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FIRM SIZE AND RESEARCH AND DEVELOPMENT EXPENDITURES: A CANADA-U.S. COMPARISON

Thitima Songsakul, Bernice Lau and Daniel Boothby,
Industry Canada

Working Paper 2008-12

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Abstract

We examine available statistical evidence on firm size and business expenditures on R&D (BERD) in Canada and the United States. We also develop a decomposition that provides a helpful framework for considering relevant research and development (R&D) variables including R&D intensity and incidence, and related firm characteristics including the firm size distribution and the relative firm output by size class.

Key words: BERD, business R&D intensity, firm size

Résumé

Nous étudions dans le document les données statistiques dont nous disposons sur la taille des entreprises et les dépenses intra-muros en recherche-développement des entreprises (DIRDE) au Canada et aux États-Unis. Nous décomposons également les données pour créer un cadre propice à l'étude des variables pertinentes de la R-D, dont l'intensité et la fréquence de la R-D, et les caractéristiques connexes des entreprises, comme la répartition de la taille des entreprises et les résultats obtenus proportionnellement à la catégorie de taille.

Mots clés : DIRDE, dépenses intra-muros en recherche-développement des entreprises, taille des entreprises

1. Introduction

Canada's innovation performance in comparison with the United States and other developed countries is the subject of considerable policy concern. Smaller firm size in Canada is often mentioned as a possible reason for poor innovation performance and for Canada's relatively low intensity of business sector research and development (R&D) expenditures. (See, for example, Industry Canada, 2007, p.27).

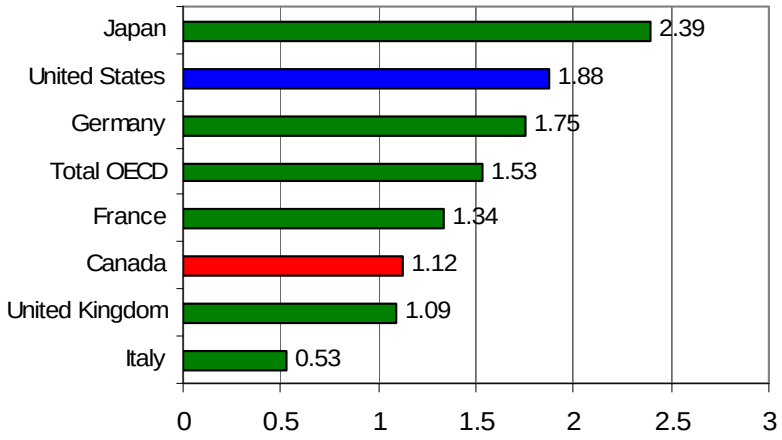
We concentrate on a narrow set of questions: What is the empirical evidence regarding the relationship between firm size and R&D intensity in Canada and the United States? What conclusions are suggested by the available evidence? Are there ways in which the available evidence might be improved using existing data sources? What further research directions do our results suggest?

In the next section, we derive a decomposition of business sector R&D intensity that provides a framework for examining how firm size might be related to R&D intensity. Sections 3 to 5 examine factors affecting aggregate business enterprise expenditures on R&D (BERD) intensity. Comparisons between Canada and the United States across firm size classes are made in terms of the value-added contribution by class, R&D intensity of performing firms, R&D incidence, and the ratio of value added of a performing firm to an average firm. In section 6, the findings are discussed. Conclusions and directions for further research are summed up in the last section.

2. How might smaller firm size lead to lower R&D intensity?

International comparisons of the ratio of BERD to Gross Domestic Product (GDP) are often cited as evidence of a relatively low level of R&D effort by Canadian businesses. Figure 1 shows values of BERD/GDP for selected OECD countries, including Canada and the United States.

Figure 1. Business R&D intensity across OECD economies, 2004, (percentage of GDP)



Source: OECD MSTI (2006/2) Table 24

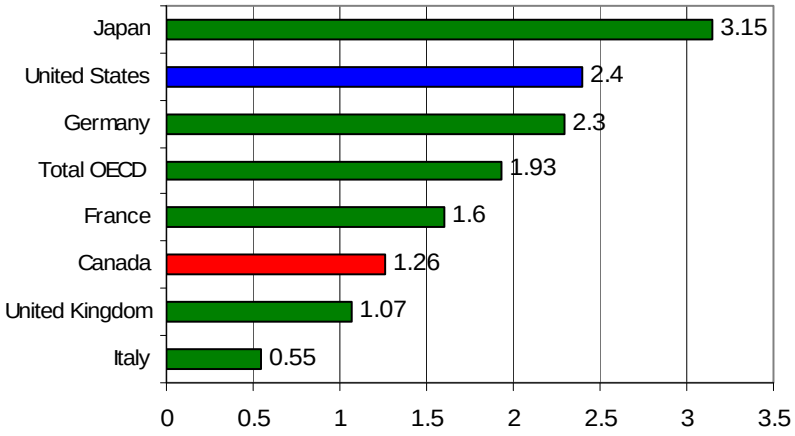
While the BERD/GDP ratio has been used in studies by others, we use (and decompose) a somewhat different measure of the business sector's R&D effort: BERD divided by value added in the business sector (BVA). The ratio BERD/BVA reflects the business sector's R&D effort relative to the size of the business sector rather than the entire economy. We feel this is a better measure of business sector R&D intensity. Figure 2 shows this variable for the G-7 countries and the OECD average. The picture of relative R&D intensity across OECD economies that emerges from Figure 2 is very similar to the picture that emerges from Figure 1. According to both the Figure 1 and 2 measures, Canada's business R&D intensity is below the OECD average and is about half the level for the United States.

We now decompose this measure of business R&D intensity by size class of firm (indicated by the subscript *i* in the following equations). In what follows, the superscript *p* indicates that a variable is restricted to firms in the size class that perform R&D. Thus $berd_i^p$ denotes average business R&D intensity of performing firms in size class *i*, s_i^p is the share of BVA of performing firms in total BVA in size class *i*, and S_i is the BVA in size class *i* as a share of total BVA.

In our first decomposition (equation 1), business R&D intensity is the sum over firm size classes of the product of three factors: the average R&D intensity of R&D performers in the size class, value added by R&D performers as a share of total value added in the size class, and the value added in the size class as a share of total value added for the business sector of the economy:

(1) $$\frac{BERD}{BVA} = \sum_i \frac{BERD_i^p}{BVA_i^p} \cdot \frac{BVA_i^p}{BVA_i} \cdot \frac{BVA_i}{BVA} = \sum_i berd_i^p \cdot s_i^p \cdot S_i \,.$$

Figure 2. Industry-financed BERD intensity across OECD economies, 2004 (percentage of value added by industry)



Source: OECD MSTI (2006/2) Table 34

Next we break down the third term on the right hand side of (1) -- the value-added share of each size class (S_i) -- into two components:

(2) $$S_i = \frac{n_i}{n} \cdot \frac{BVA_i / n_i}{BVA / n} = \frac{n_i}{n} \cdot \frac{bva_i}{bva} \,.$$

In (2), n equals the number of firms, bva_i is the average value added of a firm in size class i, bva is the average value added of all firms, and n_i/n is the share of firms in each size class.

