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Innovation and Export-market Participation in Canadian Manufacturing

by John R. Baldwin, Afshan Dar-Brodeur and Beiling Yan
Economic Analysis Division

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.. not available for a specific reference period
... not applicable
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0^s value rounded to 0 (zero) where there is a meaningful distinction between true zero and the value that was rounded
^{p} preliminary
^{r} revised
x suppressed to meet the confidentiality requirements of the *Statistics Act*
^{E} use with caution
F too unreliable to be published
* significantly different from reference category ($p < 0.05$)

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Abstract

This paper asks whether research and development (R&D) drives the level of competitiveness required to successfully enter export markets and whether, in turn, participation in export markets increases R&D expenditures. Canadian non-exporters that subsequently entered export markets in the first decade of the 2000s are found to be not only larger and more productive, as has been reported for previous decades, but also more likely to have invested in R&D. Both extramural R&D expenditures (purchased from domestic and foreign suppliers) and intramural R&D expenditures (performed in-house) increase the ability of firms to penetrate export markets. Exporting also has a significant impact on subsequent R&D expenditures; exporters are more likely to start investing in R&D. Firms that began exporting increased the intensity of extramural R&D expenditures in the year in which exporting occurred.

JEL no.: F1, L1, L2, O3

Keywords: Innovation, research and development, export, Canadian manufacturing

Executive summary

Trade and innovation are two important economic forces affecting manufacturing firms. Trade liberalization increases the competition that Canadian manufacturers face from abroad. This reinforces the importance of innovation for manufacturers in general, and exporters in particular. This paper examines the innovation profile of Canadian manufacturing firms and how it relates to their exporting behaviour in the last half of the first decade of the 2000s.

Innovation is a dynamic process that involves many dimensions, and spending on research and development (R&D) is an important component of the innovation process. There are differences in the types of expenditures that fall under the broad rubric of R&D and facilitate innovation. Innovation can involve path-breaking new products and processes, or it can involve more marginal improvements. Firms can perform R&D in-house (intramural), or purchase it or contract it out (extramural). This paper asks whether expenditures on these different types of R&D are related to the export decision of a firm.

This paper asks whether different forms of R&D drive the level of competitiveness required to successfully enter export markets and whether, in turn, participation in export markets has an immediate impact on the emphasis placed on innovation, via R&D expenditures.

The paper finds that Canadian manufacturing firms self-select into R&D and export markets. Canadian non-exporters that subsequently enter export markets are not only larger and more productive, as has been reported for previous decades, but also more likely to have invested in R&D. The existence of either extramural or intramural expenditures in a firm increases its ability to penetrate export markets. After controlling for differences in R&D, the pre-entry productivity level is still an important determinant of the subsequent entry of firms into export markets. This suggests that there are competencies besides R&D that contribute to the differences between firms in pre-entry productivity levels and that facilitate entry into export markets.

Exporting increases the likelihood that firms will subsequently invest in all types of R&D, whether intramural or extramural, immediately after entry into export markets. Entry into export markets is also associated with an immediate increase in the intensity of R&D, but only in the types of extramural expenditures that are generally reported in small firms. Immediately upon entry into export markets (in the same year as entry), R&D intensity increases for export starters relative to their non-exporting counterparts, and remains at this high level in the period after entry. This one-time relative increase points to evidence of simultaneous strategies—movement into export markets and the adoption of a more intense R&D strategy.

1 Introduction

This paper examines the innovation profile of Canadian manufacturing firms and how it relates to their exporting behaviour in the last half of the first decade of the 2000s. Trade and innovation are two important economic forces affecting manufacturing firms. Trade liberalization since the 1980s has increased the competition that Canadian manufacturers face from abroad. This has reinforced the importance of innovation for manufacturers in general, and exporters in particular. Firms entering export markets require innovative business strategies to compete internationally, where they face foreign competitors with lower production costs and prices, particularly from emerging markets.

The theoretical trade literature has pointed to heterogeneity in firm productivity or efficiency as the key determinant in the decision of a firm to export. In his seminal paper, Melitz (2003) demonstrates that more productive firms—that is, firms with lower marginal costs—are likely to self-select into export markets. Some authors have also pointed to productivity gains following the entrance into export markets. In the learning-by-exporting literature, it is argued that participation in international markets facilitates the transfer of knowledge (Grossman and Helpman 1991), which can lead to improvements in productivity. For example, firms can learn about superior technologies in foreign markets directly, through buyer–seller relationships, or indirectly, through increased exposure to the similar products of foreign competitors (De Loecker 2013). As a result, firms that export should see productivity improvements by investing in productivity-enhancing activities such as innovation (Lileeva and Trefler 2010).

The theoretical impacts of exporting on productivity have been tested empirically in the Canadian context. Demonstrating that there are both selection and learning effects, Baldwin and Gu (2004) and Baldwin and Yan (2012) show that Canadian exporters not only have higher productivity than non-exporters, but also have faster labour productivity growth after entry into export markets, among Canadian manufacturing plants.[1] The authors also find evidence for learning by exporting, with manufacturing plants more likely to adopt foreign technologies, engage in collaborative R&D projects abroad, and indicate that they face more competition than non-exporters. Lileeva and Trefler (2010) also report that, in response to tariff cuts with the United States, new exporters experience faster productivity growth than non-exporters. Export entrants were also more likely to adopt advanced technologies.

Underlying the literature on export-market participation is the theme that innovation is a potential mechanism through which exporting has an impact on the productivity of firms, either before or after export-market entry. Establishing the existence of this relationship overcomes a fundamental shortcoming in Melitz's 2003 model—that the productivity of a firm is randomly drawn from a distribution *ex ante*, with the decision to export or not following this draw. Recent literature on self-selection points to the endogeneity of productivity and innovation being an important determinant in the export-market entry decision. Constantini and Melitz (2008) develop a theoretical model in which export and innovation decisions are jointly made and influenced by the timing of trade liberalization. They show that, in anticipation of future trade liberalization, firms tend to innovate before entering export markets.[2] In a similar vein, Aw, Roberts and Xu (2011) develop a model in which R&D or technology adoption and exporting both have an impact on the productivity evolution of a firm. Empirical results for this model, using a sample of Taiwanese manufacturing plants in the electronics industry, show that the decision of a plant to export raises future productivity, compared with non-exporters. R&D investment is found to have a larger positive

1. See Wagner (2007) for a summary of evidence for other countries.
2. In support of the applicability of these "anticipation" models, Baldwin, Caves and Beckstead (2002), Baldwin, Caves and Gu (2005) and Baldwin and Gu (2009) all report that Canadian firms began to rationalize their product lines and increase production-run lengths before the actual signing and implementation of the Canada–United States Free Trade Agreement in the late 1980s.

effect on future productivity than exporting, though jointly undertaking both activities has the largest impact.

The learning-by-exporting literature and the literature that treats exporting and innovation as complements, point to innovation as a source of productivity gains *ex post*. Recent empirical evidence for Sweden shows that exporters are more productive firms that have succeeded in appropriating innovative outputs, compared with non-exporters (Jienwatcharamongkhol and Tavassoli 2014), pointing to the importance of innovation as a potential mechanism in the exporting–productivity relationship. Ito and Tanaka (2015) use a firm-heterogeneity model that forecasts a complementarity between R&D capabilities and exporting, and confirm the predictions of the model for Japanese firms.

This paper contributes to this literature by examining whether the innovation profile of Canadian manufacturing firms changes before and after export-market entry in a similar fashion to productivity. Innovation is a dynamic process involving many dimensions. Spending on R&D is an important component of the innovation process and is often the focus of analyses, as it is easier to measure. Traditional estimates produced by statistical agencies tend to use a narrowly defined measure of R&D stemming from the well-used *Frascati Manual* (OECD 2002). The Frascati definition, for example, focuses primarily on R&D performed within a firm (in-house or intramural R&D)[3] and places bounds on what expenditures can be considered as falling within the definition of R&D—those with a considerable degree of uncertainty that lead to new discoveries of a significant nature.

R&D has more dimensions than just intramural spending, and serves more purposes than the development of breakthrough innovations. As a result, the intramural data collected using just the narrow Frascati definition provide only a partial picture of the innovation that a firm may be pursuing (Baldwin and Hanel 2003). Expenditures on incremental improvements and purchased or contracted-out R&D investment (extramural R&D) play a complementary but important role in the innovation process (Mowery and Rosenberg 1999).

The distinction between intramural and extramural R&D is an important one for several reasons. First, intramural spending by enterprises (firms) understates the amount of R&D available to firms: it can also be purchased from foreign suppliers and domestic performers. National estimates that examine only intramural firm expenditures may understate the amount of R&D that is being applied to the production process in a particular country. While counting both intramural and extramural expenditures, in a closed economy, risks double counting at the aggregate level, this is not the case when extramural expenditures occur outside of the country. In an open economy, failing to incorporate extramural expenditures omits a possible important portion of R&D expenditures. In this case, adding foreign extramural expenditures to intramural expenditures is required to provide an accurate estimate of the total aggregate expenditures that are applied to the domestic production process. When foreign extramural spending on R&D is added to intramural spending, Canada's ranking increases relative to other countries (Baldwin, Beckstead and Gellatly 2005).[4] In Canada, a larger proportion of the R&D that is applied to production comes from R&D imports than in other countries.

Second, whether R&D is conducted within the firm or contracted out can potentially have different impacts on innovation. Rosa and Mohnen (2013) argue that combining intramural and extramural R&D leads to higher labour productivity growth than does adopting a single R&D strategy in Canada. Baldwin and Hanel (2003) also show that, for Canada, larger foreign-controlled firms in the most innovative industries were likely to combine internal and external R&D to support their

3. The basic measure is "intramural expenditures;" i.e., all expenditures for R&D performed within a statistical unit or sector of the economy (see OECD 1994).
4. This is because some extramural spending in Canada is foreign-based. Canadian firms import R&D services, much as they do physical capital.

innovation activities. Audretsch, Menkveld and Thurik (1996) find that internal and external R&D tend to be complementary in high-technology industries and to be substitutes in lower-technology industries. Finally, empirical research suggests that there is a relationship between external payments for R&D and actual technology acquisition. Mohnen and Lépine (1991) find that, for Canadian manufacturing, extramural payments for foreign technology and domestic intramural R&D are positively related. Similarly, Baldwin, Beckstead and Gellatly (2005) argue that Canadian manufacturing firms with domestic intramural R&D expenditures commercialize more new products and services.

