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IMPACT OF LOCAL COLLABORATION ON FIRMS' INNOVATION PERFORMANCE

by

Pierre Therrien[1]

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(Innovation Policy Branch, Industry Canada)

Abstract

Using the Survey of Innovation 1999 for Canada, we analyze the impact of being involved in collaboration agreements on the probability of launching a world class innovation. To do so, we estimate a probit model discriminating between innovators and non-innovators followed by a multinomial ordered probit model assessing the effect of different factors such as collaboration, size, and other activities linked to innovation, on the probability of being a world-first innovator. We find that being involved in collaboration agreements increases the probability of being a world-first innovator by 5.8 percentage points, which make collaboration as one of the most important factors leading to a breakthrough innovation. We also investigate the impact of different types of collaboration on firms' innovation performance and find that local collaboration (defined as partners located under 100 km) has also a positive impact on the probability of being a world-first innovator, but its effect does not outweigh the impact of other types of collaboration.

Keywords: Collaboration, Local collaboration, Innovation performance, Technological infrastructure.

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Introduction

Competition has intensified over the last few decades with both the growing openness of the global economy, as well as the reduced time-to-market demanded by new and increasingly complex technologies. Producing, or at least adopting innovation, is now recognised as crucial for firms to remain at the forefront. As competition now arises from foreign as well as domestic sources, firms must keep abreast of new technologies available worldwide.

While the demand for speed increases, this new generation of technologies, which fuse recent advances from formerly distinct fields into new ones, such as mechatronics and photonics, have made the development of novel ideas more and more complex. This shift from a single to a multi-disciplinary approach to the creation and application of knowledge has made it much more difficult for a single company to cover all disciplines, as in the past, and vertical disintegration has been observed (Wintjes, 2000).

As a result, firms-- even large ones-- have become more specialised in their core competencies and consequently have had to outsource or cooperate with others in order to acquire complementary knowledge and technologies. Technological cooperation allows firms to access new knowledge, markets, as well as to share costs and risks (OECDa, 2000). Two distinct types of collaboration are emerging-- international and local collaborative agreements-- both with different intentions and results.

The first, at the international level, is spurred on by the proliferation of faster/cheaper transportation and communication systems. Global communication networks and markets enable a firm to source information efficiently from a distance. For example, in 1995, Texas Instruments' high-speed telecommunications chip was created through an international effort. It was conceived by engineers from Ericsson Telephone Co. in Sweden, designed in Nice with software tools developed by the company in Houston. The chip was then rolled off production lines in Japan and Dallas, tested in Taiwan, and wired into Ericsson line-cards that monitor phone systems in Sweden, the U.S., Mexico, and Australia. (Quah, 1995).

The second type, local collaboration, is driven by a growing awareness of the benefits from tacit knowledge and exchange of ideas which are promoted through face-to-face contact and being closely located to one another. To flourish, local collaboration in innovation needs strong local knowledge infrastructures -- such as universities, research centres, and geographically concentrated interdependent firms.

This paper will investigate the impact of collaboration on the innovative performance of firms in Canadian manufacturing industries. Moreover, this paper will distinguish between different aspects of collaboration, based on whether the participation is local or not, and will examine the potentially different impacts of this on firms' innovative performance. An attempt to assess the impact of technological infrastructures on firms' innovative performance will also be made. A literature survey will be presented in the second section while data and the econometric method will be presented in the third and fourth part of the paper. Results will follow and finally, the last section will draw conclusions about findings described in the previous section.

Literature Survey

Collaborative effort

Several reasons for firms to participate in collaborative efforts for innovation emerge from the literature review. The most frequently mentioned benefit from collaboration is the mutual exchange of ideas and thoughts which lead to novel ideas and discoveries. Studies from Sweden (Melin, 2000, Okubo, 2000) show that collaborations lead to work of higher scientific quality, and that interactions among reseachers tend to open up new ways of thinking and bring about new ideas. They also point out that firms can continue to specialize in specific areas knowing that other competencies which they lack, are readily available when needed.

The last point, which describes the merging of outside competencies with the firm's own ability, has gained in importance in the last few years as a factor in explaining innovative performance. In a literature review, the OECD concluded that collaboration is now becoming an essential part of innovation activities because of the increasing complexity of technologies and the need for speed to market, which make it impossible for a single firm to master all the specific fields required to innovate (OECDa, 2000). Leiponen(Leiponen, 2000) points out that nowadays, performing R&D alone is not sufficient for making profitable innovations. But by joining their own R&D capabilities with those of other firms, an improved innovative performance can be achieved. Firms which possess strong internal capacities have been observed to outpace other firms (in terms of innovative and financial performance) when they collaborate with other firms. A strong innovative capacity can be developed through seeking and identifying complementarities between employees' skills , internal R&D investment, as well as other essential innovation activities such as training, acquisition of machinery and equipment, tooling up, etc. Therefore, the choices made on how innovation activities are organized, in order to appropriate the most benefit, may strongly influence the success or failure of the firm's innovative performance[2].

The main reason firms choose to be involved in cooperative arrangements is to capture "missing" knowledge that is embodied in other workers, firms, or organizations. Drastic improvements in telecommunications tools have facilitated information flows, and nowadays, a firm can choose their best partner, regardless of the distance separating them.

However, if the information shared cannot be easily transferable or codified, distance will matter because the flow of ideas and transmission of tacit knowledge between different groups tend to decrease as the geographical distance between them increases. Evidence of this behaviour is seen in results from a study by the Conference Board of Canada which show that collaboration with public organizations, such as universities and government labs, tends to decrease as distance increases. However, this trend is not perceived when firms collaborate with other private firms such as competitors or clients (The Conference Board, 2000).

