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Is Canadian Intellectual Property leaving Canada? A study of nanotechnology patenting

Catherine Beaudry[1,2,3] and Andrea Schiffauerova[1]

[1]École Polytechnique de Montréal, Montreal, Canada, C.P. 6079, succ. Centre-ville, Montréal, Québec, H3C 3A7 Canada, Phone +1 514 340-4711 poste 3357, catherine.beaudry@polymtl.ca
[2]Center for Interuniversity Research on Science and Technology (CIRST)
[3]Concordia University

Abstract In this study we explore the patent ownership for the innovations created by Canadian nanotechnology inventors. We find that although there is a great innovative potential and inventive productivity among Canadian researchers, a lot of the intellectual property actually leaves the country: Around 50% of the nanotechnology patents invented by Canadian inventors are owned by foreign assignees. We also note the predominance of private companies among the patent owners. Almost one third of all the Canadian-invented nanotechnology patents is assigned to a single American firm, Xerox Corporation. Furthermore, we explore the role of Canadian nanotechnology star inventors. The results show that the fruits of their great inventive productivity are collected outside Canada.

Keywords innovation, cluster, patents, star scientists, nanotechnology, Canada

JEL codes O31, L69, R12, R30

1 Introduction

Nanotechnology has been one of the main rapidly emerging technologies over the last two decades. Various studies, which address the progress taken in this field, document the current situation of Canada in terms of the bibliometric indicators. They show that although Canada is among the top countries producing nanotechnology research, its contribution is relatively low[1] (Yegul *et al.*, 2008). In the study of Kostoff *et al.* (2007), Canada ranks only 13th in terms of production of nanotechnology papers, and according to Miyazaki and Islam (2007), Canada ranks 10th even though its share in overall publications is steadily rising. Canada seems to be more successful in nanotechnology patenting: Li *et al.* (2007) place Canadian patent assignees to the 5th rank. Wong *et al.* (2007) make a distinction between assignees and inventors in their study. In their study, Canada ranks 6th when the total number of patents assigned is counted, but improves its position to the 5th rank when the patents invented are counted. This suggests that not all the nanotechnology patents invented in Canada are owned by Canadian entities and that the country"s inventive efforts are perhaps exploited outside its borders.

Despite its size, Canada is a small country with about a tenth of the population of its southern neighbour. The US represents both a tremendous market opportunity and a threat that the intellectual property (IP) development in Canada creates value outside its borders. Canada"s private sector is dominated by small and medium sized companies, whose research and development has to concentrate in geographical agglomerations and clusters in order to contribute to an efficient innovation system[2]. Localized knowledge spillovers are frequently claimed to be a key explanatory factor for the geographical concentration of innovative activity (Dahl and Pedersen, 2004). This phenomenon is explained by Jaffe (1989), Acs *et al.* (1992, 1994), who suggest that investments in R&D by private corporations and universities spill over for third party firms to exploit. Since it is presumed that the transmission of knowledge is distance sensitive, the ability to receive knowledge spillovers is influenced by the distance from the knowledge source, which was also empirically confirmed by Jaffe *et al.* (1993) who proposed that knowledge spills over locally and takes time to diffuse across geographical distance. Hence in industries where new knowledge plays a crucial role, innovative activity tends to cluster in locations where key knowledge inputs are available (Audretsch and Feldman, 1996).

So why is it that we find ownership of IP so far removed from where the innovation takes place? In this study we trace the ownership of IP developed in Canada and by Canadians. We find that much of the IP is in fact escaping to our southern neighbour through an R&D subsidiary of an American multinational enterprise. Large multinational enterprises working in knowledge-intensive fields are usually motivated to internationalize their R&D activities by gaining the access to the new knowledge and knowledge resources and by their integration in the global enterprise network (Edler, 2004). It is thus a necessity for these companies to go abroad to absorb and acquire technological spillovers which are associated with the innovation system of the host region, either from the local knowledge base or from specific firms (Criscuolo *et al.*, 2005). According to Patel and Vega (1999), the main purpose of foreign technological activities is to adapt products, processes and materials to suit foreign markets and to support foreign production, while other common motives for internationalization of R&D are monitoring and scanning of new technological developments in foreign centers of excellence or generating entirely new products and core technologies outside their home countries (to compensate for their weakness at home).

National governments usually try to attract multinational enterprises to invest in R&D-intensive activities, since they provide substantial benefits to the national research systems. The existing literature supports the view that R&D-intensive foreign direct investment constitutes a powerful mechanism of international technology transfer which can enable host locations to develop specialized clusters (Guimon, 2009). Not only can activities of such R&D research centers strengthen the research and innovative capacities of the firms already present in the clusters, they may also attract the entry of new firms that carry out their own research, development and innovation. Swann and Prevezer (1996) argue that new firms in biotechnology are strongly attracted to the presence of a strong science base at the location and Prevezer (1997) adds that new companies are also attracted by the entry of other new companies. Baptista and Swann (1999) find that by entry of new firms the cluster attracts even more other firms and that this cluster self-reinforcing effect could start out of the emergence of one strong firm. Feldman (2003) later develop the anchor tenant hypothesis, which suggests that large high-technology agglomerations tend to be created by the investment of large corporations. These corporations - anchor tenants - attract smaller corporations that thrive on the newly created labour market, on service firms and infrastructure, as well as on the knowledge externalities created by

[1] Canadian share in global nanotechnology related publishing is only around 1% according to Miyazaki and Islam (2007) or 2.4% according to Kostoff *et al.* (2007).