Discussions of the relation between firm size and R&D intensity often are framed in terms of either R&D intensity by size class (how much do R&D performing firms invest in R&D relative to output) or R&D incidence (the proportion of firms in each size class that invest in R&D). Business R&D intensity within size classes is already captured in equation 1 by the $berd_i^p$ variable. To capture R&D incidence, we break down the value-added weights of performers by size class (s_i^p) to obtain an explicit expression for the proportion of firms in each size class that perform R&D:

(3) $$s_i^p = \frac{n_i^p}{n_i} \frac{BVA_i^p / n_i^p}{BVA_i / n_i} = \frac{n_i^p}{n_i} \cdot \frac{bva_i^p}{bva_i} \,.$$

In (3), n_i^p / n_i denotes the R&D incidence in size class i, that is the proportion of firms in size class i performing R&D; bva_i^p is the average VA of a performing firm in size class i; and bva_i is

the average VA of a firm in size class *i*. The last term (bva_i^p / bva_i) shows the relative value added of R&D performers to all firms within each size class. It is not clear whether this last term is a significant factor in overall BERD intensity. We discuss this issue further in Section 5.

Substituting equations 2 and 3 into our main decomposition in equation 1 yields:

$$\textbf{(4)}\quad \frac{BERD}{BVA} = \sum_i berd_i^p \cdot \left(\frac{n_i^p}{n_i} \cdot \frac{bva_i^p}{bva_i} \right) \cdot \left(\frac{n_i}{n} \cdot \frac{bva_i}{bva} \right).$$

Equation (4) expresses business sector research and development intensity as the sum over business size classes of the product within each size class of multiple factors. In the order of discussion to follow, these factors are:

- Value-added contribution of firms by size class (S_i), taken up in section 3
    - Size class share of all firms (n_i/n)
    - Ratio of value added by the average firm in the size class to value added by the average firm (bva_i/bva)
- R&D intensity of firms performing R&D in the size class ($berd_i^p$), taken up in section 4
- Incidence of R&D performance in the size class (n_i^p / n_i), taken up in section 5
- Ratio of value added by the average firm performing R&D in the size class to the value added by the average firm in the size class (bva_i^p / bva_i), also taken up in section 5

At this point, we are ready to examine the evidence regarding the relationship between firm size and business R&D intensity in Canada, by comparing the factors noted above by firm size class for Canada and the United States.

3. Value-added contribution of firms by size class (S_i)

We begin our examination with the distribution of firms by size class in Canada and the United States, with "size" defined by the number of employees. This measure of size is dictated by data availability.

Whenever possible, we use data on "firms." Our concept of a firm follows that used in Statistics Canada's Longitudinal Employment Analysis Program (LEAP) (Statistics Canada, 2006a). Unfortunately, much of the other data available to us for Canada have not been linked back to LEAP firms, which limits our ability to report consistent firm-level data throughout this paper. For example, for the R&D data we have for Canada, the reporting unit is a "company" and the relationship of a company to a LEAP firm is not known.[1] Similarly, not all U.S. data we use are firm-level.[2]

[1] We point out later in discussing possible extensions of our work that much of the non-firm-level data we use for Canada could be transformed into firm-level data through linkage to LEAP or the Business Register (BR).
[2] The words "firm" and "enterprise" are used interchangeably throughout. There are differences in the concepts of a firm and of an employee as implemented in the U.S. and Canadian data. For details refer to Appendix A.

Table 1 provides estimates of the firm size distribution in the United States and Canada in 2002. Although the differences are numerically small for the firm size groupings used in table 1, note that Canada has a higher percentage of business enterprises in the 0-19 employment class and a lower percentage in the 500+ class in comparison with the United States.

Table 1. Number of business enterprises in Canada and the United States by employment size class, 2002

Employment size	Canada 2002		United States 2002	
	Enterprise	Percent	Enterprise	Percent
0-19*	923,200	92.0	5,090,331	89.3
20-99	66,200	6.6	508,249	8.9
0-99	989,400	98.6	5,598,580	98.3
100-499	11,200	1.1	82,334	1.4
Total SME	1,000,600	99.8	5,680,914	99.7
500+	2,400	0.2	16,845	0.3
Total	1,003,000	100.0	5,697,759	100.0

Source: Canada-Statistics Canada (2006a) Table 1a, United States-U.S. SBA (2006)
Note: * Zero-employee firms cannot be separately identified in Canadian LEAP data. For the U.S., 13.5% of enterprises have zero employment (included in the 0-19 size class).

Table 2 shows that large enterprises with 500+ employees hire about half of all the paid workers in the United States, but only about 42.8% of the paid workers in Canada. Moreover, small size firms (0-99 employment size) account for a lower share of employment in the United States compared with Canada (36.0% versus 41.4%, respectively).

Table 2. Number of full-time and part-time employees on payroll, by employment size class of enterprise in Canada and the United States, 2002

Employment size	Canada 2002		United States 2002	
	Employment	Percent	Employment	Percent
0-19	2,902,400	21.6	20,583,371	18.3
20-99	2,663,100	19.8	19,874,069	17.7
0-99	5,565,500	41.4	40,457,440	36.0
100-499	2,135,800	15.9	15,908,852	14.2
Total SME	7,701,300	57.2	56,366,292	50.1
500+	5,754,900	42.8	56,034,362	49.9
Total	13,456,200	100.0	112,400,654	100.0

Source: Canada-Statistics Canada (2006a) Table 5a, United States-U.S. SBA (2006)

Table 3 shows shares of employment by firm size in the manufacturing sector in selected OECD countries in 1999 based on the OECD's Small and Medium Enterprise Outlook (2002) report. According to this OECD source, large manufacturing firms with 500+ employees in the United States account for 59% of manufacturing employment, followed by Sweden at 46% and Canada at 45%. Employment shares of large firms (500+) in other countries are much smaller than for the top three countries. In terms of the smaller size firms (firms with less than 100 employees), the employment share in Canada, at 31%, is much less than all other countries except the United States with a 24% share.

Table 3. Distribution of employment in manufacturing enterprises[1] by size class, selected OECD countries, 1999 or nearest year

Country	0-99	10-499	500+	Total
United States	23.7	17.4	58.9	100
Canada	30.7	24.2	45.0	100
France	39.2	24.3	36.5	100
United Kingdom	36.8	29.5	33.6	100
France	39.2	24.3	36.5	100
Italy[2]	59.9	19.8	20.3	100
Selected OECD average	38.1	23.0	38.9	100
	1-99	**10-499**	**500+**	**Total**
Sweden	31.8	21.9	46.3	100
Germany	31.1	25.6	43.2	100
Denmark	37.1	28.6	34.2	100
Norway	41.7	28.4	29.9	100
Japan	52.6	26.2	21.2	100
Selected OECD Average	38.9	26.1	35.0	100

Source: OECD SME Outlook (2002) Table A.2
Note: 1. The Canadian and U.S. definitions for enterprise match up well, but differ from the OECD and Eurostat. For details refer to Appendix A. 2. Number of salaried employees for Italy; persons engaged for other countries.