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2 A previous study on Canadian firms show that firms will improve their probability to innovate if they are engaged in several activities linked to innovation such as R&D; training; acquisition of machinery and equipment; cooperation and tooling up (Therrien, 2001). For more references on complementarity, see for instance, Athey and Stern (1998) or Topkis (1998).

These findings are in line with the assumption that transmission of tacit knowledge (which is ubiquitous in institutions such as universities and government laboratories) decreases with distance. Nauwelaers and Wintjes (2000) remarks that "knowledge differs from innovation. For instance, distance does not seem to be a barrier to the transmission of information, but in the transmission of knowledge, it does". Unlike information, which is highly codified and easily acquired, tacit knowledge is highly disembodied, informal and needs "constant effort" to acquire[3]. Baptista and Swann (1998) expand this argument where he writes:

> *"So long as much technological knowledge has a tacit nature and cannot be codified through plans, instructions or scientific articles, it seems reasonable to expect a greater concentration of innovators. This type of knowledge can only be learned through everyday practice and use of a technology and its transmission relies for the most part, on informal personal contact.".*

Geographical proximity matters to knowledge spillovers and the exchange of ideas and tacit visions, leading to coordinated investment decisions which provide a strong knowledge base for that particular region. Local collaboration, such as a formal type of network, is only a part of the transfer of information and knowledge generated by a close proximity of inter-related firms and organizations. Firms can also benefit by locating near other firms and organizations directly related to the knowledge-based economy even without formal collaborative agreements.

Concentration of innovators and technological infrastructure

[3] Information and knowledge are two distinct concepts and the difference is well documented. See for instance Dosi (1996) or Lavoie-Roy (1998).

Contrary to the simplistic view of a linear model where the origin of the innovation can always be traced back to basic research which drives scientific discoveries to product development, a more complex and dynamic model has been emerging. Kline and Rosenberg (1986) introduced the "chain-linked" model in which research, product testing and development, market research are all interdependent and where dynamic feed-back between all actors across various stages takes place in the innovation process. According to this model, innovation may be initiated, by any actors at any stage, and tends to be circular rather than sequential.

The "chain-linked" model not only recognizes the importance of a firm's R&D capabilities, but also stresses the importance of other sources of knowledge in the innovation process. Four sources have been identified by Feldman (1994): University research, industrial R&D presence, related industry presence and business services. University research produces basic knowledge which can then be developed and refined through both industrial research and expertise gained from the experiences (manufacturing or product use - learning by doing) of related industries. Business services provide the financial and commercial knowledge[4]. Together, these resources and the interactions they generate, constitute a technological infrastructure supporting innovative activity.

4 One must not underestimate the role played by business services. In a note comparing Silicon Valley with Cambridge, UK, an emerging high-technology innovation economy, Martin Kenney remarks that, it is the lack of a business sector preventing Cambridge from becoming the Silicon Valley of Europe. Kenney mentions that what makes Silicon Valley so unique is the massive presence of specialized organizations which assist in the establishment of new firms and attracting resources (human and financial) to accelerate their growth.

Because of the cumulative nature of the knowledge required to innovate, and the way it is possible to accumulate this knowledge (along the "chain-link" model), innovation activities tend to be geographically concentrated. As stated by Arthur (1990) "an area with specialized resources for innovative activity has a comparative advantage, and, since knowledge is cumulative, this advantage is self-reinforced and lead to a geographical concentration of innovative activity". Therefore, cumulativeness of innovation is also highly relevant in geographical pattern of innovative activities and performance.

Local collaboration can be viewed as a formal attempt to take advantage of the technological infrastructure of a region. As previously stated, technological infrastructure takes its roots with university research and a strong industrial R&D presence. Cooperating with universities and other inter-related firms with strong knowledge ability is certainly an important tool for innovation.

As stated before, local collaboration is not the only channel to appropriate the knowledge generated by technological infrastructure. Seminars, professional conferences, chamber of commerce meetings can also be important sources of knowledge emanating from a strong knowledge community. However, it is difficult to distill the real effect of local collaboration from the more general effect of being located near an area with strong technological infrastructures.

Literature also identifies problems associated with collaborative arrangements. For example, "Group Think" could slow down the rate of innovation as closely related firms start to share a uniform approach to innovation and competition. Group-think tends to reinforce old behaviours, suppress new ideas and create rigidities which may prevent improvements. Truly radical innovation may be discouraged under these conditions (Strategic Policy, 1999). Another problem connected with collaboration is that under some conditions, there may be opportunities and incentives for free riders (information asymmetry involved with any type of knowledge-sharing), or for one party to extract more or even expropriate all of the gain (Nooteboom, 1999). In a similar manner, the concentration of firms in one location may have the effect of rendering human resources scarce and "bid up" their costs. There may also be other costs associated with the increased congestion created within a growing cluster which may have a negative effect on innovation (Porter, 1998).

Data and econometric methods used to assess the impact of different types of collaboration on firm's innovative performance will be presented in the next two sections.

Data[5]

This study uses data from the 1999 Survey of Innovation. The sample constitutes approximately 6000 provincial-enterprises from 31 manufacturing industries. The questionnaire was designed to identify innovative firms from the 1997-999 period as well as to analyse the innovation process itself. Respondents were asked to define the novelty of their most important innovation as: (a) new to the firm only, (b)

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5 The target population of this survey is a provincial-enterprise with gross business income of at least $250,000 and more than 19 employees. However, due to a lack of reconciliation between Statistics Canada databases, some firms with less than 19 employees were included in the sample. These firms have been removed from the whole sample. A "provincial enterprise" consists of all establishments of a given enterprise in the same industry within a province. For the remaining analysis, provincial-enterprise and firm will refer to the same concept.

Canada-first or (c) world-first innovation, as well as identify the percentage of sales derived from their new or significantly improved products.

