Catalogue no. 88F0006XIE — No. 002
ISSN: 1706-8967
ISBN: 0-662-43310-6

Working Paper

Science, Innovation and Electronic Information Division

Buying and Selling Research and Development Services, 1997 to 2002

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^{r} revised
x suppressed to meet the confidentiality requirements of the *Statistics Act*
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Statistics Canada
Science and Innovation Surveys Section
Science, Innovation and Electronic Information Division (SIEID)

Buying and Selling Research and Development Services, 1997 to 2002

Published by authority of the Minister responsible for Statistics Canada

May 2006

Catalogue no. 88F0006XIE, no. 002
ISSN: 1706-8967
ISBN: 0-662-43310-6

Frequency: Irregular

Ottawa

La version française de cette publication est disponible sur demande (n° 88F0006XIF au catalogue).

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The science and innovation information program

The purpose of this program is to develop **useful indicators of science and technology activity** in Canada based on a framework that ties them together into a coherent picture. To achieve the purpose, statistical indicators are being developed in five key entities:

- **Actors**: are persons and institutions engaged in S&T activities. Measures include distinguishing R&D performers, identifying universities that license their technologies, and determining the field of study of graduates.
- **Activities**: include the creation, transmission or use of S&T knowledge including research and development, innovation, and use of technologies.
- **Linkages**: are the means by which S&T knowledge is transferred among actors. Measures include the flow of graduates to industries, the licensing of a university's technology to a company, co-authorship of scientific papers, the source of ideas for innovation in industry.
- **Outcomes**: are the medium-term consequences of activities. An outcome of an innovation in a firm may be more highly skilled jobs. An outcome of a firm adopting a new technology may be a greater market share for that firm.
- **Impacts**: are the longer-term consequences of activities, linkages and outcomes. Wireless telephony is the result of many activities, linkages and outcomes. It has wide-ranging economic and social impacts such as increased connectedness.

The development of these indicators and their further elaboration is being done at Statistics Canada, in collaboration with other government departments and agencies, and a network of contractors.

Prior to the start of this work, the ongoing measurements of S&T activities were limited to the investment of money and human resources in research and development (R&D). For governments, there were also measures of related scientific activity (RSA) such as surveys and routine testing. These measures presented a limited picture of science and technology in Canada. More measures were needed to improve the picture.

Innovation makes firms competitive and we are continuing with our efforts to understand the characteristics of innovative and non-innovative firms, especially in the service sector that dominates the Canadian Economy. The capacity to innovate resides in people and measures are being developed of the characteristics of people in those industries that lead science and technology activity. In these same industries, measures are being made of the creation and the loss of jobs as part of understanding the impact of technological change.

The federal government is a principal player in science and technology in which it invests over five billion dollars each year. In the past, it has been possible to say only *how much* the federal government spends and *where* it spends it. Our report **Federal Scientific Activities, 1998 (Cat. No. 88-204)** first published socio-economic objectives indicators to show *what* the S&T money is spent on. As well as offering a basis for a public debate on the priorities of government spending, all of this information has been used to provide a context for performance reports of individual departments and agencies.

As of April 1999, the Program has been established as a part of Statistics Canada's Science, Innovation and Electronic Information Division.

The final version of the framework that guides the future elaboration of indicators was published in December, 1998 **(Science and Technology Activities and Impacts: A Framework for a Statistical Information System, Cat. No. 88-522)**. The framework has given rise to **A Five-Year Strategic Plan for the Development of an Information System for Science and Technology (Cat. No. 88-523)**.

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Buying and Selling Research and Development Services, 1997 to 2002

By

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May 2006

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1. Introduction

Research and development (R&D) is a crucial activity in the innovation process. Firms, especially those with high technological content that do not engage in this activity seriously jeopardize their competitiveness and their creativity in relation to competitors. The cost of access to R&D is a major barrier for many firms. Added to this cost constraint is the appropriation constraint, namely the inability of firms to retain all the benefits resulting from efforts invested in research. This is an additional barrier dissuading firms from performing R&D (Arrow, 1962). Lastly, to engage in R&D activities, a firm must first have sufficient absorptive capacity to recognize the value of new information, assimilate it and apply it to commercial ends (Cohen and Levinthal, 1990).

Not every firm is in a position to overcome all these constraints. For firms that decide to conduct R&D activities, there is a crucial strategic choice to be made. R&D performers must choose between engaging in an R&D partnership process[1] and conducting research intramurally. Should the firm decide to enter into a partnership, there are various ways to proceed.

As identified in the literature, there have traditionally been two different modes or strategies[2] by which a firm may perform its R&D activities. It may do so internally, or it may acquire R&D services externally, that is, from outside the R&D producing unit. Several empirical and theoretical studies have adopted these twin strategies as a conceptual framework to explain firms' strategic behaviour (Rador, 1991; Veugelers and Cassiman, 1999; Kamien and Zang, 2000; Cassiman et al. 2002; Arundel and Bordoy, 2002). Mindful of this body of literature, the present study seeks to expand the conceptual framework for the choice of modes of participation in R&D partnership that are available to firms engaged in R&D.

A practical way to determine whether or not a firm is participating in an R&D partnership is to observe the source or destination of R&D funding. According to this logic, a firm that funds its research intramurally that is, without any financial exchange with other organizations for R&D purposes may, a priori, be considered not to have a partnership agreement for R&D services. On the other hand, if a firm reports that it has another organization as a funding source or pays to finance its R&D under either a subcontracting arrangement or some form of external participation, it may, broadly speaking, be said to have a partnership. The term partnership is interpreted broadly here to include subcontracts, alliances, co-operation agreements, consortiums, equity participation, technology transfer and joint R&D agreements (Davy, 2004). Can a monetary exchange for R&D purposes reasonably be considered to exist if there is no contact or exchange of information? Partnership is not perceived exclusively in the formal sense (active and participatory exchange between two entities); it includes both formal and informal links as defined by Bönte and Keilbach (2005).

This study examines firms' organizational behaviour with respect to R&D according to how R&D services are carried out: doing R&D for oneself, doing it for others or having other organizations do it. This examination will be based on data on the sources of funds received and destination of payments made for R&D.

This concept is not entirely new, since Harrigan (1985) was already talking about technology transfer in terms of the buying or selling of services. Drawing on the same data source, Rose (1994) explored the relationships involved in R&D strategic alliances in the form of input-output tables.

1. In this article, the partnership process refers to whether an organization does or does not have financial transactions with another organization for R&D purposes.
2. The terms "mode" and "strategy" are used interchangeably here.

As Veugelers and Cassiman (1999)[3] point out, few empirical studies have been done on modes of participation in the R&D network. One reason why this field of research is underexploited, at least in the case of empirical studies, is a lack of data, especially quantitative data Narula (2001), Belderbos, and al. (2004), Hagedoorn and Kranenburg (2003), Miotti and Sachwald (2003), Bönte and Keilbach (2005). Most articles on firms' mode of participation in R&D draw on qualitative data and confine themselves to case studies. A few studies are based on quantitative data (Veugelers, 1997), but here again, they draw on small data sets. We identify the modes of performing R&D on the basis of both qualitative and quantitative information, covering all sectors of the economy on the basis of a census of all commercial enterprises performing R&D in Canada. Using this approach, we will be able to identify the institutional players with whom R&D producers have the most exchanges for R&D services.

The following sections describe different modes of participation available to firms with respect to expenditures on R&D services, followed by a rapid overview of the motives that lead firms performing R&D to co-operate with other institutions. On the basis of this contextualization, a descriptive analysis of the characteristics of the different modes of participation in the R&D partnership process is provided. A final section presents the results of econometric estimates for modelling and identifying the determinants of each of the strategy choices previously identified.

2. An extension of the choice of strategies for implementing research and development

Traditionally, the economic literature on the choice of strategies for performing R&D basically considers two alternatives: either R&D is performed in-house or it is acquired from outside; these two alternatives could also be combined. Many studies attempted to answer the question of substitutability or complementarity of internal and external R&D (Arora and Gambardella, 1990; Cohen and Levinthal, 1990; Radnor, 1991; Veugelers and Cassiman, 1999; Leiblein et al. 2002). The findings of these different studies seem to indicate that the answer to the question of best strategy is far from definitive and that the structure and characteristics of the firm are likely to play an important role in the choice of how R&D is performed.

The choice of the strategy for performing R&D is commonly described in the literature as "Make" or "Buy." However, we think that these choices are too restrictive. The R&D strategy adopted by a firm depends very broadly on the environment and on potential interactions between partners. Some firms fund R&D services, while others buy or sell those services. Therefore, to gain a good understanding of these choices, it is necessary to provide a complete picture of the options available to firms performing R&D.

