Industry–University Collaboration by Canadian Manufacturing Firms*

Petr Hanel[1]
Marc St-Pierre[2]

ABSTRACT. We analyze the collaboration between manufacturing firms and universities in Canada. The data comes from the Statistics Canada Survey of Innovation, 1999. After a survey of the literature we present a statistical description of collaborating firms, their reasons for collaboration and the impact of collaboration on their performance. The econometric analysis estimates the probability that a firm collaborates with universities. The results suggest that collaboration with universities is frequent in knowledge based industries. Research undertaken in partnerships complements, rather than replaces, R&D by collaborating firms. Collaboration improves the performance of innovating firms.

Keywords: University-Industry collaboration, R & D, innovation, motivation, impacts, Canadian universities

JEL Classifications: O31, O32, L60, I29

1. Introduction

The creation, exploitation, and transfer of knowledge are playing an increasingly important role in modern economies. Surveys have shown that there are multiple sources of innovation both within and outside of firms. Collaboration between users and creators of knowledge within a society is one of the main sources of ideas and technologies feeding the innovative process.

In the course of the past 20 years, collaboration between universities and the private sector has become more and more commonplace. Canada's industry–university collaboration (IUC) is ranking in the first place among G7 countries (Industry Canada, 1999). According to the Conference Board (Warda, 1995)[1] Canadian universities have been, since 1971, the second largest spender on R&D behind industry. However, despite a steady increase in real university R&D spending, its share of total R&D spending has decreased since 1971. To help funding their research Universities are increasingly collaborating with industry. Universities signed 5081 research contracts in 1997–1998, averaging 57,000 dollars in value (Warda, 1999).

In summary, the number of partnership agreements between universities and industrial firms has been increasing and more funds are being funneled from industry to universities. In Canada, governments and universities themselves still provide the majority of funds for university research, but the contribution of the private sector has nearly doubled since 1980. In 1997, 11.8% of the funds allocated to university research came from the private sector, compared to 6.3% in 1980 (OCDE, 1998). The support of university research by the private sector in Canada is the strongest among G7 countries (Industry Canada, 1999).

This article looks at the collaboration between manufacturing firms and universities in Canada. Following a brief selective overview of the empirical research, we will present results of the Statistics Canada Survey of Innovation, 1999 that are related to IUC. Using descriptive statistics and econometric methods to estimate a discreet choice model, we set out a twofold objective: first, to draw a realistic and somewhat partial picture of collaborating firms and, second, to evaluate the effect of collaboration activities on the quality and the impact of innovations produced by these firms.

The principal results suggest that partnerships with universities are occurring mainly with firms belonging to knowledge based technology sectors.

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[1]*Université de Sherbrooke and Centre interuniversitaire de la recherche sur la science et la technologie (CIRST), Département d'économique, Faculté d'administration, Sherbrooke, QC., JIK2R1, Canada*
E-mail: Petr.Hanel@USherbrooke.ca
[2]*Brown University, Department of Economics, Waterman Street, Providence, RI 02912, USA*
E-mail: marc_St-Pierre@brown.edu

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We also found that research activities undertaken in partnership with a university complement, rather than replace, R&D undertaken by the private sector firms. Collaboration increases the probability of using patents, while the reverse is not the case. Lastly, our study suggests that collaboration has a positive impact on the originality of innovation as well as on performance indicators of Canadian firms.

2. Lessons from the empirical literature

In advanced industrial economies the knowledge has replaced exploitation of natural resources and labor-intensive industries as the primary source of economic growth. Universities thus play a major social and economic role (Feller, 1990). Cohen *et al*. (1998) recognize that University is primarily motivated by the need to find funding (see also OCDE, 1998), for pursuing its objectives of increasing excellence, prestige and reputation in creation and diffusion of knowledge. In contrast, firms are mainly approaching Universities in their quest for knowledge and expertise. The type of partnership and interactions between industry and universities depends on the contribution and motivation of both parties and can be cast in the principal-agent framework (Poyago-Theotoky *et al*., 2002). Since writing a formal contract for the collaboration projects may be difficult, the academic party often participates in the project as a shareholder, a co-proprietor of a new company or as a recipient of license royalties (Jensen and Thursby, 2001). The IUC is transforming the traditional role of Universities. In addition to pursuing the academic excellence, universities are increasingly getting involved in research and other activities in order to increase their revenues from public and private sources and so are researchers. Friedman and Silberman (2003) show that universities that share the royalties with researchers–inventors succeed better in technology transfer and receive higher royalties than those that do not.

Motivations

Several authors studied the motivations of each party's willingness to establish a partnership (Lee, 2000; OCDE, 1998; Zaky and El-Faham, 1998). According to Lee, the primary motive for collaboration for industrial firms is access to new knowledge (76%) instrumental for innovation (61%). What motivates most university researchers to collaborate with the industry is obtaining funds for equipment and research assistants (69.4%), the opportunity to start their research project (68.5%), the possibility to test practical applications of their theories (64.7%), and the opportunity to obtain funds for their own research (61.1%).[2] According to Lee, firms do not always obtain what they want in a collaboration effort. Nevertheless, 94% of the universities and 91% of the companies surveyed agreed that university–industry collaboration should either grow or at least maintain its present level.