The use of direct innovation measures such as the importance of innovation or the percentage of increased sales from innovation presents some advantages over indirect measures such as R&D expenditures or patents. As it is now well recognized that R&D expenditure is not the sole channel to innovation, using this measure alone would draw an incomplete picture of the innovation activities in the economy. In a similar manner, the propensity of patenting varies across industries (which may denote different technological opportunities among industries as well as different strategies used to protect the intellectual properties) and, therefore, data on patents covers only a portion of innovative activities in the economy.

However, measures used in this survey to identify innovators and the importance of innovations are subject to the subjective biases of CEOs[6]. A counter-examination would be useful to validate if the new or significantly improved product/process reported is technically an innovation or not. Moreover, depending of the size of the firm, the perception of an innovation's importance can be biased (larger firms are expected to devote more resources for strategic intelligence[7] than smaller firms and, therefore will be more informed

6 See "Why do the surveys of innovation and R&D diverge?" in Innovation Analysis Bulletin – Vol.2, no3, Statistics Canada, September 2000.

7 Strategic intelligence is a service which allows managers to be kept informed of what competitors or other organizations are doing related to your industrial sector. For more information on Strategic intelligence, see for instance http://www.glsreseaux.com/EN/Veille.html or http://www.fuld.com/.

on the true importance of their own innovation). However, tests for the reliability of the variable related to the novelty of the innovation revealed that no specific bias should be expected[8].

Innovative firms were asked if they were actively involved in collaboration/co-operation agreements with other firms – such as suppliers, customers, and competitors – or public sector organizations – such as universities and provincial or federal labs – to develop new or significantly improved products/processes. Moreover, each collaborative firm was asked whether their collaborators are located in Canada, the United State, Europe or the Pacific Rim. It should be noted that sub-questions regarding the location of collaborators are problematic when the firm has more than one Canadian location. For single location firms, Canadian collaboration has been broken down into three distinct locations --collaborators within 100 km; in the rest of the firm's province; in the rest of Canada. Local collaboration is defined as collaboration with another firm/organization located within 100 km from the firm. However, this break-down of Canadian collaboration was not possible for multi-location firms.

Therefore, for this study, the complete sub-sample of innovative firms is first used to assess the impact of collaboration (as a whole) on performance. Second, we will remove the sub-sample of multi-location-

8 The correlation between the importance of innovation and the time lapse to the introduction of the innovation from idea to the market are significant and strong. Both variables could face the same bias (as it is measured by the same person --the CEO) but the time lapse to the introduction of the innovation is less likely to be subject to CEOs perceptions.

collaborative firms to estimate the specific effect of local collaboration on the innovative firm's performance[9].

Each manufacturing firm was assigned to a specific region and industry. In the end, there were 31 industries (using the NAICS-1997 classification) in five regions –Atlantic, Québec, Ontario, Prairies and British Columbia. The size of the firm, defined by employment, is also available. See Table A1 (appendix) for more details regarding the industrial sectors and regions studied in this paper.

Econometric approach

In this paper, the effects of being involved in local collaboration on the performance of the innovative firms involved were analysed for the period between 1997 and 1999. Performance can be defined in several ways. One can define it as innovativeness or the number of innovations that a particular firm brings to the market; the increase in sales that resulted from the innovation; the importance of the innovation; or other direct and indirect impacts (such as increased productivity, profitability, increased international market share, etc) of innovation[10].

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9 We must eliminate these cooperative multi-location firms because questions regarding local collaboration were less relevant (for these firms, there are several local areas) and therefore they can not answer that particular question. However, tests have been done to assess the impact of removing these observations from the original sample and the results on collaboration (as a whole) remain unchanged. For more details, see the results section of the paper.

10 It is important to note that each variable measures a different aspect of the firm's performance. An imitation (first in the firm) can be financially more profitable (by increasing sales) than a world-first innovation.

Using the 1999 Survey of Innovation, the dependent variables defined above are measured by categories. Novelty of innovation, for instance, has been defined as "First in the firm", "Canada-first", or "World-first" innovation. The share in sales of new or improved products has been categorized as "1 to 5%", "1 to 5%", "5 to 25%", "26 to 50%", "51 to 75%", and "76 to 100%"[11].

Working with such discrete (or categorized) dependent variables require a specific econometric method. The appropriate technique is to use either the ordered logit or probit model depending on the assumption about the distribution of the error term[12].

Moreover, as noted in the section describing the database, only innovative firms (or at least, firms which tried to innovate) answered questions regarding the importance of innovation, and sales resulting from innovation and collaboration. To obtain unbiased estimates, the two stage estimator method designed by Heckman was used (see Greene, 1997, Chapter 20). In the first stage, a probit regression was estimated to obtain the probability of being innovative, the inverse Mills-ratio was computed and inserted into the regression on the importance of innovation (second stage). The inverse Mills-ratio takes into account that we analyse only a non-random sub-sample (of innovators) of the whole population.

11 In this paper, only novelty of innovation will be analysed.

12 Usually, results from these two models are nearly identical. Change occurs only if there is an important proportion of observation at the tails of the distribution.

The two equations are, therefore:

(1) $$\textbf{innov*} = \Psi' W + \mu \ ,$$

innov =1 if innov*>0 which imply that $\mu > -\Psi' W$

=0 otherwise

Where **innov*** is a latent variable for the observed variable **innov**, W is a set of explanatory variables, and the error term $\mu \sim N(0, \sigma u^2)$.

(2) $$\textbf{incidence\_inn} = \beta' X + \varepsilon$$

Where **incidence_inn** is observed only if **innov**=1, X is a set of explanatory variables, and the error term ε is normally distributed with zero mean and variance σe^2 . Both μ and ε follow a bivariate normal distribution with zero means, variance of 1 and correlation ρ. Correction for the bias generated is obtained by computing the inverse Mills ratio from eq (1) and inserting it into eq (2).