Such an approach is possible only if we are able to determine more precisely who performs R&D and for whom this R&D is performed. To this end, we must identify the partners (if any) for whom the R&D service is intended and by whom it is acquired. This type of analysis can be carried out by observing flows of financial transactions for R&D purposes. If we know the source and destination of payments for R&D purposes for each firm performing R&D, we can identify the structure of the R&D partnership and define the strategy choices related to obtaining and financing knowledge.

So far, the various studies conducted on firms' decision-making choices regarding R&D expenditures have been based on qualitative criteria or a simple enumeration of firms. This study is based on the Survey of Research and Development in Canadian Industry (RDCI), conducted by the Science, Innovation and Electronic Information Division of Statistics Canada. This survey provides details on the origin and destination of industrial R&D funding by firms conducting R&D or firms that fund it. It will be described in greater detail in Section 4. At the same time, we use

3. "Technology sourcing strategies have not been well explored in the theoretical literature and the empirical evidence remains anecdotal."

these quantitative data to expand the conceptual framework for the strategy choices of firms deciding on their R&D expenditures and to measure the intensity of transfers of funds between partners for R&D purposes.

A firm engaged in R&D has a choice between various strategies. It can perform the R&D itself, in a closed environment. It may also choose to enter into relationships with outside parties. In this case, it may choose to meet its R&D needs by purchasing services from other organizations. It may also do R&D for other organizations. These three basic strategic options may be combined, or they may be reduced to mutually exclusive choices.

How a firm carries out its R&D activities has a direct impact on how it manages the R&D cost- and risk-sharing model. Policy decision-makers who must introduce new regulations and incentives regarding research must consider this matter, which is important for understanding the firm's organizational environment. The United States and Japan have precedents as to their policy choices with respect to partnership and risk sharing. The best known examples are the VLSI project[4] for Japan in 1975 and SEMATECH (consortium of manufacturers in the semiconductor sector) for the United States in 1987. As a result of these two developments, governments have been induced to relax their antitrust regulations to allow the formation of partnerships in the semiconductor field (Sakakibara, 1997). For Canada, the issue of R&D performance strategies is also important.

3. Motivations and partnerships in research and development

The motivation for firms to enter into R&D partnerships is a research topic that came into its own only in the 1990s, advanced by authors such as Mahoney, (1992), Hagedoorn (1993), Sakakibara (1997), Veugelers (1997) and Veugelers and Cassiman (1999). Partnership has become a joint and complementary way to organize research.[5] This phenomenon has gone hand-in-hand with the growing complexity of innovation processes. Most of the studies indicate that cooperation is complementary rather than a substitute to R&D.

There are many reasons why firms co-operate in R&D. These reasons may be grouped into two main categories: those related to the need to reduce the level of technology risk and those related to a lack of endowments[6] on the part of the firm, which, in order to compensate for its technological deficiencies, seeks to establish complementarities in R&D (Tether, 2002).

Many articles have emphasized the positive influence of R&D intensity as a factor favouring R&D partnership, including Fritsch and Lukas (2001) and Bayona et al. (2001). Thus, having one's own R&D department is considered a factor that reduces risk while increasing the probability of having partners (Kleinknecht and van Reijnen, 1992). Piga et al. (2003) consider the decision to enter into a partnership relationship as a choice that arises from the firm's prior choice to conduct R&D activity. Indeed, absorptive capacity depends on a previous R&D effort (Davy, 2004). In the article by Veugelers and Cassiman (1999), the motivation for partnership is essentially the perception of the level of risk and of appropriation of innovation.

Included in the second category of motivations toward partnership is the question of complementarity of resources and competencies (Aurora et Gambardella, 1990; Cohen and Levinthal, 1990; Vonortas, 1994; Belderbos et al. 2003; Miotti and Sachwald, 2003). In these models, partnership is seen as a mechanism for efficiently exploiting the partners' combined resources those individual members of the partnership lack (Hagedoorn et al. 2000). Firms enter

4. VLSI: Very large-scale integrated circuit.
5. The question as to whether partnership is a complement or a substitute to in-house R&D has also been examined in empirical studies; see Sakakibara (1997) and Belderbos et al. (2003). Most of these studies show that co-operation is complementary to R&D rather than being a substitute for it.
6. By lack of endowments, we mean deficiencies in terms of resources (specialized jobs, materials, natural resources, etc.).

into partnership to acquire complementarities to their internal resources, and these complementarities are not necessarily technological. This form of motivation is also a way to repatriate comparative advantages to the firm when the partner is a foreign firm (Miotti and Sachwald, 2003). Knowledge complementarity is considered one of the main motivations that lead Japanese firms to co-operate in R&D (Sakakibara, 1997).

However, most factors that motivate some form of partnership generally involve both the reduction of technology risk and the differential in firms' endowments. One example is the size of the firm, which, according to many studies and in accordance with Schumpeter's theory, plays a large and positive role in increasing the probability of co-operating in R&D (Sakakibara, 1997; Veugelers, 1997; Fritsch and Lukas, 2001; Bayona et al. 2001; Miotti and Sachwald, 2003).

An important finding of the study of Sakakibara (1997) is that motivations related to resource sharing (specializations) are more important than motivations related to risk sharing in R&D partnerships where the partners have more heterogeneous endowments. This finding reminds us that a firm's motivation largely depends on its environment and on differences in the abilities of the partners to conduct R&D activities.

4. Data source and limitations

Our study is based on Statistics Canada Research and Development in Canadian Industry survey which collects data on R&D performed in the business sector in Canada. The Statistics Canada database is constructed using two sources: an annual survey of major R&D performers, and administrative data.

In 1997, a new methodology was introduced for estimating R&D expenditure in the business sector in Canada. The new approach uses administrative data from the Canada Revenue Agency (CRA) instead of survey data for any firm that funds or performs less than $1 million worth of R&D. This enabled the elimination of around 8,000 survey mailouts for the 2002 survey, thus reducing the survey reporting burden, (Statistics Canada, 2004).

The survey is conducted annually and includes data for a four-year period. However, there is an eighteen-month lag between the publication of the data and the availability of the information provided by CRA. For this reason, Statistics Canada publishes revised data the following year, after receiving all the information. In the meantime, the data published for the reference year are preliminary. To avoid possible underestimation, our study period ends in 2002. The preliminary data are not used in this analysis.

The coverage of the survey is national. A questionnaire was sent to all firms performing or funding R&D valued at $1 million or more. The population of firms covered includes those that reported R&D activities in the previous survey, those that claimed tax relief for R&D work performed, those that reported receiving R&D contracts or grants, those that are reported by other firms as funding sources or as performers of R&D, and those that are identified in newspaper articles or trade journals.

The various results in this paper use data collected for the period 1997 to 2002 inclusive. We present cumulative statistics for these six years. This approach has the advantage of taking account of possible changes in the structure of the industry.

We have excluded from our study those industries that reported only capital expenditures. The effect of this exclusion is to eliminate firms that reported performing R&D but reported no employees in R&D, since they were spending only for buildings, land or equipment.

The three basic strategies identified in this document are not mutually exclusive. In this study, these strategies may be treated either in binary mode or using continuous values. In binary mode, each strategy takes the value 1 if the reporting firm checks at least one of the choices corresponding to the definitions in Appendix A. For each of these strategies, the total amount spent on R&D can be associated with it.

In Statistics Canada's industrial R&D survey, the choice of organizations with which the reporting unit has monetary transactions for R&D purposes was made according to the recommendations of the *Frascati Manual* (OECD, 2002). In this study, a partner is an entity that either provided R&D services by receiving a payment or purchased R&D services by providing funds to the reporting unit. Consequently, this study covers the following types of organizational entities: firms in the same group, that is, parent and affiliated firms; other firms; the government and its agencies; universities; private non-profit organizations; provincial research organizations; industrial research institutes or associations; hospitals, educational and foreign institutions.

A final point to be noted is that when collecting survey data, it is in practice impossible to capture accounting information that is perfectly balanced between the reporting unit that is the source of funding and the unit that reports receiving the funding. There are various reasons why this problem arises, starting with the differences in how R&D is interpreted between the respondent at the source of the payment and the recipient.

5. Descriptive analysis

The RDCI database contains data compiled over a number of years. This analysis focuses on years 1997 to 2002. The use of compiled data implies that a firm may be observed several times over the study period. It may also happen that some firms will appear only once.

Table 1 shows the number of firms for each year covered by the study. The column total represents the number of firm years, that is, the sum of the number of firms over the six years, including observations that may extend from one year to the next.

In the subsequent analysis, this concept of firm year will be applied. Thus, the number 60,577 is the number of observations compiled over the six years.

