Does government funding have the same impact on academic publications and patents? The case of nanotechnology in Canada

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Abstract: University patenting has become an important research outcome in the past few decades. There has been an increase in the number of faculty patents and individual scientists listed as inventors on patent applications. The effective allocation of funding to universities is of great concern to policymakers. In this paper, we evaluate whether an increase in government funding for academic scientists enhances the performance of researchers in both scientific publications and academic patents or if this merely increases publications in the academic realm. We provide summary statistics from nanotechnology data in Quebec, compare it with other provinces in Canada, and build econometric models of various publication, patenting and grant databases. The analysis illustrates the strong relationship between funding and publication productivity as well as the citation impact of publications. In the light of research performance in patenting activities of academic researchers, this empirical study finds a strong influence on the number of patents. Moreover, increased funding appears to strengthen the citation impact of patents in Quebec, which affects the citation impact of patenting activities.

Keywords: Nanotechnology, academic publications, academic patents, funding

Introduction

Universities have traditionally disclosed research findings and openly disseminated knowledge (Partha and David, 1994). Academic researchers have gained a strong reputation for generating fundamental discoveries that transfer knowledge among scientists via publications. (David, 1998). In recent years, however, the academic research environment has changed dramatically through a growing interest in patenting and commercialization activities.

Academic scientists have shown an increased interest in patenting and licensing activities, demonstrated through university-industry interactions. These interactions have been facilitated by intellectual property rights regulations in universities such as the Bayh-Dole Act and Stevenson-Wydler Act in the US, the 1998 Decree in Flanders, Belgium, and changes to German law in 2001, etc. These regulations have granted university researchers intellectual property rights to commercialize the results from government-funded research (Van Looy et al., 2006). Universities have therefore become the main knowledge-generating institutes that stimulate economic growth through knowledge production and innovation. Kodama and Branscomb (1999), for example, highlight the critical contribution of universities in rapid growth areas (biotechnology, software, medicine, nanotechnology, microelectronics, etc.) which are closely connected to the science base and require the latest research findings. Although increased patenting in academia raises concerns related to decreased publication rates and other issues stemming from university-industry relationships, these commercial interests can be used to measure the effectiveness of research funding (Geuna et al., 2003).

These commercial interests can provide a new measure of the funding effectiveness. It is argued that funding affects the performance and evaluation of research and plays a crucial role in future economic and social development. Pavitt (2000), therefore, suggests that policy makers must recognize that funding academic research can produce high-quality results and major technological opportunities. Hence, current science policies should consider both scientific and technological outputs in measuring the rate of return from academic funded research. Nanotechnology, for example, may be the most promising high technology in this century. It has attracted substantial funding over the last few decades, and governments must efficiently allocate research funding to benefit from its economic potential.

The impact of government research funding on academic patenting, however, has only been considered in a few studies (Arora and Gambardella, 2005; Carter et al., 1987; Foltz et al., 2000; Jacob and Lefgren, 2011), and the positive effect is not that clear and has not been found in all studies. Additionally, in terms of the influence that funding can have on academic research, academic publications have so far received more attention than patents.

In this empirical study, we examine government funding for nanotechnology research in Quebec and all other provinces in Canada and ask the following questions:

- Does financial support boost both publication and patent productivity?
- Does government funding positively influence the citation impact of both publications and patents in universities?
- Do policy makers need to place greater emphasis on the productivity of academic technological outputs?

Our study seeks to better understand how government funding impacts scientific and technological activities in universities. The remainder of this paper is organized as follows. We outline and describe prior studies in the next section. Section 3 focuses on data, methods and measures. Section 4 discusses the research findings and implications, and finally, conclusions, limitations of this study and future research are provided in Section 5.

Literature Review

Universities have historically been the main source of new knowledge, but over the past century, they have also become essential for industrial progress (Rosenberg, 2002). They commit to open science and their mission is to advance and disseminate knowledge, however, they have also become directly involved in patenting and commercialization activities throughout much of the 20th century after the passage of the Bayh-Dole Act (Mowery and Sampat, 2001).

