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Innovation Capabilities: Science and Engineering Employment in Canada and the United States

by Desmond Beckstead and Guy Gellatly

Micro-economic Analysis Division
18th Floor, R.H. Coats Building, Ottawa, K1A 0T6

Telephone: 1 800 263-1136

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Preface

This paper compares the size and composition of science and engineering employment in Canada and the United States. It examines the share of paid employment and paid earnings accounted for by the science and engineering workforce in both countries. Our tabulations distinguish between a core group and a related group of science and engineering workers. The core group includes computer and mathematical scientists, life scientists, physical scientists, social scientists, and engineers. The related group includes workers in health-related occupations, science and engineering managers, science and engineering technologists and technicians, a residual class of other science and engineering workers, and post-secondary educators in science and engineering fields. We examine the employment and earnings shares of science and engineering workers over the 1980-1981 to 2000-2001 period. Detailed industry comparisons are reported for 2000 and 2001.

Executive summary

Scientists and engineers have long been seen as integral to a country's industrial competitiveness. This paper compares the size and composition of science and engineering (S&E) employment in Canada and the United States—as one factor aiding in the assessment of Canada's innovation capabilities vis-à-vis the United States. It reports on the share of paid employment and paid earnings accounted for by the science and engineering workforce in both countries.

Our tabulations distinguish between a core group and a related group of science and engineering workers. The core group includes computer and mathematical scientists, life scientists, physical scientists, social scientists, and engineers. The related group includes workers in health-related occupations, science and engineering managers, science and engineering technologists and technicians, a residual class of other science and engineering workers, and post-secondary educators in science and engineering fields.

The size of the science and engineering workforce in Canada and the United States is very similar when viewed in proportional terms. In 1980 and 1981, workers employed as scientists and engineers or working in other S&E-related occupations together constituted 9.8% of paid employment in Canada and 9.6% of paid employment in the United States. Both countries have seen the relative importance of science and engineering and related occupations increase, in virtual tandem, over time. By 1990 and 1991, workers employed in these specialized occupations together accounted for 11.7% and 11.3% of paid employees in Canada and the United States, respectively. By 2000 and 2001, their numbers grew to 13.6% of total employment in both countries.

Income growth within the S&E workforce has also followed a similar course in both countries, with income gains outpacing gains in employment. From 1981 to 2001, scientists, engineers and workers in S&E-related occupations in Canada increased their share of paid earnings from 13.4% to 19.9%, while their counterparts in the United States saw their earnings share improve from 12.3% to 19.2%. Within the broader S&E workforce, scientists and engineers generate the largest incomes in relation to their numbers.

There are some differences between Canada and the United States in how intensively scientists and engineers are employed in different sectors of the economy. The sector with the largest share of scientists and engineers in both countries—professional, scientific and technical services industries—is more S&E-intensive in Canada than in the United States.

Scientists and engineers make up one-quarter of this sector's workforce in Canada, compared to about one-fifth in the United States. Conversely, the U.S. manufacturing sector is more S&E-intensive than Canada's manufacturing sector. Scientists and engineers make up 8.1% of U.S. manufacturing employment, compared to 4.8% in Canada.

Chapter 1. Introduction

Scientists and engineers have long been seen as integral to a country's industrial competitiveness. The importance of these specialized workers to economic progress is generally portrayed as clear and unambiguous. On this, the positions taken by The Progressive Policy Institute and The National Science Foundation are illustrative. The Progressive Policy Institute begins its analysis of science and engineering employment by noting that "(t)echnological innovation is one of the key drivers of overall economic progress, and it is fueled by a strong engineering and scientific workforce".[1] The National Science Foundation asserts that "these workers contribute enormously to technical innovation and economic growth, research, and increased knowledge".[2] These statements reflect the widely-held view that the labour market contributions of scientists and engineers are critical inputs to national innovation systems.