Table 1
Firms' distribution by country of control

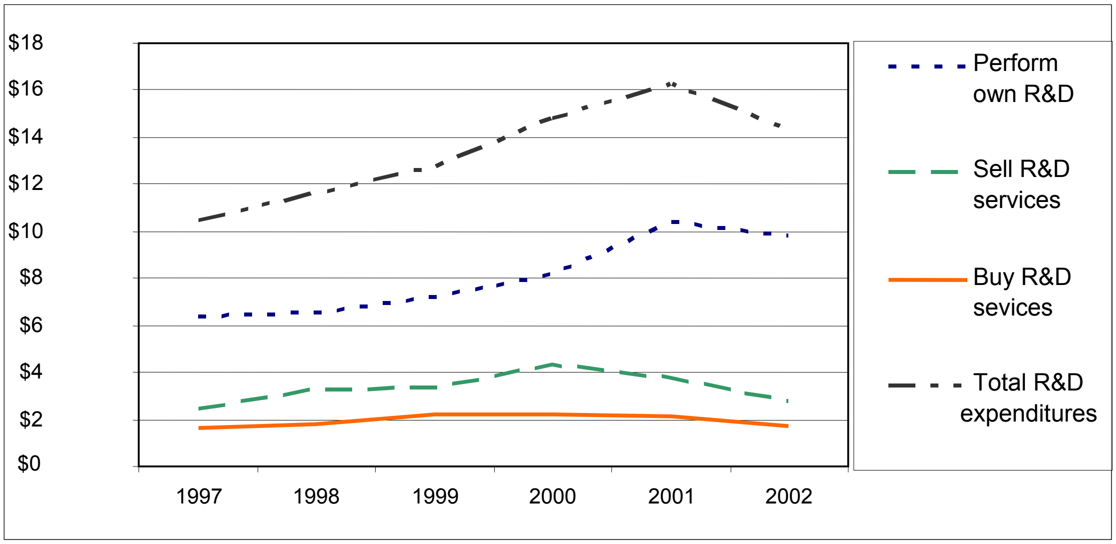
Year	Canadian controlled firms	Foreign controlled firms	Total number of firms
1997	9,109	540	9,649
1998	9,316	468	9,784
1999	9,542	425	9,967
2000	10,418	433	10,851
2001	11,001	434	11,435
2002	8,523	368	8,891
Total years' firms	**57,909**	**2,668**	**60,577**

Source: Statistics Canada, RDCI Survey

The number of firms performing R&D declined slightly between 1997 and 2002. Over the same period, the number of Canadian-controlled R&D performers grew steadily except in 2002, when there was a sharp drop in the overall number of performers. Foreign-controlled firms performing R&D accounted for 4.4% of all performers over the period as a whole.

Chart 1 gives an initial picture of how R&D expenditures evolved according to the firm's performance strategy. The "Perform own R&D" strategy is not only the most popular, but it is also the one that shows the greatest growth over the period from 1997 to 2002. It should be noted that the year 2002 marks a general slowing of industrial R&D expenditures. The “Sell R&D services” and “Buy R&D services” strategic behaviours remained very stable over time. Thus, from 1997 onward, firms performing R&D exhibited more dynamic behaviour in R&D production carried out intramurally (within the walls of the production unit). Strategies involving external partnerships, including those with subsidiaries, were much less dynamic. For these strategies involving external exchanges, the level of exchanges actually declined in absolute terms.

Figure 1
R&D expenditures by strategy for 1997 to 2002 period, (billions of dollars)



Source: Statistics Canada, RDCI survey

In 2002, total expenditures for the three R&D strategies reached more than $14 billion. Expenditures for firms doing their own R&D stood at nearly $10 billion while firms doing R&D for other organizations and those having it done by other organizations had total R&D expenditures of respectively $2.8 billion and $1.7 billion.

For information purposes, the annualized growth of expenditures for the main strategies by industry is shown in Appendix D. Some industries, such as the semi-conductor and other electronic components industry increased their expenditures for all strategies, whereas other industries, such as the non-metallic mineral products industry, reduced their R&D expenditures for all strategies.

Table 2 gives an overview of the distribution of the cumulative number of firms performing R&D over the period 1997 to 2002 according to the strategic option chosen and the country of control. As is immediately apparent, the strategy that consists of performing one’s own research is by far the strategy most often used by R&D performers, with 59,019 respondents out of a total of 60,577, or 97% of all observations.

Among those firms performing their own research, 24,590 or nearly 43% of the total of Canadian-controlled firms reported “Performing own R&D” as their only performance strategy. The corresponding proportion for foreign-controlled firms is 35%. In dollar terms, R&D done in-house accounts for almost $49 billion over the period 1997-2002, representing 62% of all R&D transaction amounts (see Table 4).[7]

7. R&D performed by firms that do it exclusively for themselves accounts for 13.6% of the total amount of R&D transactions.

Table 2
Total years' firms by type of strategy and country of control, for the period 1997 to 2002

Strategies	Canadian controlled firms		Foreign controlled firms		Total years' firms	
Perform own R&D	56,540	(97.6)	2,479	(92.9)	**59,019**	**(97.4)**
Sell R&D services	5,089	(8.8)	596	(22.3)	**5,685**	**(9.4)**
Buy R&D services	31,299	(54.0)	1,532	(57.4)	**32,831**	**(54.2)**
Perform own R&D exclusively	24,590	(42.5)	926	(34.7)	**25,516**	**(42.1)**
Sell R&D services exclusively	634	(1.1)	91	(3.4)	**725**	**(1.2)**
Do R&D for affiliated firms	1,627	(2.8)	441	(16.5)	**2,068**	**(3.4)**
Total years' firms		**57,909**		**2,668**		**60,577**

Brackets indicates the number (in percentage) of total years' firms by column
Source: Statistics Canada, RDCI Survey

Doing R&D in-house is thus the most common strategy. The amounts spent on external strategies doing R&D for others or having it done by others account for respectively 24% and 14% of all transaction amounts for R&D purposes. Canadian firms essentially do R&D themselves, do it for others or finally have it done by others.

There are a number of factors that lead firms to fund their R&D internally only, but among the factors most commonly cited in the economic literature is information asymmetry. Information asymmetry implies that one of the co-operating parties holds more information not shared with its partner. Information asymmetry can undermine bonds of confidence between partners, and this can eventually create an obstacle to external partnering. Also, the uncertain nature of R&D and the tacit knowledge that is important in this activity can often cause firms not to share their knowledge with other organizations.

As a result, a large proportion of firms fund their R&D internally only. This finding is consistent with the results of the study by Tether (2002), in which 46% of firms in the United Kingdom have no partners. Our findings also point in the same direction as those reported in Piga and Vivarelli (2003), in which 53% of firms do R&D intramurally only. By contrast, in the study by Veugelers and Cassiman (1999), only 17% of innovators opted for the "Perform own R&D" strategy, but that study is based on data from an innovation survey rather than a survey designed to measure R&D expenditures directly. The study by Kaiser (2002) also found that only 13.6% of firms co-operated for R&D purposes in Germany. Among firms engaging in an R&D partnership, most participated in a vertical association (relationship with customers and suppliers), rather than in a horizontal association (relationship with competitors). The study by Kaiser (2002) concentrates on the service sector only, in which R&D activity is known to be much more diversified and observed only 165 firms co-operating in R&D, which limits the robustness of the results.

The "Buy R&D services" strategy is chosen by 54% of performers. It is interesting to note that in relative terms, this strategy is at least as important for foreign-controlled firms as for firms under Canadian control. More important yet in relative terms for foreign-controlled firms is the "Sell R&D services" strategy, which is chosen by 22% of all foreign-controlled performers, compared to 9% of Canadian performers. However, if these same proportions are compared in terms of the amounts spent (see Table 4), it emerges that foreign- and Canadian-controlled firms spend similar proportions, that is, approximately 23% and 25% respectively.

It is recognized in industry organizational theory that businesses' strategic behaviours are not homogenous according to the size. Table 3 illustrate that most R&D firms (76%) have less than 50 employees.

Businesses with more than 500 employees represent less than 4% of all R&D performers. Nevertheless, whatever performing strategy used, these firms account for 63% of R&D expenditures over 1997 to 2002, more than $49 billion (table 4).

For very large firms, over 2000 employees, the share of outward strategies increase significantly. The "Perform own R&D" strategy remains relatively constant whatever the size. This suggests that the use of outward strategies requires a substantial level of resources, at the level available in large firms. A large absorptive capacity together with a high R&D intensity is required to increase the likelihood of engaging in partnerships, (Leiponen, 2001).