According to Fox (1983), publication is the most fundamental research output of scientific community in universities; in addition to diffusing knowledge, it allows scientists to gain professional advancement, recognition and promotion. Hence, this can be an appropriate indicator to measure scientific productivity and performance of academic researchers. Counting publications and citations are appropriate techniques as they are indicators of productivity and can be used to evaluate scientific activity (Narin, 1976). High performance researchers are generally identified from their scientific production and the number of citations their papers receive (Alonso et al. 2010; Kosmulski, 2011). Bibliometric indicators are commonly used to evaluate research performance and provide a quick impression of the quality of research. Citation analyses generate relatively short-term quantifiable measures based on an assumption of a linear relationship between scientific quality and citation counts.

Since patenting derived from public funded university research has dramatically increased in recent years, academic technological output has come into the focus of governments (Jaffe, 1989; Henderson et al., 1998). Patent counts and patent citations are also commonly accessible and viable measures to capture the innovative performance of inventors, and many studies consider them as reasonable measures of innovative activity (Cantwell and Hodson, 1991; Griliches, 1998; Patel and Pavitt, 1995).

There are however a number of limitations regarding the use of publication and patents and their citations. For example Gulbrandsen and Smeby (2005) indicate that researchers may write reports instead of journal articles. Critics such as Adler et al. (2009) highlight that citation analysis does provide worthwhile information and should be part of the evaluation process, but not its sole measure. Poomkottayil et al. (2011) also raised the problem of disparity in citation rates of papers published in English compared to other languages.

According to Bornmann and Leydesdorff (2013), research quality is a complex attribute for which no single specific formula exists to quantify its quality. Citation-based indicators are nonetheless widely acknowledged as quality metrics and assess the influence of research (Leydesdorff, 2009). Daim et al. (2006) point out that patents are vastly different in their importance, a fact that patent counts cannot capture. As a consequence, patent citations present a measure of patent quality based on the presumption that the impact of a patent is correlated with the number of times it is cited in other patents as their relevant prior art (Hagedoorn and Cloodt, 2003).

Despite these limitations in using publications and patents as proxies of academic productivity, they are considered to be appropriate indicators. For example, although Arundel and Kabla (1998) and Mansfield (1986) raise some critical concerns on the general use of patents as a measure of innovative performance, they suggest using these indicators in many high technology fields.

Although sources of academic research funding shifted to include more funding from companies in the industry, federally funded research contribute to substantial amount of academic research (Fabrizio and Di Minin, 2008). Over recent years, increasing commercially oriented activities in academia has attracted industry involvement and private financing for research. Nevertheless, public funding is still the prominent source of funding for university research particularly for the high technologies.

Although academic research has become increasingly industry funded, a substantial amount is still federally funded (Fabrizio and Di Minin, 2008). According to Bard (2014), the future of high technologies is strongly attached to government-funded academic centers. Salter and Martin (2000) review the economic benefits of publicly funded research and show that there is extensive evidence on economic benefits of such government-funded research. Liefner (2003), however, highlights that universities are expected to produce high quality research yet their research outputs are bound by the constraints of government funding. Many governments have implemented mechanisms to base funding on academic performance, specifically policies related to emerging technologies. Policy makers, therefore, play an important role in shaping the future of fields such as nanotechnology.

It is pertinent to understand scientific research funding given its important role in technological change. Research sponsors are more likely to value the usefulness of research in topics that are more demand driven for private sectors. The role of universities has greatly evolved and academic researchers currently experience pressure from industry to produce short-term applied knowledge (Gibbons et al., 1994; Goldfarb et al., 2009). In the past, researchers used to determine their research goals and the intent of funding was to support the researcher, but now sponsors fund the research that fits their programs. According to Goldfarb (2008), the objectives of sponsors influence the research results and their publications and subsequent citations. However, the growing involvement of universities in commercialization activities has also attracted more attention to academic patenting and to extent stimulated academic patenting (Mowery et al., 2001).

Debates still remain on the relationship between patenting and publications as some scholars have found a positive relationship (Agrawal and Henderson, 2002; Breschi et al, 2007). Meyer (2006) explored this relationship for the field of nanotechnology and found that inventor-authors who both publish and patent are more productive, however these researchers are not among the most highly cited authors.