This paper compares the size and composition of science and engineering employment in Canada and the United States—as one factor aiding in the assessment of Canada's innovation capabilities vis-à-vis the United States. We report on the share of paid employment and paid earnings accounted for by scientists, engineers and related workers in both countries. Our tabulations distinguish between a core group and a related group of science and engineering workers. The core group includes computer and mathematical scientists, life scientists, physical scientists, social scientists, and engineers. The related group includes workers in health-related occupations, science and engineering managers, science and engineering technologists and technicians, a residual class of other science and engineering workers, and post-secondary educators in science and engineering fields. We report the employment and earnings shares of S&E workers over the 1980-1981 to 2000-2001 period. Detailed industry comparisons are reported for 2000 and 2001.

The organization of the paper is as follows. Section 2 outlines the motivation for this analysis. Our tabulations are based on the premise that comparative estimates of science and engineering employment shed light on the relative size of Canada's innovation system. Section 3 discusses the classification scheme that is used to quantify the size and composition of the science and engineering workforce in Canada and the United States. This classification scheme distinguishes between a core set of science and engineering occupations and a related set of occupations that contain a significant science or engineering component.

Our estimates of S&E employment and paid earnings are reported and discussed in Section 4. We present these in the form of employment and income shares—the portion of total employment and total paid earnings accounted for by individuals working in S&E and S&E-related occupations. These estimates derive from Canadian and U.S. census data covering the 20-year period from 1980-1981 to 2000-2001. Industry-specific S&E estimates are reported for 2000 and 2001. Section 5 concludes.

Endnotes

1. Atkinson and Court (1998: 41).
2. National Science Board (2004: Chapter 3, 5).

Chapter 2. Estimates of science and engineering employment–some context

There is a rich empirical literature describing the characteristics of national innovation systems.[3] Much of this literature explores cross-national differences in the size and scope of innovation inputs, such as the extent to which different countries are devoting resources to research and development (R&D). Canada's innovation climate is sometimes portrayed as disadvantaged because proportionately fewer resources are devoted to R&D in Canada than in many other countries, most notably the United States.[4] In a recent paper, Baldwin, Beckstead and Gellatly (2005) reported that a standard measure of the intensity with which businesses devote funds to innovation—the BERD-to-GDP ratio[5]—may significantly understate the relative size of Canada's innovation expenditures, because Canadian firms rely more extensively than do firms in many other countries on the acquisition of R&D and technological know-how from abroad. These acquisitions of foreign-produced R&D and technology are sometimes overlooked in cross-national evaluations of innovation performance, which often focus disproportionately on domestic R&D.

This paper extends our research on comparative innovation inputs by examining an alternate measure of the economic resources that can be devoted to the innovation process—the size of the economy's science and engineering workforce.

There are compelling reasons to focus on the labour market contributions of scientists and engineers when evaluating cross-border differences in innovation intensity. The activities of scientists and engineers have long been regarded as essential to technological innovation and economic growth. In practice, these activities take many different forms. Some involve formal R&D. Others do not. All involve applying science and technology in some way to the innovation process.

The scope of these labour market activities warrants emphasis. In a recent assessment of Canada's R&D performance, The Conference Board of Canada (2002: 4) warned that Canadian firms "are in dire need of more scientists, engineers and technologists", skilled workers that are required in great numbers "to carry out new R&D". While the centrality of scientists and engineers to R&D is not in dispute, many of these workers contribute to the innovation process via activities that fall outside the scope of what statisticians formally measure as R&D—notably through firm-specific advances in production engineering and technology adaptation. Seminal research by Mowery and Rosenberg (1989) has emphasized the importance of the technological breakthroughs that occur in production and engineering departments. This, in turn, has aided in advancing a view of the innovation process in which the impetus for innovation can originate from a variety of sources within the firm—from

R&D laboratories, to production departments to management teams.[6] Assessments of innovation capabilities that focus on large cross-sections of science and engineering workers are consistent with this diverse view of the innovation process, in that these are workers that are actively engaged in a broad array of knowledge-creating activities, both within and outside the boundaries of formal R&D.