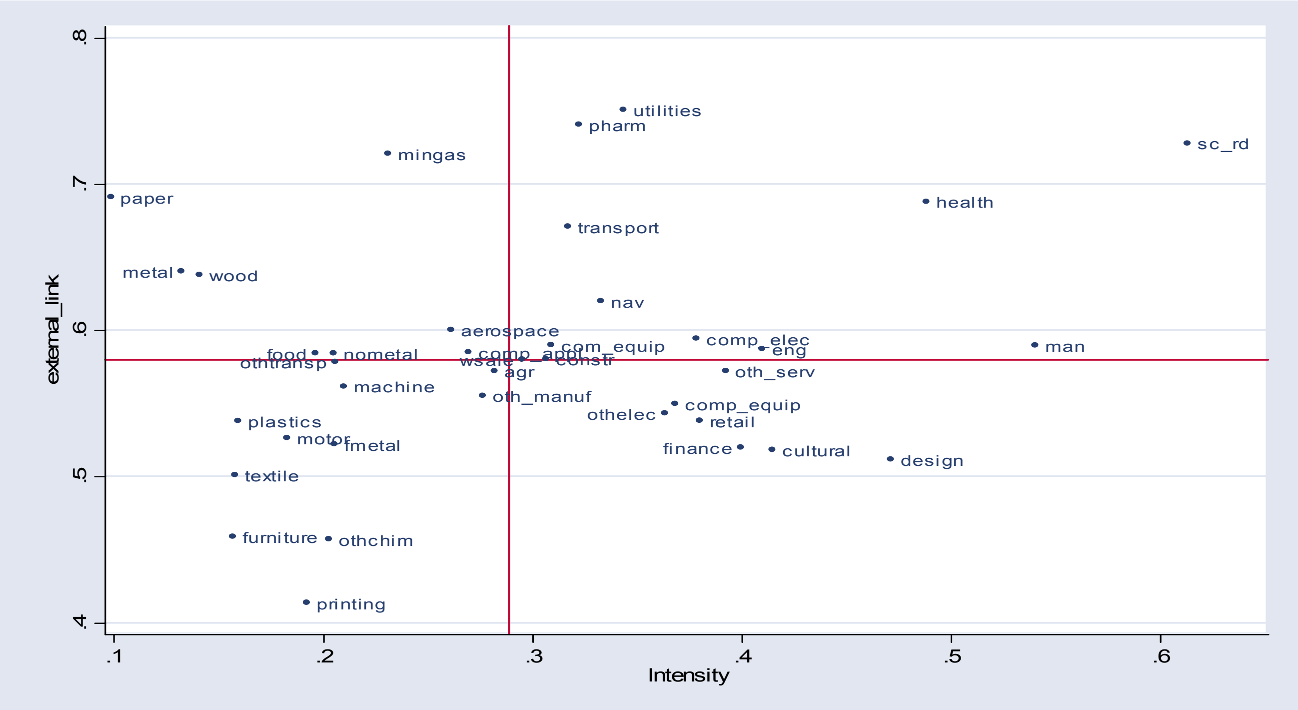
Table 3
Number of years' firms by size and strategies, 1997 to 2002 period

	1-49	50-99	100-199	200-499	500-999	1000-1999	2000-4999	> 4999
Strategy								
Perform own R&D	44,714	5,842	3,703	2,537	905	677	392	249
%	(97.4)	(97.8)	(97.7)	(97.6)	(96.6)	(97.3)	(95.6)	(96.9)
Sell R&D services	4,058	540	372	281	143	118	86	87
%	(8.8)	(9.0)	(9.8)	(10.8)	(15.3)	(16.9)	(20.9)	(33.8)
Buy R&D services	24,493	2,225	2,096	1,508	537	452	318	202
%	(53.3)	(37.2)	(55.3)	(58.0)	(57.3)	(64.9)	(77.6)	(78.6)
Total years' firms	45,914	5,973	3,790	2,600	937	696	410	257

Numbers in brackets are percentages of years' firms for each strategy compared to total number of firms by size class.
Source: Statistics Canada, RDCI Survey

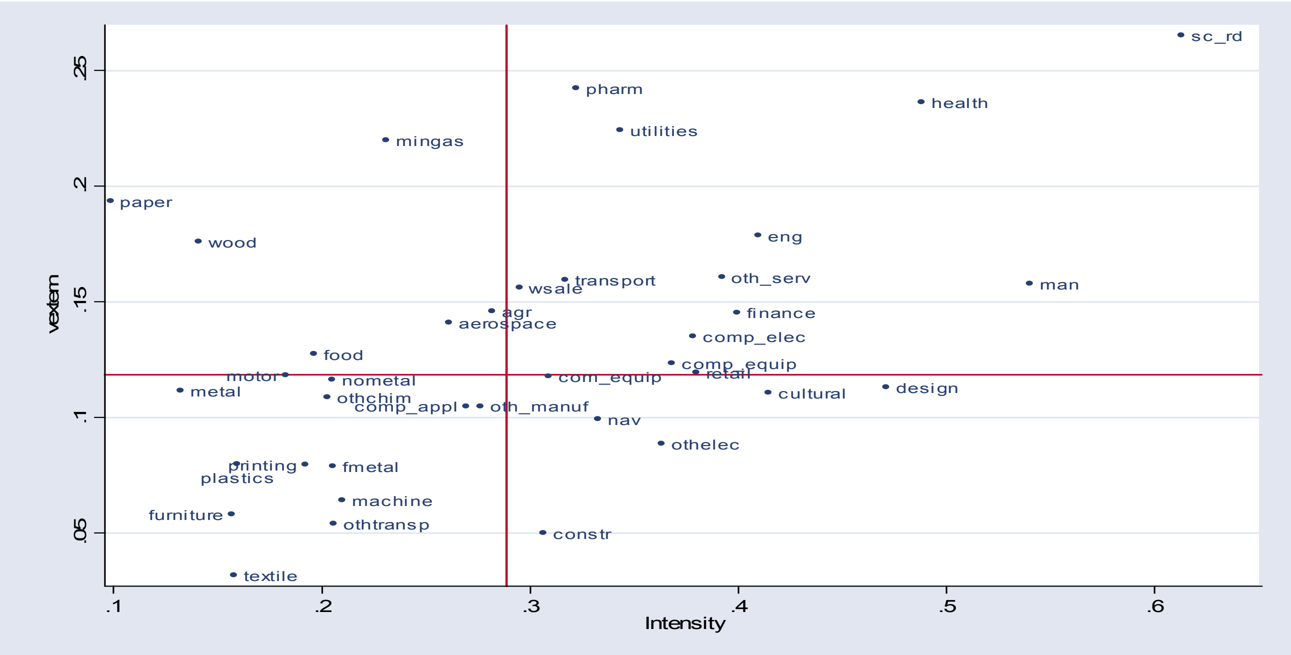
It is remarkable to see how important the "Sell R&D services" strategy is for firms with more than 4,999 employees (34%). This observation also applies to the relative importance of large firms with respect to expenditures on R&D. As Table 4 shows, for firms with more than 500 employees, the "Sell R&D services" and "Buy R&D services" strategies account for respectively $14 billion and $7 billion, or 75% and 68% of total expenditures on each of these strategies, whereas the corresponding percentage for the "Perform own R&D" strategy is only 58%. In comparison, expenditures on the "Perform own R&D" strategy by firms with fewer than 50 employees account for 15% of total expenditures on this strategy, while the percentages for the "Sell R&D services" and "Buy R&D services" strategies are only 8% and 14% respectively.

Figure 2
R&D intensity by industry and propensity to forge external links



Source: Statistics Canada, RDCI Survey. See Appendix for definitions

Figure 3
R&D intensity by industry and relative propensity to expend in R&D for external links



Source: Statistics Canada, RDCI Survey. See Appendix for definitions

As already noted, the theoretical literature with Leiponen (2001) and the applied literature with Belderbos et al. (2004) make much of the positive relationship that exists between R&D intensity and the different types of external relationships that R&D performers may have. We analyse the effects of these types of relationships in Section 6. But before engaging in such an analysis, it is important to differentiate industries according to R&D intensity and their propensity to enter into partnerships with outside players.[8] This allows us to form four separate groups of industries according to these characteristics. In figures 2 and 3, the horizontal and vertical lines represent the medians separating axes into four separate quadrants.

Figures 2 and 3 show types of relationship for the various observations over the period 1997 to 2002. The difference between these two figures is attributable to the y-axis, where in the first case we reported external relationships (external-link) in terms of the number of relationships by industry,[9] whereas the second figure illustrates R&D expenditures associated with external relationships (vextern).

As expected, R&D intensity, in relation to the propensity to forge external links does not vary significantly according to the number of external relationships per industry or the associated amounts of R&D expenditures. Only certain industries construction, textiles, navigational instruments, measuring, medical and control instruments, other services and finance underwent major changes. The finance industry went from being an industry with high-intensity R&D status and a low number of external relationships to being a high-intensity R&D industry with a high propensity to spend for R&D services (figure 3).