The influence of government funds that are spent on university research on economic performance is of great importance. Jaffe et al. (1998) examined government-awarded patents and studied their subsequent citations to analyze technological impact and knowledge spillovers. The government has devoted substantial resources to support university patents (Gieger, 1993), however the correlation between research funding and patents is still ambiguous. For example, Payne and Siow (2003) observed mixed results with respect to this relationship. Using a simple OLS model, they observed that an increase in federal funding results in more patents, but under a Tobit model, they found this relationship had a minor and imprecise impact. Azagra-Caro et al. (2006) studied patent production and showed that university-owned patents are more likely to benefit from public funding compared to non-university-owned patents which are more responsive to industrial funding. Additionally, Foltz et al. (2001) studied federal and state funding for agricultural biotechnology patents and observed that only state funding is significantly positive.

Data and Methodology

This research is based on various sources of funding, publication and patent data. Publication data was extracted from Elsevier's Scopus, which contains all information pertaining to authors, citations, affiliations, etc. We have extracted patents from the United States Patent and Trademark Office (USPTO) instead of the Canadian Intellectual Property Office (CIPO) to account for a larger market, as Canadian inventors wish to commonly protect their patents in the United States. We deliberately chose keywords to extract only nanotechnology-related publications and patents and to clearly identify individuals in Canada using their affiliations.

Furthermore, funding data was provided by a government-managed system. We merged these databases to obtain data for a 20-year period (1985-2005), and then invested a considerable amount of effort to clean the data, and eliminate duplicate individuals and possible ambiguities. We defined four dependent variables for publications and patents; two variables account for the number of these outputs (*NumberPaper*, *NumberPatents)* and two measure the number of citations received after 5 years to measure their citation impact (*CitationPaper, CitationPatent*). Additionally, to take into account the time discrepancy between the investment period and the eventual outcome, we include a one-year lag for research funding and publishing / patenting in our econometric models and measure them with the *PublicFunding* variable in our models. To account for the time periods for processing a patent application, we use the application year to count the number of patents, but for the citations we must use the grant year. Additionally, we include a cumulative number of patents for each scientist in the past three years (*PastPatents*).

We recognize that research funding is an endogenous variable given that scientists who received more funding in the past are recognized as higher quality scientists and are more likely to receive more funding in the future. To correct the model for this endogeneity, we include instrumental variables to estimate our funding variable using Two-Stage Residual Inclusion (2SRI), as suggested by a number of scholars (Cai, et al. 2011; Terza et al. 2008).

Additionally, a number of instrumental variables were added to our econometric model: a cumulative number of articles for each scientist in the past three years (*PastPapers*), an ordinal indicator (*ResearchChair*) as a proxy of scientist quality which takes the value of 0 if a researcher has never held a research chair, the value 1 for being an industrial chair, the value 2 for being a research chair of one of two Canadian federal granting councils, and the value 3 if a scientist is a Canadian research chair. The other instrument that we use in our model is the career age (*CareerYears*) of a scientist since his/her first nanotechnology-related patent or publication. We also control the relationship between scientists in co-publication and co-invention social networks to measure the effect of these relationships. Two variables are defined for co-publications (*BetweennessPublication ClusteringPublication*) and two for co-invention relationships (*BetweennessPatent, ClusteringPatent*). BetweennessPublication/Patent illustrates the importance of a researcher who is a necessary information intermediary between various parts of the network. Accordingly, scientists with higher betweenness are critical to collaboration within a scientific or technological network (Brandes, 2001). The other network variables quantify how well connected the neighbors of a researcher are in a network. The clustering coefficient describes the tendency to form connected subgroups in a network and measures the extent to which researchers tend to cluster together (Zhang et al., 2008).

We employ a Probit model to estimate the increase in probability attributed to a one-unit increase in a given predictor. The Probit model constrains the estimated probabilities to between 0 and 1, which means that an increase in the predictor leads to an increase/decrease in the predicted probability (Ai and Norton, 2003). To use the Probit model in this empirical study, we define dummy variables for the number of papers (*dart*) which take a value of 1 if the number of papers for a researcher in a given year *t* is greater than 0; otherwise it takes a value of 0. Similarly, we define other dummies for the number of patents (*dpat*), paper /patent citations (*dcit*). Eq.1 and Eq.2 present our econometric models:

$$\begin{Bmatrix} dart_{it} \\ dcit_{it} \end{Bmatrix} = f\begin{pmatrix} \ln(PublicFunding_{it-1}), PastPatents_{it-1}, \\ \ln(10^3 \times betweennessPublication_{it-2}), \\ \ln(10^4 \times ClusteringPublication_{it-2}) \end{pmatrix} \quad (1)$$

$$\begin{Bmatrix} dpat_{it} \\ dcit_{it} \end{Bmatrix} = f\begin{pmatrix} \ln(PublicFunding_{it-1}), PastPatents_{it-1}, \\ \ln(10^3 \times betweennessPatent_{it-2}), \\ \ln(10^4 \times ClusteringPatent_{it-2}) \end{pmatrix} \quad (2)$$