Characteristics of the protagonists

Mansfield and Lee (1996) estimated that the probability for a business to accept financing research and development activities in a university is negatively related to the distance between the two parties. Quality is also an issue since, at any given distance, the probability for a business to invest in R&D activities in a university increases with the quality of the department involved. Berman (1990) found that the level of private funding in universities is positively related to the scope of research undertaken at the university. According to Beise and Stahl (1999), German universities prefer collaborating with large firms because of their better financing capacity and the scientific orientation of their research. However, distance has no impact on the probability of university–industry collaboration in Germany. In Canada, large firms are also more inclined, compared to small firms, to get involved in partnerships with universities (Baldwin and Hanel, 2003; Warda, 1995). According to Warda (1999) and Baldwin and Hanel (2003) foreign owned firms collaborated with Canadian universities at least as often as with the locally owned firms.[3] Also, firms facing external competition are more likely to collaborate with universities compared to firms facing only local competition. According to Berman (1990) and Beise and Stahl (1999), collaboration with universities is a stimulus for future R&D spending within collaborating firms. In order to benefit from any technological externality, firms must build an absorption capacity within their own R&D to be able to incorporate this external knowledge in their innovation process (Cohen and Levinthal, 1989). Far from being a substitute, access to university R&D is complementary to firm's own R&D.

Several studies suggest that presence of a university is associated with increased R&D spending by neighboring private firms Jaffe (1989); Anselin *et al.* (1997). The positive externality from university presence appears to be limited to sectors where the knowledge is difficult to codify. Anselin *et al.* (2000), found that no externality effect of university research was felt in the areas of chemicals, pharmaceuticals, and machinery (industries where new technology is easily codified), while a highly significant effect was found in the areas of electronics and instrumentation relying more on tacit knowledge. The tendency of firms to collaborate more frequently with universities in their regions (states or metropolitan areas) is also apparent in patent statistics (Jaffe *et al.*, 1993). According to the studies mentioned above, university research is of a "partially" public nature, at least in the short term, since externalities of university research are geographically clustered (e.g. Silicon Valley in California or Waterloo region in Ontario) and therefore not accessible to all.

Impacts of collaboration

Mansfield (1991, 1992) estimated that the social return on university research investment during the 1975–1978 period was about 28–40%. Link and Rees (1990) corroborated this result. They calculated a rate of return of 34.5% for private firms who maintained links with universities and of 13.2% for those who did not during the same period.

In his 1991 study, Mansfield estimated that without the input of university research of the 15 previous years 10% of innovations would not have been developed during the 1975–1985 period at all or would have been introduced much later. A German study using Mansfield's approach concluded that in the 1993–1996 period, 40% of German firms[4] produced an innovation that could not have been developed without the support of recent university research (Beise and Stahl, 1999). Collaboration with universities is also crucial for the most original innovations. In Statistics Canada's 1993 Survey of Innovation and Advanced Technology, collaboration with universities is cited as the second most important external source of technologies[5] used in the introduction of world first innovations (Baldwin and Hanel, 2003, p. 207).

The principal hypotheses emanating from the overview of empirical studies of the collaboration of industrial firms with universities are presented in Table I.

3. Empirical analysis

The data for the study presented here comes from a representative sample of 5 944 manufacturing "provincial enterprises" included in Statistics Canada Survey of Innovation, 1999.[6] The questionnaire included a question regarding the firm's participation in cooperative or collaborative arrangements with other firms or organizations (including specifically universities) to develop new or significantly improved products or manufacturing processes during the previous 3 years under study (1997–1999). Our present analysis of the Canadian firms who collaborated with at least one university during the period 1997–1999 is restricted to innovators as defined in the Oslo manual.[7]

Importance and motivations

Firms collaborate with several partners. In total, 33% of innovators engaged in at least one collaboration agreement during the 1997–1999 period. Among those, collaboration is mostly frequent with trading partners such as vendors (71.4%) or clients (64.9%) and the collaboration with universities comes in the fifth place (23.7%). Our observations suggest that there are three motives[8] that statistically differentiate IUC from other type of collaboration. First, firms collaborating with universities mention more often (67.6%) the access to R&D as an incentive to collaborate than firms collaborating with other partners (50.36%). Second, the access to critical knowledge is more frequently mentioned by firms collaborating with universities (61.76%), than by other collaborating firms (53.2%). Lastly, the cost sharing is less of a motivation for firms having non-university partners (39.77%) than for firms with university partner (50%).