The scientific research and development services industry shows both the highest level of R&D intensity and the highest propensity to forge external links. The pharmaceutical and medicine industry and the utilities industry, as well as the health care and social assistance industry, are also high R&D-intensity industries with a high level of external relationships. The pharmaceutical industry accounts for a sizable share of firms conducting biotechnology activities. The utilities industry includes distributors of electricity and gas and sanitation services. In both these industries, the level of research and external links is naturally high, owing to the nature of the activity involved. The importance of external relationships and complementarities was already highlighted in earlier research, namely Arora and Gambardella (1990).

In the lower left quadrant is the group of industries with a low level of R&D intensity and a low level of external relationships. The industries in this group include plastic products, petroleum products, machinery, furniture and related products, printing, and motor vehicles and parts. Most of these industries are indeed low-intensity R&D industries; our findings corroborate the indicators of current intramural R&D expenditures as a percentage of the performing firm's revenues, reporting Table 12 of Statistics Canada (2004). Many of the industries found in this part of figures 2 and 3 are subcontracting or primary processing production units. They have few research laboratories and have reached a state where they no longer really produce research; in particular, this is the case with the automotive and textile sectors, in which R&D is done elsewhere than in Canada.

In the group of industries that have low-intensity R&D and a high propensity to engage in external relationships, there are paper products, wood products, primary metal manufacturing and mining and oil and gas extraction. These industries require a high level of specialized skills. They have a high level of know-how and probably carry on many inter-industry exchanges. However, these are also industries in which there are large economies of scale and the average number of

8. R&D intensity is the ratio of full-time employees assigned to R&D to the total number of employees in the firm. The propensity to forge external links is calculated in the first figure as the percentage of outside links, other than with subsidiaries, by industry. Figure 2 illustrates the amount of expenditures associated with this propensity out of the total transaction amounts for all strategies.
9. To count the number of relationships, a dichotomous variable takes the value 1 if the firm in a given industry reports having had monetary transactions for R&D purposes with an external organization other than a subsidiary (i.e., with a university, research centre, hospital, etc.).

employees per firm is among the highest. Another point to be noted is that this is the quadrant with the fewest industries, which tends to support the commonly held idea that it is the high-intensity R&D sectors that have the most external ties.

Lastly, many industries fall into a central tendency zone, that is, near the centre of the median axes. This is notably the case with agriculture, forestry, fishing and hunting, communications equipment, semiconductors and other electronic components, wholesale trade, and aerospace products and parts.

Table 4 shows that the manufacturing sector does much more R&D intramurally than does the service sector.

Of all firms that receive federal grants a total of 4,081 firms perform and fund their own R&D for a total of $10,243 million. While only 6.7% of all firms that perform R&D received federal grants, those firms account for 21% of total expenditures devoted to the “Perform own R&D” strategy, 20% of those devoted to the “Sell R&D services” strategy and 22% of those devoted to the “Buy R&D services” strategy. Thus the amount that grant-receiving firms spend on R&D is out of proportion with their numbers.

The group of industries with high-intensity R&D and a high level of external relationships spend the most on R&D, regardless of the strategy adopted.

Figure 4 shows that R&D activities are highly concentrated. Foreign-controlled firms account for only 4.6% of all performers but generate 32% of all R&D expenditures. Firms that receive federal grants account for only 6.4% of all performers, but they generate 21% of all R&D expenditures. The manufacturing and service sectors represent respectively 9.8% and 3.7% of performers but generate 66% and 30% of expenditures.

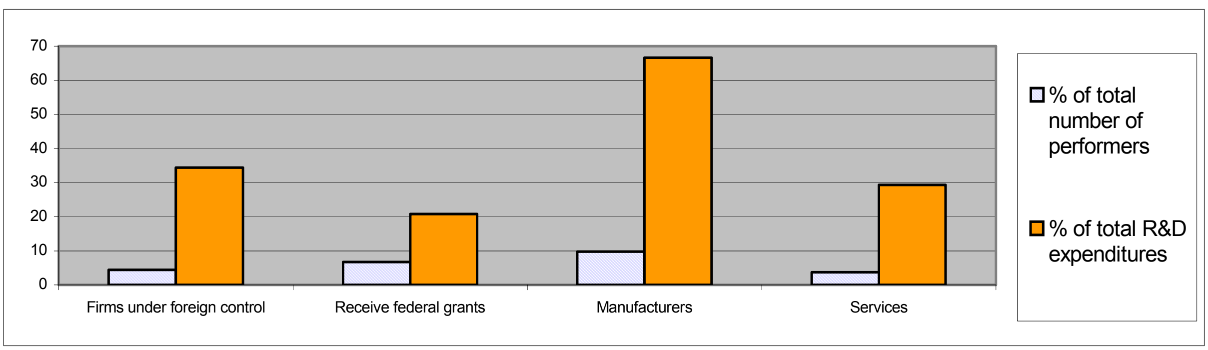
Table 5 illustrates how R&D performance strategies are defined. The amounts indicated in this table show the source and destination of R&D funding for firms performing R&D. Almost $49 billion in funding was provided between 1997 and 2002 by firms performing R&D for themselves, as shown in the first column. This does not mean that those firms did not also have external funding, or that they did not pay to have R&D performed by other organizations.

Table 4
Breakdown of the total amount expended by type of strategy for R&D purpose according to characteristics of the firm, for the period 1997 to 2002 (millions of dollars)

Characteristics	Perform own R&D	Sell R&D services	Buy R&D services	**Total**
Canadian controlled firms	33,673	12,239	7,029	**52,941**
Foreign controlled firms	14,945	6,525	3,999	**25,469**
Less than 50 employees	7,278	1,548	1,410	**10,237**
Between 50 and 499 employees	13,230	3,197	2,185	**18,612**
More than 500 employees	28,110	14,019	7,431	**49,560**
Receive R&D grants from Federal Government	10,243	3,748	2,403	**16,394**
Don't receive R&D grants from Federal Government	38,374	15,016	8 624	**62,014**
Manufactures	30,755	13,956	7,098	**51,809**
Services	15,596	4,503	3,252	**23,351**
High level of R&D Intensity/High level of external link	19,971	13,818	7 220	**41,009**
High level of R&D Intensity/Weak level of external link	8,715	1,587	891	**11,193**
Weak level of R&D Intensity/High level of external link	9,754	1,490	1,071	**12,315**
Weak level of R&D Intensity/Weak level of external link	10,159	1,869	1,848	**13,876**
Perform own R&D exclusively (current activity)	10,697	-	-	**10,697**
Sell R&D services exclusively (current activity)	-	1,811	-	**1,811**
Total expenditures by Strategy	**48,618**	**18,764**	**11,027**	**78,409**

Source: Statistics Canada, RDCI Survey

Figure 4
Percentage of firms and R&D expenditures for selected group of firms, for the period 1997 to 2002



Source: Statistics Canada, RDCI survey

The second column shows the amount of payments associated with organizations that pay firms to do R&D. Nearly 80% of transaction amounts are from subsidiaries, with a large proportion from foreign subsidiaries. Nevertheless, government contracts account for 5% of payment sources. Government is the fourth-ranking partner for firms that perform R&D. Over the six-year period, Canadian firms provided $863 million in R&D services to government. Thus, when a firm performs R&D, it does it mainly for its subsidiary or for another firm.

The last column in table 5 shows organizations that are also partners to whom firms make payments for the performance of R&D. Once again, subsidiaries and firms account for the large majority of transactions. Universities (domestic and foreign) rank third in importance as partners of firms that have R&D done, with nearly $865 million for performing R&D services. Of this amount, 12% goes to foreign universities. Hospitals outrank research institutes and associations in terms of amounts spent on research and development.

The reason why firms enter into R&D relationships with universities, and more generally with research institutes or the academic sphere, is not necessarily to obtain a product or innovation that can be commercialized. More often the main reason for entering into an agreement is either the long-term relationship or the prestige of the university, institute or researchers (Tether, 2002). This could also explain why partnerships with universities are so important. It should be kept in mind that our database covers all industries and all sizes of firms. For small firms, partnership with universities is often the only way to acquire necessary resources, as well as a way to access cutting-edge technology. This may also possibly explain why firms have more R&D performed by universities than they perform for universities.

Lastly, it is useful to note that small firms (those with fewer than 50 employees) account for the lions' share of R&D performers (see table 3). Small firms are more often involved in the early stages of development. This makes them less vulnerable to the problems arising from partnership in the later stages of development of a research project. For example, large firms that commercialize products resulting from R&D activity are more exposed than smaller firms to the problem of appropriation when they must co-operate with customers and suppliers, to say nothing of competitors (Veugelers and Cassiman, 2003). Consequently, the nature of projects in partnership with universities and research centres makes small firms less vulnerable to the issue of appropriation, which might explain the success of relationships between firms and universities, especially for small firms.