There are also differences in the types of expenditures that fall under the broad rubric of R&D and facilitate innovation, because innovation has numerous dimensions. Innovation can involve path-breaking new products and processes. Or, it can involve a multitude of more marginal improvements. This paper asks whether expenditures on one or both of these dimensions are related to the export decision and then, in turn, whether R&D is enhanced by exporting.

The paper is organized as follows. Section 2 discusses the concept of R&D that is used in this paper and describes the datasets that are used to generate the measures associated with different aspects of R&D expenditures. Section 3 outlines trends in the R&D profile of Canadian manufacturing. Section 4 examines how the R&D profile of firms changes upon entry into export markets and provides a multivariate analysis of the relationship between R&D intensity and entry. Section 5 concludes the paper.

2 Data

2.1 Information on research and development

R&D expenditures are directed towards the development of new products and production processes.[5] They can result in brand-new or revolutionary changes in products and processes, or they can add improvements to existing products and processes. These improvements range from the incremental to the substantive. Overlapping these distinctions are those that arise from whether the R&D program involves considerable uncertainty or not. Statistical programs that rely upon the Frascati or Oslo manuals (OECD 1994, 2002) focus on expenditures that generate more original innovations.[6]

Statistical collection processes also distinguish between R&D that is conducted in-house (regardless of whether the sources of funds are internal to the firm or are external contracts or grants) and R&D that is conducted elsewhere for the firm in question. The former is referred to here as intramural and the latter as extramural. Focusing on only intramural spending and omitting extramural spending allows for the production of estimates of total R&D expenditures in a country without double counting. But this method misses some R&D expenditures when R&D is being contracted from abroad.

A study on the effects of R&D on export activity requires information that captures different dimensions of the R&D process to investigate the changes that occur in the different dimensions.

This study uses two different sources of R&D expenditures that are collected by Statistics Canada. One is the dataset entitled Research and Development in Canadian Industry (RDCI), and the other is the Annual Survey of Manufactures (ASM). To understand the differences in the

5. R&D expenditures make up only a subset of innovation expenditures. For a further discussion, see Baldwin, Beckstead and Gellatly (2005) or Baldwin, Gu and Macdonald (2012).
6. For a more extensive discussion of these issues, see Baldwin and Hanel (2003, Chapter 5).

underlying data that are used, the data sources and the methodology used to produce each source must be described.

The universe for the survey questionnaire underlying the RDCI data consists of all firms known or believed to be involved in the performance or funding of R&D. Firms are identified through many sources, but, most frequently, firms are added from the Scientific Research and Experimental Development (SR&ED) tax incentive program of the Canada Revenue Agency (CRA) (T661 files). For the period of this study, the definitions of R&D used by the CRA and Statistics Canada are very similar, coming basically from the *Frascati Manual* of the Organisation for Economic Co-operation and Development.[7] The R&D data from the survey and the CRA's SR&ED program are cross-examined and reconciled. The CRA specifies a number of criteria that these expenditures must meet. These include whether there was scientific or technological uncertainty in the investigations that tried to develop the innovation, whether the effort involved testing and formulating hypotheses to reduce the uncertainty in the investigation, whether the investigation was systematic, and whether the approach was aimed at a scientific or technological advancement, among other issues (CRA 2015). Two of these dimensions—uncertainty and degree of advancement—involve considerable subjectivity. Recorded R&D data therefore only cover a portion of total expenditures associated with the innovation process.

The RDCI file distinguishes between intramural and extramural expenditures, because the official program that publishes data on gross domestic expenditures on R&D in Canada uses only the former for its estimates of aggregate R&D expenditures. For the purposes of this study, both intramural and extramural expenditures are extracted from this file. The data is collected at the level of the enterprise that can produce a complete set of financial statements and have a business number (BN) attached to it.

The ASM is conducted at the level of the operating production entity, sometimes referred to as an establishment. This is lower than the level of the enterprise (with a BN) used in the RDCI file. The ASM focuses on sales and expenditures data primarily associated with manufacturing. The production entities, or establishments, are asked to report basic data on sales or revenue, and expenditures on goods, materials and services, using the data that are easily available in their accounting systems. Plants or establishments are generally able to report basic data related to the value of products made, and materials and service costs, but not detailed information beyond this, except in special circumstances. The contact phase of the 1993 Survey of Innovation and Advanced Technology showed that detailed information on R&D was better obtained not from manufacturing establishments, but from R&D centres within the firm. These centres are often not included in the production-establishment universe used for the ASM, which is focused primarily on sales and materials costs related to production.

Nevertheless, the ASM universe has been used as a sample frame for special surveys that have investigated the use of different types of technologies and R&D that focus only on whether R&D is available to the production process, and not directly on dollars spent on R&D. These include the 1989 Survey of Manufacturing Technology (Statistics Canada 1991), the 1993 Survey of Innovation and Advanced Technology (Baldwin and Hanel 2003, Chapter 5) and the 1998 Survey of Advanced Technology in Canadian Manufacturing (Sabourin and Beckstead 1999). In these surveys, manufacturing plants were requested to provide information on whether they made use of R&D.

Information on the nature of R&D incidence and the purpose of R&D at the manufacturing-establishment level can be derived from these surveys. For example, in the 1989 survey, some 60% of plants indicated that they conducted R&D. In the 1993 survey, information collected at the

7. For more detailed information on the RDCI database, consult Statistics Canada (2015) or visit http://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=4201&Item_Id=1407&lang=en or http://www.statcan.gc.ca/pub/88-202-x/2015000/technote-notetech1-eng.htm.

firm level found that more than 65% of manufacturing firms reported doing some R&D. In the 2009 survey, some 55% of the manufacturing plants reported doing some R&D.[8] These levels of intensity are considerably greater than the intensity derived from the RDCI file (12% in Table 1), as would be expected, because the RDCI definition imposes strict qualifying conditions before an expenditure is considered to qualify as R&D.

Some of the difference is attributable to the fact that manufacturing plants refer both to full-time R&D labs that generate the type of innovation that better qualifies for tax deductions and to other types of R&D that are done on an occasional basis and that probably do not qualify as easily. In the technology surveys, not all manufacturing businesses had ongoing R&D units that conducted R&D on a regular basis. Of those reporting that they conducted R&D, some 38% in the 1993 survey and 43% in the 1998 survey did so on an ongoing basis. Some 63% of the total did so on an occasional basis in the 1993 and 1998 surveys respectively (Baldwin and Hanel 2003, p. 104; Sabourin and Beckstead 1999, p. 55).

R&D in manufacturing is conducted in special R&D units, in various other units or departments throughout the firm, and via outside contracts. The 1993 survey found that some 25% of those conducting R&D did so in a separate R&D facility, some 63% obtained it from various non-R&D-dedicated departments and some 22% contracted it out (Baldwin and Hanel 2003, p. 104). The 1998 survey confirms the importance of third parties, with 36% of R&D performers conducting R&D jointly with others and 25% contracting it out (Sabourin and Beckstead 1999, p. 54). Thus, some 61% of R&D performers conducted R&D with third parties. It is these types of expenditures, which have relatively straightforward bookkeeping trails at the plant level, that we believe the ASM is reporting.

R&D expenditures reported in manufacturing are used to create brand-new products and processes that fall within the guidelines for originality used in the RDCI file, and they also include spending that is used to help adapt technology purchased from others. Some three-quarters of establishments in the 1998 survey reported using R&D for new products, while 56% reported it was used for new processes (Sabourin and Beckstead 1999, p. 55). More relevant to the issue at hand, around 50% of manufacturing establishments that reported R&D expenditures indicated that they were used either for substantially adapting technology acquired from others or for introducing off-the-shelf equipment or process technology. Both types include considerable activities that are not likely to be included in either the novelty or the uncertainty categories that are used in the more traditional definitions of R&D in the *Frascati Manual*. This accords with the finding that less than one-quarter of large manufacturing firms that reported doing R&D in the 2003 survey made claims for tax credits, which would therefore have been included in the RDCI file (Baldwin and Hanel 2003, p. 341). All this suggests that the number of manufacturing firms that benefit from R&D is larger than the number of those that can be found in the tax files. This is borne out by the much-higher rates of reported R&D incidence in the ASM file than in the RDCI file, as reported in Table 2.

The ASM R&D data used here begin in the post-2000 period, when manufacturing establishments were asked to report R&D expenditures. To interpret the R&D data derived from the ASM, it is essential to understand the sample used, the instructions given to the respondents and the nature of the questions.

First, it should be noted that no specific instructions were given in the ASM about what is included in or excluded from the definition of R&D. No attempt was made to restrict the definition to just those projects producing considerable novelty or involving considerable uncertainty, or to just those projects that involved internal expenditures, as in the CRA data that are the foundation of

8. The 2003 survey was conducted at the level of the firm using the Business Register, while the 2009 survey used the plant or establishment level—a finer level of detail. A multi-plant firm is more likely to report performing R&D than an individual plant.

the RDCI file. The reported ASM expenditures should therefore include a broader spectrum of R&D than the payments found in the RDCI file.

Second, respondents to the ASM are generally production units, because the value of manufacturing output is the primary product of the ASM. Auxiliary establishments, such as separate warehouses or R&D units, are not primary producers and are not the focus of the survey. Respondents were instructed that they only had to provide data that were kept in their books.[9] Data on R&D expenditures made elsewhere or in other departments of the firm are not generally available at the plant level and are therefore not likely to be reported.