Table 4 shows the average number of employees in each size class for Canada and the United States. For all firm sizes except large firms, the average number of employees is very similar in Canada and the United States. In the 500+ employee size class, the average number of employees is much greater in the United States than in Canada. Thus we see that the greater share of employment in the largest firms in the United States is primarily due to the fact that the firms with 500+ employees are larger on average in the United States than in Canada.[3]

[3] If we had a more complete distribution of firms by employment in the open-ended 500+ category, we would expect to find a greater percentage of U.S. firms in the largest size classes. The results may be misleading as to the comparative **worldwide** sizes of firms with **headquarters** in Canada and the U.S., because they are based on employment in Canada or the U.S. only. It seems likely that very large Canadian multinationals would have a greater share of their total employment in the U.S. than the share of employment in Canada of very large U.S. multinationals. The measures of relative size cited here are the right measures for our purposes, because we are concerned with the R&D conducted within Canada (the U.S.) relative to output within Canada (the U.S.) and not with the R&D conducted by firms with headquarters in Canada (the U.S.) relative to the output of these firms. Our calculations from Compustat data show that the largest 10% of publicly traded firms in the U.S. have much higher average employment and sales than the largest 10% of publicly traded firms in Canada.

Table 4. Average number of employees in each employment size class, Canadian and U.S. enterprises, 2002

Employment size class	Canada	United States
0-19	3	4
20-99	40	39
100-499	191	193
500+	2398	3327
All firms	13	20

Source: Calculations based on Canada-Statistics Canada (2006a) Tables 1a & 5a, United States-U.S. SBA (2006)

The greater employment share of the largest firms in the United States than in Canada has immediate implications for the value-added share of different sized firms (S_i in equations 1 and 2) in the two countries. Suppose, for example, that in each country the value added per employee is the same for all firm sizes. Then the share of value added in each firm size group would be the same as its share of employment. Consequently, the largest firms would account for more of the value added in the United States.[4] These data support the arguments made below as to the distribution of value added by firm size in the two countries.

We do not know of reported findings on average value added of *firms* by size class in Canada and the United States. The available data from Baldwin, Jarmin, and Tang (2006) (BJT) are for aggregate value-added shares for *establishments*, rather than firms, in the *manufacturing* sector, rather than the entire business sector.

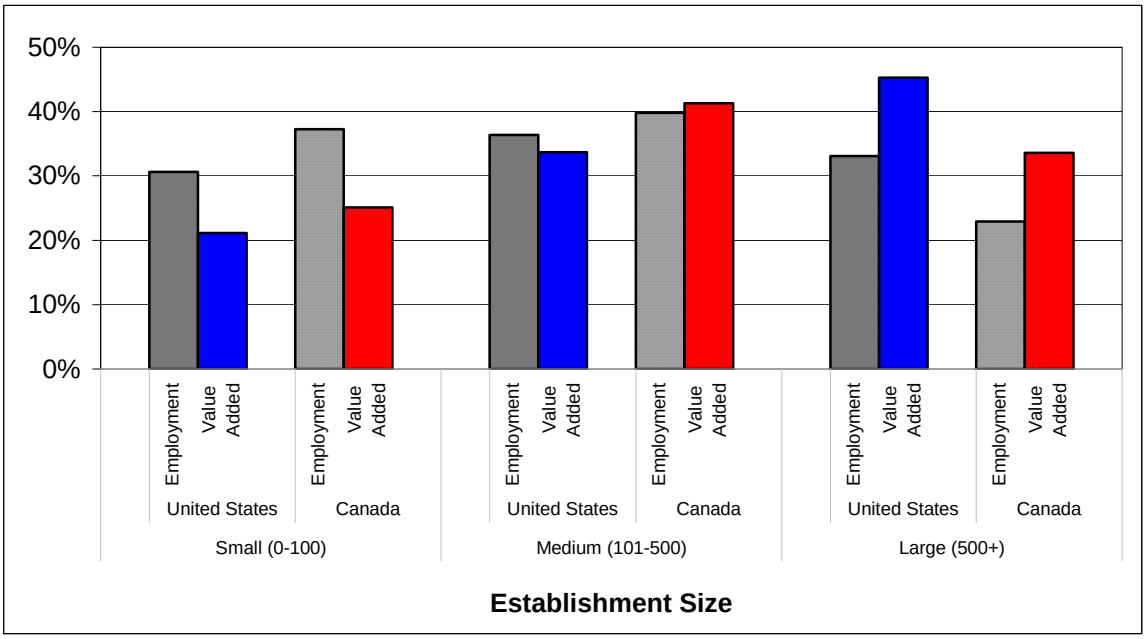
Figure 3 reproduces the results of BJT for 1997, with that being the last year of data available to us. Large manufacturing establishments (500+ employees) account for 33% of manufacturing employment and 45% of manufacturing value added in the United States. The corresponding percentages for Canada are 23% and 34%. Small establishments (less than 100 employees) account for 37% of manufacturing employment and for 25% of manufacturing value added in Canada; the corresponding figures for the United States are 31% and 21%.

Evidence from BJT suggests that small establishments in Canadian manufacturing account for a greater share of employment and value added than those in the United States. We also find in Tables 2 and 3 that small firms in Canada account for a greater share of employment than in the United States. This leads us to believe that, economy-wide, small firms in Canada contribute more in terms of employment and value-added than small firms in the United States. As already noted, the greater concentration of employment and value added in large firms and large establishments in the United States occurs mostly because those with 500 or more employees are, on the whole, bigger in the United States than in Canada. We note also that since small firms

[4] In fact, Baldwin, Jarmin and Tang (2004) show that larger manufacturing firms have higher productivity per employee. This means that value-added shares will be even more skewed towards the largest firms than employment shares.

and establishments produce a small part of business-sector value added in both countries, the R&D intensity of small firms, and inter-country differences in this, is not likely to have much impact on overall R&D intensity.[5]

Figure 3. Employment and value-added shares in manufacturing
by employment class size, Canadian and U.S. establishments, 1997



Source: Baldwin, Jarmin and Tang (2004)

4. R&D intensity by size class of performing firms ($berd_i^p$)

The data on business R&D expenditure in Canada comes from a publication titled *Industrial Research and Development* (IRD), *2005 Intentions* (Statistics Canada, 2006), which covers R&D performing firms (firms known or believed to be involved in the performance or funding of R&D; for survey details see Appendix B). Data from the IRD are used in the computation of the BERD series for Canada. Industrial R&D activity[6] is made up of current intramural expenditures (costs of wages and salaries plus other current costs associated with workers who are usually permanent employees) and capital expenditures (costs of fixed assets used in R&D programs such as land, buildings or major R&D equipment).