[2] The reason behind the agglomeration of innovative activities is the fact that geographical proximity facilitates knowledge sharing, since knowledge does not spill over large distances (Audretsch and Feldman, 1996).

the anchor. Chabchoub and Niosi (2006) in their study on software clusters create a new hypothesis which suggests that innovation activities are also linked to anchors, and that it is not simply the cluster phenomenon as described by Feldman (2003). Similarly, Agrawal and Cockburn (2003) develop and test the hypothesis that the presence of an anchor tenant enhances the regional innovation system. Wolfe and Gertler (2004) emphasize the importance of an anchor firm for the cluster and give practical examples when entire clusters developed out of the formation of one or two critical firms. In this paper, we also attempt to identify the anchor tenants of Canadian major nanotechnology clusters and to determine their role in the birth and the development of the clusters.

While studying nanotechnology innovation in Canada we find that there is a great innovative potential and inventive productivity among Canadian nanotechnology researchers. We realize that the innovation production among the Canadian inventors is not uniform and is in fact concentrated in the hands of several extremely prolific Canadian scientists. The literature supports the view that the extremely productive scientists called star scientists are a key driving force behind the growth and innovation in some knowledge intensive industries. Zucker and Darby (1996) and Zucker *et al.* (1998) show the importance of star scientists in the biotechnology sector and emphasize the positive effects on the performance of the firms collaborating with the stars, and Zucker and Darby (1996) demonstrate that the collaboration between the stars and the companies is also reflected in the higher scientific productivity of the star scientists themselves. Moreover, Zucker et al. (1998) and Prevezer (1997) argue that in the biotechnology sector, star scientists often capitalize on their knowledge through firm start-ups. Zucker and Brewer (1994) and Zucker *et al.* (1998) provided considerable evidence suggesting that the timing, location and the success of new biotechnology firms is primarily explained by the presence at a particular time and place of scientists who are actively contributing to the basic science. Darby and Zucker (2006) extend the concept of biotechnology star scientists to the nanotechnology sector as well. The great importance of the star scientists suggested by the existing literature leads us to investigate whether their inventive efforts are serving mainly Canadian interests or are also exploited predominantly outside Canada. Unfortunately we discover that the fruits of their enormous inventive production are again gathered by foreign hands! It seems that not only is the ownership of the IP escaping through Canadian borders, but it is also our most valuable IP - developed by the most important and distinguished Canadian nanotechnology scientists – which is leaving Canada.

And what is the effect in the long run of this exportation of IP a long way from where it was developed? Shand and Wetter (2007) describe a major role of IP in winning the huge nanotechnology global market. In the nanotechnology domain, there is a unique opportunity to patent the most basic enabling tools, as well as the ability to patent nanomaterials and also the methods of making them. This is in contrast with other enabling technologies of the twentieth century - including the computer, software, the Internet, and even biotechnology – which, for various reasons, all ended up in the public domain (Lemley, 2005). In nanotechnology however, both companies and universities are patenting early and often. And since a single nanoscale innovation (materials, devices and processes) can be relevant for widely different applications across multiple industry sectors, it will be the ownership of IP that will decide who will capture the nanotechnology market, and who will get access to nanoscale technologies and at what price (Shand and Wetter, 2007). Control and ownership of nanotechnology should thus become an alarming issue of concern for the Canadian government.

In this paper, our objective is threefold. First we investigate where innovation creation takes place within Canada and identify 8 nanotechnology clusters for the purpose. Second, we then examine the types and location of organisations that own the patents partly developed by Canadian inventors in order to identify the proportion of IP retained by Canadian assignees. Having identified a non negligible portion of IP "leaving" Canada, we then turn to evaluate the extent of the damage and who is to blame, and third, we study the star-inventors that contribute to these patents and the strength of the patents to which they contribute. We find that prolific inventors (including star-scientists) collaborate three times more often on patents owned by foreign organisations whereas the trend is the reverse for sporadic inventors. In addition, nearly 60% of strong patents, i.e. with a large number of claims, are owned by foreign organisations while the weak patents are owned mainly by Canadian organisations. It would seem that we do export our best!

The paper is organised as follows: section 2 presents the data and methodology underlying the study, section 3 presents the basic characteristics of Canadian nanotechnology clusters, section 4 describes the patent ownership structure within these clusters with a particular attention to foreign versus Canadian ownership, section 5 focuses on star scientists and the strength of their patents, distinguishing between foreign and Canadian owned patents, and finally section 6 concludes.

2 Data and Methodology

In order to build the database of Canadian nanotechnology inventors we used the patent data contained in Nanobank.

Nanobank is a public digital library comprising data on nanotechnology articles, patents and federal grants, as well as firms engaged in using nanotechnology commercially. The Nanobank patent database is based on data extracted from the United States Patents and Trademarks Office (USPTO) database. This is the only patent database that provides the geographical location of the residence for each inventor (unlike the Canadian IP Office database (CIPO) or the European Patent Office (EPO)). The use of the USPTO database instead of the CIPO for the analysis of Canadian nanotechnology may have caused a certain bias in the data, but we consider it minimal, since Canadian inventors usually patent both in Canada and in the US. The much larger and easily accessible nanotechnology American market offers them a greater potential than the nanotechnology market in Canada. Especially in the case of nanotechnology, Canada has not been found (Yegul *et al.,* 2008) very successful in terms of patents when patent databases other than USPTO (i.e. CIPO, EPO, JPO, Derwent) were taken as data source for bibliometric research.

We reviewed some of the patent search strategies used by a number of researchers and employed additional filters to the Nanobank database which seems to use extremely vague definition of nanotechnology and includes large numbers of nanotechnology unrelated patents (Schiffauerova and Beaudry, 2009). This enabled us to pick out only the patents that are strictly related to nanotechnology. We have selected the patents in which at least one inventor resides in Canada and created a Canadian nanotechnology patent database which comprises 1443 patents. Our work involves a quantitative analysis of the information extracted from these patents.

