0.078 (0.054)</td>
</tr>
<tr>
<td><strong>Financial factors (grant amount)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Academic research funds and councils (Ln)</td>
<td>0.132** (0.037)</td>
<td>0.08** (0.03)</td>
<td>0.088** (0.026)</td>
<td>0.072* (0.032)</td>
<td>-0.003 (0.016)</td>
</tr>
<tr>
<td>Federal government (Ln)</td>
<td>0.03 (0.02)</td>
<td>0.03 (0.02)</td>
<td>0.01 (0.01)</td>
<td>0.023 (0.017)</td>
<td>0.011 (0.013)</td>
</tr>
<tr>
<td>Provincial government (Ln)</td>
<td>0.028** (0.015)</td>
<td>0.03 (0.023)</td>
<td>0.024** (0.01)</td>
<td>0.003 (0.012)</td>
<td>0.007 (0.007)</td>
</tr>
<tr>
<td>Private sources (Ln)</td>
<td>0.008 (0.016)</td>
<td>0.008 (0.015)</td>
<td>-0.002 (0.11)</td>
<td>-0.015 (0.014)</td>
<td>0.008 (0.008)</td>
</tr>
<tr>
<td><strong>R²</strong></td>
<td>.26</td>
<td>.29</td>
<td>.24</td>
<td>.23</td>
<td>.14</td>
</tr>
<tr>
<td><strong>Statistical significance</strong></td>
<td>.000****</td>
<td>.000***</td>
<td>.00**</td>
<td>.000***</td>
<td>.03**</td>
</tr>
<tr>
<td><strong>F</strong></td>
<td>7.35</td>
<td>5.54</td>
<td>6.55</td>
<td>6.213</td>
<td>2.28</td>
</tr>
<tr>
<td><strong>N</strong></td>
<td>174</td>
<td>145</td>
<td>165</td>
<td>174</td>
<td>112</td>
</tr>
</tbody>
</table>