Third, ASM respondents were asked to report R&D expenditures excluding wages of R&D personnel, which is difficult to do at the plant level, in any case. They were also asked to report totals of all wages all materials, and the amortization of all investments separately from R&D. They were instructed not to worry about reporting if they had to divide up expenditures in a way that was not in keeping with their normal bookkeeping entries to answer a question. Because each of these categories is unlikely to be divided at the level of the establishment in a way that allows the division of expenditures between non-R&D manufacturing activity and R&D activity to be reported, it is unlikely that expenditures in each of these categories (materials or plant and equipment investment) are included in local-plant R&D expenditures. Thus, because wages of R&D personnel are deliberately excluded, and because the other categories are probably excluded based on practicality, this leaves only outside contracts for extramural R&D or extramural expenditures as the residual category that is likely covered by the ASM data. For this reason, this paper refers to the ASM data as basically capturing extramural R&D expenses, but refers to these as extramural ASM expenses to indicate that they are probably broader than the extramural RDCI expenses.[10]

2.2 Data sources

This paper relies on two main data sources: the Annual Survey of Manufactures (ASM) and the Research and Development in Canadian Industries (RDCI) file.

The ASM contains key variables such as the value of sales, exports, the country of control and industry affiliation, as well as expenditures on what is described here as extramural R&D. The ASM is made into a longitudinal database that tracks manufacturing firms from 2000 to 2011 by aggregating commonly owned establishments into enterprises.[11] This serves as the basis for this analysis of export-market participation and innovation in Canadian manufacturing.

The ASM underwent a significant redesign in 2004, in part to reduce the response burden on small firms. As a result, the smallest 10% of firms by North American Industry Classification System (NAICS) code and geography were dropped from the sample from 2004 onwards and replaced with data from tax or aggregate records, or imputed data. This paper analyzes microdata from after 2004 without these imputed records to have a consistent file.

9. The reporting guide for the questionnaire notes in its instructions for expenses that “this section is organized to easily record your costs/expenses according to your normal accounting practices.” (Statistics Canada 2005, p. 7). It is recognized that narrow manufacturing expenses may differ from broader expenses that include sales costs or R&D, and the firm is told not to try and separate these two if their books do not allow for this.
10. As noted below, when data on extramural expenditures from the RDCI file and from the ASM are reported for the same firm, they are similar.
11. These enterprises may be defined at a slightly lower level than legal entities, because they consist only of commonly owned establishments in manufacturing. A legal entity may include both manufacturing establishments and service establishments.

Two types of R&D activities are included in the analysis: intramural and extramural. The ASM provides what—it will be argued—are basically extramural R&D expenditures.[12] The RDCI file contains information on both intramural and extramural R&D.

R&D information for all plants is available in the ASM after 2004. Prior to 2004, smaller manufacturing firms received a short-form survey questionnaire that mainly contained questions about major financial variables, but not R&D, while the larger firms received a longer, more detailed one that included a question on R&D. In 2004, all firms received one detailed form. Therefore, ASM R&D data are available from 2004 to 2011 on a consistent basis for both small and large firms. This allows for analysis of the relationship between entry into export markets and R&D expenditures for the entire last half of the first decade of the 2000s. These years correspond to a rapid increase in the Canada–U.S. exchange rate and a decline in the competitiveness of the manufacturing sector. The database that is used to examine how R&D responds to entry into export markets contains some 17,000 observations, with 15,700 non-exporters and 2,000 new exporters over the period from 2004 to 2009. Some 11% of the non-exporter population entered the export market over the period, and this provides the population investigated here.

Intramural and extramural R&D are available from the RDCI database from 2000 to 2009. This paper focuses on manufacturing-sector firms in the RDCI file that have either internal or external R&D expenditures (external R&D includes contracted expenditures made both inside and outside Canada). The RDCI data cover the years 2000 to 2009 and are at the enterprise level.[13]

To facilitate analysis across the datasets and to have a more easily interpretable statistical unit, all data are aggregated and linked at the firm or business-enterprise level (see the Appendix [Subsection 7.1]). To better understand the two R&D data sources, Table 1 compares the R&D estimates derived from the ASM and the RDCI file. In the table, firms are classified into four categories: firms that report extramural R&D in both the ASM and the RDCI file, firms that report neither, firms that report extramural R&D in the ASM but not in the RDCI file, and firms that report extramural R&D in the RDCI file but not in the ASM. For those firms that report extramural R&D in both the ASM and the RDCI file, the amount of R&D in the former is slightly larger than in the latter. This accords with the hypothesis that the R&D reported in the ASM is primarily extramural. In addition, firms that report R&D RDCI data in the linked ASM–RDCI database are typically larger firms: they have much higher employment, shipments and exports.

3 The dimensions of innovation

3.1 The research and development profile of Canadian manufacturing firms

The majority of Canadian manufacturing firms report R&D expenditures in the ASM. On average, 73% of manufacturing firms report the purchase of R&D services between 2004 and 2009.[14] The R&D expenditures of these firms are around 0.5% of their total sales, on average (Table 2).

R&D performed within firms and R&D contracted out to other organizations are also compared using the linked RDCI dataset (Table 2). Between 2004 and 2009, manufacturing firms in the

12. While the expenditures may also include a small amount for materials that are purchased for the R&D operations, this is unlikely because of bookkeeping requirements, as argued above.
13. The enterprise in the RDCI file is sometimes defined at a slightly higher level than it is in the data from the ASM, since the former may include in its definition of a manufacturing firm the operations from other industries.
14. The proportion of firms is calculated as the ratio of firms with positive R&D to the total number of firms.

RDCI file are more likely to perform intramural R&D (25%) than to contract it out (12%), and to spend more of their sales revenue on intramural R&D (1.9%) than on extramural R&D (0.4%).

3.2 Research and development profile by export status

The probability of R&D spending is higher for exporters than non-exporters. Some 75% of exporters report R&D expenditures in the ASM between 2004 and 2009, compared with 70% of non-exporters. This difference also holds true when looking at the larger firms that report R&D in the RDCI file over the same time period. Some 33% of exporters report intramural RDCI R&D, and 16% report extramural RDCI R&D, compared with 17% and 7% of non-exporters, respectively (Table 2).

The average ratio of extramural R&D to sales in the Canadian manufacturing sector is higher for non-exporters than for exporters in the ASM between 2004 and 2009: 0.7% versus 0.5%, respectively. This is also the case for the larger firms that report extramural and intramural R&D in the RDCI file: 0.5% for extramural R&D and 2.0% for intramural R&D for non-exporters, compared with 0.4% and 1.9% for exporters, respectively (Table 2). These differences are not as large as the differences in the probability of conducting R&D.

3.3 Research and development profile by industrial sector

There are considerable differences in the probability and the intensity of R&D spending across sectors. Manufacturing industries are classified into five groups: natural resources, labour intensive, scale based, product differentiated and science based.[15] The probability and the intensity of R&D is highest in science-based industries, followed by the product-differentiated sector. In science-based industries, 84% of firms report having purchased R&D in the ASM, and 26% and 49% of firms report extramural and intramural R&D, respectively, in the linked RDCI file. This compares with the average of 73%, 12% and 25%, respectively (Table 2 and Appendix Charts 1 and 2).

The differences are similar if calculated in terms of R&D expenditures as a percentage of sales. The science-based sectors have the highest intensity: 2.7% in the ASM, and 1.4% for extramural R&D and 9.0% for intramural R&D in the linked RDCI file. The average intensity for all industries is 0.5%, 0.4% and 1.9%, respectively (Table 2).

3.4 Research and development profile by other firm characteristics

The R&D profile also differs by other firm characteristics, such as size, age and country of control. To examine how R&D spending varies with firm characteristics, the following regression was estimated with each of the firm characteristics as the dependent variable:

$$Z_{f,t} = f\left(R_{f,t}\right), \quad (1)$$

where $Z_{f,t}$ stands for a set of firm characteristics for firm f at time t that includes a measure of labour productivity (the logged value of sales per worker), a measure of size (the logged value of employment), a measure of maturity (the logged value of age) and a dummy variable for foreign control. $R_{f,t}$ stands for either an R&D dummy variable for the existence of any R&D or for R&D intensity measured as the ratio of R&D to sales for firm f in year t. A probit model is used for the case where foreign control is the dependent variable. All regressions control for the effects of

15. Baldwin and Rafiquzzaman (1994) provide further information on this taxonomy.

year and industry (three-digit code of the North American Industry Classification System [NAICS]), as well as employment size, except for the employment characteristics regression.

Mean differences on pooled cross-sectional data over the 2004-to-2009 period are reported in Table 3. Compared with firms with no R&D spending, firms with R&D spending are more likely to be domestically owned and to be more productive in terms of sales per worker. The marginal effect on foreign control is from -0.01 to -0.02, statistically different at 1% level. Firms that report R&D in the ASM are on average 10% more productive than firms of similar size (after controlling for the level of employment) that do not. For the larger firms in the linked RDCI dataset, firms that have extramural or intramural R&D are on average 8% and 6% more productive, respectively, than firms that do not, after correcting for size.

Firms that report R&D in the ASM are 60% smaller than firms that do not. Compared with all manufacturing firms in the ASM, firms that report extramural or intramural R&D in the RDCI file are, respectively, 97% and 85% larger. This again confirms the findings in Table 1 that firms in the RDCI data file are much larger. And, this suggests that it is primarily the smaller firms that report the type of expenditures that are captured in the ASM—occasional activity or activity that is contracted out to contribute to an important but less dramatic innovation agenda.

Among firms of similar size, younger firms are more likely to contract out R&D (extramural R&D), while older firms are more likely to perform R&D within the firm (intramural R&D).

Among firms that have positive R&D spending, those with higher R&D intensity tend to have lower labour productivity and to be smaller and younger, after allowing for differences in employment.[16]

4 Dynamics of research and development strategies and export decisions

The subsequent analysis investigates whether R&D expenditures adjust to entry into export markets. It begins with a straightforward graphical depiction of change in R&D intensity, followed by multivariate analysis that tests for significance in the relationships.