Equation (2) becomes:

(2') $$\textbf{incidence\_inn} = \beta' X + \beta_\lambda ' \lambda (\Psi' W) + v$$

where $\lambda(\ )$ is the inverse Mills ratio computed from eq (1) and β_λ estimates ρ which is the correlation between μ and ε.

Explanatory variables for the model are:

Industrial sectors:

The technological environment influences a firm's innovation performance. Even though the capability to transform technological opportunities into successful innovations is intrinsic to the firm, it is well understood that each firm in a specific industry faces a similar environment in terms of opportunity and appropriability, degree of cumulativeness and type of knowledge required to sucessfully run a business. However, because this technological environment varies across industries, effects on the innovation performance of firms will vary across industries.

Provinces:

Ideally, the impact of technological infrastructures on firms innovative performances would be measured by an index using the four aforementioned sources of knowledge – university research, industrial R&D presence, related industry presence and business service. However, in practise, technological infrastructure could be proxied by the specific location of the firm. To do so, a more precise location of the firm (than the province) would have been preferred. However, the province to which the firm belongs can still be valuable in understanding the innovative process and the influence of location on the innovative performance of firms. In other words, a firm might innovate more by being in a particular region because of the specific infrastructures found there.

Size of the firm:

Attempts to innovate are not costless. Results from the 1999 Survey of innovation show that the two major impediments to innovation are the high cost of developing innovation and the inability to devote enough staff to new product or process development projects because of current production demands (Statistics Canada, 2001). This in combination with the observation that larger firms can more easily fund research (with larger financial and human capacities) indicates that size matters in innovation.

Innovation activities:

Combining several innovation activities would increase the firm's innovation performance if those activities were complementary. Firms that are able to combine these activities optimally (innovation management, R&D, training, acquisition of machinery and equipment, collaboration with private or public partners, use of government support programs) are expected to outperform their counterparts in the industry.

Collaboration for innovation:

Collaboration can be viewed as another innovation activity. Because of the increasing complexity of technologies and the need for speed to market, it is becoming an essential part of the firm's strategy for innovation and, therefore, will be studied separately from other innovation activities.

The basic models (in two steps) to be estimated are, therefore:

Step 1- Probit on innovation[13]

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13 Choice of regressors used in the first probit equation (being innovators or not) come from the results from a previous paper by one of the authors (Therrien, 2001). The regressors were a combinaison of industry and regional dummies, use of government programs, size of the firm and some qualitative variables regarding the

$$\text{Innovation} = \alpha_0 + \sum_j \alpha_j \text{Ind}_j + \sum_m \alpha_m \text{Region}_m + \pi_S(\text{Succes\_ factors}) + \pi_e(Environment) + \pi_g \text{Gvt\_inn} + \mu$$

Step 2 - Ordored probit on incidence of innovation:

$$\textbf{Novelty\_inn} = \beta_0 + \beta_1\textbf{Coll} + \beta_2\textbf{Act\_inn} + \beta_3\textbf{Gvt\_ inn} + \sum_j \delta_j \textbf{Ind}_j + \sum_m \delta_m \textbf{Province}_m + \beta_\lambda \lambda + v$$

where *Innovation* is whether or not the firm introduced a new or improved product/process, *Novelty_inn* represents the most important firm's innovation. *Novelty_inn* can take three values; world-first, Canada-first or First-in-the-firm. *Coll* is a dummy indicating whether or not a firm is engaged in collaboration, *Gvt_inn* represents government support programs used by a firm and*Act_inn* represents a set of variables related to activities linked to innovation. Succes_factors and *Environment* refer respectively to a set of selected firms' success factors and selected variables indicating the competitive environment faced by a firm *Province* will proxy technological infrastructures. λ is the inverse Mills-ratio computed from the first step regression and, finally, μ and ν are the error terms.

Variables qualifying the collaboration – such as local collaboration (a dummy indicating whether or not a firm is engaged in collaboration with partners within 100 km) and other types of collaboration (collaboration

perception of the managers on competitive environment and firm success factors. Results from regressions using the correction for selection bias are very similar of those without correction.

which is not local) will be added to the model to test if the impact of collaboration is the same whether it is local or not.

Results

Table 1 shows that more than 80% of firms introduced, in their firm, a new or improved product/process. By looking at the regional distribution of innovators, we can see that the percentage of innovative firms in each province (or region) is close to the Canadian average. Ontario and Québec are slightly over the Canadian average with 83%. The Prairies and British Columbia are the least innovative provinces but three-quarters of firms in these provinces are still innovative.

In examining the entire sample, the medium-tech sector[14] is the largest industrial sector with more than 50% of all observations. It is followed by the low-tech sector with more than 40% and finally, the hi-tech sector which account for less than 4% of the whole sample. The hi-tech sector in Canada is growing but is still a small part of the entire Canadian economy[15]. As expected, firms from the hi-tech sector are more likely to be innovative as reflected by the frequency of innovative firms in this group (90%), which is well over the Canadian average.

The proportion of small firms ($20 \leq$ employees ≤ 49) which have introduced a new or improved product or process is slightly under the overall average with 75% of innovative firms, while the proportion of medium-size firms ($50 \leq$ employees ≤ 249) that bring an innovation in the market is approximately the same (82%)

14 Aggregation of industries into low, medium and hi-tech sectors follows the OECD`s taxonomy and is based on the intensity of R&D (Hatzichronoglou,1997).

15 See Lavoie-Therrien (1999). The employment in hi-tech industries grows steadily but still remains the smallest group in manufacturing.

as the overall average. Finally, larger firms (employees≥250) are the most innovative with 88% of firms counted as innovative.