[5] In other words, since S_i is small for small firms, it takes large differences in R&D intensity for small firms to have much impact on overall R&D intensity differences between Canada and the United States. Indeed, in Appendix E, below when we assign our estimate of value-added shares by size class for the United States to Canada, overall business R&D intensity in Canada falls because of a shift in value-added share away from medium-size firms towards small firms.

[6] R&D is defined as a systematic investigation carried out in the natural and engineering sciences by means of experiment or analysis to achieve a scientific or commercial advance. It excludes market research, social sciences or humanity research, natural resource explorations, for example (following the Scientific Research and Experimental Development section of the Income Act Tax).

Statistics Canada (2006) suggests that individual companies do not regularly incur capital expenditures related to the production of R&D, so current intramural expenditures may be a reasonable indicator of a firm's commitment to R&D. Our analysis of trends in R&D activity focuses on current intramural expenditures for reasons of data availability. Published data on current intramural R&D expenditures intensity by size class of firm include expenditures from all sources of funds for Canada. The denominator of the intensity measure for Canada is company revenue.[7] The survey unit is the "performing company" which is the organization that carried out the R&D and submitted the return. Appendix C provides details of the measures of intensity we constructed for Canada and the United States.

Table 5 shows measures of R&D intensity among Canadian R&D performing firms. The table shows lower R&D intensity for larger firms. Companies in the small employment size groups have R&D intensities ranging from 5% to over 8% of total revenue, while those in larger size groups have R&D intensities of 4% or less.

Table 5. Current intramural R&D expenditures (from all funding sources) as a percentage of performing company revenue, by employment size class, Canadian enterprises 2002

Employment size	2002	2003 (preliminary)
1-49	5.7	5.8
50-99	8.6	6.8
100-199	5.7	5.3
200-499	3.8	3.9
500-999	3.2	4.3
1,000-1,999	2.2	2.0
2,000-4,999	1.1	2.0
5,000+	1.2	0.8
Total	**2.1**	**2.1**

Source: Statistics Canada IRD 2005 Intentions (2006b) Table 15

Turning to the evidence from the United States, Table 6 reports R&D intensity for performing firms based on current expenditures, excluding funds from the U.S. federal government.[8] The data from the publication, *Research and Development in Industry* (RDI) *2002* (NSF, 2006), show that small enterprises (5-99 employees per enterprise) spend about 8% of net sales on R&D. R&D intensity as a share of net sales for medium size enterprises (100-499 and 500-999 employees) is roughly 6%; and that of larger enterprises is 3-4%. like the Canadian situation, the smaller size group shows higher R&D intensity than the larger groups.

While it is difficult to compare the data from the two countries, Tables 5 and 6 suggest that there are significant differences between Canada and the United States in the relation between firm

[7] By definition, company revenues are revenues from sales, net of sales and excise taxes, plus revenues from other sources. They will tend to be greater than value added, which is the denominator of the intensity variable in our decomposition, so this measure for Canada tends to understate intensity relative to our desired measure.

[8] Federal expenditures account for around 10% of business R&D in the U.S., but for only about 2% in Canada (see sources of R&D funds in Appendix D). By including R&D expenditures from all sources for Canada, we thus slightly overstate expenditures in Canada, relative to the concept used for the U.S. in Table 6, since our Canadian measure includes federally funded expenditures.

size and R&D intensity for performing firms. There appears to be a pattern of overall higher intensity in all size classes in the United States than in Canada, with the differences being especially pronounced for very large enterprises.

Table 6. R&D intensity (industrial R&D by company and non-federal funds, as percentage of net domestic sales) by size class, U.S. enterprises, 2002

Employment size	Number of performing firms	Total BERD ($millions)	Net Domestic Sales ($millions)	R&D Intensity
5-49	16,917	7,057	89,179	7.9%
50-99	3,820	5,701	80,296	7.1%
100-499	4,985	19,992	324,494	6.2%
500-999	951	9,394	136,145	6.9%
1000-4999	1,050	27,640	691,000	4.0%
5000+	477	104,625	3,602,084	2.9%
Total	28,200	174,409	4,923,198	3.5%

Source: NSF RDI 2002 (2006) Tables 14 & 27

5. R&D incidence (n_i^p / n_i) and average value-added ratio (bva_i^p / bva_i)

Innovation Surveys have been used to study R&D incidence in Canada. For a number of reasons they are not well suited for our purposes. The first reason is that the United States has not conducted innovation surveys, so a Canada-U.S. comparison is not possible. Other reasons include survey coverage of only a limited range of industries and a typical lower cut-off of firms with 15 or more employees. Finally, the levels of R&D incidence reported in these surveys are very difficult to reconcile with the overall level of business expenditures on R&D in Canada, no doubt because the R&D expenditures data are based on a more restrictive definition and cover a single year, rather than a three-year period. Results from the Innovation Surveys (see for example, chapter 7 in Baldwin and Hanel, 2003) show that small firms are less likely to engage in ongoing R&D activities than larger firms.

R&D incidence in our framework is the percentage of firms that have reported R&D expenditures as measured in BERD. We have not found any published data for Canada reporting R&D incidence according to this definition.[9] The IRD does, however, publish the number of R&D performing units by size class of the reporting unit. We have used this data to perform a rough calculation of R&D incidence by dividing the number of R&D performing companies from the IRD by the population of enterprises from LEAP by size class. Note that the units of measurement from the two surveys for (performing companies and enterprises, respectively) differ, and that the small size class covers different groups (1-99 employees in IRD versus 0-99 in LEAP).[10] The results are shown in Table 7.

Table 7 shows a very strong relation between firm size and the performance of R&D. R&D incidence for the largest firm size class (500+ employees) is almost fifteen times that for the small size class (1-99 employees) and one and a half times that for the intermediate size class.

[9] In principle, it should be possible to produce such data by linking reporting units from the IRD to LEAP.
[10] U.S. data suggest that there may be a significant number of 0-employee firms, see the note to Table 1.

Table 7. R&D incidence by size class, Canadian enterprises, 2002

Employment size class	Number of R&D performing companies (IRD 2002)	Number of enterprises (LEAP 2002)	R&D incidence
1-99*	10,734	989,400	1.1%
100-499	1,149	11,200	10.3%
500+	371	2,400	15.5%
All firms	12,254	1,003,000	1.2%

Source: Statistics Canada IRD 2005 Intentions (2006b) Table 1.8 and Business Dynamics in Canada (2006) Table 1a
Note: * Data from the IRD exclude firms with zero employees, but LEAP data include them. Therefore, the R&D incidence for the small size group here is underestimated.

We performed the same computation of incidence for the United States as for Canada, using published data from the RDI survey on the number of firms performing R&D by size class and published data on the number of firms by size class. The results are shown in Table 8 below. They are strikingly similar to our results for Canada.