Table I
Hypotheses to explore as suggested by the literature review

Aspect	Hypothesis
Motivation	R&D access is an incentive to collaborate for firms (Lee, 2000 (+); Zaky and El-Faham, 1998 (+))
	Recruitment of graduates student is an incentive to collaborate (Lee, 2000 (+))
	Cost sharing is an incentive to collaborate (Rahm, 1994 (+))
Size	Firm size is positively correlated with collaboration (Baldwin and Hanel, 2003 (+); Beise and Stahl, 1999 (+); Godin and Landry, 1995 (−); Warda, 1995 (+))
	Larger research units are more likely to establish contacts with industry than the smaller ones (Czarnitzki and Rammer, 2003 (+))
Competitiveness	Highly competitive environment is harmful for collaboration (Baldwin and Hanel, 2003 (+))
Industries	The firms belonging to high-tech industries collaborate more frequently (Doutriaux and Barker, 1995 (+); Godin and Landry, 1995 (+); Jaffe, 1989 (+); Mansfield, 1991 (+))
Distance	The frequency of collaboration is inversely related to physical distance between collaborators (Beise and Stahl, 1999 (−); Mansfield, 1994 (+))
R&D	Private R&D is complementary to the research available through collaboration (Beise and Stahl, 1999 (+); Berman, 1990 (+); Cohen and Levinthal, 1989 (+))
Impacts	
Originality	Collaborating firms come out with more original innovation (Baldwin and Hanel, 2003 (+))
Profitability	Innovations of collaborators are more profitable than other firm's innovation (Link and Rees, 1990 (+))
Innovation	Collaborators innovate more frequently than other firms (Beise and Stahl, 1999 (+); Mansfield, 1991 (+))

Note: The authors who tested the hypothesis are also quoted with a mention (+) if their results are in agreement with the hypothesis as quoted. Conversely, a mention (−) indicates the refutation of the hypothesis as quoted.

Industrial and technological context

The inclination to collaborate with universities and colleges is closely related to technological opportunities. Manufacturing industries are linked by a complex structure of inter-industrial transactions. Parallel to the flow of goods between the various industries, there is a flow of ideas and technical information contributing to the widespread diffusion of innovations throughout the global manufacturing industry. Using an analysis of innovations introduced in the United Kingdom during the post-war era, Robson *et al.* (1988) classified industries that are the main source of innovation as the Core sector. These industries diffuse new technologies by selling their products to two downstream sectors. The Secondary sector receives ideas and innovations from the Core sector, but it also creates new products and processes. At the end of this channel, the Other sector receives inputs, equipments and new technologies from the two upstream sectors. The Other sector, being mainly a user of innovations developed by the two upstream sectors, innovates less but must still find creative ways to adopt new technologies. Appendix 1 lists the industries surveyed and their classification.

Using this three-sectors technological classification, we notice that innovative firms of the Core sector have a stronger inclination to collaborate with universities or colleges in their innovative process (13.4%) compared to innovative firms of the Secondary sector (8.0%) and of the Other sector (5.2%). Table II details the collaboration rates by industry.

Innovation requires a set of characteristics and skills that are hard to put together for small firms. Thus, the frequency of innovation increases with the size of firms (Baldwin and Hanel, 2003; Beise and Stahl, 1999; Warda, 1995). The tendency to collaborate increases also with the size of firms. Nearly one fifth of firms employing more than 500 employees engaged in a collaboration agreement with a university or a college during the 1997–1999 period. These numbers drop to about 10% for firms with 100–499 employees, while the other firms show a collaboration rate of about 6%. The tendency of larger firms to engage in R&D activities is a key factor, as we will show in the following section.

Complementarities between R&D and collaboration

Indeed, firms who collaborate with universities distinguish themselves by engaging in systematic R&D activities.[9] We used the existence of a separate R&D department as an indicator of the level of a company's engagement in R&D. Companies doing R&D in a separate department shows a greater inclination to collaborate than those who do not, all sectors included. The complementarities between R&D and collaboration become even more obvious when comparing the Other sector with the Secondary sector, and the Secondary sector with the Core sector. In order to benefit from, and to engage in, collaboration, firms must already be involved in R&D so that they can integrate the inputs from university research.

Symptomatic of the complementarities between R&D and collaboration is the fact that geographical proximity is more important for the Core sector, where 70% of collaborating firms partnered with universities located within 100 km. This proportion is 55.6% for the Secondary sector and only 40.7% for the Other sector. It is very likely that firms of the Core sector are already located in a milieu where universities are present, so to benefit from agglomeration and technological externalities. For example, personal contacts, a form of externalities, generally facilitate the transfer of knowledge, and particularly that of tacit knowledge, which increases both the return to R&D and to IUC.

Large firms are better able to carry R&D activities than smaller ones, since they benefit from economies of scale and scope (Baldwin and Hanel, 2003; Cohen and Klepper, 1996). Proportionally, they also engage in more partnerships. However, as shown in the Figure 1, in each group size, the proportion of firms engaged in both R&D and collaboration with universities is larger than that of firms only engaged in collaboration without being involved in R&D. This suggests that the size of firm matters for IUC because of factors other than R&D alone. Some related findings show that collaborating firms put more emphasis than the non-collaborating ones on personnel training and developing their external information networks via public training support programs (36 vs. 21%), information services or Internet (24 vs. 11%) and technological assistance programs (23 vs. 8%).