Measuring entry into export markets is based on a four-year window, where the exporting status of a firm is defined according to its exporting activity over four years. A firm is defined as an export starter if it exports neither in the first year nor in the second year, but starts to export in the third year and continues exporting in the fourth year. A firm is defined as a continuing non-exporter if it has no exports in all four years. The main advantage of using the four-year rule is that it distinguishes short-lived or transient exporters from entrants that export more permanently—that is, firms that export for only one period, versus entrants that continue to export. The disadvantage is that it slightly reduces the degree of freedom for testing hypotheses.

Because data coverage for R&D spending differs between the ASM and the RDCI file, the analysis focuses on four-year intervals from 2004 to 2011 when using ASM R&D data, and on four-year intervals from 2000 to 2009 when using the linked RDCI data. This results in five cohorts for the former and seven cohorts for the latter.

Appendix Charts 3(a) and 3(b) plot the average R&D intensity of export starters relative to that of non-exporters across cohorts over the four-year period, where R&D intensity is measured as total R&D expenditures divided by total sales. The charts show that firms self-select into R&D and export markets. Non-exporting firms that subsequently enter export markets have more intensive R&D expenditures before entry. For example, the R&D purchase intensity in the ASM for entrants,

16. Drawing conclusions about causal effects requires a more complex multivariate analysis that is not pursued here.

averaged across all cohorts, is 1.4 times higher than that of non-exporters in year 1 and year 2 prior to entry. Similarly, for the larger firms in the RDCI data file, the intensity of contracted-out extramural R&D is 2.7 and 3.0 times higher for exporters in year 1 and year 2 prior to entry, respectively, and the in-house intramural R&D intensity is 2.5 and 2.4 times higher, respectively (Table 4).

Beginning to export is associated with an immediate increase in extramural R&D intensity, as reported by the generally smaller firms in the ASM, but with less change for the larger firms reporting R&D in the RDCI file (Table 4). To make the data sources more comparable and to remove possible different-cohort effects, Table 5 recalculates the R&D intensity for common cohorts between 2004 and 2009. It shows that there is an increase in R&D intensity in the year of entry into export markets, whether in terms of extramural R&D intensity in the ASM (24% increase), or extramural and intramural R&D intensity in the linked RDCI file (8% increase for each type). The extramural R&D intensity derived from the ASM experienced a further increase (4%) one year after entry. For the larger firms in the RDCI file, the intensity for extramural R&D dropped by 39% one year after entry, but the intensity for intramural R&D experienced a further increase of 3% one year after entry.

The following section examines the relationship between exporting and R&D using multivariate analysis. It answers two questions: are export starters more likely to have higher initial R&D spending, and, in the short run, does exporting subsequently raise in a significant way the incidence of R&D investment and the growth in R&D intensity, compared with non-exporters? To make results comparable across data sources, three samples of continuing plants are pooled over four-year durations—2004 to 2007, 2005 to 2008 and 2006 to 2009. The samples are restricted to export entrants and their comparison group, continuing non-exporters.

4.1 Impacts of research and development on export-market participation

The model that is used to estimate the probability of beginning to export for all non-exporters is the following:

$$\Pr\left(X_f = 1\right) = \varnothing\left(R_{f,pre}, Z_{f,pre}\right), \tag{2}$$

where $\varnothing$ is the normal cumulative distribution. X_f is a dummy variable that indicates whether firm f is an export entrant or not. It equals 1 if a firm exports neither in the first year nor in the second year, but begins exporting in the third year and continues exporting in the fourth year; it equals 0 if a firm has no exports in all four years. $R_{f,pre}$ represents the incidence and the relative intensity of the R&D investment of firm f prior to entry. R&D incidence is represented by a dummy variable that equals 1 if there are R&D expenditures in either of the first two years, and 0 otherwise. The average relative R&D intensity is measured as total R&D expenditures per dollar of shipments of a firm, relative to the NAICS four-digit-industry average, over the first two years. The vector $Z_{f,pre}$ contains initial firm characteristics that may also influence the decision to subsequently enter export markets. They include a foreign-ownership dummy variable, the age of the firm, the relative labour productivity, and the relative size of employment. Each of these is a proxy for the competencies that are hypothesized to be associated with greater efficiency. According to Melitz, this efficiency would have an influence on whether the costs of a firm are low enough to lead it to begin exporting in response to events that shift the desirability of entering export markets. Relative labour productivity and relative employment are measured as total shipments per worker and total employment for the firm relative to the NAICS four-digit-industry average, respectively, over the first two years.

The probit model controls for three-digit-industry-specific and cohort-specific fixed effects. The marginal effects derived from Equation (2) are reported in Table 6. Columns 1 to 3 report results for each of the three R&D types separately, and Columns 4 and 5 report the joint effects of extramural and intramural R&D on the probability of non-exporters becoming exporters. There are three key findings.

First, younger, larger and more productive firms are more likely to enter export markets. This is indicated by statistically significant marginal effects. This is the standard productivity self-selection effect. Nationality is not a factor in determining whether non-exporters will enter export markets, probably because most non-exporters are domestic firms.

Second, in addition to the standard positive productivity self-selection effects relating to productivity and size, firms that have invested in R&D of any type are more likely to subsequently begin exporting than firms that do not have any initial R&D spending. At the margin, an average firm reporting R&D in the ASM (generally a smaller firm) has a likelihood of exporting that is 5 percentage points greater than that of a firm without R&D.[17] An average firm reporting extramural or intramural R&D in the RDCI file (generally a larger firm) is, at the margin, 2 to 3 percentage points more likely to export than a firm without R&D, statistically significant at the 1% level for intramural R&D (columns 3 to 5 of Table 6) and in 2 out of 3 cases for extramural R&D (columns 2, 5, 6 of Table 6).[18]

Third, the intensity of R&D spending does not have any significant effect on subsequent export behaviour, as the marginal effect of R&D intensity relative to the industry average is statistically insignificant.

In conclusion, firms that invest in all three types of R&D that are measured here increase their ability to penetrate export markets. It is the tendency, not the intensity, that matters.

4.2 Impacts of export-market participation on research and development

The close relationship between R&D and exporting is further bolstered by a tendency for new exporters to subsequently continue to invest in R&D and increase R&D intensity relative to non-exporters, at least in the short run.

4.2.1 Impacts of export-market participation on research and development incidence

To investigate this issue, the probability of firms investing in extramural or intramural R&D after entry into export markets $(D_{f,post})$ is estimated as a function of a dummy variable indicating whether firm f is an export entrant or not (X_f), a vector of pre-entry R&D status $(D_{f,pre})$ and a vector of initial firm characteristics prior to entry $(Z_{f,pre})$, as follows:

17. An alternate measure of experimental development R&D, defined as ASM R&D minus RDCI extramural R&D, was also highly significant.
18. Column 5 of Table 6 reports the joint effect of extramural and intramural R&D dummies in the RDCI data file on the probability of entering into the export market. The coefficient on the extramural R&D dummy is no longer significant, while that on the intramural R&D dummy remains statistically significant. This could be because extramural and intramural R&D undertakings are highly correlated in the RDCI file, with a correlation coefficient of 0.65.

$$\Pr\left(D_{f,post}=1\right)=\varnothing\left(X_f,D_{f,pre},Z_{f,pre}\right), \tag{3}$$

where $D_{f,post}$ is an R&D dummy variable that equals 1 if there are R&D expenditures in either the third year or the fourth year of the post-entry period and that equals 0 if there are no R&D expenditures in these years. $D_{f,pre}$ is an R&D dummy variable that equals 1 if there are R&D expenditures in either the first year or the second year of the pre-entry period and that equals 0 if there are no R&D expenditures in these years. The export-entrant dummy variable X_f and all other variables are defined as in Equation (2). The probit regression controls for NAICS three-digit-industry and cohort fixed effects. Table 7 reports the marginal effects of each covariate on the probability of post-entry investment in R&D.

Entry into export markets has a significant and positive impact on the probability that firms subsequently invest in R&D, independent of the type of R&D (Table 7). Upon entry into export markets, manufacturing firms reporting extramural R&D in the ASM (generally smaller firms) are, at the margin, 7 percentage points more likely to purchase R&D, compared with continuing non-exporters. Upon entry into export markets, the firms in the linked RDCI file (generally larger firms) are, at the margin, 1 to 2 percentage points more likely than non-exporters to contract out R&D, and 4 percentage points more likely to perform intramural R&D (Columns 1 to 7 of Table 7).

Because of the continuity in firm strategies, a significant predictor of the likelihood of future R&D investment by a firm is its past R&D spending. For all manufacturing firms in the ASM, the probability of R&D spending by a firm in the post-entry period increases by 55 percentage points at the margin if it also has R&D spending in the pre-entry period. This is also true for firms reporting R&D in the RDCI file: the probability of expenditures on extramural R&D and intramural R&D increases by 19 and 52 percentage points at the margin, respectively (Columns 1 to 3 of Table 7).

There is also a complementarity between extramural and intramural R&D derived from the RDCI file. Firms with extramural R&D expenditures in the pre-entry period, whether they are for the type of R&D reported in the ASM or the type reported in the RDCI file, are more likely to subsequently conduct intramural R&D as reported in the RDCI file (Columns 6 and 7 of Table 7). And, vice versa, firms with intramural R&D expenditures in the pre-entry period are more likely to subsequently perform extramural R&D (Columns 4 and 5 of Table 7). This accords with the previous finding that the two sources of R&D are so closely related that their impact on entry into export markets cannot be separated.

4.2.2 Impacts of export-market participation on research and development intensity

Entry into export markets may also affect the intensity of R&D investment. The descriptive results in the previous section show that export entrants have a large increase in R&D intensity in the year of entry, but do not have much of an acceleration in the growth of R&D intensity in the years after entry, when compared with R&D intensity in the pre-entry period. To test this more formally, the following two equations are estimated:

$$\Delta I_f = I_{f,post} - I_{f,pre} = f\left(X_f, I_{f,pre}, Z_{f,pre}\right) \tag{4}$$

$$d\left(\Delta I_f\right) = \Delta I_{f,post} - \Delta I_{f,pre} = f\left(X_f, I_{f,pre}, Z_{f,pre}\right), \tag{5}$$

where ΔI_f stands for the growth rate of R&D intensity, measured as the difference between the average R&D intensity after entry in years 3 and 4 $(I_{f,post})$ and the average R&D intensity before entry in years 1 and 2 $(I_{f,pre})$. Change in the growth rate of R&D intensity $(d(\Delta I_f))$ is measured as the difference between the post-entry growth rate of R&D intensity in years 3 and 4 $(\Delta I_{f,post})$ and the pre-entry growth rate of R&D intensity in years 1 and 2 $(\Delta I_{f,pre})$.