Table 8. R&D incidence by size class, U.S. enterprises, 2002

Employment size class	Number of R&D performers* (RDI 2002)	Number of enterprises (SBA 2002)	R&D incidence
5-99	20,737	2,132,933	1.0%
100-499	4,985	82,334	6.1%
500+	2,478	16,845	14.7%
All firms	28,200	2,232,112	1.3%

Source: NSF RDI 2002 (2006) Table 14, U.S. SBA (2006)
Note: * R&D performers are firms spending R&D expenditures excluding federal funds.

Based on Tables 7 and 8 above, a clear pattern seems to emerge – in both countries, the smallest firm size class shows much lower R&D incidence than larger enterprises.[11] *However, it does not seem to be the case that small firms in Canada are lagging their U.S. counterparts in terms of R&D incidence. In fact, we find the incidence of R&D to be similar for the small and large firm size classes in Canada and the United States.*

The remaining element from equation 4 to examine is the ratio of average value added by performing firms to average value added by all firms within a size class, bva_i^p / bva_i. We have not found any data that allow us to compute this ratio. There are, however, data for the average number of employees of R&D performing firms and of all firms within given size classes for the United States. These data are reported in Table 9. They show little difference in the number of

[11] The available data we used in Table 7 understate the R&D incidence of small businesses in Canada relative to the U.S. because the small size class in Canada starts from performing firms with more than one employee while the minimum employment size of firms in the U.S. is 5. In addition, the denominator of the incidence estimate for Canada includes firms with zero employment. We consider the 1.1% incidence of small firms in Canada as a lower bound estimate relative to U.S. concepts.

employees in performing and non-performing firms – at most, performing firms have 10% more employees within a size class. Note that large productivity differences between performing and non-performing firms would be required for bva_i^p / bva_i to be large.[12]

Table 9. Average number of employees per enterprise, performing firms versus all firms, United States, 2002

Employment size	R&D performing firm (1)	All firms (2)	Ratio of (1) to (2)
5-24	11	10	1.10
25-49	35	34	1.03
50-99	73	68	1.07
100-499	216	193	1.12
500-999	717	689	1.04
1000-4999	2,207	2,028	1.09
5000-9999	6,808	6,937	0.98
10000+	35,930	33,442	1.07

Source: Calculations based on data from NSF RDI 2002 (2006) Tables 5 & 39, and U.S. SBA (2006)

6. Effect of small firms on aggregate business R&D intensity

Our decomposition of business R&D intensity by firm size class in equation 1 expresses overall business R&D intensity as the sum over size classes of the product of three factors: R&D intensity for performers in the size class, the share of value added within the size class by firms that perform R&D, and the size class share of total value added in the business sector. (The latter two factors are further decomposed in equations 2 and 3). We are now able to draw tentative conclusions.[13]

First we consider the value-added share of firms in different size classes. Equation 2 decomposes this share into two factors: the proportion of all firms in a size class and the ratio of the average value added by a firm in the size class to the average value added by a firm across all size classes. The distribution of firms by size class is similar between Canada and the United States, but differs in ways that may be important when it comes to understanding the Canada-U.S. difference in business R&D intensity.

There is good reason to think that the share of value added by large firms is bigger in the United States than in Canada. We found evidence that the greater employment share of large firms in the United States occurs primarily because large firms are bigger in the United States than in Canada. This would suggest that the value-added share of large firms is likely to be bigger in the United States because big firms are bigger in the United States, rather than because there are more small firms in Canada.

[12] There is reason to think that firms of a given size that engage in R&D will have significantly higher productivity than those that do not engage in R&D. Tang and Le (2007) use data for Canadian manufacturing firms to examine the influence of various innovation inputs on productivity growth from 1997 to 1999. Their results (Table VII) show that all else (including number of employees) equal, firms that engage in R&D have productivity growth about 4.6 percentage points higher than those that do not.

[13] The numerical exercise of the decomposition is provided in Appendix E.

We next examine R&D intensity for performers. This is higher for small firms than for large firms in our results, so that overall business R&D intensity would decrease in Canada if small firms that perform R&D had the same average R&D intensity as large firms that perform R&D. Comparison with the United States is especially difficult for this variable, since the concepts used differ between the two countries (and the desired denominator, value added, is not available for either country).

The U.S. data on R&D intensity show a similar pattern to the Canadian data, with intensity decreasing as firm size grows. There is nothing in the data reported here that suggests that small Canadian firms performing R&D have a lower R&D intensity relative to small firms in the United States than is the case for larger Canadian firms performing R&D relative to their U.S. counterparts. The Canadian R&D intensities for firms performing R&D are lower in all size classes than the corresponding intensities in the United States, but the data are not fully comparable. Thus the data on R&D intensity suggest that lower intensity in all size classes may contribute to the overall Canada-U.S. difference in business sector R&D intensity, but that the Canada-U.S. gap in R&D intensity is no bigger among R&D performers for small businesses than for larger businesses.

Lastly, we consider the proportion of value added in size classes by firms that perform R&D (in equation 1). This is broken down in equation 3 into the product of R&D incidence (n_i^p / n_i) and the ratio of value added by the average performing firm in the size class to value added by the average firm in the size class (bva_i^p / bva_i). Turning to R&D incidence, we have already noted that incidence in small and large firm size classes is similar for Canada and the United States. Consequently, a lower incidence of R&D in any size class (including small firms) is not a source of the overall difference in business sector R&D intensity. We do not know the ratio of value added by the average performing firm to value added by the average firm in the size class, but we have no reason to believe that this factor is large, nor that it would vary significantly between the two countries within a size class.

In sum, we find some evidence that overall BERD intensity is lower in Canada than in the United States across **all** size classes of firms. Lower BERD intensity in Canada for all sizes of firm, taken together with the conclusions of the preceding paragraphs, would imply that firm size has little to do with the reasons for the Canada-U.S. BERD intensity gap. One needs to be cautious on this point, because of the limitations of the data used in our comparisons of R&D intensity for performing firms.

As a final piece of evidence, we include Table 10. The table provides the share of total intramural R&D spending attributable to firms in various size classes in Canada and the United States. The R&D expenditures share of all firm size classes, except the largest (more than 5000 employees), is much bigger in Canada than in the United States. Hence the R&D spending share of very large firms in United States (62%) is much larger than in Canada (29%). The share of the smallest firms among R&D performers is bigger in Canada than in the United States. (78% versus 61%), and the share of all other size classes among R&D performers is smaller in Canada. In our view, these observations tend to confirm that the principal sources of the BERD intensity gap are (i) lower R&D intensity in all firm size classes in Canada, and (ii) a much bigger share of very large firms in employment and in value added in the United States than in Canada. The

most remarkable aspect of Table 10, in our view, is the high concentration of business R&D expenditure in the United States in very large firms.