Table II
Collaborative agreements during the 1997–1999 period

Manufacturing industries	Innovator firms		
	Collaboration (all partnerships)	Among them, those who collaborate with a university	Collaboration with a university as % of all innovators
	Percentage	Percentage	Percentage
Total, manufacturing industries	33.0	23.7	7.8
Food manufacturing	32.1	24.6	7.9
Beverage and tobacco product manufacturing	49.7	33.4	16.6
Textile mills	32.0	9.1	2.9
Textile product mills	36.4	10.6	3.9
Clothing manufacturing	15.9	19.5	3.1
Leather and allied product manufacturing	36.3	14.9	5.4
Sawmills and wood preservation	22.1	8.0	1.8
Veneer, plywood and engineered wood product manufacturing	40.2	31.1	12.5
Other wood product manufacturing	18.0	27.2	4.9
Paper manufacturing	39.0	28.9	11.3
Printing and related support activities	26.9	7.1	1.9
Petroleum and coal product manufacturing	34.1	35.7	12.2
Chemical manufacturing (excluding 3254)	39.3	35.6	14.0
Pharmaceutical and medicine manufacturing (3254)	61.4	45.7	28.1
Plastics and ruber products manufacturing	33.4	18.8	6.3
Non-metallic mineral products manufacturing	32.4	27.0	8.7
Primary metal manufacturing	39.0	31.8	12.4
Fabricated metal product manufacturing	30.4	20.1	6.1
Agricultural, construction and mining + industrial machinery manufacturing (3331 & 3332)	40.0	18.4	7.4
Machinery manufacturing (excluding 3331 & 3332)	38.7	18.1	7.0
Computer and peripheral equipment manufacturing	53.1	23.4	12.4
Communication equipment manufacturing	46.9	33.1	15.5
Semi-conductor and other electronic equipment manufacturing	56.5	68.3	38.6
Navigational, measuring, medical and control instruments manufacturing + manufacturing and reproducing magnetic and optical media	50.1	34.4	17.2
Electrical equipment, appliance and component manufacturing	44.1	36.7	16.2
Motor vehicle manufacturing + motor vehicle body and trailer manufacturing + motor vehicle parts manufacturing	38.0	28.8	10.9
Aerospace product and parts manufacturing	50.9	30.9	15.7
Railroad rolling stock manufacturing + ship and boat building + other transportation equipment	41.7	23.1	9.6
Furniture and related products manufacturing	20.3	10.0	2.0
Miscellaneous manufacturing	34.3	10.8	3.7

Source: Statistics Canada database, Survey on innovation 1999.

They also resort more often to R&D grants and tax credits (33 vs. 10%, and 67 vs. 38%, respectively).

Economic impacts of partnership with universities on collaborating firms

The following figure shows the proportion of firms who viewed as "significant"[10] a series of statements regarding the impact of the innovations they introduced during the period 1997–1999. Recall that the data presented in the Figure 2 is computed from the sample of Oslo innovators only. Proportionally, firms that collaborated with a university viewed most of these statements as more significant than the other firms. The largest differences between the two groups were noted in the answers to the following statements: *maintaining a competitive position, maintaining a profit margin,*

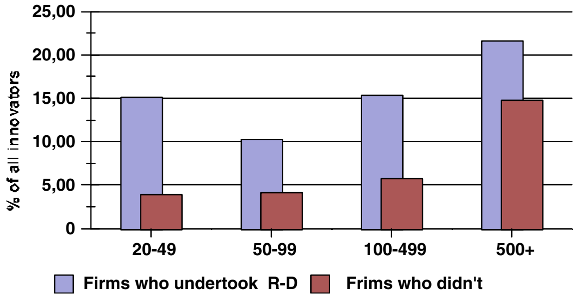

Figure 1. Collaboration with universities, R&D and Firm's employment.

increasing the international market share, increasing the domestic market share and finally, *better adaptability and increasing profitability*. Thus, firms engaged in IUC perceive a higher benefit from their innovations than their non-collaborating counterparts.

Originality

Innovating firms were also asked whether their "most important" innovation was a *world first*, a *Canadian first* or a *firm first*.[11] Firms collaborating with universities make up a group whose innovations are more original than those of other innovators.[12] For example, nearly 22% of collaborating companies introduced a *world first* as opposed to 10% for other innovators and half the collaborating firms introduced a *Canadian first*

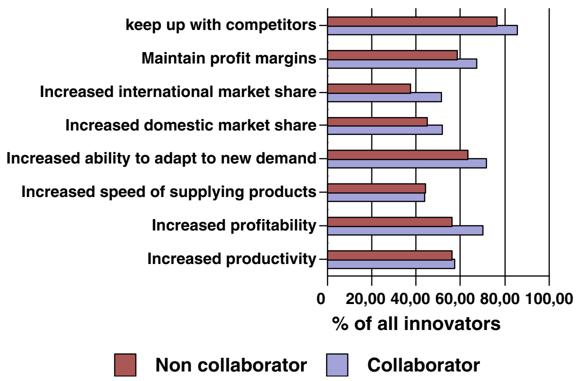

Figure 2. Impact of university collaboration on economic performance.

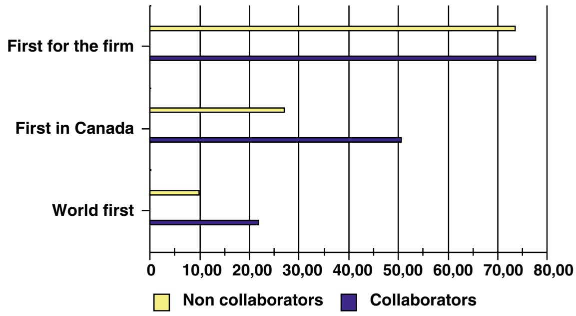

Figure 3. Originality of the most important innovation. *Recall that the abcisse should interpreted as the percentage of firms, among the considered subset of Oslo innovators, that reported their most important innovation to be one of the three, non-exclusive, listed quality: World first, First in Canada and first for the firm.

innovation while only a quarter of the other firms did. Although it is impossible to determine whether the more original innovation capacity is due to collaboration, the data does not reject that view.