Table 1 also shows some selected variables reflecting the perceptions of CEOs (such as firm success factors and competitive environment factors) as well as the firm's behaviours (use of government support programs for innovation). Out of the 16 factors which potentially improve or explain a firm's success, only two factors were retained, performing R&D within the firm, and developing new products or processes. These two factors have already been identified as the most important factors for distinguishing innovative firms from non-innovative ones[16]. Table 1 shows that for innovative firms, performing R&D within the firm and developing new products and processes are by far more important to firm success than for non-innovative firms. In the same manner, using CEO perceptions about the competitive environment, the only significant factor that emerged in distinguishing an innovator from a non-innovator is the recognition that production technology changes rapidly.

Table 2 shows descriptive statistics qualifying the novelty of innovations brought into the market. 14% of firms introduced a new or improved product/process that was a world-first, while 24% of innovative firms introduced a Canada-first innovation (which was not a world-first innovation), and finally, 61% introduced a new product/process into their firms that was not new to the market[17].

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16 See Therrien (2001) for more details. In the questionnaire, firm success factors were split into three categories: market and products (such as seeking new markets), human resources (hiring experienced workers) and other factors (which include performing R&D and developing new products and processes).

17 One may note that all innovative firms did not answer the question regarding the novelty of their innovation. Some firms did not answer while other firms gave ambiguous answers (for example, some did not know

Disaggregating innovative firms by the novelty of the innovation shows more internal variance between all variables (such as size, provinces, etc) than comparing innovative (as a whole) and non-innovative firms. Firms from the Atlantic region and British Columbia have less world-first innovators than the Canadian average, while Ontario and the Prairies are above the Canadian average (14%). Similarily, small firms (low-tech firms) tend to be under the Canadian average while larger firms (hi-tech firms) are far over the Canadian average of world-first innovators. These results may indicate that being located in Ontario (and/or representing a large firm and/or a hi-tech industry) increases the probability of being a world-first innovator; but for now, it is too early to draw such a conclusion. These assumptions will be tested later using a structural econometric model.

In examining activities to innovate, a clear pattern arises where the use of government support programs to innovate as well as other specific activities linked to innovation such as: be engaged in R&D; industrial engineering; tooling-up; or training linked to the introduction of a new product-process, are more often cited by world-first innovators than for other innovators. However, although this channel is used frequently by world-first innovators, the acquisition of machinery and equipment is not an activity which can be used to distinguish world-first innovators from other types of innovators. It is also worthwhile mentioning that almost all world-first innovators (95%) are engaged in R&D activities.

how to rank their most important innovation). Therefore, our sub-sample of innovative firms is restricted to firms which described their most important innovation and gave unambiguous answers regarding the novelty of their innovation. However, tests showed that using the assumption that firms which gave ambiguous answers would be considered as First-Firm innovator, would give similar results.

Summing up these activities shows that, on average, world-first innovators are engaged in more activities (4.33) than first-in-the-firm innovators (3.72). This result gives some positive arguments for the assumption that complementarity of activities linked to innovation leads to better innovative performance. Finally, world-first innovators are more often involved in collaborative arrangements than other types of innovators.

These results suggest that world-first innovators share some particular characteristics. Therefore, it will be possible to draw a profile and identify best practices followed by these firms and, more precisely, the impact of being engaged in collaboration on firm innovative performance. The next section will turn to examining results from the more structured model described in the previous section.

Collaboration and technological infrastructures

The first part of table 3 presents estimates from the first stage Probit on innovation. Being located in Québec or Ontario increases the probability of innovating (with the Atlantic region as a baseline). Technological infrastructures in these two provinces can make diffusion of technology more effective as shown in the previous result. This finding is in line with the distribution of research chairs and other federal and provincial programs designed to improve diffusion and creation of innovation within Canada (such as Networks of Centres of Excellence program as well as public laboratories). Québec and Ontario (primarily Montreal and Toronto) receive the lion's share of these programs[18].

[18] It should be noted that Québec and Ontario represent the most populous provinces in Canada. Nevertheless, the percentage of research chairs from 2000 to 2005 is projected to approximate 66% for Québec and Ontario together while the joint population of these two provinces in 2000 is 62%. Source: Industry Canada (Knowledge Infrastructure Directorate) and Statistics Canada, CANSIM, matrices 6367 à 6378 and 6408-6409.

The size of firm matters, given that medium-sized firms as well as larger firms are more likely to innovate (with firms having 20 to 49 employees as the baseline). As expected, selected variables reflecting the perception of the CEO are all positive and significant, showing that CEOs who agree with these statements are also more likely to be innovative. Finally, firms which use government support programs to innovate are also more likely to be innovative.

Surprisingly, being a hi-tech firm does not have a significant effect on the probability of being an innovative firm (using the low-tech sector as the baseline). One should note that, by definition, a firm does not have to introduce a new or improved product and/or process into the market to be considered innovative but must only introduce it into the firm[19]. This definition encompasses the adopter of technology as well as the creator of technology. Fortunately, the questionnaire distinguishes adopters from creators of technology by distinguishing world-first innovators (creator) from firm-innovators (adopter). Analysis by the importance of innovation will follow.

Using the information gathered by the first Probit on innovation and correcting the bias generated by the use of a non random sub-sample, it is now possible to interpret results from the (second stage) ordered probit on the importance of innovation (see table 3)[20]. The model predicts that probabilities of being

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19 One should note that the definition used (the Oslo definition) is the internationally accepted definition of innovation developed by the OECD (see OECDb, 1997)

20 There is a proportional test related to the ordered probit about the assumption of constancy of effects across categories (testing whether the coefficients remains the same if the novelty of innovation moves from first-firm to Canada-first and from Canada-first to World-first). The proportional test is rejected but if the model is recomputed using a dependent variable as world-first versus all other innovators, results remain comparable.

world-first and Canada-first innovators are respectively 12% and 25.5%. These results are in line with the actual frequency using the whole sample (14% and 25% respectively for world-first and Canada-first) which validates the model used.