Results and discussion

This paper uses nanotechnology data in Quebec and other provinces in Canada to estimate the impact of public funding on academic publications and patents. The results on the impact of funding on publications are presented in Table 1 and Table 2, and those regarding patents are shown in Table 3 and Table 4.

The analysis illustrates a strong relationship between funding and publication productivity, implying that an increase in the amount of grants leads to an increase in the probability of publishing. We control the possible endogeneity of public funding with the 2SRI model and our instrument variables are all significant. This determines that our two-step procedure corrects the potential endogenous problem. In terms of citation impact, we only observe this strong positive coefficient in Quebec but not in the other provinces. We also find that our network variables are significant and influence the probability of publishing articles and being cited. Further, collaboration is seen to enhance the probability of publishing through knowledge sharing.

In light of academic researchers' involvement in commercial activities, academic patents appear to benefit from an increase in research funding. This observation suggests that government funding has a positive impact on technological activities. We observe that increasing grants for scientists increases the probability of patenting, but we only find a positive impact on the probability of getting cited in Quebec and not in the other provinces.

Table 1. Second Stage of regression results – Impact of government funding on the number of nanotech papers in Quebec

Variables	dart		dcit	
	1-1 (NO End.)	**1-2 (2SRI)**	**2-1 (NO End.)**	**2-2 (2SRI)**
ln(PublicFunding$_{it-1}$)	0.0779 ***	0.2311 ***	0.0138	0.0998 ***
	(0.0266)	(0.0327)	(0.0251)	(0.0294)
[ln(PublicFunding$_{it-1}$)]^2	-0.0067 **	-0.0088 ***	0.0004	-0.0008
	(0.0027)	(0.0027)	(0.0025)	(0.0025)
PastPatents$_{it-1}$	0.0737 **	0.0826 **	0.0899 ***	0.0956 ***
	(0.0347)	(0.0357)	(0.0309)	(0.0309)
[PastPatents$_{it-1}$]^2	-0.0021 *	-0.0026 **	-0.0021 *	-0.0025 **
	(0.0012)	(0.0012)	(0.0011)	(0.0011)
ln(10^4 x BetweennessPublication$_{it-2}$)	0.1515 ***	0.1624 ***	0.1385 ***	0.1454 ***
	(0.0405)	(0.0403)	(0.0362)	(0.0360)
ln(10^3 x ClusteringPublication$_{it-2}$)	0.7934 ***	0.6478 ***	1.0563 ***	0.9731 ***
	(0.0955)	(0.0970)	(0.0846)	(0.0855)
[ln(10^3 x ClusteringPublication$_{it-2}$)]^2	-0.1081 ***	-0.0880 ***	-0.1461 ***	-0.1347 ***
	(0.0140)	(0.0142)	(0.0124)	(0.0125)
residual[ln(PublicFunding$_{it-1}$)]		-0.1419 ***		-0.0788 ***
		(0.0177)		(0.0149)
Constant	-0.1856 ***	-0.5760 ***	-1.1857 ***	-1.4066 ***
	(0.0265)	(0.0524)	(0.0287)	(0.0486)
Years	Yes	Yes	Yes	Yes
Nb observations	13968	13968	13968	13968
Nb groups	1164	1164	1164	1164
Loglikelihood	-7681.46	-7600.98	-5362.88	-5344.41
χ^2	1423.73 ***	1405.60 ***	819.43 ***	861.51 ***

Note: *, **, * show significance at the 1%, 5% and 10% levels and Standard errors are presented in parentheses**

Table 2. Second Stage of regression results – Impact of government funding on the number of nanotech papers in other provinces in Canada