Equations (4) and (5) compare the level and the growth of R&D intensity before and after entry across export entrants and continuing non-exporters to assess whether export entrants increase the level and growth of their R&D intensity relative to the group of non-exporters to which they belonged before entry. Besides the export-entrant dummy variable (X_f), the comparison also controls for firm differences in initial R&D intensity $(I_{f,pre})$ and firm characteristics $(Z_{f,pre})$, as well as NAICS three-digit-industry and cohort fixed effects. Two main findings emerge from the results (Table 8).

First, for firms reporting extramural R&D in the ASM (generally smaller firms), export entrants experience a larger increase in the level of extramural R&D intensity between the pre-entry and post-entry periods, compared with non-exporters. The increase in extramural ASM R&D intensity is 6.0 percentage points higher for firms that entered export markets than for those that did not (Column 1 of Table 8). For firms reporting RDCI R&D (generally larger firms), becoming an exporter does not increase R&D intensity, whether it is contracted out or done in-house (Columns 2 and 3 of Table 8).

The greater impact of entering export markets on small firms is confirmed in Table 9, where the ASM sample is divided into large and small firms (large firms have more than 100 employees). It shows that becoming an exporter increases the purchased R&D intensity for small firms, but not for large ones (Table 9).

Second, firms that begin with higher R&D intensity tend to have a slower subsequent increase in R&D intensity. For firms reporting positive pre-entry R&D purchases in the ASM, the initial level of R&D intensity has a negative and significant impact on the change in R&D intensity between the periods before and after entry (with a coefficient of -0.037), indicating that reversion to the mean takes place. The same reversion to the mean is observed for the larger firms that contract out R&D or perform in-house R&D, as reported in the RDCI file, with coefficients of -0.022 and -0.182, respectively (Columns 2 and 3 of Table 8).

Results for the changes in growth of R&D intensity tend not to be significant. Entry into export markets does not have a significant impact on the change in growth rates of R&D (Columns 4 to 6 of Table 8).

5 Conclusion

Previous studies have reported that, in Canada, it is the more productive firms that enter export markets, and they have found that becoming an exporter, in turn, raises productivity. Productivity is the revealed manifestation of certain competencies or capacities that are associated with success in the export market, whether they are developed before entry or while exporting.

This paper examines in depth one of the possible mechanisms used to develop these competencies: research and development (R&D) expenditures. It asks whether different forms of R&D drive the level of competitiveness required to successfully enter export markets and whether, in turn, participation in export markets has an immediate impact on the emphasis placed on innovation, via R&D expenditures.

R&D can be done within firms (intramural R&D) or contracted out (extramural R&D). The majority of Canadian manufacturing firms (73%), typically smaller firms, report doing R&D of a type that is not reported to the tax authorities as either extramural or intramural expenditures. For firms that do report to tax authorities (typically larger firms), more firms engage in intramural R&D (25%) than extramural R&D (12%), and the intensity of intramural R&D is five times higher than that of extramural R&D. This makes intramural R&D the dominant source of R&D expenditures for large firms in the Canadian manufacturing sector. In addition, firms with R&D expenditures, whether intramural or extramural, are more likely to be exporters and in science-based or product-differentiated sectors.

Firms self-select into R&D and export markets. Non-exporters that subsequently enter export markets are not only larger and more productive, as is often reported in the literature, but also more likely to have invested in R&D. The existence of both extramural and intramural expenditures in a firm increases its ability to penetrate export markets. Even after controlling for differences in R&D, the pre-entry productivity level is still an important determinant of the subsequent entry of firms into export markets. This suggests that there are competencies besides R&D that contribute to the differences between firms in pre-entry productivity levels and that facilitate entry into export markets.

Exporting increases the likelihood that firms will subsequently invest in all types of R&D, whether intramural or extramural, immediately after entry into export markets. Entry into export markets is also associated with an immediate increase in the intensity of R&D, but only in the types of extramural expenditures that are generally reported in small firms. Immediately upon entry into export markets (in the same year as entry), R&D intensity increases for export starters relative to their non-exporting counterparts, and remains at this high level in the period after entry. This one-time relative increase points to evidence of simultaneous strategies—movement into export markets and the adoption of a more intense R&D strategy.

There is a complementarity between the type of extramural and intramural R&D. Firms with extramural R&D expenditures in the pre-entry period are more likely to subsequently conduct intramural R&D. And, vice versa, firms with intramural R&D expenditures in the pre-entry period are more likely to subsequently perform extramural R&D.

In conclusion, innovation associated with R&D is a key factor that increases the probability of firms entering export markets. These impacts extend from the type of R&D that qualifies for tax deductions because of its originality to the expenditures that make more marginal improvements to products and processes that are more common in smaller firms. These competencies are in turn further expanded in smaller firms at the time of entry, as new exporters increase the intensity of their extramural R&D. Exporting also increases the likelihood that firms, small or large, will subsequently invest in R&D, whether intramural or extramural.

6 Tables

Table 1
Comparison of three R&D measures from the linked micro-data bases, Canadian manufacturing sector, 2004 to 2009

	Average size				Average R&D expenditure per firm			Average R&D intensity per shipment		
Linkage category[1]	**Proportion of firms**	**Employment per firm**	**Shipments per firm**	**Exports per firm**	**Extramural R&D, using ASM data**	**Extramural R&D, using linked RDCI data**	**Intramural R&D, using linked RDCI data**	**Extramural R&D, using ASM data**	**Extramural R&D, using linked RDCI data**	**Intramural R&D, using linked RDCI data**
	percent	units	millions			thousands			percent	
ASM = No; RDCI = No	24.53	58	18	5	…	…	49	0.000	0.000	0.280
ASM = No; RDCI = Yes	2.71	194	105	49	…	221	1,424	0.000	0.210	1.360
ASM = Yes; RDCI = No	63.90	35	10	3	41	…	61	0.400	0.000	0.600
ASM = Yes; RDCI = Yes	8.86	151	66	23	433	330	1,405	0.650	0.500	2.120
Average	…	110	50	20	118	138	735	0.260	0.180	1.090

… not applicable

1. The linkage category is based on the availability of extramural research and development (R&D) expenditures in the linked ASM–RDCI datasets.

Note: The linked dataset uses the Annual Survey of Manufactures (ASM) as the base data, supplemented by R&D information from the Research and Development in Canadian Industry (RDCI) file. The ASM contains information on extramural R&D (purchased from domestic and foreign suppliers), while the RDCI file has information on both extramural and intramural R&D (performed in-house).

Sources: Statistics Canada, Annual Survey of Manufactures and Research and Development in Canadian Industry databases.

Table 2
R&D expenditure, Canadian manufacturing firms, 2004 to 2009

	Extramural R&D from ASM	Extramural R&D from RDCI	Intramural R&D from RDCI
		percent	
Proportion of firms with R&D expenditure			
All firms	**72.91**	**11.58**	**25.01**
By export status			
Non-exporters	70.43	6.89	16.69
Exporters	75.17	15.91	32.69
By industrial sectors			
Natural resources	70.52	9.76	20.59
Labour intensive	68.61	7.82	18.28
Scale based	72.77	10.92	23.52
Product differentiated	78.69	15.26	34.23
Science based	84.44	25.89	48.76
R&D intensity			
All firms	**0.52**	**0.40**	**1.92**
By export status			
Non-exporters	0.65	0.53	2.02
Exporters	0.51	0.39	1.91
By industrial sectors			
Natural resources	0.10	0.17	0.71
Labour intensive	0.34	0.29	1.75
Scale based	0.18	0.38	0.84
Product differentiated	1.11	0.49	3.08
Science based	2.66	1.39	8.66

Notes: The proportion is calculated as the ratio of firms with positive research and development (R&D) spending to the total number of firms in the ASM. Extramural R&D is purchased from domestic and foreign suppliers. Intramural R&D is performed in-house.
Sources: Statistics Canada, Annual Survey of Manufactures (ASM) and Research and Development in Canadian Industry (RDCI) databases.

Table 3
Differences in characteristics between firms with and without R&D, 2004 to 2009

Firm characteristics (dependent variables)	Independent variables					
	R&D dummy[1]			R&D intensity for firms with positive R&D		
	Extramural R&D, using ASM data	Extramural R&D, using linked RDCI data	Intramural R&D, using linked RDCI data	Extramural R&D, using ASM data	Extramural R&D, using linked RDCI data	Intramural R&D, using linked RDCI data
	units					
Log of sales per worker	0.102 **	0.083 **	0.058 **	-4.675 **	-1.395 **	-1.298 **
Log of employment	-0.597 **	0.968 **	0.849 **	0.002 **	-8.326 **	-4.449 **
Log of age	0.008	-0.014 **	0.040 **	-0.618 **	-1.079 **	-0.627 **
Foreign control	-0.010 **	-0.013 **	-0.017 **	-0.030 **	0.124 **	0.012

** significantly different from reference category ($p < 0.01$)

1. The research and development (R&D) dummy equals 1 for firms with positive R&D, equals 0 otherwise

Notes: All regressions control for year and industry (North American Industry Classification System three-digit code) fixed effects, as wells as employment size (except when the dependent variable is employment). Regressions for foreign control are based on probit models. Where the R&D dummy equals 1 for firms with positive R&D and 0 otherwise, the number of observations for extramural R&D (R&D purchased from domestic and foreign suppliers) using data from the Annual Survey of Manufactures (ASM), for extramural R&D using linked data from the Research and Development in Canadian Industry (RCDI) database and for intramural R&D (R&D performed in-house) using linked RDCI data is 168,424. For the R&D intensity for firms with positive R&D, the number of observations for extramural R&D using ASM data is 121,644 to 122,544, it is 19,410 to 19,486 for extramural R&D using linked RDCI data and 42,106 to 42,314 for intramural R&D using linked RDCI data.