As expected, firms which belong to medium and hi-tech industrial sectors as well as larger firms are more likely to produce world-first innovations. These results are not surprising given that, in the hi-tech sector for instance, opportunities to make a breakthrough innovation are more prevalent than in low-tech industries. Moreover these firms, by definition, rely more on advances in technology for success and are driven almost exclusively by constant technological change.

Regarding the size of the firm, the literature points out that the emergence of Information Technologies (IT) has reduced the cost of codifying and diffusing information, and as a result, has lowered cost barrriers to innovate (OECDc (2000)). Moreover, complexity of technology would favour highly specialized firms which can move quickly to new technologies. These new opportunities should leave more room for small firms to innovate. However, results from Table 4 show that smaller firms have yet to benefit from these new opportunities as they are still less likely (regardless of industrial sector) to introduce breakthrough innovations.

Estimates for Québec and Ontario are no longer significant, leading to the conclusion that even though these provinces have been successful in providing a good environment for diffusion of technology, they have not been successful in providing an environment for breakthrough innovations. The Prairies constitute a puzzling case because even though they represent the least innovative region (see Table1), firms in the prairies are more likely to introduce a world-first innovation than the other provinces. The previous result indicates that firms and organizations in the prairies have been successful in building up technological infrastructures leading to few but important innovations. However, one should be aware that using provinces or regions as a proxy for assessing the impact of technological infrastructure remains quite hazardous. Provinces remain only a crude estimator as smaller geographical areas of study are preferable to determine the impact of proximity on innovative performance of firms but, at the time of the analysis, more disaggregated measures were not available.

Estimates of activities linked to innovation reveal, again, a clear pattern where the use of innovative tools will positively affect the probability of becoming a world-first innovator. Using government support programs are helpful in introducing world-first innovations. In the same manner, increasing the number of activities linked to innovation (such as performing R&D, acquiring Machinery and equipment, training, etc) will increase the probability of being a world-first innovator.

Finally, being involved in collaborative agreements has a positive effect on the probability of introducing a breakthrough innovation into the market. Calculating the marginal effect of the change in regressors shows that being involved in collaboration increases the probability of being a world-first innovator by more than 5.8 percentage points[21]. In other words, a firm would see its probability of being a world-first innovator

[21] Marginal effect is computed by difference in predicted probabilities. Predicted probabilities are computed by giving the variable of interest a value of 1 and 0 (for binomial variables) or by a change of one unit for count variables (such as the number of activities linked to innovation).

increased by 5.8 percentage points just by being engaged in collaboration (recall that the probability of being world-first innovators is about 12% with all variables at their mean values). This marginal effect is larger than other marginal changes involving variables such as using government support programs (change of 2.7 percentage points), size of the firm (respectively 2.8 and 3.3 for medium and large firms), or the number of activities linked to innovation (change of 2.4 percentage points)[22]. This result confirms that technology is becoming more and more complex and nowadays, it is unlikely that a firm, alone, can make a breakthrough innovation easily without external expertise.

Local collaboration

Disaggragating collaboration into two different parts, namely local collaboration and other type of collaboration is not a simple task. First, only firms which already designate themselves as collaborators were asked to qualify their collaborative agreements. Second, collaborative firms have been split into two different categories – firms with only one Canadian location and firms with more than one Canadian location. Only the former category answered questions about local collaboration (defined as collaboration with a partner within 100 km of the firm). One solution to assessing the impact of local collaboration on firm's innovative performance would be to limit the sample to only single-location firms which are involved in collaboration agreements. Such a sub-sample would require corrections because it would not be a random selected sub-sample of the whole population. Tests on this restricted sub-sample have been done and the result was that all regressors used were non significant. These results would tell us either that local

22 It is worth to note that to perform R&D activity (as a particular activity to innovate) increase substantially the probability of being a world-first innovator (9 percentage points) (not shown in tables). Its effect is even greater than the marginal effect of being involved in collaboration agreements.

collaboration has no marginal effect compared to the overall effect of collaboration (whether the collaboration is local, national or international) or it would also tell us that this model suffers from strong collinearity[23].

Another solution would be to use a sub-sample where the collaborative firms with more than one Canadian location firms would be removed. Such a sub-sample would regroup single-location firms (which the information about local collaboration is available) and all other non-collaborative firms. The model described in Table 3 has been re-computed using the latter sub-sample and results show (see Table A2 in appendix) that the effect of each variable remains unchanged (signs of all variables remains the same and all variables which were significants remain statistical significants)[24]. This result is comforting enough to continue investigation about the effect of local collaboration on firm's innovative performance (see Table A3 in appendix for descriptive statistics by different types of collaboration using the sub-sample of single-location firms and other non-collaborative firms).

Estimates from Table 4 using the sub-sample of single location firms and non-cooperative but innovative firms are very similar to those from Table 3. Collaboration has been spit into two components – local collaboration and other types of collaboration (excluding local collaboration). Both variables are

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23 Collinearity occurs when two or more variables have the same behaviour which turn out that there is no room for variation and, therefore, leads to estimating problems.

24 Computing the marginal effect of each regressors reveal only minor change except for the variable "collaboration" which effect decrease significantly. This was expected since removing all cooperative firms with more than one Canadian location decrease significantly the frequency of collaborative firms in the sub-sample while means for all other variables remains practically unchanged.

statistically significant and positive implying that local collaboration (as well as other collaboration) affect positively the probability of being world-first innovators. Calculating marginal effects show that being involved in local collaboration increases the probability of being a world-first innovator by 4.5 percentage points while the marginal effect of other collaboration increases probability by 3.9 percentage points. For comparison, using government support programs increases probability of introducing world-first innovation by only 2.9 percentage points.