Variables	dart		dcit	
	1-1 (NO End.)	**1-2 (2SRI)**	**2-1 (NO End.)**	**2-2 (2SRI)**
ln(PublicFunding$_{it-1}$)	0.1013 ***	0.3019 ***	-0.0267 *	0.0194
	(0.0165)	(0.0202)	(0.0157)	(0.0178)
[ln(PublicFunding$_{it-1}$)]^2	-0.0086 ***	-0.0104 ***	0.0039 **	0.0035 **
	(0.0017)	(0.0017)	(0.0016)	(0.0016)
PastPatents$_{it-1}$	0.0285	0.0113	0.0922 ***	0.0882 ***
	(0.0209)	(0.0228)	(0.0193)	(0.0197)
[PastPatents$_{it-1}$]^2	-0.0002	0.0011	-0.0023 **	-0.0021 *
	(0.0009)	(0.0010)	(0.0011)	(0.0011)
ln(10^4 x BetweennessPublication$_{it-2}$)	0.2177 ***	0.2530 ***	0.1917 ***	0.2000 ***
	(0.0278)	(0.0271)	(0.0248)	(0.0246)
ln(10^3 x ClusteringPublication$_{it-2}$)	0.5818 ***	0.2811 ***	1.0175 ***	0.9495 ***
	(0.0647)	(0.0660)	(0.0600)	(0.0609)
[ln(10^3 x ClusteringPublication$_{it-2}$)]^2	-0.0764 ***	-0.0350 ***	-0.1420 ***	-0.1327 ***
	(0.0095)	(0.0096)	(0.0088)	(0.0089)
residual[ln(PublicFunding$_{it-1}$)]		-0.1978 ***		-0.0449 ***
		(0.0106)		(0.0084)
Constant	-0.1425 ***	-0.5965 ***	-1.1929 ***	-1.2961 ***
	(0.0141)	(0.0268)	(0.0162)	(0.0230)
Years	Yes	Yes	Yes	Yes
Nb observations	44664	44664	44664	44664
Nb groups	3722	3722	3722	3722
Loglikelihood	-24005.8	-23460.0	-15655.0	-15636.1
χ^2	4742.38 ***	4672.04 ***	2187.05 ***	2229.66 ***

Note: *, **, * show significance at the 1%, 5% and 10% levels and Standard errors are presented in parentheses**

Table 3. Second Stage of regression results – Impact of government funding on the number and citation of nanotech patents in Quebec

Variables	dpat		dcit	
	1-1 (NO End.)	1-2 (2SRI)	2-1 (NO End.)	2-2 (2SRI)
$ln(PublicFunding_{it-1})$	0.2027 ***	0.2685 ***	0.1473	0.3158 **
	(0.0552)	(0.0601)	(0.1099)	(0.1335)
$[ln(PublicFunding_{it-1})]^2$	-0.0201 ***	-0.0210 ***	-0.0161	-0.0202 *
	(0.0055)	(0.0055)	(0.0109)	(0.0109)
$PastPatents_{it-1}$	0.1875 ***	0.1950 ***	0.3022 ***	0.3260 ***
	(0.0313)	(0.0309)	(0.0505)	(0.0499)
$[PastPatents_{it-1}]^2$	-0.0031 ***	-0.0034 ***	-0.0054 ***	-0.0064 ***
	(0.0009)	(0.0009)	(0.0014)	(0.0014)
$ln(10^4 \times BetweennessPatent_{it-2})$	0.1713	0.1543	0.0340	0.0078
	(0.1914)	(0.1942)	(0.2058)	(0.2107)
$ln(10^3 \times ClusteringPatent_{it-2})$	0.1926	0.2150	0.5991 **	0.6542 **
	(0.1908)	(0.1926)	(0.2584)	(0.2552)
$[ln(10^3 \times ClusteringPatent_{it-2})]^2$	-0.0279	-0.0319	-0.0734 **	-0.0831 **
	(0.0277)	(0.0280)	(0.0369)	(0.0367)
$residual[ln(PublicFunding_{it-1})]$		-0.0633 **		-0.1359 ***
		(0.0279)		(0.0413)
Constant	-0.2549 ***	-0.4424 ***	-2.9188 ***	-3.3936 ***
	(0.0583)	(0.0777)	(0.1686)	(0.2568)
Years	Yes	Yes	Yes	Yes
Nb observations	3456	3456	3456	3456
Nb groups	288	288	288	288
Loglikelihood	-1914.92	-1908.43	-254.25	-250.48
χ^2	296.16 ***	312.26 ***	542.20 ***	528.45 ***