Sources: Statistics Canada, Annual Survey of Manufactures and Research and Development in Canadian Industry databases.

Table 4
R&D intensity of export starters relative to non-exporters, averages over all cohorts, 2000 to 2011

	Before entry into export markets		After entry into export markets	
	Year 1	Year 2	Year 3	Year 4
	units			
Extramural R&D, using ASM data				
Extramural R&D intensity, export starters relative to non-exporters	1.38	1.40	2.20	2.07
Growth of relative extramural intensity	…	0.02	0.45	-0.06
Extramural R&D, using linked RDCI data				
Extramural R&D intensity, export starters relative to non-exporters	2.69	2.98	2.47	2.19
Growth of relative extramural intensity	…	0.10	-0.19	-0.12
Intramural R&D, using linked RDCI data				
Intramural R&D intensity, export starters relative to non-exporters	2.47	2.41	2.30	2.37
Growth of relative intramural intensity	…	-0.03	-0.05	0.03

… not applicable

Notes: Extramural research and development (R&D) is R&D purchased from domestic and foreign suppliers. Intramural R&D is R&D performed in-house. The growth rate is calculated as the log difference of a variable between the current and previous year.

Sources: Statistics Canada, Annual Survey of Manufactures (ASM) and Research and Development in Canadian Industry (RDCI) databases.

Table 5
R&D intensity of export starters relative to non-exporters, averages over all cohorts, 2004 to 2009

	Before entry into export markets		After entry into export markets	
	Year 1	Year 2	Year 3	Year 4
	units			
Extramural R&D, using ASM data				
Extramural R&D intensity, export starters relative to non-exporters	1.12	1.22	1.55	1.61
Growth of relative extramural intensity	…	0.09	0.24	0.04
Extramural R&D, using linked RDCI data				
Extramural R&D intensity, export starters relative to non-exporters	1.70	1.91	2.06	1.40
Growth of relative extramural intensity	…	0.12	0.08	-0.39
Intramural R&D, using linked RDCI data				
Intramural R&D intensity, export starters relative to non-exporters	1.80	1.58	1.71	1.75
Growth of relative intramural intensity	…	-0.13	0.08	0.03

… not applicable

Notes: Extramural research and development (R&D) is R&D purchased from domestic and foreign suppliers. Intramural R&D is R&D performed in-house. The growth rate is calculated as the log difference of a variable between the current and previous year.

Sources: Statistics Canada, Annual Survey of Manufactures (ASM) and Research and Development in Canadian Industry (RDCI) databases.

Table 6
Marginal effects of R&D on subsequent export participation

Explanatory variables, prior to entry into export markets	Dependent variable, export entry (marginal effects, Equation [2])					
	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
Extramural R&D dummy, using ASM data						
Coefficient	0.052 **	…	…	0.051 **	…	0.049 **
Standard error	0.005	…	…	0.005	…	0.005
Extramural R&D dummy, using RDCI data						
Coefficient	…	0.028 **	…	…	0.012	0.025 **
Standard error	…	0.007	…	…	0.009	0.007
Intramural R&D dummy, using RDCI data						
Coefficient	…	…	0.026 **	0.024 **	0.020 **	…
Standard error	…	…	0.006	0.006	0.007	…
Relative extramural R&D intensity, using ASM data						
Coefficient	0.000	…	…	-0.000	…	0.000
Standard error	0.001	…	…	0.001	…	0.001
Relative extramural R&D intensity, using RDCI data						
Coefficient	…	-0.001	…	…	-0.001	-0.001
Standard error	…	0.000	…	…	0.000	0.000
Relative intramural R&D intensity, using RDCI data						
Coefficient	…	…	-0.000	-0.000	0.000	…
Standard error	…	…	0.001	0.001	0.001	…
Foreign-owned						
Coefficient	-0.001	-0.006	-0.003	0.001	-0.005	-0.002
Standard error	0.014	0.014	0.014	0.014	0.014	0.014
Age						
Coefficient	-0.002 **	-0.002 **	-0.002 **	-0.002 **	-0.002 **	-0.002 **
Standard error	0.000	0.000	0.000	0.000	0.000	0.000
Relative labour productivity						
Coefficient	0.011 **	0.010 **	0.011 **	0.011 **	0.010 **	0.009 **
Standard error	0.003	0.003	0.003	0.003	0.003	0.003
Relative employment						
Coefficient	0.008 **	0.006 **	0.005 **	0.007 **	0.005 **	0.007 **
Standard error	0.001	0.001	0.001	0.001	0.001	0.001
Number of observations	17,419	17,101	17,472	17,285	17,101	17,019

… not applicable

** significantly different from reference category ($p < 0.01$)

Notes: All regressions include three-digit industry (from the North American Industry Classification System) and cohort fixed effects. Extramural research and development (R&D) is R&D purchased from domestic and foreign suppliers. Intramural R&D is R&D performed in-house.

Sources: Statistics Canada, Annual Survey of Manufactures (ASM) and Research and Development in Canadian Industry (RDCI) databases.

Table 7
Marginal effects of export-market participation on the probability of subsequent R&D investment

	Marginal effects, Equation (3)						
	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7
Explanatory variables, prior to entry into export markets	**Extramural R&D from ASM**	**Extramural R&D from linked RDCI**	**R&D from linked RDCI**	**Extramural R&D from ASM**	**Extramural R&D from linked RDCI**	**R&D from linked RDCI**	**Intramural R&D from linked RDCI**
Export-starter dummy							
Coefficient	0.074 **	0.018 **	0.039 **	0.069 **	0.013 **	0.038 **	0.036 **
Standard error	0.015	0.005	0.010	0.015	0.004	0.010	0.010
Extramural R&D dummy prior to entry, using ASM data							
Coefficient	0.545 **	…	…	0.543 **	…	…	0.029 **
Standard error	0.009	…	…	0.009	…	…	0.008
Extramural R&D dummy prior to entry, using RDCI data							
Coefficient	…	0.188 **	…	…	0.091 **	0.028 *	…
Standard error	…	0.006	…	…	0.005	0.012	…
Intramural R&D dummy prior to entry, using RDCI data							
Coefficient	…	…	0.524 **	0.070 **	0.088 **	0.511 **	0.522 **
Standard error	…	…	0.009	0.010	0.004	0.010	0.009
Foreign-owned							
Coefficient	-0.059 *	-0.012	-0.046 *	-0.049 †	0.002	-0.047 *	-0.045 *
Standard error	0.027	0.011	0.023	0.027	0.009	0.023	0.023
Age							
Coefficient	-0.000	-0.000	0.001 *	-0.001	-0.000	0.002 *	0.002 **
Standard error	0.001	0.000	0.001	0.001	0.000	0.001	0.001
Relative labour productivity							
Coefficient	0.009	0.003	0.006	0.008	0.004	0.006	0.006
Standard error	0.007	0.003	0.006	0.007	0.002	0.006	0.006
Relative employment							
Coefficient	-0.018 **	0.006 **	0.012 **	-0.020 **	0.004 **	0.012 **	0.014 **
Standard error	0.004	0.001	0.003	0.004	0.001	0.003	0.003
Number of observations	17,636	17,604	17,636	17,636	17,604	17,636	17,636

… not applicable

* significantly different from reference category ($p < 0.05$)

** significantly different from reference category ($p < 0.01$)

† significantly different from reference category ($p < 0.10$)

Notes: All regressions include three-digit industry (from the North American Industry Classification System) and cohort fixed effects, with robust standard errors. Extramural research and development (R&D) is R&D purchased from domestic and foreign suppliers. Intramural R&D is R&D performed in-house.

Sources: Statistics Canada, Annual Survey of Manufactures (ASM) and Research and Development in Canadian Industry (RDCI) databases.

Table 8
Impact of export participation on subsequent R&D intensity

	Growth in R&D intensity (Equation [4])			Change in the growth of R&D intensity (Equation [5])		
	Extramural R&D, using ASM data	Extramural R&D, using linked RDCI data	Intramural R&D, using linked RDCI data	Extramural R&D, using ASM data	Extramural R&D, using linked RDCI data	Intramural R&D, using linked RDCI data
	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
Export-starter dummy						
Coefficient	0.060 **	-0.016	0.002	0.035	-0.050	0.132
Standard error	0.023	0.018	0.061	0.029	0.032	0.115
Extramural R&D dummy, using ASM data						
Coefficient	-0.064 **	…	…	-0.005	…	…
Standard error	0.015	…	…	0.022	…	…
Extramural R&D dummy, using RDCI data						
Coefficient	…	-0.040	…	…	-0.007	…
Standard error	…	0.058	…	…	0.101	…
Intramural R&D dummy, using RDCI data						
Coefficient	…	…	0.450 **	…	…	-0.814 **
Standard error	…	…	0.120	…	…	0.260
Relative extramural R&D intensity, using ASM data						
Coefficient	-0.037 **	…	…	-0.019 †	…	…
Standard error	0.005	…	…	0.012	…	…
Relative extramural R&D intensity, using RDCI data						
Coefficient	…	-0.022 *	…	…	-0.002	…
Standard error	…	0.009	…	…	0.016	…
Relative intramural R&D intensity, using RDCI data						
Coefficient	…	…	-0.182 **	…	…	0.051
Standard error	…	…	0.024	…	…	0.056
Foreign-owned						
Coefficient	-0.034	-0.104	-0.201	-0.005	-0.039	-0.179
Standard error	0.045	0.071	0.019	0.067	0.104	0.289
Age						
Coefficient	0.000	0.001	0.006 *	-0.002	-0.000	-0.001
Standard error	0.001	0.001	0.003	0.002	0.002	0.005
Relative labour productivity						
Coefficient	0.005	0.006	-0.011	0.009	-0.002	-0.022
Standard error	0.008	0.005	0.019	0.014	0.009	0.033
Relative employment						
Coefficient	-0.004	0.009 **	0.004	-0.003	0.001	0.037 *
Standard error	0.003	0.003	0.009	0.005	0.005	0.015
Number of observations	17,419	17,101	17,472	17,419	17,101	17,472
Adjusted R-squared	0.04140	0.04760	0.08720	0.00366	-0.00032	0.00696

… not applicable

* significantly different from reference category ($p < 0.05$)

** significantly different from reference category ($p < 0.01$)

† significantly different from reference category ($p < 0.10$)

Notes: All regressions include three-digit industry (from the North American Industry Classification System) and cohort fixed effects. Extramural research and development (R&D) is R&D purchased from domestic and foreign suppliers. Intramural R&D is R&D performed in-house.