In all, inter-firm transactions and transactions between firms and their subsidiaries total more than $24 billion, representing 81% of all external transactions (excluding intramural R&D amounts of almost $49 billion). In other words, partnership outside affiliated firms accounts for 19% of all external transactions.

Thus, other than their spending with subsidiaries, firms mainly spent with other firms. R&D complementarities are primarily achieved through firm-to-firm relationships. However, this is a relatively risky type of relationship, since it also opens the door to competition. As indicated in Table 3, as firm size increases, so does the proportion of firms that have R&D performed by others. This may be explained by the fact that large firms have less to fear from competition from other firms with which they voluntarily do business, provided that they share only a limited portion of their knowledge.

Table 5
Total R&D expenditures for each main strategy by sources and destinations of payments for R&D purpose, for the period 1997 to 2002 (millions of dollars)

Organization at the source or destination of payments	Perform own R&D	Sell R&D services (source)		Buy R&D services (destination)	
Reporting unit + R&D grants from federal government	48,618	-		-	
Parent or affiliated company	-	1,832	(9.8)	1,832	(16.6)
Parent or affiliated foreign company	-	13,130	(70.0)	5,285	(47.9)
Firms	-	1,089	(5.8)	1,089	(9.9)
Foreign firms	-	1,670	(8.9)	762	(6,9)
Government	-	863	(4.6)	-	
Private non-profit organizations + Provincial research organizations	-	-		24	(0.2)
Industrial research institutes or associations	-	-		326	(2.9)
Hospitals	-	-		516	(4.7)
Universities	-	-		762	(6.9)
Foreign universities	-	-		103	(0.9)
Other (government, educational institutions)	-	180	(0.9)	328	(3.0)
Total expenditures by strategy	**48,618**	**18,764**		**11,027**	

Brackets indicate the amount in percentage of the total by column.
Source: Statistics Canada, RDCI Survey

In the introduction and the section on motivations for entering into a partnership, we noted the importance of complementarities as one of the main factors motivating R&D performers to obtain outside resources. Intramural research is commonly considered a prerequisite for any external acquisition of or investment in R&D. Accordingly, a positive correlation between intramural and extramural R&D is to be expected. The literature offers ample evidence of the complementarity between intramural and extramural R&D, but in almost all cases that evidence is based on discrete values. Table 6 shows the complementarities in terms of amounts spent on R&D for the strategic options for R&D performance. The amounts indicate, assuming a given strategic option, how many dollars were spent on R&D for the other strategic options. For example, performers opting for the “Perform own R&D” strategy spent almost $15 billion on the “Sell R&D services” strategy and $9 billion on the “Buy R&D services” strategy.

Table 6
R&D expenditures complementarities by different strategies’ combinations, 1997 to 2002 (millions of dollars)

	Perform own R&D	Sell R&D services	Buy R&D services
Conditionally:			
Perform own R&D	48,627	14,898	9,461
Sell R&D services	15,262	18,764	7,616
Buy R&D services	35,927	1,562	11,027

Source: Statistics Canada, RDCI Survey

Thus, it may be seen that opting for the “Buy R&D services” strategy implies expenditures of nearly $36 billion for perform own R&D. Performers that do R&D for other organizations have $15 billion in intramural expenditures on R&D services. The most significant apparent complementarities are therefore between the “Buy R&D services” and the “Perform own R&D” strategies and between “Sell R&D services” and “Perform own R&D”. This would indicate that there are indeed complementarities between internal and external strategies. Cassiman and Veugelers (2002) also pointed out that firms that adopt the in-house innovation strategy introduce far fewer innovative products and processes than firms that combine internal and external resources. Such a combination is the result of complementarities between internal and external R&D. This finding is consistent with the observations of Piga and Vivarelli (2003), for whom the decision to enter into an external R&D relationship depends on an earlier decision to conduct R&D activities.

Firms that opted for a “Sell R&D services” strategy performed only $7.6 billion worth of R&D services in the form of purchases of R&D services. Firms that adopted a “Buy R&D services” strategy sold $1.5 billion worth of such services.

6. Multinomial analysis of R&D performance strategies

A firm must choose from among several options regarding its organizational strategy. It can perform R&D for itself, perform it for other organizations, have it performed by other organizations or opt for a combination of these strategies.[10] The following analysis illustrates how a firm makes simultaneous choices regarding the six mutually exclusive strategies available to it. Through this simultaneous decision-making (taking the alternative choices into account), the firm’s decision to maximize its profits takes the various possible alternatives into consideration.

The assumptions associated with the multinomial logit model (MLM) are based on precisely this type of decision. This model is appropriate for estimating how the characteristics that influence the firm’s decision affect the likelihood of opting for a given strategy.

The estimation of this type of model must nevertheless satisfy the assumption technically known as the *independence of irrelevant alternatives* (IIA). In the case of an MLM, this assumption reflects the fact that the relationship of two probabilities associated with two specific events is independent of other events. Appended are the results of Hausman tests that compare the estimated coefficients of a model based on the six strategy choices with estimates of a limited model that excludes one of the strategies.

6.1 Variables

Our database limits our choice of the independent variables that determine the firm’s strategic decision regarding R&D performance. We can nevertheless control the firm’s decision for the most common variables found in this type of study.

In accordance with the “Schumpeterian” approach, large firms traditionally have an advantage in terms of their ability to produce research and innovate (Veugelers and Cassiman, 1999; Breschi et al., 2000). However, the relationship between the size of the firm and its strategic choice on how to conduct R&D is not necessarily a linear function. It is therefore useful to verify the relationship that exists between the size of the firm in terms of the number of employees and the type of strategic decision made by it.

The motivations that lead foreign-controlled firms to do research in the host country for themselves, do it for others or have it done by other organizations depend on numerous factors: policies supporting R&D, the tax environment, etc. It is assumed that national firms and foreign-controlled firms take the same factors into consideration, but the weighting that they assign to these factors may differ. For example, foreign-controlled firms may seek endowment complementarities in host countries. If this is the case, we should observe a difference in performance strategies for foreign-controlled firms. These firms should more often opt for “Sell R&D services” and “Buy R&D services” strategies. The descriptive analysis yielded some partial answers pointing in this direction. The task now is to determine the impact of this variable on the

10. It should be kept in mind that firms that are categorized to the “Buy R&D services exclusively” strategy had only R&D capital expenditures and no current expenditures. We intentionally excluded these firms from our study, and therefore this strategy is not included in our analysis.

different strategies, controlling for the co-variation induced by the other independent variables. Country of control is a dichotomous variable that takes the value 1 when the country of control is Canada.

The study of Belderbos et al. (2004) showed that R&D intensity (R&D_intensity) in terms of the number of employees assigned to R&D as a proportion of total employment varies according to the type of partner. R&D intensity has an impact on the way R&D is performed. Firms with high-intensity R&D have a higher level of knowledge appropriation and are therefore less concerned by the risk of sharing knowledge that comes with a partnership relationship. In such a situation, the firm might opt for a strategy of doing R&D for other organizations or doing it for itself. We will also introduce the square of intensity $(R\&D\_intensity)^{(2)}$ in order to take the non-linearity of the relationship into account. Beyond a certain level of intensity, the firm's absorptive capacity declines as the effects of economies of scale diminish (Belderbos et al., 2004).

Finally, we will test the hypothesis that industries that have the characteristic of being both R&D-intensive and open to partnership have a higher propensity to produce research for other organizations.

6.2 Results

Tables 7 and 8 report the marginal effects of the independent variables on the probability of choosing one of the six research and development performance strategies. Coefficients indicate the impact on the probability of choosing one of these strategies compared to the other choices considered.

For each table, a different specification applies. In the first case (Table 7), independent variables include size, country of control, R&D intensity and sectoral differentiation. In the second case (Table 8), we replaced the variables R&D intensity and sectoral differentiation with four dichotomous variables that cover the different industry groups according to characteristics that reflect both R&D intensity and the level of openness to relationships with external partners (other than subsidiaries). These variables identify the quadrants in charts 2 and 3. For these two specifications, the reference strategy chosen is the "Perform own R&D" strategy.