Table 10. Share of total business R&D (from all sources of funds) and share of performing companies by size class, Canada and the United States, 2002

Employment size	Canada		United States	
	Share of total intramural R&D expenditures[1]	Share of performing companies	Share of total industrial R&D funds	Share of performing companies
1 to 49 (Canada) 5-49 (United States)	13.3	78.4	4.2	60.9
50 to 99	7.6	9.2	3.2	13.3
100 to 499	18.4	9.4	11.0	17.3
500 to 999	8.5	1.3	5.1	3.3
1000 to 4999	23.6	1.4	14.8	3.6
5000+	28.5	0.4	61.8	1.6
Total	100.0	100.0	100.0	100.0

[1] Total intramural R&D includes capital expenditures

Sources: Canada-Statistics Canada IRD 2004 Intentions (2005) Tables 1.8 & 17, United States-NSF RDI (2006).

7. Conclusions and directions for further research

We will discuss two dimensions for further research—additional data development that would improve the results we report here, and broader research directions suggested by our results.

The most useful data for improving our results would be firm-level data on value added that could be linked to data on R&D expenditures. This should be possible for the manufacturing sector, since establishment-level value-added data are available for this sector. This would not be a small project, as it would require linking the establishments reporting in the Census of Manufacturers and the companies reporting in the RDCI to the firms of LEAP or of the Business Register. This linkage would allow direct computation of R&D incidence, intensity, the relative value added of performers and all firms within a size class and the value-added share of a size class.[14]

Of course, comparison of data of this type with the United States would require the availability of similar data for the United States. In general, co-operative projects designed to produce comparable data would be useful.

[14] The decompositions we develop could also be used to examine industry contributions to R&D intensity, so that data of this type would allow work on how different industries contribute to the overall R&D intensity of the manufacturing sector.

Ideally, such a project would cover not only the manufacturing sector, but the entire business sector. Right now, there is a lack of any source of readily available establishment or firm-level data for value added for firms or establishments outside the manufacturing sector. The absence of such data for the service sector is problematic, given the growing predominance of services in the economy of Canada.

Less ambitious projects to improve our results would be to link LEAP and the RDCI to provide better information on R&D incidence and to use LEAP to provide a finer division of large firms by size class. Since our results suggest some of the differences between the United States and Canada may lie with very large firms, it would be useful to have a more detailed breakdown of large firms than the 500+ open-ended category in published LEAP data.

In terms of broader directions for further research, a better understanding of the role of very large firms in R&D intensity would be useful. Table 10 shows that a few very large firms' R&D expenditures account for 60% of R&D spending in the United States. Our data also suggest that firms in this size class are more prevalent in the United States than in Canada. However, we worry that our employment counts for very large firms (which are for *domestic* employment) may be misleading. Very large Canadian-based multinational firms may have proportionately more of their workforces outside the home country in comparison with U.S. multinationals. Also, some (unknown) proportions of large and very large Canadian firms are subsidiaries of U.S. firms (and vice versa).

Is a high concentration of R&D spending in very large firms typical of countries other than the United States? Are there, in fact, proportionately fewer of these firms in Canada than in the United States? If so, is this also true of other small economies that, unlike Canada, have high R&D intensity such as Finland or Sweden? Or do these economies also have a higher proportion of very large firms than Canada? If this is the case, is it because being highly innovative is a prerequisite for becoming a large firm? Is R&D spending in countries such as Sweden or Finland highly concentrated in very large firms? Are there structural differences of this type between these countries and Canada? If so, then why?

If very large firms are in fact multinational firms, a better understanding of how multinationals choose where to conduct R&D activities would be useful. The RDCI survey indicates (Appendix D) that about 15% of Canadian BERD is funded by foreign sources. Are these research mandates from multinational parents? If so, is this substantial part of Canada's already low BERD at risk from R&D in emerging economies? Does it matter for Canadian innovativeness in what country multinationals that operate in Canada conduct their R&D?

If firm size plays a role in the gap at all, it is differences in the presence and R&D performance of very large firms that might matter. Our suggestions for research directions above are aimed at a better understanding the role of these firms in BERD intensity.

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Appendix A

A.1 Survey Definitions of Firm/Enterprise

	Canada		United States	
Source	Unit	Definition	Unit	Definition
Statistics Canada Business Dynamics in Canada, LEAP (2006a)	Firm	A legal entity with paid employees, and includes all private and public sector entities which, during the reference years, remitted social security and tax deductions on behalf of these employees to Canada Revenue Agency. For the unincorporated sector, each legal entity with paid employees, was treated as a separate firm. May exist in more than one province.	--	--
U.S. SBA (2006)	--	--	Firm	An aggregation of all establishments owned by a parent company (within a geographic location and/or industry) with some annual payroll.
OECD SME Outlook (2002)	Enterprise	A business unit that directs and controls the allocation of resources relating to its operations, and for which consolidated financial and balance sheet accounts are maintained. The enterprise corresponds to an institutional unit engaged in economic activity as defined in the System of National Accounts 1993.	Enterprise	A business organization consisting of one or more domestic establishments that were specified under common control or ownership. The enterprise and the establishment are the same for single-establishment firms.
Statistics Canada IRD 2005 Intentions (2006b)	Performing company	The organization which carried out the R&D and submitted the return. In the case of a consolidated return, performing company could include several companies. It also includes divisions of an enterprise which send separate returns or organizations such as industrial non-profit organizations.	--	--
NSF RDI 2002 (2006)	--	--	Company/ firm/ enterprise	Include all establishments under common ownership or control.

A.2 OECD Definitions of Enterprise

Canada	A business unit that directs and controls the allocation of resources relating to its operations, and for which consolidated financial and balance sheet accounts are maintained. The enterprise corresponds to an institutional unit engaged in economic activity as defined in the System of National Accounts 1993.
United States	A business organization consisting of one or more domestic establishments that were specified under common control or ownership. The enterprise and the establishment are the same for single-establishment firms.
OECD	A legal entity possessing the right to conduct business on its own; for example to enter into contract, own property, incur liabilities for debts, and establish bank accounts. It may consist of one or more local units or establishments corresponding to production units situated in a geographically separate place and in which one or more persons work for the enterprise to which they belong.
Eurostat	The smallest combination of legal units that is an organizational unit producing goods or services, which benefits from a certain degree of autonomy in decision-making, especially for the allocation of its current resources. An enterprise carries out one or more activities at one or more locations. An enterprise may be a sole legal unit.