Domestic R&D-to-GDP ratios steadfastly remain at the core of international comparisons of innovation performance.[7] R&D expenditures, as Holbrook (1991: 259) notes, “are often used as the prime indicator of the level of technological resource inputs to an economy”, and are “examined minutely as part of an overall examination of science policy.” For its part, the OECD has historically “made the most of promoting this indicator (the GERD-to-GDP ratio) as central to science and technology development” (Voyer, 1999).

Our focus herein is on one particular measure of an economy’s scientific and technology capability—the proportional size of its S&E workforce. We report these tabulations mindful of the fact that, like R&D intensity, estimates of scientific and engineering labour are but one indicator of the resources that are available to the innovation system, and should be regarded as such.[8] Comprehensive cross-national evaluations of innovation performance require healthy cross-sections of input and output measures—the consideration of which is beyond our scope here.[9] Rather, the labour estimates reported in this paper are intended to provide information on a dimension of the innovation process other than R&D. We look to these new data on science and engineering labour to learn more about whether, on the input side, Canada’s innovation system is as disadvantaged as conventional R&D-to-GDP comparisons would suggest.

Endnotes

3. For background on innovation systems, see Lundvall (2004).
4. For discussion of Canada's R&D deficit, see Harris (2005). For a recent analysis that examines the role that "structure" and "intensity' effects play in explaining Canada's R&D gap relative to the United States, see ab Iorwerth (2005).
5. Two statistical measures are commonly used to gauge an economy's R&D effort, the GERD and the BERD. The former denotes gross domestic expenditure on research and experimental development, and "covers all R&D carried out on national territory in the year concerned" (OECD, 2002: 3). The BERD is a more restrictive measure, and includes only the subset of domestic R&D expenditures that occur in the Business Enterprise Sector.
6. This broader view of a diversity of innovation inputs is well supported by Canadian innovation surveys. For discussion, see Baldwin and Hanel (2003) and Baldwin and Gellatly (2003).
7. There are numerous studies that discuss the limitations of standard R&D to GDP comparisons. For discussion on how differences in industrial structure affect the precision (i.e., coverage) of R&D statistics, see Kleinknecht, Poot and Reijnen (1991); for an analysis of the scale effects inherent in R&D measurement, see Holbrook (1991) and Katz (2005).
8. A reliance on any single indicator can distort cross-national comparisons of innovation performance. In a recent paper on European innovation systems, Roper and Hewitt-Dundas (2005) reported country rankings for a variety of output-based measures of innovation activity after controlling for differences in industrial structure. The authors note that, in several cases, the choice of indicator will significantly alter cross-country perceptions of innovative performance, advising, in turn, that evaluations of innovation performance be based on a "basket of indicators".
9. For an excellent overview of innovation measurement, see Kleinknecht (1996). Godin (1996) discusses the statistical measures that have been developed to gauge the state of science and technology activity in Canada. The Conference Board of Canada's (2004) assessment of Canada's innovation climate is a good example of a comprehensive analytical framework—it examines 17 specific indicators in 4 broad categories: knowledge performance; skills performance, innovation environment, and community-based innovation.

Chapter 3. Measuring the size of the science and engineering workforce

The S&E estimates reported in this paper are based on an occupational structure that has been developed and used by the National Science Foundation (NSF) to profile the U.S. science and engineering population. As Pollak (1999) and Wilkinson (2002) note, there are two ways to estimate the size of this population, either via (a) a count of workers employed in S&E occupations or (b) a count of individuals who have attained science or engineering degrees. The use of one or the other method will dramatically affect the size and scope of the S&E population under study. The magnitude of these differences warrants emphasis. When S&E estimates are based on individuals employed in S&E occupations, the size of the United States S&E workforce in 1999 stood at about 3.5 million; alternatively, when these estimates are based on S&E degree holders, the S&E population increases to over 10 million (Wilkinson, 2002).[10] In Canada, individuals holding S&E degrees outnumber individuals employed in S&E occupations by a ratio of 2.2 to 1.