3 Basic characteristics of Canadian nanotechnology clusters

Nanotechnology patent production is not uniform throughout Canada, since most of the Canadian nanotechnology innovation is concentrated in a few regions only. We have identified eight Canadian nanotechnology clusters[3], four of which are important nanotechnology agglomerations - Toronto, Montreal, Ottawa and Vancouver; whereas the other four are much smaller nanotechnology concentrations – Edmonton, Quebec, Kingston and Calgary. A summary of the basic statistics regarding the clusters is presented in Table 1. Even though only 14%[4] of the patents in our database are invented by foreigners, the bulk of the patents (44%) is assigned to the foreign entities, most of which (77%) are located in the US. In fact, 69% of the patents owned by non-Canadian subjects are assigned to a single American company – Xerox Corporation. This high level of foreign ownership is rather extraordinary in Canada. For example, in biotechnology, which is another emerging and science-driven field, only 21% of patents are owned exclusively by foreign assignees. Similarly, 78% of these are also Americans. To return to the nanotechnology data, 80%[4] of these foreign owned patents are invented by Canadians (see the second column in Table 1), most of whom (62%) reside in the Toronto cluster, which is also (together with Montreal) the most important Canadian nanotechnology cluster (by the number of patents owned). Most of the Canadian nanotechnology activities take place within the clusters, usually the few main ones, but the quality (measured by the average number of patent claims[5]) of the patents whose assignee resides outside the clusters (especially outside Canada) is much higher than the quality of other patents. American-owned patents in particular have a higher quality than those owned solely by Canadians. The superior value of American-assigned patents, as measured by the average number of claims, has been already observed by Tong and Frame (1994). The situation changes dramatically when the number of nanotechnology inventors residing in each location is compared. Nearly 30% of the inventors in the database have their addresses outside Canada (77% of them in the US), while the Toronto cluster leads the Canadian nanotechnology inventive activity – with one quarter of all the inventors living in the cluster.

[INSERT TABLE 1 NEAR HERE]

Considering the disproportional distribution of patents and inventors in Canadian nanotechnology clusters, it

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[3] The cluster in this study is defined as a geographically continuous region active in nanotechnology (as measured by the patent production).

[4] Based on fractional counting of patents: when a patent has several inventors residing both in Canada and outside, Canada is attributed only a fraction of that patent that corresponds to its share in the number of inventors. We use a method similar to that of Guellec and van Pottelsberghe de la Potterie (2001)

[5] Patent claims are a series of numbered expressions describing the invention in technical terms and defining the extent of the protection conferred by a patent (the legal scope of the patent). A high number of patent claims is an indication that an innovation is broader, has a greater potential profitability and is indicative of higher patent value (Tong and Frame, 1994; van Zeebroeck and van Pottelsberghe de la Potterie, 2006). However, there are some shortcomings related to the use of claims as a patent quality indicator as well. The number of claims also depends on the technology field, the ownership country and on the time of patent granting (Lanjouw and Schankerman, 2001).

is interesting to compare the numbers of patents per inventor in various clusters, as presented in the fifth column of Table 1. The number is extremely low for the Toronto cluster, to which only relatively little patents are assigned, even though it has many inventors. This suggests that many nanotechnology inventors residing in Toronto work for companies headquartered in the US. As mentioned above, 62% of inventors whose patents were assigned to the foreign subjects reside in the Toronto cluster. The sixth column also shows the number of „patents per inventor", which was however calculated in a way that disregards the patent"s ownership and thus better captures the inventors" real productivity. In most of the clusters this measure is around one. Using this inventor productivity measure shows that Toronto clearly has the most productive inventors.

The seventh column shows the numbers of all the organization types of assignees in each cluster, while in the seventh column only the assignees recognized as private firms are selected. This method allows us to find out how many of the companies in each cluster are engaged in nanotechnology. We are aware that we cannot capture all the firms that deal with nanotechnology, because only the companies which have at least one nanotechnology patent registered at the USPTO are considered. Firms may have been left uncounted for various reasons: First, this method excludes all the nanotech companies that patent solely at different patent offices (e.g. CIPO, EPO). However, as explained earlier we assume that the number of patents registered in other offices will not be substantial. Second, it obviously also excludes the firms which do not protect their inventions. According to the survey of nanotechnology companies (McNiven, 2005) only 39% of Canadian nanotechnology companies use IP instruments to protect their inventions. Third, an innovative firm engaged in nanotechnology will not be included if it prefers an alternative means of IP protection. However, there are not many such firms, since 88% of the IP instruments used by Canadian nanotechnology companies are reported to be patents or pending patents (McNiven, 2005). Thus, even though patents cannot be set equal to innovation, they could still be considered as a reasonably good indicator of innovative action in Canadian nanotechnology.

Since a considerable number of patents of Canadian inventors are assigned to foreign companies, we follow the evolution of foreign ownership of nanotechnology patents over time. Figure 1 shows the evolution of the production of the Canadian invented patents by their ownership type. Even though the foreign ownership is increasing in absolute values, the proportion of the patents assigned only to foreign subjects is in fact decreasing in time. There used to be around 60-80% of foreign owned patents in 1985-1994, whereas during the last years measured (2000-2004) this percentage is only around 35-40%. The proportion of Canadian ownership of nanotechnology patents invented by Canadian scientists is thus increasing in time.

A number of questions remain. For instance, are the owners of Canadian patents firms or public institutions? Are the foreign owned patents mainly owned by firms? In the next section we have examined the ownership structure of the nanotechnology patents from the organization type point of view.