Marginal effects for local collaboration and other types of collaboration are very similar. Each one contributes to increase the probability of being a world-first innovator by almost the same extent. Local collaboration, per se, does not seem to leverage a higher amount of knowledge in bringing breakthrough innovation to the market (at least not a significantly higher effect than collaboration as a whole). Therefore, for Canadian firms, being involved in local collaboration does have a positive and significant effect on the probability of being a world-first innovator, but its effect does not outweigh the impact of collaboration as a whole.

Conclusion

This paper has sought to determine the effect of the new innovative paradigm where collaboration as well as proximity are now seen as primordial to the innovative performance. Using data from the 1999 Survey of Innovation on Canadian manufacturing firms, we found that collaboration is very important in the introduction of breakthrough innovations. Being involved in collaboration has a larger effect on the probability of being a world-first innovator than other factors, such as the size of the firm. This result supports the conclusion that due to the increasing complexity of technology, a firm standing alone cannot easily introduce world-first innovations without external expertise.

The importance of geographical proximity was analysed under two different but linked aspects – local collaboration and technological infrastructures. Local collaboration has been examined and the results show that local collaboration does have an impact on the probability of being a world-first innovator, but it seems that there is no additional impact of collaboration based on whether collaboration is local or not. An attempt to assess the impact of technological infrastructures on the firms' innovative performance has been done, but the sample design placed additional constraints and a much larger geographical area was used than previously desired. However, results show that Québec and Ontario have been successful in providing a flourishing environment that promote the diffusion of technology, but they have not been as successful in providing technological infrastructures for breakthrough innovation.

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Table 1 Descriptive data for selected variables —Innovators and non-innovators

Variables	Status of the firm		All firms	
	Innovators	Non-innovators	(percentage)	(n)
	(80.7%)	(19.3%)		
Province				
Atlantic	77%	23%	100%	451
Quebec	83%	17%	100%	3125
Ontario	83%	17%	100%	2931
Prairies	74%	26%	100%	1106
British Columbia	74%	26%	100%	896
Industry				
Low-tech industries	79%	21%	100%	3670
Med-tech industries	82%	18%	100%	4552
Hi-tech industries	90%	10%	100%	287
Size of the firm				
20≤ employees ≤49	75%	25%	100%	2598
50≤employees ≤249	82%	18%	100%	4738
employees ≥250	88%	12%	100%	1173
Activity related to inn.				
Use of Gvt. Pgm.	59%	32%	54%	4558
Selected Firm Success Factor				
Firm Success-RD	59%	24%	52%	4464
Firm Success-Developing new pdt	72%	33%	65%	5500
Selected Competitive environment factor				
Production technology change rapidly	43%	23%	39%	3330
TOTAL (weighted)	6866	1643		8509

Source: Author's tabulation from 1999 Survey of Innovation, Statistics Canada.

Table 2 Descriptive data for selected variables —by novelty of innovation

Variables	Importance of innovation			All innovative firms*	
	World-First	Canada-First	First-Firm	(percentage)	(n)
Province					
Atlantic	12%	21%	67%	100%	256
Quebec	13%	23%	64%	100%	1772
Ontario	16%	27%	57%	100%	1962
Prairies	16%	24%	60%	100%	583
British Colombia	12%	21%	67%	100%	485
Industry					
Low-tech industries	9%	22%	69%	100%	2063
Med-tech industries	18%	26%	56%	100%	2819
Hi-tech industries	27%	27%	46%	100%	177
Size of the firm					
$20 \leq employ \leq 49$	10%	20%	70%	100%	1325
$50 \leq employ \leq 249$	15%	24%	61%	100%	2930
$employ \geq 250$	19%	34%	47%	100%	803
Activities related to innov.					
Use of Gvt. Pgm.	77%	69%	55%	62%	3127
Collaboration	54%	41%	29%	36%	1804
Local Collaboration	16%	12%	9%	11%	556
RD activities	96%	89%	73%	80%	4062
M&E activities	88%	90%	88%	88%	4461
Engineering act.	83%	80%	59%	68%	3424
Tooling-up act.	79%	81%	70%	74%	3740
Training act.	87%	89%	82%	84%	4270
Number of innovative activities	4.33	4.28	3.72		3.95
TOTAL	727	1241	3090		5058

Note: * This is a sub-sample of innovative firms which gave unambiguous answer regarding the importance of innovation

Source: Author's tabulation from 1999 Survey of Innovation, Statistics Canada.

Table 3- Probit Model -- Using Collaboration (as a whole)

Variables	Probit on innovation		Ordered probit on importance of innovation	
	Coefficient	S.E.	Coefficient	S.E.
Intercept	-0.231 **	(0.08)	-1.879 **	-0.13
Region				
Quebec	0.136 *	(0.08)	-0.037	-0.09
Ontario	0.203 **	(0.08)	0.12	-0.09
Prairies	-0.071	(0.08)	0.226 **	-0.1
British Colombia	-0.014	(0.09)	0.067	-0.1
Industries				
Med-Tech	0.090 **	(0.04)	0.288 **	-0.04
Hi-Tech	0.136	(0.11)	0.299 **	-0.1
Size of the firm				
50≤employ≤249	0.108 **	(0.04)	0.128 **	(0.04)
employ≥250	0.217 **	(0.06)	0.258 **	(0.06)
Competitive environment				
Production technologies change rapidly	0.402 **	(0.04)	—	
Success factors				
Performing R&D	0.373 **	(0.04)	—	
Developing new product-process	0.681 **	(0.04)	—	
Activities related to innovation				
Use of Gvt. Pgm.	0.406 **	(0.04)	0.136 **	(0.04)
Nb-activities to innovate	—		0.115 **	-0.02
Collaboration	—		0.279 **	(0.04)
Inverse Mill ratio	—		-1.055 **	-0.11
Prob(Y=World-First)	—		**0.12**	
Prob(Y=Canada-First)	—		**0.255**	
-2 log L	-3476.75		-4345.506	
Nb. Obs. (weighted)	8508		5058	