In this paper, we utilize the occupation-based method to estimate the size of the S&E population—focusing on individuals who are employed in a predetermined set of S&E and S&E-related occupations.[11] We have opted for an occupational definition because our main interest is in comparing the proportional size of the S&E workforce. It is these S&E workers that many regard as actively engaged in the creation of scientific and technical knowledge. They do so in many different segments of the labour market: in private companies, government departments, universities, and public- and privately-funded research institutes, to name but a few. The vast majority of these S&E workers were formally educated in S&E fields. But there are large numbers of individuals that possess S&E degrees that work in non-S&E occupations—workers who also contribute, in some measure, to the stock of scientific and engineering knowledge embedded in either country's workforce. While cross-national comparisons that include all S&E-trained individuals may be of interest to some, the more narrow focus on S&E occupations serves as the focal point for the comparative tabulations reported herein.

The National Science Foundation's S&E framework has traditionally designated two types of occupations: S&E-based and non S&E-based. S&E occupations are drawn from five basic categories: computer and mathematical scientists, physical sciences, life sciences, social sciences and engineering. All other occupations outside of these five categories were traditionally classified as non S&E occupations. Recently, the NSF has revised its binary classification scheme to include a third major occupational category—S&E-related occupations. These are jobs that contain a very substantial science or engineering component, but were originally classified as non S&E-based. In general terms, many of the individual

Table 1 Scientists and engineers and science and engineering-related occupations

Scientists and engineers
Computer and mathematical scientists
Computer and information scientists
Mathematical scientists
Post-secondary teachers—computer and math sciences
Life and related scientists
Agricultural and food scientists
Biological and medical scientists
Environmental life scientists
Post-secondary teachers—life and related sciences
Physical and related scientists
Chemists, except biochemists
Earth scientists, geologists and oceanographers
Physicists and astronomers
Other physical and related scientists
Post-secondary teachers—physical and related sciences
Social and related scientists
Economists
Political scientists
Psychologists
Sociologists and anthropologists
Other social and related scientists
Post-secondary teachers—social and related sciences
Engineers
Aerospace and related engineers
Chemical engineers
Civil and architectural engineers
Electrical and related engineers
Industrial engineers
Mechanical engineers
Other engineers
Post-secondary teachers—engineering
Science and engineering-related occupations (science and engineering-related workers)
Health-related occupations
Science and engineering managers
Science and engineering pre-college teachers
Science and engineering technicians and technologists
Other S&E-related occupations

Source: The National Science Foundation (NSF).

occupations that are included in this related S&E category have a more substantial applied or practical focus (e.g., technicians and technologists) than many of the research-oriented occupations included in the core S&E definition. We present this classification system in Table 1.

In this paper, we use the term “scientists and engineers” in direct reference to the five occupational categories noted above that together form the basis for the NSF’s original S&E occupational framework. Similarly, we use the term S&E-related workers when referring to individuals employed in occupations that have recently been re-classified by the NSF as S&E-related. When we make reference to the broader scientific and engineering community within the economy, it is with reference to the union of these two occupational groups—S&E workers and S&E-related workers.

The S&E statistics reported in the following section are employment and earnings shares derived from recent Census of Population data for Canada and the United States.[12] These data are the most comprehensive available that allow us to derive comparable estimates of S&E employment and S&E earnings for the two countries. That said, there are several measurement issues that warrant emphasis.

First, the Canadian census is conducted at 5-year intervals. Canadian estimates are available for five separate census years: 1981, 1986, 1991, 1996 and 2001. By comparison, the U.S. census is conducted at 10-year intervals; U.S.-S&E estimates are available for 3 census years, 1980, 1990 and 2000. Canada/U.S. comparisons for specific periods are thus based on data collected in adjacent years (e.g., 1991 in Canada versus 1990 in the United States.). Given the stability of these employment and earnings shares over time, cross-country comparisons based on adjacent years do not, in our view, substantially diminish their interpretability. In what follows, our cross-sectional comparisons focus on the three census periods for which detailed U.S. micro-data are available: 1980-1981, 1990-1991 and 2000-2001.