[INSERT FIGURE 1 NEAR HERE]

4 Patent ownership structure in Canadian nanotechnology clusters

The examination of the patent ownership structure allows us to compare the different institutional compositions of nanotechnology (see Figure 2). Most patents (73%) are assigned to companies, much less to universities, institutions or individual inventors. Nanotechnology is a scientific field with potentially high financial revenues, which probably contributes to the high entrepreneurial interest and thus high representation of the private sphere among the nanotechnology assignees. Moreover, commercial interests push the private firms to protect their most important assets by employing appropriate mechanisms (such as patents), whereas the registration of the university or governmental inventions at the patenting offices may not seem so urgent to the particular inventors. We also observe that the patents whose assignees are firms have a higher average patent quality than those owned by universities or institutions.

[INSERT FIGURE 2 NEAR HERE]

The analysis at the cluster level shows that in almost all the clusters, the majority of patents (50-70%) are assigned to companies. We have calculated the proportion of Canadian and foreign owned patents per nanotechnology cluster for each type of assignee. In most clusters, the bulk of the IP (70-100%) remains in Canada (for each type of assignee), with the exception of Toronto for which only 28% of the patents are owned by Canadian organisations. This is due to foreign firms, which own 78% of the patents associated with Toronto inventors. In particular, in this cluster are located the headquarters and Xerox Research Centre of Canada (XRCC) which owns most of the foreign-owned patents of the cluster.

To find out whether the proportion of foreign owned patents is a growing trend and should be a cause for concern, we calculated the evolution of the proportion of Canadian versus foreign ownership of patents (Figure 3) for the clusters of Toronto and Montreal and for Canada for the period 1985-2005. The general tendency for the country has been increasing from the mid-nineties to slightly less than 60% of Canadian ownership. During the last decade of the sample: in Montreal, the proportion of Canadian ownership is decreasing, while in Toronto it is increasing. Since firms own most of the patents, we observe similar results if we reproduce Figure 3 only for patents owned by companies. The increasing tendency of Canadian ownership in the Toronto cluster is certainly a positive sign, however, knowing that most of the foreign owned patents in the cluster are assigned to Xerox, the study of its impact on the cluster‟s evolution deserves further investigation.

[INSERT FIGURE 3 NEAR HERE]

In the introduction to the paper, we discussed the possibility of R&D-intensive foreign direct investment becoming an enabling mechanism for the development of specialized clusters in the host locations as an anchor tenant. We further explore the role of Xerox in the Toronto cluster to learn whether its activities there produced such an effect. The first few patents in the cluster (granted in 1984) are assigned to the University of Toronto and to Xerox Corporation in Connecticut, via XRCC in Mississauga. From then on, a number of foreign companies collaborate with Toronto inventors, which we presume are based mostly within the university where the expertise has developed. Until the late 1990s, foreign ownership of patents dominates the Toronto patent scene. Then, Toronto-based firms, and other organisations to a lesser extent, start to patent themselves. Furthermore, we observe the proliferation of the number of innovative firms in the Toronto region that actively patent in nanotechnology. The proportion of patent foreign ownership then decreases from about 88% to about 62% in the last years of our sample. Throughout the period examined, Xerox has maintained its innovation level and contributed to the development of expertise in the area. As such, the Toronto-based research center can be qualified as an anchor tenant. We have traced the evolution of each cluster and conclude that nowhere else in Canada has any firm or university influenced so significantly nanotechnology innovation and fostered such an effervescent environment.

5 Do foreign firms own our "best"?

Having identified a non-negligible portion of IP "leaving" Canada, in this section we evaluate the extent of the damage: Are we "losing" our most productive inventors and the patents of the highest value?

First we identify the most prolific inventors in the database and find that most of the inventive output is produced by only a few individuals. These highly productive scientists are called star scientists and their important role has been already discussed. We define star scientists in our dataset based on patent quantity only, or based on both the quantity and quality simultaneously. According to the number of patents as the only discriminatory factor, we identify 40 prolific inventors (15+ patents), out of which 23 are considered to be star inventors (21+ patents). In addition, we incorporate patent quality as a second discriminatory factor and calculate the *Quantity and Quality Patent Index (QQI)* based on Schiffauerova and Beaudry (2010), which takes into consideration both the patent counts and the mean patent value for each inventor[6]. According to QQI we identify 37 QQ prolific inventors (QQI value of 20+), out of which 18 are QQ star inventors (QQI value of 30+).

This methodology enables us to identify 48 prominent inventors (29 of which are indicated as prominent by both measures concurrently). At the cluster level, Toronto is an absolute leader in the number of prominent inventors in the cluster (34 inventors) with Montreal far behind (6 inventors). The average number of patents authored or co-authored by an inventor is also much higher for Toronto (4.31) than for other clusters (the average number of patents per inventor in the database is 2.45)[7].

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[6] Quantity and Quality Patent Index (QQI) for inventor *i*: $QQIndex_i = \frac{N_i * C_i^{avg}}{C^{avg}}$, where

N_i……..…..number of patents at the USPTO invented or co-invented by inventor *i*

…......average number of patent claims for all the patents at the USPTO invented or co-invented by inventor *i*

C^{avg}……......average number of patent claims for all the inventors in the database

[7] It is an unwritten law that the director of the research unit is always mentioned in both journal publications and patent filings, even if his or her contribution is minimal or even non-existing (Deng et al., 1999; Narin and Noma, 1987). As a consequence, these may appear in our data as much more prolific (probably even stars) than others, even though their real contribution to the research is in fact not as stellar.