We can conclude that the most profitable innovations introduced by firms who collaborated with university partners led to a superior economic performance compared to non-collaborating firms. Also, collaborating firms produced the most significant and original innovations (Figure 3).

4. Econometric approach

In this section we use econometric modeling to overcome the problem of determining the combined effects of several variables.

Collaboration

We assume that the firms collaborate with an aim of making a profit. We suppose that a firm i anticipates a *net expected return* r_i from collaboration that depends on a list of N exogenous variables, $x_i = [x_{i1},\ldots,x_{iN}]$, which is referred to as the *firm's i characteristics*. We will also assume that the firm's characteristics affect the net return to collaboration in a simple way, that is,

$$r_i = b'x_i + u_i \tag{1}$$

where $b = [b_1,\ldots,b_n]$ is a vector of coefficients associated with the exogenous variables and u_i is a random term independent of these characteristics and that has zero expectation, i.e. $E[u_i|\ x_i]=0$. Unfortunately, the net expected return r_i, is not known to us (i.e. it is latent). To circumvent this problem we define a new variable c_i, which we assume to take two possible values depending on the value of r_i, as follows:

$c_i = 1 \Leftrightarrow r_i \geq 0 \Leftrightarrow$ The firm$i$ collaborated

$c_i = 0 \Leftrightarrow r_i < 0 \Leftrightarrow$ The Firm$i$ did not collaborate

Since we can observe whether firm i collaborated, that is, if $c_i=0$ or $c_i=1$, then we can assess the impact of the exogenous factors x_i, not on its expected return r_i as in the Equation (1), but on the probability that the firm i collaborates. That is, the cost of not observing the expected net return r_i is that we can only assess the impact of the exogenous factors on the probability that the firm i collaborate, $P(c_i=1|\ x_i)=F(cx_i)$ where F is the *cumulative density function* (CDF) of u_i. In order to keep the model tractable, it is assumed that u_i follows a logistic distribution, the so-called Logit model.

Exogenous variables

The list of exogenous factors or firm's characteristic that we include in the specification is presented in the Table III. The table is self-explanatory but the reader might want to refer to the following additional information while reading it.

R&D

The reader might be concerned that these measures of R&D might be biased toward some firms (large). We considered other definitions of R&D. However, it is not clear which definition was the least biased. For example, we could consider that a firm did R&D based on whether it had answered in the affirmative to whether it had undertaken R&D activities during the period 1997–1999. However, this definition could make the definition of R&D too broad. We refer the reader to a short discussion of this issue in St-Pierre (2003).

Strategies

The collaboration with a university is just one among the various strategies of development for a firm. For example, a strategy centered on the development of human resources can see collaboration with universities as means of recruitment of new graduates (Lee, 2000).

Objectives

Innovation may require external competencies. The variable *cost* reflects whether the "high cost elaboration of products or new or appreciably improved processes" slowed down or even caused problems during the innovation process for the period 1997–1999. It is a proxy for collaborating with an aim of reducing costs.

Information sources or spillovers from technological infrastructure

The new ideas inspiring innovation do not only come from internal sources such as R&D activity, management or sale employees. The innovation sources may be external.

Intellectual property protection (IPP)

Other results not presented here, and the review of the literature suggests, that collaborating firms use more frequently the various means of IPP.

Government programs

Because of market imperfections, the private sector invests less in innovation than what would be optimal from the point of view of the society. Available public support seeks to compensate for some of these imperfections.

Competitive context

The collaboration between firms and universities is also affected by the market structure and competition (Baldwin and Hanel, 2003). We constructed a variable *comp1*, which represents the level of uncertainty that the firms perceived vis-à-vis their competitors.

Proximity or geographical clustering effect

To measure the clustering effect we constructed the variable *ipp* to be the number of universities present in the province in which that firm is located.