Sources: Statistics Canada, Annual Survey of Manufactures (ASM) and Research and Development in Canadian Industry (RDCI) databases.

Table 9
Impact of export-market participation on subsequent R&D intensity level, by firm size, using ASM data

	Growth of R&D intensity (Equation [4])		Change in the growth of R&D intensity (Equation [5])	
Explanatory variables, prior to entry into export markets	**Small firms**	**Large firms**	**Small firms**	**Large firms**
Export-starter dummy				
Coefficient	0.052 **	0.236	0.043	-0.173
Standard error	0.020	0.247	0.029	0.186
Extramural R&D dummy, using ASM data				
Coefficient	-0.045 **	-0.337 †	-0.009	0.018
Standard error	0.014	0.191	0.022	0.086
Relative extramural R&D intensity, using ASM data				
Coefficient	-0.041 **	0.004	-0.017	-0.043 *
Standard error	0.005	0.010	0.013	0.018
Foreign-owned				
Coefficient	0.026	-0.071	0.015	-0.217
Standard error	0.046	0.173	0.077	0.154
Age				
Coefficient	0.001	-0.005	-0.002	0.003
Standard error	0.001	0.010	0.002	0.007
Relative labour productivity				
Coefficient	0.005	0.030	0.009	0.009
Standard error	0.009	0.041	0.015	0.024
Relative employment				
Coefficient	0.007	-0.004	-0.003	0.003
Standard error	0.006	0.005	0.009	0.006
Number of observations	16,843	576	16,843	576
R-squared	0.048	0.098	0.005	0.059
Adusted R-squared	0.04670	0.05330	0.00361	0.01240

* significantly different from reference category ($p < 0.05$)

** significantly different from reference category ($p < 0.01$)

† significantly different from reference category ($p < 0.10$)

Notes: All regressions include three-digit industry (from the North American Industry Classification System) and cohort fixed effects, with robust standard errors. Extramural research and development (R&D) is R&D purchased from domestic and foreign suppliers. Intramural R&D is R&D performed in-house.

Source: Statistics Canada, Annual Survey of Manufactures (ASM) database.

7 Appendix

7.1 Data linkage

The Annual Survey of Manufactures (ASM) is linked to the Research and Development in Canadian Industry (RDCI) data to help provide an innovation profile of Canadian manufacturing. While the ASM data are at the plant level, the RDCI data are at the level of the nine-digit business number (BN). The BN is a tax concept and not a statistical one. It is a unique identifier, most easily interpretable as an account number, assigned to every business in Canada that is registered with the Canada Revenue Agency. In the simplest case, one BN is associated with one enterprise (firm) and one location (plant). In more complex business structures where firms have more than one plant, one BN may be associated with more than one plant. As such, the RDCI data are at a more aggregate business level than one plant (though, in some cases, the level may be the same as in the ASM). Thus, the statistical level of the BN is more aggregate than a plant, but can be less aggregate than an enterprise. Because performers of R&D are more likely to be larger firms, the RDCI file is likely to contain more multi-plant firms. The ASM and RDCI data are linked by BNs that come from Statistics Canada's Business Register. Details of this linkage are provided in Appendix Table 1.

Appendix Table 1
Linkage of ASM to RDCI database by business number, 2000 to 2009

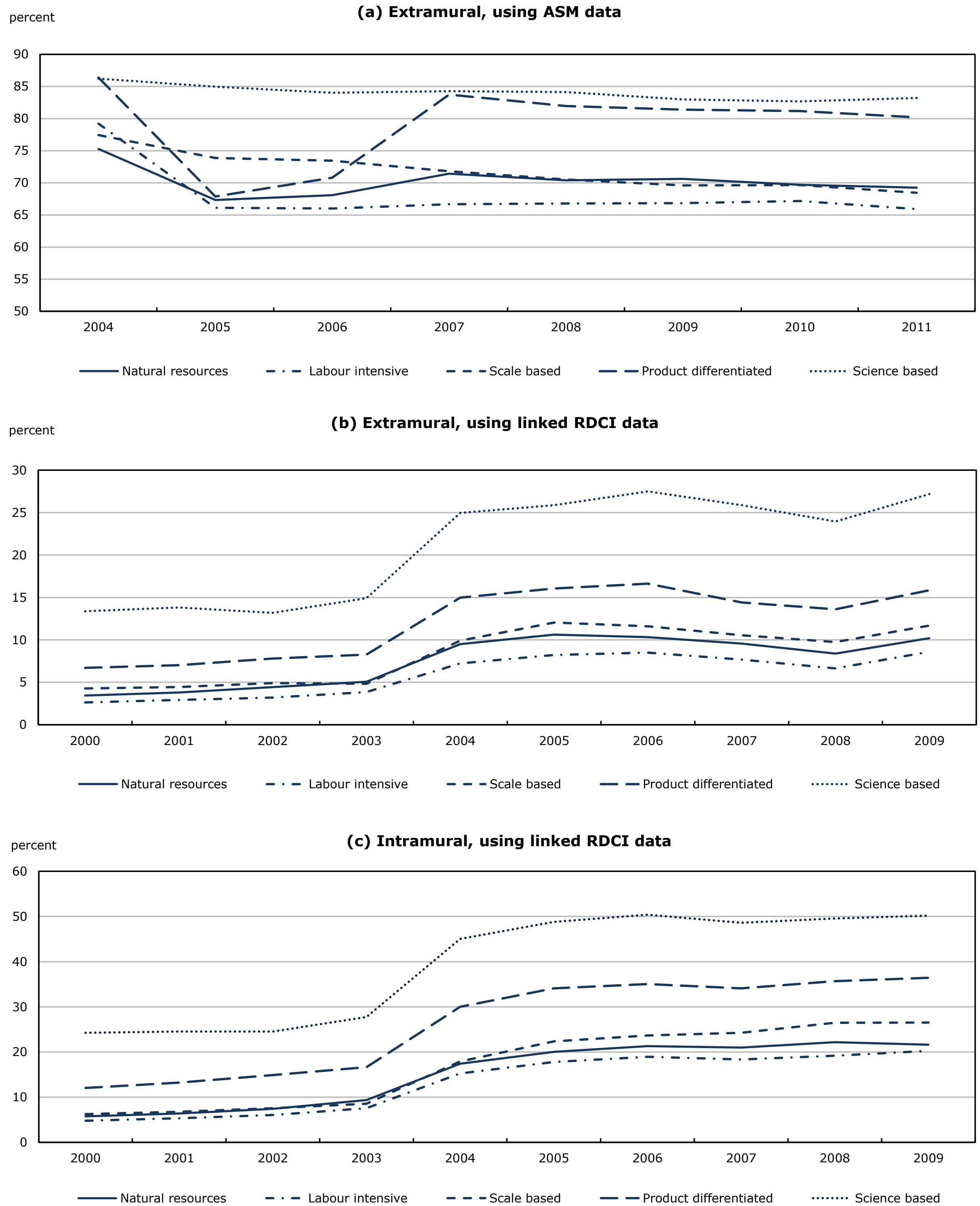
Year	Number of manufacturing businesses (ASM)	Total number of businesses (RDCI)	Number of manufacturing businesses (RDCI)	Overall link to ASM[1]
		number		
2000	52,651	11,408	5,065	5,468
2001	53,316	12,662	5,411	6,007
2002	53,375	13,945	6,032	6,859
2003	53,196	16,442	7,132	8,036
2004	47,719	18,969	8,192	8,693
2005	47,870	20,746	8,921	9,236
2006	48,350	22,003	9,550	9,937
2007	51,993	23,803	9,904	10,093
2008	50,780	25,202	10,218	10,465
2009	48,993	25,685	9,974	10,354

1. In some cases, the number of BNs that link to the Annual Survey of Manufactures (ASM) exceeds the number of BNs considered to be manufacturing businesses in the Research and Development in Canadian Industry (RDCI) file. This is because some BNs not assoicated with manufacturing businesses in the RDCI file link to the ASM (based on North American Industry Classification System codes in the RDCI). These linked businesses are included, because they are considered to be manufacturing businesses by the ASM.

Sources: Statistics Canada, Annual Survey of Manufactures and Research and Development in Canadian Industry databases.