So with whom do these inventors work and more importantly where does the IP they develop end up? We find that all the stars and QQ stars in Toronto are involved with Xerox patents. We trace these individuals and to our surprise we find that none of them is also working as an academic at a university. All of the stars and QQ stars have been filing their patents as employees of XRCC in Mississauga. Moreover, we trace down the publication record of each of them and except for their PhD work they have never published scientific articles under a university affiliation (or under double university-Xerox affiliation) and quite rarely with an academic co-author. This is in a sharp contrast to the situation in Montreal, where a number of the stars are employed by universities and transfer the technology developed in their labs to industry.

Table 2 shows the number of patents associated with Canadian and foreign assignees to which four types of inventors have contributed according to their innovation productivity measured by their number of patents. The three columns on the right show the number of inventors that have worked on patents owned by Canadian and foreign organisations. The results are striking. The more prolific is an inventor, the more likely are his patents to be owned by foreign organisations. The same is true if we consider what we have qualified as QQ-stars. But what is the cause and what is the consequence? Is it that foreign organizations select Canadian inventors, because they are prolific or is it that these inventors become prolific only because they file with foreign organizations? None of the stars and QQ-stars that live in the Toronto cluster has filed any of its patents outside the Xerox umbrella, which may suggest that it was Xerox that made them prolific. The fact still remains that these are outstanding scientists and their enormous potential escapes from Canada to be gathered on the other side of the border. Is Canadian nanotechnology sector not able to take advantage of its talents? It does not seem to appear in the patent data. However, McNiven (2007) in his study on Canadian nanotechnology mentions that technology transfer agreements represent 26% and licensing agreements 20% of the IP activity. Foreign ownership is declining, and transfer and licensing activities are modest yet non negligible.

We observe a similar trend when considering the patent quality or strength as measured by the number of claims of each patent (see Table 3). Foreign owned patents are more likely to have a greater number of claims. Now this is more problematic for the successful implementation of a number of Canadian industries based on nanotechnologies if this situation remains unchanged in the future.

[INSERT TABLE 2 NEAR HERE]

[INSERT TABLE 3 NEAR HERE]

In order to investigate this, Figure 4 illustrates the evolution of the proportion of foreign patents according to patent strength. Although the trend in the proportion of foreign-owned patents is decreasing as implied by Figure 4, the proportion of strongest patents are still overwhelmingly in the hands of foreign organisations compared to the weak patents which remain under Canadian control. On average, strong patents are about twice as likely to be under foreign ownership as weak patents. This is in part due to the fact that most foreign patents (to which Canadians have contributed) are owned by firms and these patents traditionally have more claims. Indeed as the greatest proportion of patents produced by individuals and institutions belongs to Canadian assignees. Considering only Canadian and foreign firms yields the same results. However, recall that 69% of the foreign patents are owned by one large multinational enterprise (Xerox) and large companies are usually more rigorous in pursuing their IP rights (Graham *et al,* 2003; Graham and Harhoff, 2005), so their patents may involve higher numbers of claims as a protection against later litigations. Moreover, the prevalence of the strong patents in the hands of American owners could be also partly explained by the fact that an average US-owned patent in the USPTO database has a higher number of claims than an average non-American one (Lanjouw and Schankerman, 2001),

[INSERT FIGURE 4 NEAR HERE]

6 Discussion and conclusion

To answer the title question – yes, about 50% of the IP developed partly in Canada over 20 years belongs to foreign entities, mainly firms. Should Canada be worried? For the patents partly or completely invented in the Toronto cluster, over 70% is under foreign ownership. Is this a healthy level? On the one hand, it certainly illustrates not only that Canadian R&D tax credits are working as an incentive, but also Canadian inventors have what it takes! On the other hand, this is 70% of what has been partly developed in Canada that will create value elsewhere.

The main culprit has been clearly identified – Xerox Corporation, USA and its research centre established in the Toronto area in 1974 – XRCC. With its 120 scientists and engineers its mission is to research and to develop strategic materials for Xerox worldwide. As of 2009, the XRCC has received more than 1,400 US patents, all of them assigned to its parent company - Xerox Corporation, USA. What does this mean for Canada? We have shown that XRCC employs our best nanotechnology scientists who create great patentable ideas and our strongest nanotechnology patents (see Appendix), but the fruit of their effort is gathered in the US. Should we be concerned? Looking also at the other side of the coin, we see considerable benefits to the Canadian research system. As it was discussed, establishing XRCC enabled the Toronto area to develop a highly specialized nanotechnology cluster. XRCC acted as an anchor tenant and attracted other nanotechnology R&D-intensive firms into the region and strengthened the research and innovative capacities of the firms already present in the cluster. In no other Canadian nanotechnology cluster we find such significant impact of any company or university. Moreover, a positive influence should also be seen in increasing the dynamics of the national innovation system through the active collaboration of the XRCC with other companies, research centers and universities. A high degree of embeddedness of foreign-owned firms in the national innovation system is considered to be a necessary condition to maximize the benefits of technology transfer (Rama, 2008). However, the strong collaboration with local universities does not seem to have materialized in this case. Only one Xerox patent is co-assigned with a Canadian university (University of Toronto), while this is a much more common phenomenon in the Montreal cluster. Also, it seems that the Xerox star scientists quite rarely co-author their papers with Canadian academics. Finally, an important benefit has also been an increase in employment through the creation of new qualified jobs. Even though XRCC employs only around 120 highly qualified scientists and engineers, its successful research programs contribute to the development of operations of Xerox Canada, which nowadays employs over 4,000 professionals in Canada.