Table III
Exogenous factors

Exogenous variables	Definition
Size	
Sizea, Sizeb, Sizec, Sized	Four binary variables which take value 1 when the firm considered falls in the category (a) 20 and 49 employees, (b) 50 and 99 employees, (c) 100 and 499 employees or (d) more than 500 employees and which takes the value 0 otherwise.
R&D	
Rdsep	Binary variable, rdsep = 1 if the firm considered carries out its R&D in a separate department and rdsep = 0 otherwise.
Rdcontr	Binary variable, rdcontr = 1 if the firm considered contracts R&D out to other firms and resep = 0 otherwise.
Sectors	
S_core, S_secondary, S_other	Three binary variables each of which takes value 1 when the firm considered belongs to that given sector and 0 otherwise. The list of sectors is: Core, Secondary and Other.
Strategies	
	Five binary variables, each of which takes value 1 when the firm considered the strategy in question as being an important or a very significant factor and 0 otherwise. The strategies are:
Newmt	Newmt: The search of New Market.
Expmt	Expmt: The search for Export Market.
Newstu	Newstu: The recruit of recently Graduated Students.
Skill	Skill: The recruit of Specialized Workers outside the Country.
Form	Form: The training of its Employees.
Information source	Three binary variables, each of which takes value 1 when the firm used given external information sources for its innovations. The list is
Exhi	Exhi: The firm used Information obtained at Trade Fairs and Exhibitions
Net	Net: The firm used Internet or an Information Network.
Conf	Conf: The firm obtained Information for Innovation at a Professional Conference or from a Specialized Publication.
Objectives	Three binary variables, each of which takes value 1 when the firm innovated with an aim of reaching a specific goal. The goals are
E	E: To reduce the environmental damage
Regl	Regl: To conform to any Governmental Policy
Cost	Cost: To reduce Costs. See the text.
Competition	The variable *comp1*. See the text.
IPP	Five binary variables, each of which takes value 1 when the firm used the following IPP means during the surveyed period and 0 otherwise.
Patents	Patents: The use of Patents
Tradem	Tradem: The use of Trademarks.
Secret	Secret: The use of Secret.
Copyr	Copyr: The use of Copyrights.
Confid	Confid: The use of Confidentiality Agreements.
Government programs	Six binary variables, each take the value 1 if the firm used the following government program and which takes value 0 otherwise.
Gvt_txc	Gvt_txc: Tax Credit for R&D.
Gvt_s	Gvt_s: R&D Subsidy.
Gvt_ris	Gvt_ris: Venture Capital support.
Gvt_assist	Gvt_assist: Technology support and Assistance.
Gvt_fo	Gvt_fo: Governmental support for Manpower Training.
Gvt_int	Gvt_int: The use of Government Information or Internet Services.
Proximity	The variable *ipp*. See the text.
Provinces	
Ten variables	For each province *j* and each firm *i* the provincial variable takes value 1 if firm *i* is located in the province *j* and takes value 0 otherwise.

Provincial dummies

The set of conditions—education system, fiscal and industrial policies and other governmental and para-governmental interventions, creates in Canada, a regional or provincial system of innovation. To capture this effect, we created 10 dummy variables.

5. The results

All exogenous variables from Table III were included in the estimation of Equation (1) by the logit model. It is estimated on the whole sample of Oslo innovators. The results are presented in Table IV. The estimated coefficients indicate the sign, not the magnitude, of the marginal impact of the associated variable on the probability that the firm collaborates with a university. For example, a statistically significant coefficient taking a positive value indicates a positive impact of the associated variable (or characteristic) on the probability of collaborating. For presentation purposes, we eliminated the characteristics that did not appear significant.[13] To avoid multicollinearity, the variables *s_other*, *sizea* and the binary variable for the province of Manitoba were omitted. Consequently, a firm of Manitoba of less than 50 employees and belonging to the Other sector constitutes the reference case. The model classifies correctly 82.2% of the cases and the presence heteroskedasticity seems to not significantly affect the results.[14]

All things being equal, the probability of collaborating increases with the size of the firm. This result suggests that larger firms are more likely to collaborate than the smaller ones. It may be, like Beise and Stahl (1999) claim, that the large firms have more resources and have a scientific orientation that enable them to benefit more from collaboration with the researchers from academia.

The firms which, attach an importance to R&D and which carry it out in a separate department, are more likely to collaborate with universities than those that consider R&D less vital. It is worth pointing out that the firms, which contract R&D out, are also more likely to collaborate with universities than those that do not undertake any R&D. The firms of the Core sector, more dependent on scientific progress, have a stronger probability of collaborating than those of the Other sector.

The development strategies used by a firm matters for collaboration. Firms putting the search for new markets, as measured by *newmt*, as an important strategy or success factor are more likely to collaborate than those that do not. In contrast, the search for export markets (*expmt*) decreases the probability of collaboration. This strategy can require practical knowledge of the markets and marketing, which are not the universities specialty (Mansfield, 1994).

Human resources development is clearly very important to collaboration. All three variables (*newstu*), (*skill*), (*form*) have a positive and significant impact on the probability of collaboration. A firm, which seeks to recruit new graduates (*newstu*), benefits from more intimate contacts with academia. However, the direction of causality is not clear. The recruit of new graduate students could foster collaboration at first and then, once collaboration is established between that firm and that university, further recruitment of graduate students could happen as well as new collaboration projects and so on... making the relation between recruiting of graduate students and collaboration quite complex. Thus, we only postulate a correlation between collaboration and the recruitment of graduate students. Also, the firms that rely on training of their employees (*form*), or on recruitment of skilled individual outside the country (*skill*) also show a higher compatibility with university collaboration.