Note: ** means significant at 5%, * means significant at 10%

Table 4- Probit Model -Distinghishing Local collaboration and Other type of collaboration

	Ordered probit on importance of innovation		
	Coefficient		**S.E.**
Intercept	-1.996	**	-0.14
Region			
Quebec	0.013		(0.10)
Ontario	0.195	*	-0.11
Prairies	0.297	**	(0.11)
British Colombia	0.187		(0.11)
Industries			
Med-Tech	0.329	**	(0.04)
Hi-Tech	0.322	**	(0.12)
Size of the firm			
50≤employ≤249	0.169	**	(0.05)
employ≥250	0.263	**	(0.07)
Activities related to innovation			
Use of Gvt. Pgm.	0.166	**	(0.05)
Nb-activities to innovate	0.106	**	-0.02
Collaboration			
Local collaboration	0.225	**	-0.06
Other type of collab.	0.174	**	(0.06)
Inverse Mill ratio	-1.045	**	-0.12
Prob(Y=World-First)	**0.103**		
Prob(Y=Canada-First)	**0.242**		
-2 log L	-3487.411		
Nb. Obs. (weighted)	4224		

Note:First stage probit on innovation has been done. Results are similar as in the Table3.

APPENDIX

Table A1 Region and industry definitions

	Definition	
Regions		
Atlantic	Provinces of Newfoundland, IPE, Nova Scotia and New Brunswick	
Quebec	Province of Quebec	
Ontario	Province of Ontario	
Prairies	Provinces of Manitoba, Saskatchewan and Alberta	
British Colombia	Province of British Colombia	
Industry	**NAICS**	**Definition**
Low-tech industries	311	Food
	312	Beverages and tobacco
	313	Textiles
	314	Textiles product mills
	315	Clothing
	316	Leather and allied products
	321	Wood product manuf.
	322	Paper
	323	Printing
	337	Furniture and related products
Med-tech industries	324	Petroleum and coal products
	325	Chemical (except Pharmaceutical & Medicine)
	326	Plastic and rubber
	327	Non-metallic mineral product
	332	Fabricated metal product
	333	Machinery
	3345	Navigation, measuring, medical equipment
	3346	Magnetic & optical equipment
	335	Electrical equipment, appliance & components
	336	Transportation (except Aerospace)
	339	Miscellaneous manufactures
Hi-tech industries	3254	Pharmaceutical & medicine manufactures
	334	Electronics
	3364	Aerospace product manufacture

Source: Industry Canada from 1999 Survey of Innovation, Statistics Canada.

Table A2- Probit Model (using sub-sample of single-location firms)

	Ordered probit on importance of innovation	
	Coefficient	**S.E.**
Intercept	-1.997 **	(0.13)
Region		
Quebec	0.014	(0.10)
Ontario	0.197 *	-0.11
Prairies	0.298 **	(0.11)
British Colombia	0.189	(0.11)
Industries		
Med-Tech	0.329 **	(0.04)
Hi-Tech	0.326 **	(0.12)
Size of the firm		
50≤employ≤249	0.17 **	(0.05)
employ ≥250	0.261 **	(0.07)
Activities related to innovation		
Use of Gvt. Pgm.	0.166 **	(0.05)
Nb-activities to innovate	0.106 **	-0.02
Collaboration		
COLL$_i$	0.203 **	(0.05)
Inverse Mill ratio	-1.048 **	-0.12
Prob(Y=World-First)	**0.103**	
Prob(Y=Canada-First)	**0.243**	
-2 log L	-3487.635	
Nb. Obs. (weighted)	4224	

Note:First stage probit on innovation has been done. Results are similar as in the Table3.

Table A3 Descriptive data by different types of collaboration

	Type of collaboration			Innovative-Firm	
	Local	**Other type**	**No collab.**	**(percentage)**	**(n)**
	(13.2%)	(9.7%)	(77.1%)	(100%)	
Province					
Atlantic	10%	12%	78%	100%	208
Quebec	13%	9%	78%	100%	1584
Ontario	14%	11%	76%	100%	1538
Prairies	9%	7%	84%	100%	485
British Colombia	18%	11%	72%	100%	410
Industry					
Low-tech industries	10%	8%	82%	100%	1763
Med-tech industries	14%	11%	74%	100%	2345
Hi-tech industries	31%	12%	57%	100%	115
size of the firm					
20≤employ≤49	13%	10%	77%	100%	1146
50≤employ≤249	13%	8%	79%	100%	2511
employ ≥250	13%	16%	71%	100%	566
Activities related to inn.					
Use of Gvt. Pgm.	76%	76%	56%	60%	2545
Collaboration	100%	100%	0%	23%	969
Local Collaboration	100%	0%	0%	13%	557
RD activities	90%	87%	75%	78%	3306
M&E activities	90%	89%	87%	88%	3704
Engineering act.	76%	79%	62%	65%	2761
Tooling-up act.	77%	80%	71%	72%	3057
Training act.	87%	87%	82%	83%	3499
Number of innovative activities	4.21	4.21	3.76	3.87	
TOTAL (weighted)	557	412	3255		4224

Source: Author's tabulation from 1999 Survey of Innovation, Statistics Canada

Sub-sample of single-location firms and non-collaborative firms