The proportion of foreign ownership of patents in the Toronto cluster follows a decreasing trend. In contrast, for the Montreal cluster, the trend is increasing, but it started from an entirely Canadian ownership until the mid-1990s. In Toronto, foreign ownership increased until the late-1990s and has been decreasing ever since. The two clusters therefore show opposite trends. This raises an interesting question regarding the emergence of a new technological domain in a particular region. Toronto started to patent earlier than Montreal, a phenomenon mainly driven by foreign firms and by a strong anchor tenant effect from XRCC. Montreal did not manage to attract foreign firms until the mid-1990s, and does not seem to benefit from an anchor tenant, but developed an expertise that remains largely under Canadian ownership. Although the two clusters are moving towards one another in terms of the proportion of foreign IP ownership, the conditions of emergence of the cluster seem to be one of the main factors that could explain the proportion of foreign ownership. The reasons behind this phenomenon however need to be investigated further. Another avenue of research would be to examine what sparks contribute to the fast development of a high technology cluster. Does the influx of foreign money into specific research groups contribute to kick start the development of expertise that can then act as an attractor to other investors? Is the anchor tenant the only catalyst? Moreover, what needs to be evaluated is the proportion of foreign ownership that brings enough life to the cluster without hindering the development of a healthy local industry and research infrastructure to sustain the development cycle of IP in the long run. As such, Montreal, Vancouver and Edmonton will be interesting clusters to follow in the coming years.

Another possible direction for future research is to disentangle the nanotechnology sub-domains present in each cluster in order to follow the development of niches throughout Canada. For instance, has Toronto developed an expertise in a particular type of nanotechnology that is very close to commercialisation for which there is no industry yet in Canada? Can we foresee the future of other clusters depending on the niche they are currently developing? The subdivision of nanotechnology into subcategories could help answering these questions.

An important aspect of cluster growth certainly regards technology transfer from university to industry that can be examined by identifying which inventors are also academics. We are currently in the process of merging two databases to our patent database: one of scientific articles and another on grants awarded to researchers. This should allow us to follow the development of knowledge to its application and hence identify some of the mechanisms of technology transfer. One such mechanism is also the influx of university graduates that go and work for local firms. It would indeed be very interesting to know the number of graduates of Toronto universities that went to work for Xerox Canada and thus did not contribute to new firm start-ups and to the growth of firms in the area. The question would then be: can an anchor tenant be too big?

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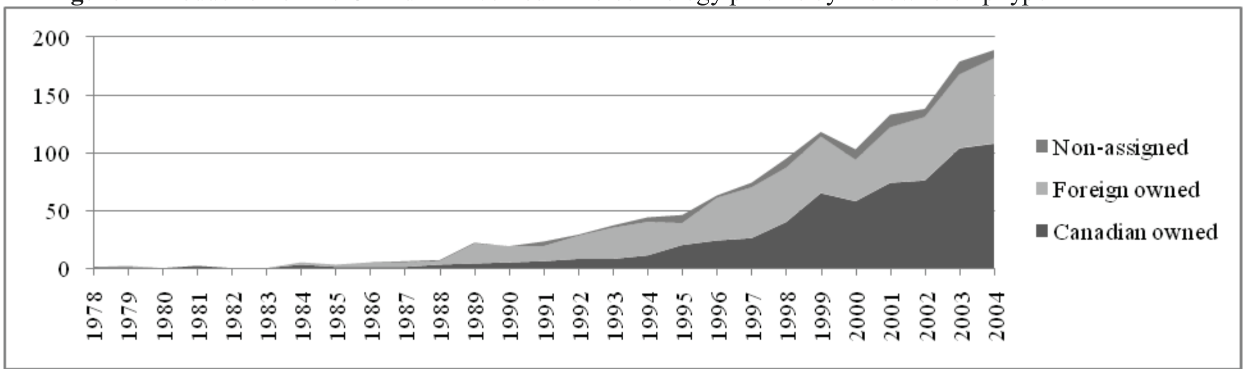
Figure 1 Production of the Canadian invented nanotechnology patents by the ownership type



Note: The foreign-owned patents are those whose owners have exclusively foreign addresses

Figure 2 Patents by the organization type of the assignee and average number of claims

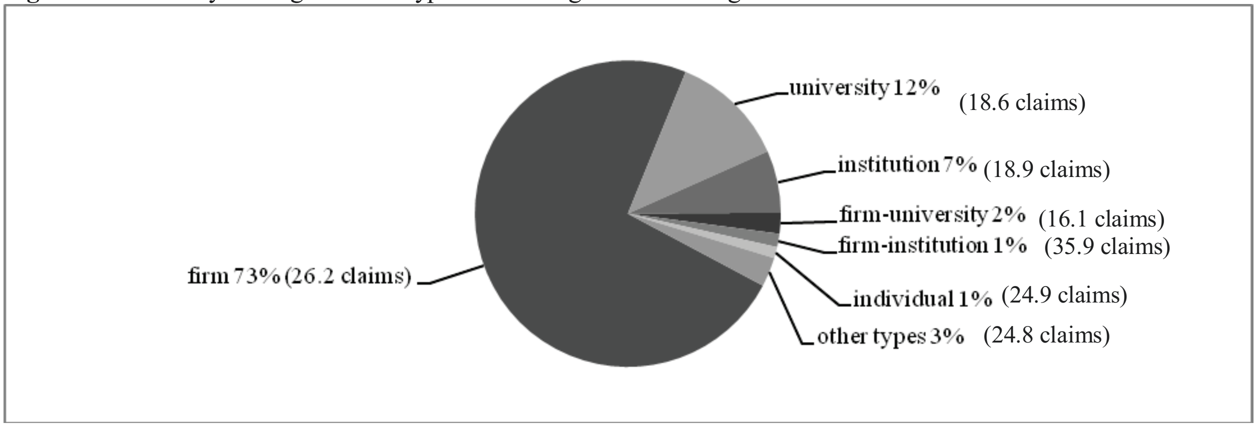


Figure 3 Evolution of the proportion of Canadian and foreign owned patents in Canada as well as in the Toronto and Montreal clusters