7.2 Charts

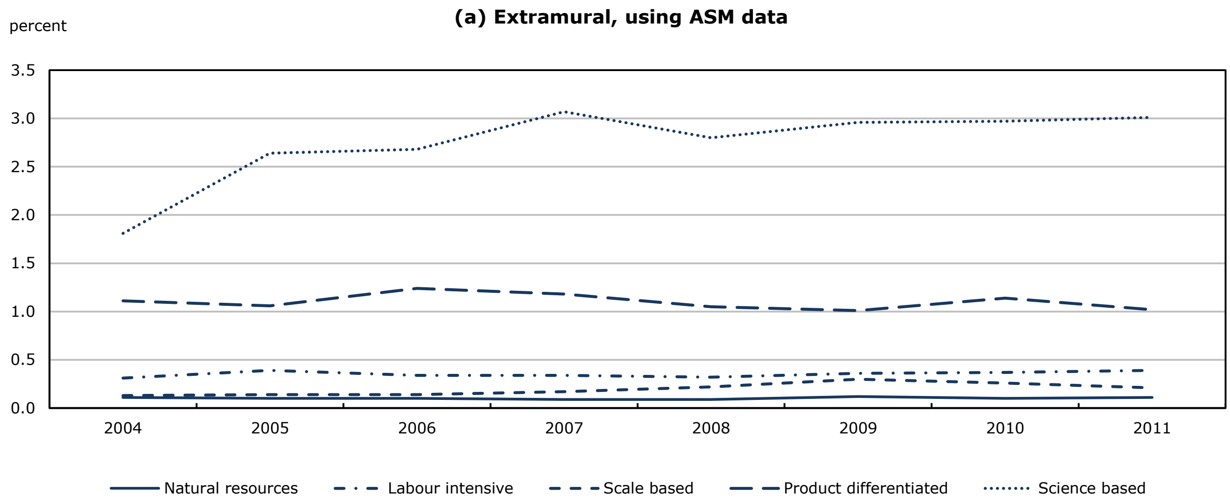
Appendix Chart 1
Proportion of firms with R&D expenditures, by industrial sector

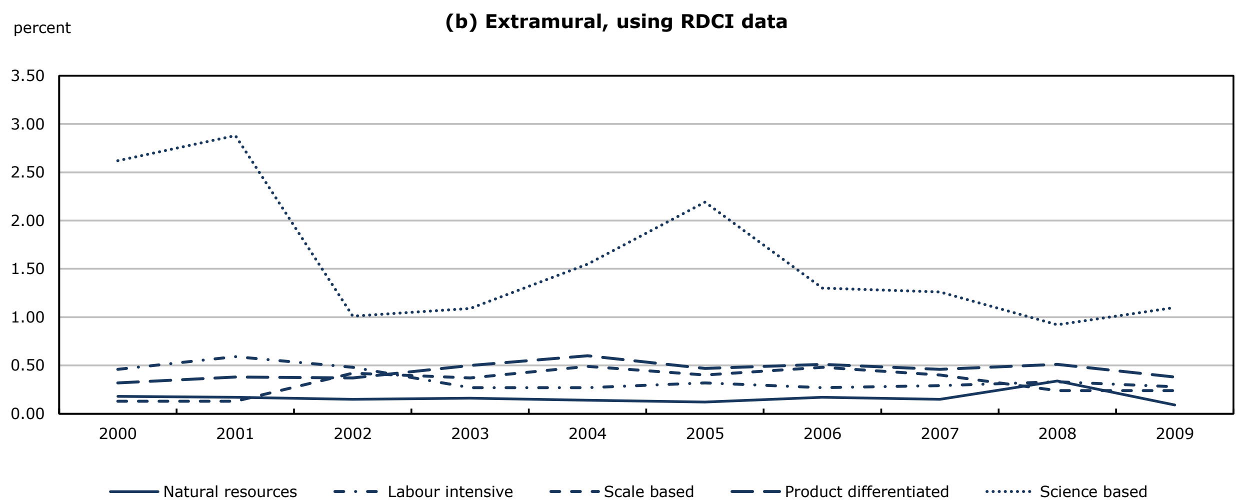


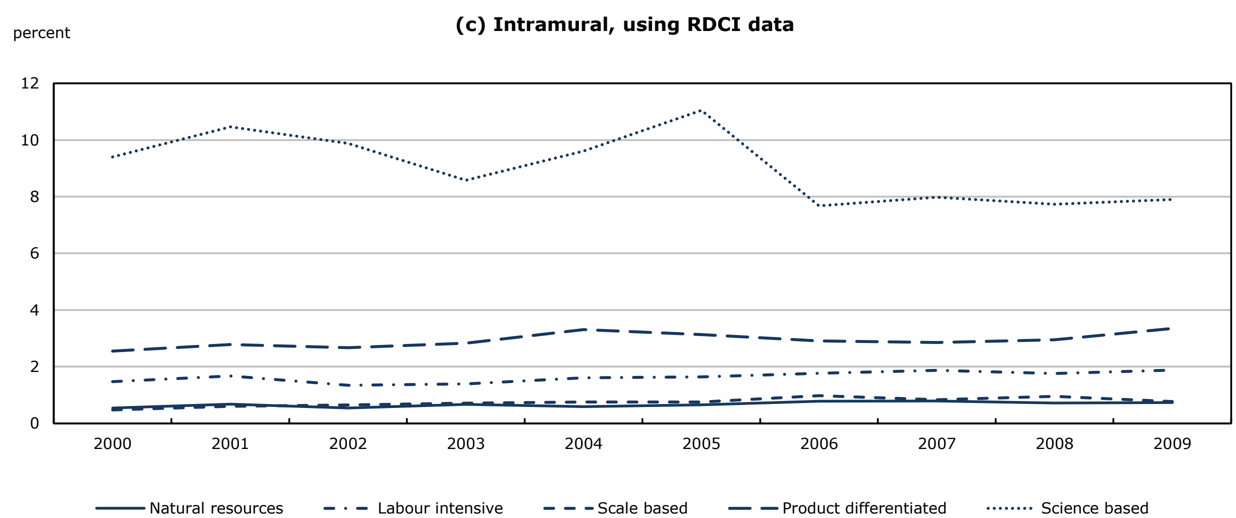
Note: Extramural research and development (R&D) is R&D purchased from domestic and foreign suppliers. Intramural R&D is R&D performed in-house.

Sources: Statistics Canada, authors' calculations from Annual Survey of Manufactures (ASM) and Research and Development in Canadian Industry (RDCI) databases.

Appendix Chart 2
Weighted average of R&D intensity of firms with positive R&D expenditure, by industrial sector



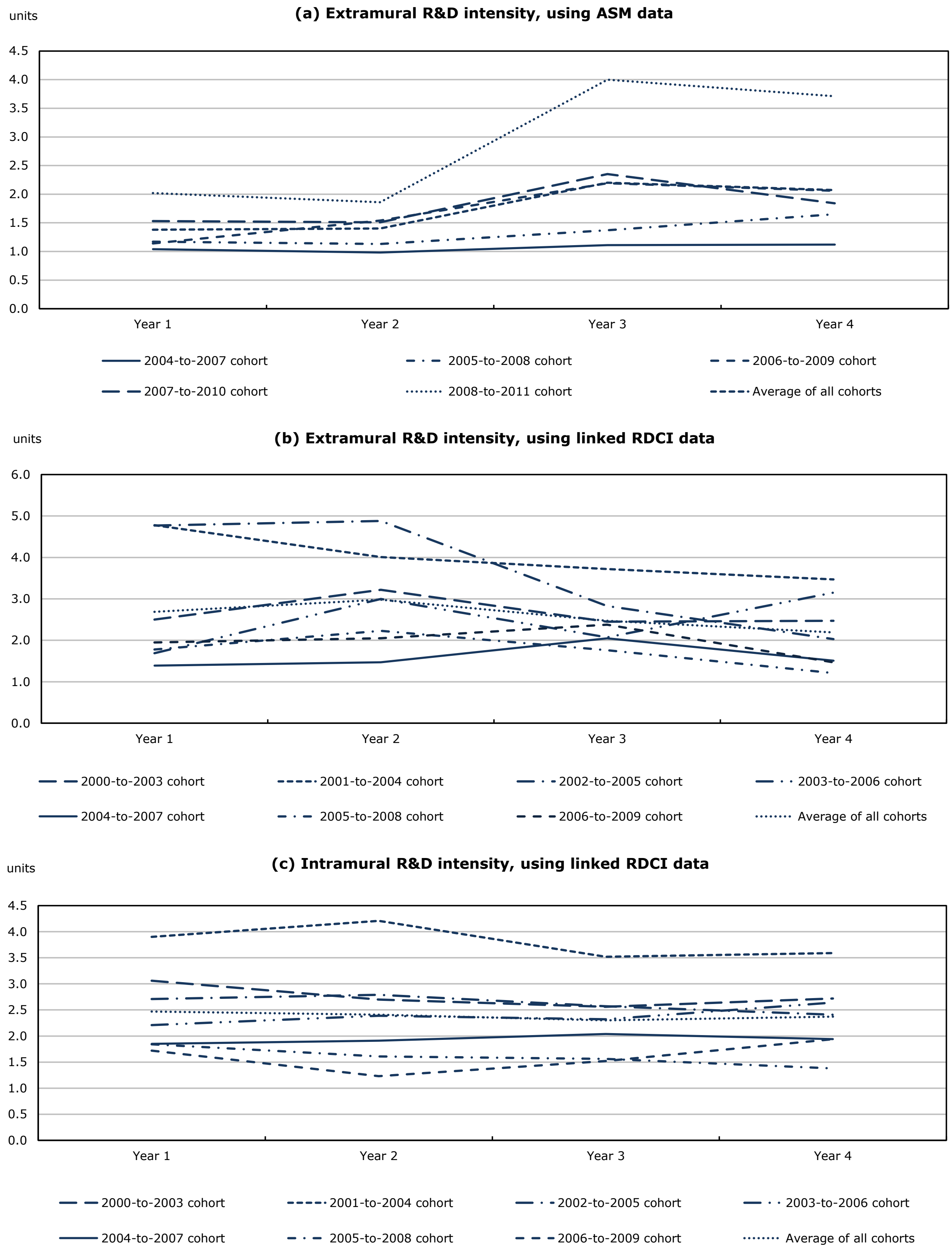




Note: Extramural research and development (R&D) is R&D purchased from domestic and foreign suppliers. Intramural R&D is R&D performed in-

Sources: Statistics Canada, authors' calculations from Annual Survey of Manufactures (ASM) and Research and Development in Canadian Industry (RDCI) databases.

Appendix Chart 3
Average R&D intensity of export starters relative to continuing non-exporters



Notes: Extramural research and development (R&D) intensity is measured as the share of total extramural R&D expenditures in total shipments. Intramural R intensity is measured as the share of total intramural R&D expenditures in total shipments. Extramural R&D is R&D purchased from domestic and foreign supp Intramural R&D is R&D performed in-house.

Sources: Statistics Canada, authors' calculations from Annual Survey of Manufactures (ASM) and Research and Development in Canadian Industry (RDCI) databases.

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