Table 7 (First specification)
Logit multinomial model marginal impacts of various strategies compiled data for 1997 to 2002 period[11]

	Perform own R&D	Sell R&D services	Perform own R&D and Sell R&D services	Perform own R&D and Buy R&D services	Perform own R&D, Sell and Buy R&D services	Sell and Buy R&D services
Log of the number of employees	-0.043 (-24.44)	0.002 (9.36)	0.007 (17.67)	0.019 (11.15)	0.013 (28.70)	0.002 (6.60)
Country of control	-0.003 (-0.35)	-0.018 (-5.69)	-0.008 (-2.53)	0.078 (7.37)	-0.023 (5.65)	-0.026 (-6.19)
R&D Intensity	-0.435 (-16.02)	0.044 (11.75)	0.103 (15.59)	0.042 (1.58)	0.196 (23.24)	0.050 (11.13)
R&D Intensity squared	0.223 (9.48)	-0.025 (-7.76)	-0.070 (-11.74)	0.030 (1.31)	-0.131 (-17.11)	-0.027 (-7.08)
Manufacture	0.070 (8.12)	-0.006 (-4.76)	-0.011 (-5.06)	-0.035 (-3.99)	-0.012 (-4.12)	-0.006 (-4.22)
Services	0.063 (7.27)	-0.0006 (0.49)	-0.003 (-1.55)	-0.057 (-6.65)	-0.003 (-1.00)	0.0001 (0.10)
Probability to choose a strategy	42.70	0.80	2.14	49.71	3.64	1.01
Number of observations	60451					
Likelihood	-61776.7					
Pseudo R2	0.0266					

Between brackets significant at 5%
Source: Statistics Canada, RDCI Survey

The data show that the “Perform own R&D” and “Perform own R&D and Buy R&D services” strategies have the strongest probabilities of being chosen, regardless of how the multinomial model is specified.

Table 7 shows that while significant, the increase in firm size in terms of number of employees has a negligible impact on the choice of strategies for the performance of R&D. An increase in the number of employees increases the probability of opting for all strategies except the “Perform own R&D” strategy.

On the other hand, being a Canadian-controlled firm increases the chances of opting for the “Perform own R&D and Buy R&D services” strategy by 7.8% but reduces the chances of opting for the other strategies.

As expected, the effect of the level of R&D intensity on strategy choices is positive and concave, since the coefficients are positive for the terms that capture the linearity of the relationship and negative and significant for the quadratic terms, with the exception of the “Perform own R&D” strategy where the relationship is reversed. An increase in R&D personnel reduces the likelihood of choosing to do R&D for oneself but increases the likelihood of doing it for others. If the firm opts to do R&D for itself, then increasing its R&D personnel would result in increases of its marginal absorptive capacity. These results are consistent with the findings of Belderbos et al. (2004).

11. Specification after elimination of firms reporting zero employees.

Table 8 (second specification)
Logit multinomial model marginal impacts of various strategies, compiled data for 1997 to 2002 period[12]

	Perform own R&D	Sell R&D services	Perform own R&D and Sell R&D services	Perform own R&D and Buy R&D services	Perform own R&D, Sell and Buy R&D services	Sell and Buy R&D services
Log of the number of employees	-0.013 (-10.32)	-0.0005 (-2.18)	0.003 (7.97)	0.006 (5.02)	0.006 (14.28)	-0.001 (-5.86)
Country of control	0.0426 (4.03)	-0.035 (-6.76)	-0.014 (-3.77)	0.084 (8.05)	-0.034 (-7.15)	-0.044 (-7.23)
High level of R&D Intensity/High level of external link	-0.097 (-19.60)	0.012 (8.61)	0.023 (11.31)	-0.004 (-0.73)	0.051 (18.27)	0.015 (9.32)
High level of R&D Intensity/Weak level of external link	-0.060 (-8.89)	-0.002 (-1.39)	-0.007 (-3.75)	0.068 (9.82)	-0.0008 (-0.30)	0.001 (0.84)
Weak level of R&D Intensity/High level of external link	0.003 (0.55)	0.011 (8.53)	0.008 (5.13)	-0.034 (-6.82)	0.004 (2.18)	0.008 (5.45)
Probability to choose a strategy	42.58	0.97	2.23	49.26	3.78	1.18
Number of observation	60 451					
Likelihood	-62367.7					
Pseudo R2	0.0173					

Between brackets significant at 5%
Source: Statistics Canada, RDCI Survey

Sectoral differentiation has only a slight impact on the firm's decision as to the strategy chosen.

The second specification (Table 8) reveals that all things being otherwise equal, industries that are highly R&D intensive and open to relationships with external partners other than subsidiaries reduce their probability of doing R&D for themselves but increase their probabilities for all alternative strategies. Thus, an increase in the number of firms that fit the characteristics of high R&D intensity industries and openness to external relationships would increase the likelihood of doing R&D by a combination of strategies rather than doing it intramurally. This finding suggests that an increase in certain industries such as the pharmaceutical industry could generate an increase in the use of strategies that involve exchanges of services for R&D purposes. As the results of our analysis show, having a high level of both R&D intensity and openness to external relationships yields a 5.1% increase in the chances of doing R&D by combining the three main performance strategies, namely "Perform own R&D" "Sell R&D services" and "Buy R&D services"

As in the first specification, being a Canadian-controlled firm increases the chances of opting for the "Perform own R&D and buy R&D services" strategy but also the internal strategy that consists in doing R&D exclusively for oneself. In both cases, the impact is sizable and significant. Thus, being a Canadian-controlled firm increases the chances of opting for the strategy of doing R&D for oneself by 4.3%. These results confirm the descriptive analysis, which showed us that proportionally more foreign-controlled firms do R&D for other organizations, while Canadian-

12. Specification after elimination of firms reporting zero employees.

controlled firms tend to do their R&D themselves or have other organizations do it. However, it should be kept in mind that in terms of amounts, the relationship is reversed: Canadian firms spend more to do R&D for other organizations and foreign-controlled firms spend relatively more to have R&D done by other organizations; (see Table 4).

7. Conclusion

This study expands our thinking on the choice of R&D performance modes. In previous studies, firms' strategic choices regarding R&D performance are essentially binary: either the firm has R&D performed in-house or it obtains R&D services through an external partnership. Drawing on data from the R&D survey conducted by Statistics Canada, we have expanded this concept of performance mode. We have shown that the R&D performer can do R&D for its own purposes or have it done by other organizations, or it may also do it for other organizations.

We presented these different R&D performance modes in the form of different relationships with external partners but also with subsidiaries. For this purpose, the intensity of the relationship was quantified in monetary terms and not by merely counting the firms involved, as is more often done in the empirical literature.

The study showed that 62% of R&D expenditures are of internal origin and 38% are of external origin. More specifically, 24% of all transaction amounts for R&D purposes are for R&D performed by firms for other organizations. The R&D that Canadian firms have others perform for them accounts for 14% of all transaction amounts for R&D purposes. The more in-depth examination also revealed that of the percentage of transaction amounts spent on external strategies, 81% was spent in relations between firms and their subsidiaries. Consequently, the use of external partnerships other than with subsidiaries covers only 19% of R&D transaction amounts for the sale or purchase of R&D services.

Forty-two percent of firms performing R&D produce research internally only, with no partnership relationship. These firms that do only in-house R&D spent $10.7 billion on R&D, representing 13% of total expenditures recorded in transactions for the various R&D strategies. Essentially, partnerships with other firms and between firms and their subsidiaries explain most of the amounts transacted for R&D purposes, that is, more than $22 billion out of the $30 billion in transactions for all strategies other than "Perform own R&D" over the period 1997 to 2002. Governments account for 5% of payment sources for firms that do R&D for other organizations. Universities too are a relatively important external organization. Nearly 8% of all amounts spent on R&D performed by other organizations come from universities, and 5% from hospitals. Other organizations such as private non-profit organizations and provincial research centres contribute to a very small extent to the amounts exchanged for R&D. We have shown that the manufacturing sector relatively does R&D for other organizations and that the service sector has R&D done by other organizations.

Consistent with hypotheses found in the literature, entering into external R&D relationships requires a pre-existing absorptive capacity. In other words, to opt for a "Sell R&D services" or "Buy R&D services" strategy requires a degree of complementarity with the strategy that consists in doing R&D for oneself.

Finally, multivariate analysis identified the determinants of each strategy. This analysis revealed that firm size is a factor that has little impact on the choice of a strategy. Another interesting highlight revealed by this analysis is that belonging to a Canadian-controlled firm increases the chances of doing R&D exclusively in-house. Thus, foreign-controlled firms are more likely to carry out R&D activities in the form of a partnership. Lastly, we showed that R&D intensity and the degree of openness to external partnership relationships (other than with subsidiaries) at the industry level are variables with differing effects on the choice of strategy.

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Appendix A. Definitions

(1) Perform own R&D: R&D intramural work performed or funded within the reporting unit (including Federal grants).

(2) Sell R&D services: R&D performed by the reporting unit but funded by other organizations (including Parent, affiliated and subsidiary companies) where the results are transmitted to funds' purveyor.