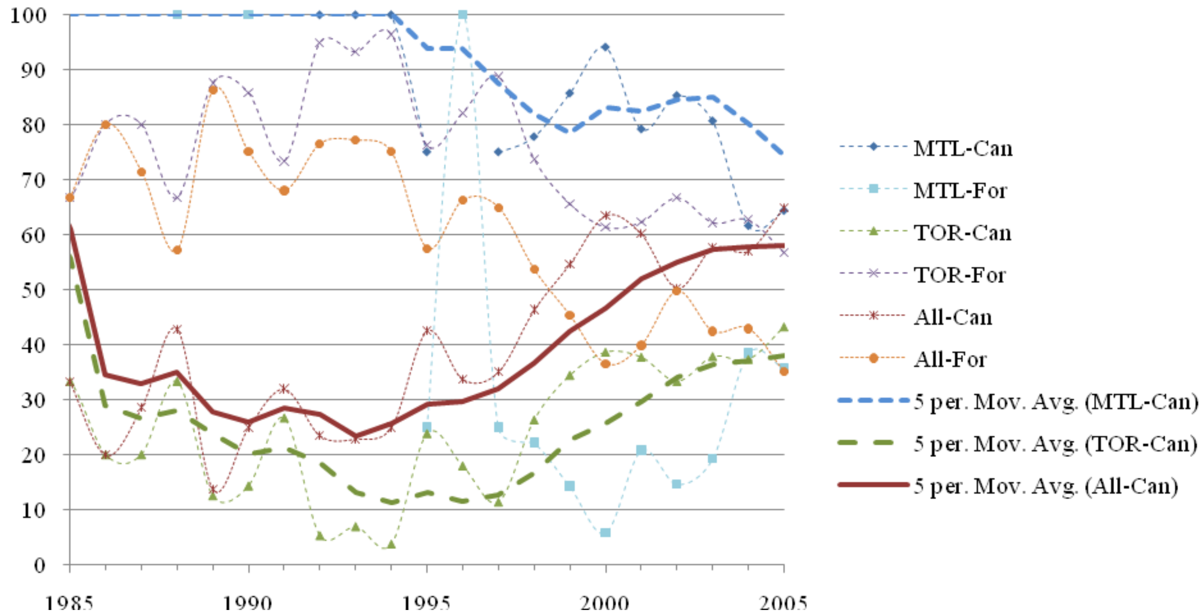


Figure 4 Evolution of the proportion of foreign-owned weak (1-15 claims), average (16-35 claims) and strong (36+ claims) patents over the period 1985-2005 (the highest patent strength of the patents to which an inventor has contributed is associated to the inventor)