Note: *, **, * show significance at the 1%, 5% and 10% levels and Standard errors are presented in parentheses**

Table 4. Second Stage of regression results – Impact of government funding on the number and citation of nanotech patents in other provinces in Canada

Variables	dpat		dcit	
	1-1 (NO End.)	1-2 (2SRI)	2-1 (NO End.)	2-2 (2SRI)
ln(PublicFunding$_{it-1}$)	0.1274 ***	0.2784 ***	0.0103	0.1203
	(0.0464)	(0.0541)	(0.0776)	(0.0854)
[ln(PublicFunding$_{it-1}$)]^2	-0.0122 ***	-0.0135 ***	-0.0010	-0.0019
	(0.0047)	(0.0049)	(0.0077)	(0.0077)
PastPatents$_{it-1}$	0.1469 ***	0.1490 ***	0.3790 ***	0.3801 ***
	(0.0255)	(0.0253)	(0.0366)	(0.0365)
[PastPatents$_{it-1}$]^2	-0.0044 ***	-0.0039 ***	-0.0122 ***	-0.0118 ***
	(0.0013)	(0.0013)	(0.0019)	(0.0019)
ln(10^4 x BetweennessPatent$_{it-2}$)	-0.0379	-0.0469	-0.3220 **	-0.3354 **
	(0.0939)	(0.0967)	(0.1413)	(0.1420)
ln(10^3 x ClusteringPatent$_{it-2}$)	0.0899	0.0995	0.6433 ***	0.6492 ***
	(0.1097)	(0.1090)	(0.1367)	(0.1337)
[ln(10^3 x ClusteringPatent$_{it-2}$)]^2	-0.0138	-0.0160	-0.0835 ***	-0.0850 ***
	(0.0161)	(0.0160)	(0.0200)	(0.0196)
residual[ln(PublicFunding$_{it-1}$)]		-0.1495 ***		-0.1071 ***
		(0.0233)		(0.0324)
Constant	-0.1045 ***	-0.4788 ***	-2.9877 ***	-3.2777 ***
	(0.0351)	(0.0582)	(0.1573)	(0.1840)
Years	Yes	Yes	Yes	Yes
Nb observations	7104	7104	7104	7104
Nb groups	592	592	592	592
Loglikelihood	-4273.64	-4215.58	-572.64	-568.91
χ^2	517.89 ***	513.83 ***	451.08 ***	483.68 ***

Note: *, **, * show significance at the 1%, 5% and 10% levels and Standard errors are presented in parentheses**

Additionally, we take into account the non-linear impact of funding on the probability of academic outputs. Figure 1a and Figure 1b show this impact on the publication probability. While we observe that the probability of publishing rises as government funding increases, more interestingly, our results show a negative coefficient of the quadratic measure of funding on the probability of patenting. Our findings show that in simple models the influence of funding on the probability of patenting is positive, but when we increase the complexity of the model by adding its quadratic term, the results reflect a limited positive effect of funding on the probability of patenting. Beyond the maximum value, the graphs exhibit a negative relationship for Quebec while this decreasing effect is about to start in other provinces in Canada.

This observation highlights that if researchers "too much" receive funding in any given year, the probability of increasing their technological output will not continue to increase, at some point, this probability will start to decrease (see Figure 1c).