Source: OECD SBS Expert Meeting "Towards better Structural Business and SME Statistics" (2005)

A.3 Survey Definitions of Employment and/or Employee

	Canada		United States	
Source	Unit	Definition	Unit	Definition
Statistics Canada Business Dynamics in Canada (2006a)	Employee/ Average labour unit (ALU)	Derived by dividing the business's T4 payroll by the corresponding NAICS industry/ province /size annual average earnings by employee (from SEPH system). This measure is not a full-time equivalent count, and does not distinguish between part-time and full-time work.	--	--
U.S. SBA (2006)	--	--	Employment category	Based on the national employment size of the firm in all industries. If a firm has 20 employees in a given industry or location and has 10,000 total employees, the firm will be in the 500+ employee category for that given industry or location.
Statistics Canada IRD 2005 Intentions (2006b)	Employees	Average number of employees on payroll in Canada.	--	--
NSF RDI 2002 (2006)	--	--	Employment, total	Number of people employed in the 50 U.S. States and D.C. by R&D-performing companies in all activities during the pay period that included the 12th of March of the study year.
OECD SME Outlook (2002)	Employee	Includes all persons, workers and employees, covered by a contractual arrangement and working in the enterprise and who receive compensation for their work, whether full-time or part-time. In particular, the following are considered as employees: salaried managers, students who have a formal commitment whereby they contribute to the unit's process of production in return for remuneration and/or education services, employees engaged under a contract specifically designed to encourage the recruitment of unemployed persons. Includes persons on sick leave, paid leave or vacation. Excludes working proprietors, active business partners, unpaid family workers and home-workers, irrespective of whether or not they are on the payroll.		

Appendix B: Micro Datasets

B.1 Canadian Firm-level Data

	Longitudinal Employment Analysis Program	Business Register	Survey of Employment, Payroll and Hours	Annual Survey of Manufactures
Target population	**All private and public sector businesses or organizations**	All active businesses	All employers	All manufacturing establishments as well as associated sales offices
Truncation	**Issue T4 slips to employees for taxation purposes**	Have a corporate income tax (T2) account, are an employer or have a GST account with an annual gross business income of over $30 000	Except those primarily involved in agriculture, fishing and trapping, private household services, religious organizations and military personnel of defence services	Above certain thresholds that vary by province, by industry and survey year
Sample unit	**Enterprise**	Establishment	Enterprise	Establishment
Design	**Census with longitudinal design**	Census	Census with cross-sectional design	Sample survey with cross-sectional design
Framework	**--**	--	BR	BR
Data collection	**Collected directly form other Statistics Canada surveys and/or other sources**	Directly from survey respondents, extracted from administrative files and derived from other Statistics Canada surveys and/or other sources	Combination of the Business Payroll Survey results and the payroll deductions administrative data	Collected directly from survey respondents and extracted from administrative files

B.2 Canadian R&D Surveys

	Research and Development in Canadian Industry 2005	Survey of Innovation 2002-2005	Survey of Innovation 2001-2003	Survey of Innovation 1997-1999	Workplace and Employer Survey 2003
Target population	**All firms known or believed to be involved in the performance or funding of R&D**	Manufacturing and logging industries	ICT industries, selected professional, scientific and technical services industries, selected natural resource support service industries and selected transportation industries	Manufacturing and selected natural resource industries	All business locations operating in Canada that have paid employees in March
Truncation	**Postal survey only for those funding more than $1 million in R&D**	At least 20 employees Revenues of at least $250 000	At least 15 employees Gross business income of at least $250 000	At least 20 employees Gross business income of at least $250 000	Except: a) Employers in YK, NU and NWT b) Employers operating in crop production and animal production; fishing, hunting and trapping; private households, religious organizations and public administration
Sample unit	**Enterprise (R&D credit filer)**	Establishment	Establishment	"Provincial enterprise"	Establishment
Design	**Census with cross-sectional design**	Sample survey	Sample survey	Sample survey	Sample survey with longitudinal design
Data Collection	**Directly from survey respondents and extracted from administrative files**	Directly from survey respondents	Directly from survey respondents	Directly from survey respondents	Directly from survey respondents
Response rate	**N/A**	71.9%	70.5%	Manufacturing 95% Selected natural resource 94%	Workplace 83.1%[1]
Number of realized observations	**13 704**	6 143	2 123	Manufacturing 5 455 Selected natural resource 582	Business locations 13149 Employers 6565
Non R&D performers included	**No**	Yes	Yes	Yes	Yes

[1]Non respondents were either out-of-business, seasonally inactive, holding companies or out-of-scope
Majority of non-respondents were owner-operators with no paid help and in possession of a payroll deduction account

B.3 U.S. Firm-level Data

Business Register

Target population	Establishments of all domestic employer and non-employer businesses (except private households and governments) and organizational units of multi-establishment businesses
Truncation	--
Sample unit	Establishment and Enterprise
Design	Census
Framework	--
Data collection	Directly from survey respondents, extracted from administrative files and derived from other surveys

B.4 U.S. R&D Survey

Survey of Industrial Research and Development 2002

Target population	All industrial companies that perform R&D in the United States
Truncation	At least 5 employees
Sample unit	Company (defined as one or more establishments under common ownership or control)
Design	Sample survey
Data Collection	Directly from survey respondents
Response rate	80.9%
Number of realized observations	29 001
Non R&D performers included	No

Appendix C: Measures of R&D Intensity of R&D Performing Firms for Canada and the United States

Basically the measure of R&D intensity captures the amount of R&D dollars as a percentage of some output measure for the business sector such as revenues, sales, or value added. We use publicly available data to compute R&D intensities for the United States and Canada, and the comparability between the two countries for the available data is far from perfect.

First, while the research and development expenditures concepts of the Canadian and American surveys (definitions given in RDCI and IRD surveys) appear to be quite similar, the breakdown of expenditures differs. In U.S. surveys, the R&D amount never includes capital expenditures, while in Canadian data, "total intramural R&D" is comprised of companies' capital expenditures in addition to current R&D expenditures. Secondly, the breakdown by sources of funds is considerably different.
Furthermore, we are particularly interested in the breakdown by employment size of firms and this restricts us further as to the data we can use.

The R&D intensity of Canadian R&D performing companies reported in Table 5 comes directly from a publicly available table in Statistics Canada's Industrial Research and Development, 2005 Intentions (publication year 2006, Table 15). It reports current intramural R&D expenditures from all sources of funds as a percentage of performing company revenues by employment size.

To reconcile the OECD figures, we try to use R&D expenditures for U.S. firms excluding expenditures funded by the federal government (Table 6 in the text). Federal expenditures account for around 10% of business R&D in the United States, but for only about 2% in Canada. This means we slightly overstate expenditures in Canada, relative to the concept used for the United States, since our Canadian measure includes federally funded expenditures.

The denominator used to compute reported intensity is company revenue in Canada and sales from domestic operations in the United States. Roughly, sales from domestic operations are firm sales and shipments f.o.b. (net of excise taxes and shipping costs) excluding those by subsidiaries operating outside the 50 states and Washington, D.C. Sales from domestic operations explicitly exclude income from interest, dividends and commissions (except for financial sector firms) and from royalties and other non-operating income, all of which are included in the firm revenue concept used in Canada. (see U.S. Census Bureau, 2006 for further details). Consequently, the denominator of the U.S. intensity expression is likely to be smaller than it would be based on the Canadian concept, so that the U.S. intensity is overstated relative to the Canadian measure. We have no evidence as to how big this difference might be or as to whether its magnitude varies across firm size classes.