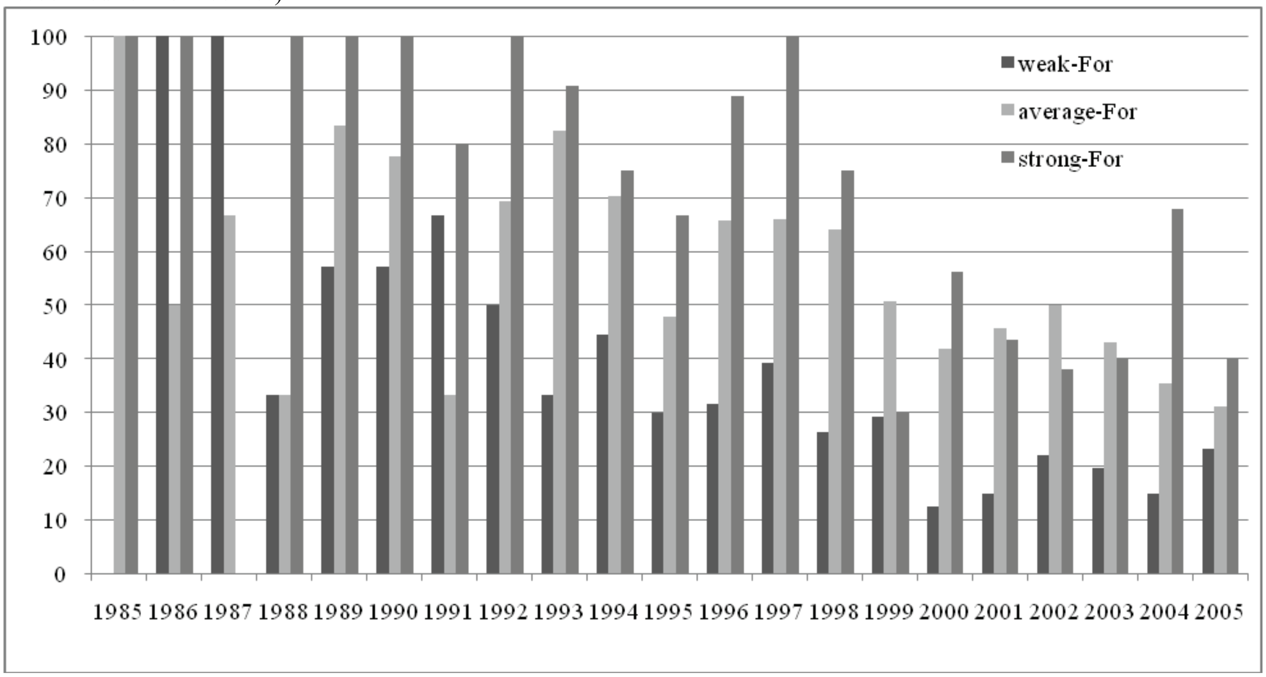


Table 1 Basic statistics regarding Canadian nanotechnology clusters

Cluster	*Patents*[a]		*Claims*	*Inventors*[c]	*Patents per inventor*		*Assignees*	*Firms*[f]
	nb (%)	*Canadian invented (%)*[b]	*avg nb*	*nb (%)*	*I*[d]	*II*[e]	*nb*	*nb*
Toronto	169 (12%)	92%	21.6	487 (24%)	**0.35**	**1.52**	82	53
Montreal	162 (11%)	86%	21.3	180 (9%)	**0.90**	1.16	32	28
Ottawa	103 (7%)	94%	18.2	179 (9%)	0.58	0.92	14	8
Vancouver	103 (7%)	90%	24.7	142 (7%)	0.73	0.95	23	21
Edmonton	57 (4%)	95%	22.5	79 (4%)	0.72	0.94	13	10
Quebec	23 (2%)	85%	21.2	47 (2%)	0.49	0.79	11	7
Kingston	14 (1%)	100%	20.9	35 (2%)	0.40	1.05	2	1
Calgary	34 (2%)	92%	15.2	33 (2%)	1.03	1.30	14	13
Out of clusters	52 (4%)	95%	26.1	201 (11%)	0.26	0.87	28	19
Foreign	**640 (44%)**	**80%**	**27.5**	**585 (30%)**	**1.09**	0.73	151	102
Unassigned	86 (6%)	90%						
Total	1443	86%	24.17	1968	0.69	1.03	370	262

[a] Based on assignees‟ addresses;
[b] Proportion of patents assigned to the cluster invented by Canadians based on fractional counting[48];
[c] Based on inventors‟ addresses (most frequent address was used for inventors with multiple addresses);
[d] Counted as the number of patents allocated to the clusters by assignees‟ addresses divided by the number of inventors allocated to that cluster based on their most frequent addresses;
[e] Counted as the number of patents co-invented by at least one inventor from the cluster divided by the number of inventors who patented at least once while living in that cluster;
[f] Only inventive firms (i.e. those which have patented at least one nanotechnology patent) are counted;

[8] As a comparison measure, we found that the proportion of foreign inventors of Canadian owned patents represents only 6.81 % of the inventors using fractional counting.

Table 2 Number of patents and inventors by inventor productivity and patent ownership

	Number of patents[a]			*Number of inventors*		
Inventor productivity	*Canadian*	*Foreign*	*Total*	*Canadian*	*Foreign*	*Total*
Sporadic (1 patent)	189 (75%)	63 (25%)	252	773 (63.78%)	439 (36.22%)	1212
Active (2-5 patents)	350 (76.25%)	109 (23.75%)	459	381 (61.95%)	234 (38.05%)	615
Outstanding (6-14 patents)	137 (65.24%)	73 (34.76%)	210	44 (43.56%)	57 (56.44%)	101
Prolific (15+ patents)	127 (24.33%)	395 (75.67%)	522	10 (25%)	30 (75%)	40
Total	803 (55.65%)	640 (44.35%)	1443	1208 (61.38%)	760 (38.62%)	1968

[a] The highest inventor productivity of the inventors that have contributed to a patent is associated to the patent

Table 3 Number of patents and inventors by patent strength and patent ownership

	Number of patents			*Number of inventors*[a]		
Patent strength	*Canadian*	*Foreign*	*Total*	*Canadian*	*Foreign*	*Total*
Weak (0-15 claims)	333 (74%)	117 (26%)	450	363 (68.62%)	166 (31.38%)	529
Average (16-35 claims)	368 (49.4%)	377 (50.6%)	745	605 (64.78%)	329 (35.22%)	934
Strong (36+ claims)	102 (41.13%)	146 (58.87%)	248	240 (47.52%)	265 (52.48%)	505
Total	803 (55.65%)	640 (44.35%)	1443	1208 (61.38%)	760 (38.62%)	1968

[a] The highest patent strength of the patents to which an inventor has contributed is associated to the inventor

Appendix

Assignees with at least 10 nanotechnology patents

Organization name	*No of patents*	*Avg claims*	*Avg inventors*	*Cluster*	*Country*	*Org. type*
Xerox Corporation	444	29.8	3.9	-	US	firm
National Research Council Canada	57	21.3	3.0	Ottawa	CA	inst
Northern Telecom Limited	42	21.6	2.5	Montreal	CA	firm
McGill University	32	14.8	3.1	Montreal	CA	univ
Hydro-Quebec (public corporation)	31	27.4	4.0	Montreal	CA	firm
D-Wave Systems Inc.	29	29.8	3.3	Vancouver	CA	firm
University of British Columbia	26	17.9	2.8	Vancouver	CA	univ
Adherex Technologies Inc.	20	11.2	3.2	Ottawa	CA	firm
Centre National de la Recherche Scientifique	19	34.3	3.9	-	FR	inst
University of Calgary	18	11.9	2.6	Calgary	CA	univ
Hospital for Sick Children	16	18.6	3.9	Toronto	CA	hosp
Westaim Technologies. Inc.	16	21.9	3.5	Edmonton	CA	firm
Connaught Laboratories. Inc.	14	9.4	3.6	-	US	firm
University of Toronto	14	20.8	2.8	Toronto	CA	univ
Université de Montreal	14	17.7	2.7	Montreal	CA	univ
Zenon Environmental Inc.	12	16.8	2.9	Toronto	CA	firm
University of Alberta	12	14.8	2.8	Edmonton	CA	univ
Angiotech Pharmaceuticals Inc.	11	22.6	2.2	Vancouver	CA	firm
Queen‟s University	10	20.4	3.7	Kingston	CA	univ
Alberta Research Council	10	28.5	2.3	Edmonton	CA	inst
Her Majesty the Queen in the right of Canada	10	11.5	2.9	Ottawa	CA	inst