(3) Buy R&D services: R&D work performed by other organizations (including parent, affiliated and subsidiary companies) and paid by the reporting unit.

Appendix B. Tests for validity of Independence from Irrelevant Alternatives (IIA) - Hausman-Type test

Table 9 Hausman-type test (IIA) for model 1

Omitted Strategy	chi2(28)	Prob>chi2	Ho
Sell R&D Services	36.45	0.1059	Not reject
Perform own R&D and Sell R&D services	14.98	0.9696	Not reject
Perform own R&D and Buy R&D services	-2.35	-	Statistics not defined
Perform own R&D, Sell and Buy R&D services	25.78	0.5308	Not reject
Sell and Buy R&D services	27.55	0.4883	Not reject

Table 10 Hausman-type test (IIA) for model 2

Omitted Strategy	chi2(28)	Prob>chi2	Ho
Sell R&D Services	-114.40	-	Statistics not defined
Perform own R&D and Sell R&D services	-6.67	-	Statistics not defined
Perform own R&D and Buy R&D services	16.18	0.8815	Not reject
Perform own R&D, Sell and Buy R&D services	41.62	0.0142	Not reject
Sell and Buy R&D services	55.89	0.0002	Not reject

Appendix C. Table of simple correlations (N=60451)

	Log of the number of employees	Country of control	R&D Intensity	Manufacturing	Services	High level of R&D Intensity/ High level of external link	Weak level of R&D Intensity/ High level of external link	High level of R&D Intensity/ Weak level of external link	Weak level of R&D Intensity/ Weak level of external link
Log of the number of employees	1.0000								
Country of control	-0.3280	1.0000							
R&D Intensity	-0.6294	0.0986	1.0000						
Manufacturing	0.2716	-0.0884	-0.2757	1.0000					
Services	-0.2579	0.0869	0.2900	-0.8776	1.0000				
High level of R&D Intensity/High level of external link	-0.1157	0.0229	0.1787	-0.2055	0.2527	1.0000			
Weak level of R&D Intensity/High level of external link	0.1781	-0.0868	-0.1351	0.3207	-0.3389	-0.1904	1.0000		
High level of R&D Intensity/Weak level of external link	-0.1429	0.0745	0.1870	-0.4935	0.5711	-0.2428	-0.2142	1.0000	
Weak level of R&D Intensity/ Weak level of external link	0.1171	-0.0332	-0.2306	0.4361	-0.4412	-0.4290	-0.2759	-0.4826	1.0000

Appendix D. Annual growth of R&D expenditures by industry

	Number of observations (% of total)	Annual rate of growth (1997-2002) For R&D expenditures		
Industrial classification RDCI		Do for oneself	Do for others	Have others do
Agriculture, forestry, fishing and hunting	1623 (2.68)	+ + +	+ + +	+ +
Mining and oil and gas extraction	622 (1.02)	-	+ + +	- -
Utilities	289 (0.48)	- - -	+ + + +	+ + + +
Construction	1422 (2.34)	-	+ + + +	+ + + +
Food, beverage and tobacco	1779 (2.93)	-	- - - -	+
Textiles	735 (1.21)	+ + +	- - - -	- -
Wood products	858 (1.42)	- -	+ + + +	+ + + +
Paper Products	585 (0.96)	+ + + +	-	- - -
Printing	433 (0.71)	+ + + +	- - - -	- - - -
Pharmaceutical and medicine	543 (0.89)	+ + + +	+ + + +	-
Other chemicals	1856 (3.06)	+ +	+ + +	+ + + +
Petroleum and coal products, plastic products, rubber products	2008 (3.31)	-	+	- - -
Non-metallic mineral products	661 (1.09)	- - -	- - - -	- - - -
Primary metal (ferrous)	583 (0.96)	+ + +	-	- - -
Primary metal (non-ferrous) , and Fabricated metal products	2993 (4.94)	+ + +	- - - -	- - - -
Machinery	4971 (8.20)	+ + +	+ +	- - - -
Computer and peripheral equipment	597 (0.98)	+ + +	- -	- - - -
Communications equipment	731 (1.21)	+ + + +	- - - -	- - - -
Semiconductor and other electronic components	803 (1.32)	+ + + +	+ + + +	+ + + +
Navigational, measuring, medical and control instruments	1554 (2.56)	+ + +	+ + + +	+ + + +
Other computer and electronic products	221 (0.36)	-	- - - -	- - - -
Electrical equipment, appliance and components	1180 (1.94)	+ + +	-	+ + +
Motor vehicles and parts	935 (1.54)	+ + + +	- - - -	-
Aerospace products and parts	375 (0.62)	-	- - -	+ + +
All other transportation equipment	327 (0.54)	+	- - - -	+ + + +
Furniture and related products	608 (1.00)	+ + + +	+ + + +	- - - -
Other manufacturing industries	1974 (3.26)	+	- - - -	+
Wholesale trade	4736 (7.81)	- -	+ + + +	-
Retail trade	1019 (1.68)	- -	+ + + +	- - - -
Transportation and Warehousing	343 (0.57)	+ + + +	- - - -	-
Information and Cultural Industries	2058 (3.39)	+ + + +	+	+ + + +
Finance, insurance and real estate	743 (1.22)	+	+ + + +	+ + + +
Architectural, engineering and related services	3861 (6.37)	+ + +	-	-
Computer system design and related services	8192 (13.52)	+ + + +	+ + + +	+ + +
Management, scientific and technical consulting services	1594 (2.63)	+ + + +	+ + + +	+ + + +
Scientific research and development services	2590 (4.27)	+ + + +	+ + + +	+ + +
Health care and social assistance	516 (0.85)	+ + + +	+ + +	+ + + +
All other services	3659 (6.04)	+	- - -	- -

Source: Statistics Canada, RDCI Survey

0 ≤ growth < 3 %	+	0 ≤ decrease < -3 %	-
3 ≤ growth < 5 %	+ +	-3 ≤ decrease < -5 %	- -
5 ≤ growth < 10 %	+ + +	-5 ≤ decrease < -10 %	- - -
growth ≥ 10 %	+ + + +	decrease ≥ -10 %	- - - -

Appendix E. Acronyms for Industries

Arg = Agriculture, forestry, fishing and hunting
Mingas = Mining and oil and gas extraction
Utilities = Utilities
Constr = Construction

Manufacturing

Food = Food, Beverage and tobacco
Textile = Textile
Wood = Wood products
Paper = Paper products
Printing = Printing
Pharm = Pharmaceutical and medicine
Othchim = Other chemicals
Plastics = Petroleum and coal products, Plastic products, Rubber products
Nometal = Non-metallic mineral products
Fmetal = Primary metal (ferrous)
Metal = Primary metal (non-ferrous) , and Fabricated metal products
Machine = Machinery
Comp_equip = Computer and peripheral equipment
Com_equip = Communications equipment
Comp_elec = Semiconductor and other electronic components
Nav = Navigational, measuring, medical and control instruments
Othelec = Other computer and electronic products
Comp_appl = Electrical equipment, appliance and components
Motor = Motor vehicle and parts
Aerospace = Aerospace products and parts
Othtransp = All other transportation equipment
Furnitures = Furniture and related products
Oth_manuf = Other manufacturing industries

Services

Wsale = Wholesale trade
Retail = Retail trade
Transport = Transportation and Warehousing
Cultural = Information and Cultural Industries
Finance = Finance, insurance and real estate
Eng = Architectural, engineering and related services
Design = Computer system design and related services
Man = Management, scientific and technical consulting services
Sc_rd = Scientific research and development services
Health = Health care and social assistance
Oth_serv = All other services

Variables

Vextern = R&D expenditures associated with external relationships
External_link = number of external relationship

Catalogued publications

Science, Technology and Innovation statistical publications

88-001-XIE	Science statistics
88-003-XIE	Innovation analysis bulletin
88-202-XIE	Industrial research and development, intentions (with 2004 preliminary estimates and 2003 actual expenditures) (annual)
88-204-XIE	Federal scientific activities (annual)
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88F0017MIE	Science, Innovation and Electronic Information Division research papers

88-001-X Volume 30 – 2006

No. 1 Provincial distribution of federal expenditures and personnel on science and technology, 1997/1998 to 2003/2004 (February)

No. 2 Biotechnology scientific activities in federal government departments and agencies, 2004/2005 (March)

88-001-X Volume 29 – 2005

No. 1 Distribution of federal expenditures on science and technology by province and territories, 2002-2003 (January)

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No. 1 Provincial distribution of federal expenditures and personnel on science and technology, 1997-1998 to 2003-2004 (April)

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No. 1 Federal government expenditures and personnel in the natural and social sciences, 1995/96 to 2004/05 (January)

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