Lastly the reporting unit of firm used in the two surveys differs to some extent. In the Canadian RDCI surveys, the reporting unit is generally the company or enterprise (which can have several establishments or even subsidiaries). In the case of a company with decentralized research units, the reporting unit may be the division. Non-commercial firms can be "performing companies" but we do not include them in the tables reported in this paper. Employment size of companies covered in the Canadian surveys ranges from 1 to more than 4,999 employees. In the U.S. IRD surveys, company is defined as a business organization of one or more establishments under common ownership or control. Companies were categorized by total number of domestic employees. The U.S. surveys exclude companies with fewer than five employees.

Appendix D: Sources of Funds for Business R&D Expenditures

Sources of funds for business R&D, Canadian and U.S. enterprises, 2002

Canada	**Sources of funds for total intramural R&D**				
Employment size	**Performing companies**	**Federal government**	**Foreign sources**	**Other[2]**	**Total**
1 to 49	85.4	2.7	6.7	5.2	100.0
50 to 99	69.2	2.0	23.4	5.4	100.0
100 to 499	75.5	1.3	16.7	6.5	100.0
500 to 999	65.1	4.5	23.7	6.7	100.0
1000 to 4999	76.1	1.9	16.0	6.0	100.0
Greater than 4999	88.3	1.4	9.1	1.3	100.0
Total	78.8	2.0	14.5	4.8	100.0
United States	**Sources of funds for total industrial R&D**				
Employment size	**Company and other non-federal funds**	**Federal government**			**Total**
5–49	87.1	12.9			100.0
50–99	92.5	7.5			100.0
100–499	93.9	6.1			100.0
500–999	94.6	5.4			100.0
1,000–4,999	96.6	3.4			100.0
5,000+	89.9	10.1			100.0
Total	91.5	10.1			100.0

[1] Total intramural R&D includes capital expenditures

[2] Funds from provincial governments and other Canadian sources

Sources: Canada-Statistics Canada IRD 2004 Intentions (2005) Table 22, United States-NSF RDI 2003 (2007) Table2.

Appendix E: Decomposition Exercise

According to the OECD, aggregate BERD intensities (as a percentage of value added in industry) in 2002 for Canada and the United States are 1.35% and 2.44%, respectively (the first row in Table E.1). We come close to duplicating these estimates using published data from the Canadian and U.S. R&D surveys for total business R&D expenditures. (We use OECD estimates of business value added throughout). For Canada, however, we are forced to use a broader measure of R&D expenditures that includes capital expenditures to compute R&D intensity for performers within firm size classes, because there are no published data by size of firm for the narrower concept (current expenditures only) used by the OECD. As shown in Table E.1, the results with broader measure is 1.57% (in boldfaced text), somewhat higher than the OECD benchmark figure of 1.35% using the narrower concept. Since the United States collects data on current R&D expenditures only, this problem does not arise for the United States.

The limitations of our evidence emerge clearly from an attempt to reconcile the measures reported above with business R&D intensity in Canada and in the United States. If we multiply our estimates for intensity by our estimates for incidence, weight by value-added shares for size classes from BJT and add the weighted result across size classes, we underestimate BERD intensity in both countries by a factor of approximately 5.5 for Canada and 6.2 for the United States.

We know that part of this difference is accounted for by the use of a sales or revenue denominator, rather than value added, in our intensity measure. For the manufacturing sector, BJT shows the ratio of shipments to value added on the order of 2.5 for Canada and 2 for the United States. We have argued above that 1.5 is a reasonable upper bound for the factor of adjustment based on the ratio of average value added between firms that perform R&D and all firms in a size class. We now multiply 1.5 x 2.5 = 3.75 for Canada and 1.5 x 2 = 3 for the United States. Even making these adjustments, we fall short of being able to reconcile our results by size class with overall intensity by a factor of about 1.5 (5.5/3.75 = 1.47) for Canada and about 2 (6.2/3 =2.07) for the United States.

It is possible that the required adjustment to R&D intensity for the entire business sector is greater than the adjustment implied by the data from the manufacturing sector cited in the previous paragraph, but we have no way of knowing if this is so. Worse, not only do we not know the exact adjustment required to our intensity measures, we have no way of knowing how this might differ by size class of firm or how much the adjustment changes from the Canadian denominator for intensity (firm revenue) to the U.S. denominator (sales from domestic operations). Thus one should be very cautious about any conclusions drawn from our intensity measures.

We would argue that our incidence measures are reasonably accurate. Our value-added shares per size class are inexact (since they are based on data for manufacturing establishments), but large shifts in these shares are required to make much difference in the overall BERD intensity. If we assign the value-added shares we used for the United States to Canada, BERD intensity falls, due to a shift in the value-added share away from medium-sized firms, where Canada does relatively well.

Table E.1 Calculation of BERD intensity in Canada and the United States using different R&D expenditure measures, 2002

Canada

Description of BERD	**BERD** ($millions)	**BVA** ($millions)	**BERD/ BVA**
OECD indicator as a benchmark figure Industry-financed BERD as a percentage of value added in industry (OECD MSTI 2006/2 Table 34)	---	---	**1.35%**
Total intramural R&D expenditures, from all sources of funds, including capital expenditures, excluding non-commercial firms, performing company >1 employee (Table 1.7, IRD 2005 Intentions)	**13,203**	**838,629**	**1.57%**
Current intramural R&D expenditures, from all sources of funds, excluding capital expenditures, including non-commercial firms, performing company >1 employee, breakdown by employment size not available. Corresponds to R&D expenditures measure used to compute intensities shown in Table 5. (Table 1.4, IRD 2005 Intentions)	12,257	838,629	1.46%
Total intramural R&D expenditures, from business enterprise source of funds (i.e., Canadian performing companies M$10587 + related companies M$460 + R&D contracts for other companies M$180), including capital expenditures, including non-commercial firms, performing company >1 employee, breakdown by employment size not available (Table 19, IRD 2005 Intentions)	11,227	838,629	1.34%

United States

Description of BERD	**BERD** ($millions)	**BVA** ($millions)	**BERD/ BVA**
OECD indicator as a benchmark figure Industry-financed BERD as a percentage of value added in industry (OECD MSTI 2006/2 Table 34)	**---**	**---**	**2.44%**
Funds expended for industrial R&D, from company and non-federal sources, performing company > 5 employees, excluding capital expenditures (Table 2, RDI: 2002)	**174,409**	**7,277,600**	**2.40%**

Notes:

1. CAN-BVA and U.S.-BVA from OECD-MSTI 2006/2 Table D adjusted for PPP exchange rate
   CAN-BVA = 681812*1.23 = 838,629
   U.S.-BVA = 7277600*1 = 7,277,600
2. Boldfaced concepts are those used in our calculations.