The Internet became a significant tool of communication and its use by the firms can be a mean of establishing new contacts leading to new research partnerships (Grant and Scott, 1997). Indeed, our results show a positive effect of the Internet use (*net*) on the probability to collaborate. Thus, even though the use of Internet might be already quite important among innovators, it is even more for firms collaborating with universities. Also, the participation in congresses and professional meetings and the consultation of specialized publications (*conf*) increase a firm's probability of collaborating with a university. However, the direction of the causality is again not clear, especially for firms that have a culture of collaboration with universities. Finally, the firms that used information obtained at trade

Table IV
Estimation results

Exogenous variable	Collaboration model		
	Estimate	Std error	Prob
Constant	−6.7117	0.4962	0.0001
Size			
Sizec	0.2073	0.1088	0.0568
Sized	0.6300	0.1693	0.0002
R&D			
Rdsep	0.3260	0.1693	0.0002
Rdcontr	0.5448	0.1082	0.0001
Sectors			
S_Core	0.3109	0.1080	0.0040
S_second	Excluded		
Strategies			
Newmt	0.5402	0.2028	0.0077
Expmt	−0.3115	0.1086	0.0041
Newstu	0.5362	0.1039	0.0001
Skill	0.3186	0.1458	0.0288
Form	0.8255	0.4090	0.0436
Information source			
Exhi	−0.2249	0.1172	0.0550
Net	0.3391	0.1081	0.0002
Conf	0.5853	0.1150	0.0001
Objectives			
E	0.1523	0.1160	0.1892
Regl	0.0954	0.0337	0.0047
Cost	0.4401	0.1072	0.0001
Competition			
Compl	−0.2117	0.0503	< 0.0001
IPP			
Patents	0.6239	0.1134	0.0001
Tradem	−0.4113	0.1126	0.0003
Secret	0.1760	0.1061	0.0971
Copyr	0.1015	0.1332	0.4461
Confid	0.8786	0.1269	0.0001
Government programs			
Gvt_fo	0.4113	0.1062	0.0001
Gvt_txc	0.1889	0.1218	0.1208
Gvt_s	0.8486	0.1194	0.0001
Provinces			
Qc	−0.0699	0.1301	0.5910
Ont	−0.2955	0.1287	0.0217
Pei	0.4269	0.5537	0.4407
ipp	Excluded		
Number of observations	4244		
−2Log L	2989.59		
% Correctly classified	82.2%		
LR test ($b = 0$)	815.6432 (rejected)		

fairs or exhibitions are less likely to collaborate (*exhi*). This is not surprising since industrial firms use trade fairs and exhibitions more for marketing of products and services than for the display of academic research.

A more uncertain competitive environment, as measured by the variable *comp1*, decreases the probability of collaboration. That suggests a connection between the transfer of knowledge and competition. Collaboration is a rather long-term project whose riskiness is higher in more uncertain competitive context all things being equal. In turn, this would deter a risk-averse firm to engage in collaboration for a given return on the project.

The results show that the use of patents or confidentiality agreements is narrowly correlated with collaboration. However, the direction of causality is not obvious. It seems probable that the use of IPP and the decision to collaborate are neither independent between them nor independent of innovation[15].

The use of public subsidy programs in R&D is correlated positively with the probability of collaborating with a university. This is not surprising because certain programs directly aims at fostering the collaboration with a university. However, we should be aware that when a firm ask for an R&D grant and organize their research activities, including that of collaboration, according to program eligibility criteria, then the causality is reversed.

The propensity to collaborate with universities does not show strong regional differences. The only singular case are Ontario firms which have a somewhat lower probability to collaborate with universities than firms from other provinces. Moreover, we cannot find any evidence of agglomeration economies on the decision to collaborate with a university, as the variable *ipp* does not appear to be significant.

6. Conclusion

The present study is based on a representative survey of Canadian manufacturing firms over the period of 1997–1999. We turned our attention to the sub-sample of some 8% of firms that collaborated with universities and colleges in their innovating activities. The R&D being an increasingly expensive activity, the partnership with a university is often motivated by the desire to share research costs. However, the major incentive to collaborate with a university is the access to research and critical competencies, which allows firms to reach the very edge of contemporary technology. Moreover, our results show that firms in the Core sector—the most important source of innovations, technologically advanced equipment and inputs used in the technologically less progressive sectors—are intimately linked to scientific knowledge, more often commit to R&D and, consequently, are more interested in collaboration with universities than companies in the downstream sectors. To support this observation, we found that IUC with academic establishments located within 100 km of the firms are more frequent in the Core sector.

One can draw up a portrait of a "typical" firm engaged in collaboration with universities. Such a firm of rather big size and active in R&D, whose financing is supported by the public programs, is likely to be part of an industry in the Core or Secondary sectors where innovation is very significant and where the competition too uncertain. This typical firm is also likely to emphasize the development of its human resources by training activities and recruitment of university graduates, thus benefiting from privileged contacts with the academic world. Finally, it is likely to use patents and the confidentiality agreements to protect its intellectual property.[16]

Our study suggests that collaboration with universities has a positive impact on the originality of innovations and their contribution to the perceived economic performance of the innovating firm such as to maintain their competitive position, the maintain of their profit margins, the increase in their share of the international market and their increase of profitability.

Last but not least, we want to remind the reader that the questionnaire of the survey of innovation 1999 was not formulated for a specific study of industry–university collaboration. This has led us to make some restrictive assumptions. It is important to notice that IUC is a two-way relationship and that any ceteris paribus analysis type must be done carefully. Many factors are both a cause and a consequence of IUC, especially for firms that have a culture of collaboration with universities. Thus, the results must be interpreted with caution but their principal message seems clear and robust. Collaboration with universities and colleges plays a significant role in the Canadian innovation system. Given the importance of collaboration for innovation and its contribution to the growth of the economic welfare, the subject deserves further study based on data susceptible to answer questions raised in this article.