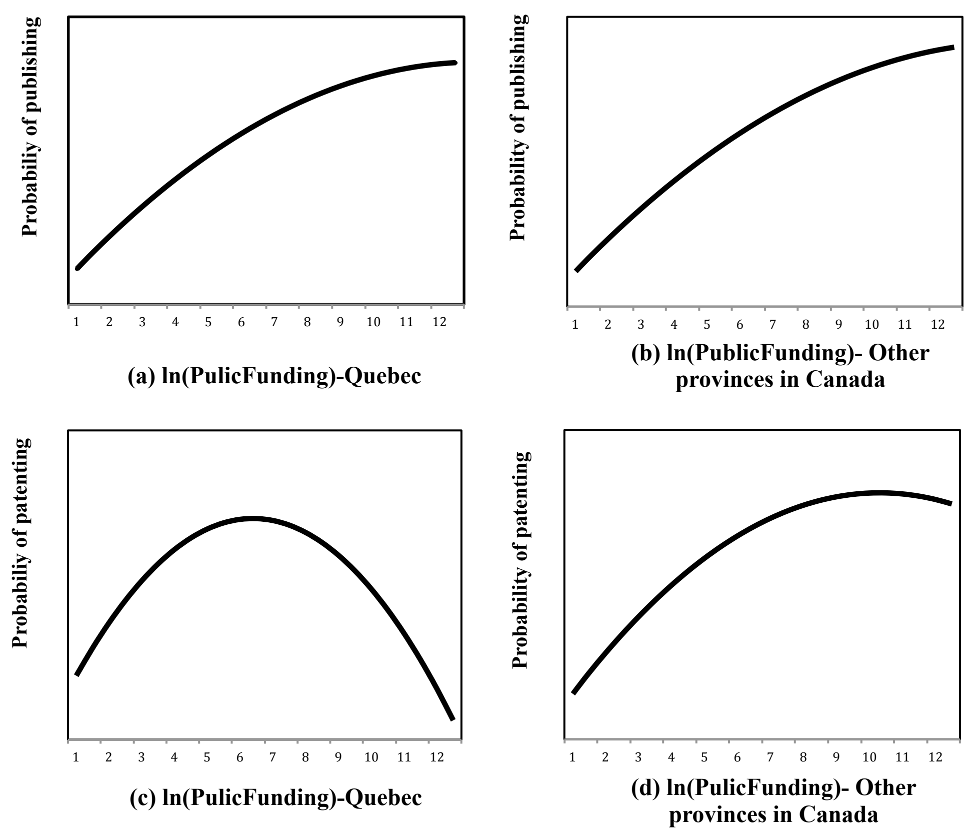

Fig. 1. The non-linear impact of funding on the probability of publishing in (a) Quebec, (b) other provinces in Canada, on the probability of patenting in (c) Quebec, (d) other provinces in Canada

We also include two non-linear effects of *ClusteringPublications* and *ClusteringPatents* in our models to examine the efficiency of clustered networks from an empirical point of view. The results show that researcher's past collaboration positively influences subsequent knowledge productivity. However, too much clustering in the co-publication and co-invention networks would not be fruitful. While we observe a positive impact of clustering on the probability of publishing, and on the probability of getting cited in papers and patents, this relationship exhibits diminishing returns with increasingly more clustered networks.

Finally, including the number of patents filed by researchers in the past three years shows that the impact of patenting follows an inverted U shaped curve on the probability of publishing, patenting and getting cited. This suggests that at first patents tend to reinforce the productivity of researchers, but contributing to a greater number of patents would then imply a negative impact.

Conclusion

Responses to our research questions have high policy relevance given that academic research might need to rely on government funding in terms of enhancing scientific performance and technological activities. Universities have historically fostered open science and shared knowledge, yet patenting activities have become increasingly common in recent decades. Concerted efforts must be made to better understand the determinants that increase innovative productivity and scientific performance. In this paper, we examine academic productivity using panel data for publications, patents and grants that were allocated to academic researchers. We also analyze the diverse roles of universities in the economic system. These contributions examine the quality of academic outputs, which focuses on the citation impact of publications and patents in following years.

Our results have numerous implications on emerging technology and universities given that academic research relies on government funding to enhance scientific performance and conduct patenting activities. We argue that government financial support facilitates higher performance in academia, and that the effect is strong for both publications and patents. Additionally, our paper aims to further understand the role of collaboration in enhancing researcher productivity.

This research reveals two insights into government funding of academic technological outputs within universities: first, the government must find ways to efficiently allocate financial resources to universities. Our results show that a mere increase in research funding does not always increase research production and citation impact as we observed a clear limitation. Given funding constraints, strategists and policy makers must measure the productivity of funding programs in various fields to strategically foster economic development.

Second, since several government funding programs strongly encourage academic research in high technology fields, and considering the lack of financial sources, a specific mechanism is required to enhance innovation productivity of academic researchers.

To sum up, our analysis reveals that public funding greatly enhances technological outputs in the academic realm. However, industry funding or government-industry research programs can influence on producing academic patents that may translate into economically successful industry products.

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