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Notes

1. See also Industry Canada, 1999.
2. The percentages represent the share of respondents that considered the given reason to be the "most significant" or "very significant".
3. According to the Survey of Innovation and Advanced Technology of 1993 (Statistics Canada, 1993, special tabulation), of all Canadian-owned firms that undertook R&D collaboration and introduced innovation, 44% had had partnerships with Canadian universities, compared to 52% among foreign-owned firms. The percentage of collaboration with American universities was 4.9% and 13.6%, respectively.
4. As a proportion of all firms having received public funding during this period.
5. Only the contribution of affiliated companies is cited more often (43%) than collaboration with colleges and universities (38%) by firms involved in R&D who produced a world-first innovation.
6. See Schaan and Nemes (2003) for details on the survey.
7. We purposely kept the unsuccessful innovators out of the sample for the following three reasons. (1) The fraction of collaboration in that group of firms was significantly distinct than the corresponding fraction in the group of Oslo innovators and (2) was not statistically different of zero at a 2.5% level. (3) The number of firm in the group of unsuccessful innovator represented 10% of the Oslo innovators.
8. The list of motivation was: Accessing new distributions channels, Accessing new markets, Accessing critical expertise, Scaling-up the production process, Prototype development, Accessing R&D, Spreading risk and Sharing costs.
9. The three R&D measurement methods (R&D, R&D tax credits and R&D done in a separate department) give very similar results (St-Pierre, 2003).
10. Respondents had to express their agreement with the statements on a scale of 1–5, 1 being strong disagreement and 5 strong agreement. We assumed that a 4 or 5 answer meant that the firm viewed a statement as significant.
11. Since about 26% of the Oslo innovators did not answer properly the question, the analysis of this section is restricted to a subset (74%) of the Oslo innovators.
12. Proportions differ significantly at the 5% threshold for the three categories: world first, Canadian first and business first.
13. The rejection of the variables was based on the chi-square test for the significance level of 10%.
14. The estimation of the variance by a robust method (White) provided an estimate of 3% higher than usual estimation method that did not change the statistical significance of the coefficients.
15. The first experiments with a simultaneous logit model which postulates interdependence of collaboration with universities and the use of intellectual property rights led us to the belief that the direction of causality between the use of patents and collaboration are not necessarily in conformity with the results of the model C-1 (St-Pierre, 2003). Baldwin and Hanel (2003) and Hanel (2003) show that the uses of the intellectual property rights and the decision regarding innovation should be treated like an interdependent phenomenon. Unless the relationship is estimated as a simultaneous equation system, the interdependence of these two variables may introduce a simultaneity bias. The interdependence between the decisions concerning collaboration, the uses of intellectual property rights and innovation becomes even more complicated and difficult to treat with the data we have.
16. St-Pierre (2003) tried to disentangle the relationship between the use of patents and collaboration with a university with the help of a simultaneous equation model. The findings were that, indeed, the collaboration causes the use of patents and not the reverse. In fact, there, it was found that the use of patents reduces the probability of collaboration. We do not present these results here but we believe that the relation between the use of intellectual property rights and the collaboration of any kind deserves a separate analysis of its own. It is worth mentioning, as a robustness check, that all of the qualitative results we found in the current paper still held under that specification.

Appendix 1
Conversion of classification NAICS into technology sectors according to Robson *et al.* (1988) taxonomy

NAICS	Description	Sector
Other		
311	Food manuf.	Other
312	Beverages and Tobacco	Other
313	Textile mills	Other
314	Textile products	Other
315	Clothing	Other
316	Leather & allied prod.	Other
3211	Sawmills and wood pres.	Other
3212	Veneer etc.	Other
3219	Other wood. Prod.	Other
322	Paper	Other
323	Printing	Other
337	Furniture	Other
339	Miscellaneous	Other
3346	Other	Other
Core		
324	Petroleum and coal prod.	Core
3251	Chemicals	Core
3252	Chemicals	Core
3253	Chemicals–paints, coating	Core
3254	Pharmaceuticals	Core
3255	Chemicals	Core
3256	Chemicals	Core
3259	Chemicals	Core
3331	Ind. machinery	Core
3332	Ind. machinery	Core
3333	Eqpmt. manufacturing	Core
3334	Eqpmt. manufacturing	Core
3339	Engines manufacturing	Core
3341	Computer and periph. eqpt.	Core
3342	Communication eqpt.	Core
3343	Audio–video eqpt.	Core
3344	Semiconductors	Core
3345	Instruments scientifiques	Core
335	Electrical eqpt.	Core
Secondary		
326	Plastics–rubber prod	Secondary
327	Non-metallic mineral products	Secondary
331	Primary metals	Secondary
332	Fabricated metals	Secondary
3335	Fabricated metal products	Secondary
3361	Motor vehicles	Secondary
3362	Motor vehicles-body & trailers	Secondary
3363	Motor vehicles-parts	Secondary
3364	Aerospace products	Secondary
3365	Railroad Eqpt.	Secondary
3366	Ship and boat building	Secondary
3369	Other transport eqpt.	Secondary

Note: Author's conversion

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