An S&E employment share is defined as the ratio of employment in S&E occupations to total employment, based on counts of paid workers obtained from different census files.[13] Analogously, S&E earnings shares measure the portion of total paid earnings accounted for by workers in S&E occupations. The second measurement issue that warrants emphasis concerns the development of comparable census-based income estimates for the two countries. While both these employment and earning shares are conceptually straightforward, the latter cannot be computed directly from U.S. public-use census files. Earnings data on these files are *top coded*, a practice whereby income data for individuals in the top ranges of the income distribution are suppressed. Consequently, we rely on an alternate means of computing S&E earnings shares. For each country, we derive estimates of the share of total earnings accounted for by each S&E worker category by multiplying the number of S&E workers by their median earnings, and then dividing this estimate of total S&E earnings by the corresponding earnings estimate for all workers. These income shares have the general form:

$$inc\_shr_c^i = \frac{n_c^i * y_c^i}{\sum_i n_c^i * y_c^i} \quad (1)$$

where $inc\_shr_c^i$ denotes the share of earnings accounted for by a specific set of occupations, i, in country c, n_c^i is the number of workers employed in occupations of type i in country c, y_c^i is the median income of these workers. The denominator in equation (1) is the estimated aggregate earnings of employed workers in country c. This technique yields accurate estimates of earnings shares across a range of different occupational categories.[14]

The third measurement issue is related to the accuracy of occupational coding on the Census of Population. Occupation coding is, in practice, a difficult task because it depends upon the completeness of the occupational description provided by the respondent. Based on this information, an occupational code is assigned to each respondent based on a coding operation. The coding error rate is felt to be high for certain occupations, particularly for management categories (Statistics Canada, 1999). Accordingly, we have avoided using detailed occupational categories in this paper. In our view, estimates for the higher-level occupational aggregates reported here are comparable for the two countries given the similarities in the methods used to derive the occupational data.[15]

We present our estimates of S&E employment and earnings in the next section.

Endnotes

10. The scope of the NSF's official S&E population is based on the union of these two methods—the non-duplicated sum of individuals working in S&E occupations or holding S&E degrees. For discussion, see Kannankutty and Wilkinson (1999).

11. An earlier Canadian study (Hansen, 1999) used *field of study* data to estimate the size of Canada's science and technology-based (S&T) workforce. The study then reported on the labour market outcomes (employment status, industry of location) associated with different categories of S&T workers.

12. Other organizations such as the OECD routinely publish comparisons involving many countries. Because of data availability and the longstanding practice of benchmarking Canadian economic data against U.S. data, we have limited our scope to a Canada/United States comparison.

13. This straightforward count-of-workers approach raises an issue of direct relevance to innovation measurement—distinguishing between labour effort that involves science and engineering activities and that which does not. Not all scientists and engineers are doing work relevant to the creation of scientific and engineering knowledge; in addition, of those who are carrying out relevant work, most undoubtedly divide their time between these knowledge-generating S&E activities and other more mundane tasks. Business surveys that collect information on the size of the R&D workforce handle this problem by asking business respondents to report their R&D effort in terms of full-time equivalents. Under this method, R&D workers are assigned a weight that is equal to the share of their labour effort that is devoted to R&D. For example, workers that spend all of their time on R&D receive a weight of one; those that spend one-half of their time on R&D receive a weight of 0.5. While the adjustment handles the 'part-time' problem in theory, it is difficult to achieve full-time equivalents (FTEs) in practice because respondents often do not keep information on the matter. FTE adjustments of this sort are well beyond our scope here, as our tabulations are derived from Canadian and U.S. census files, not from industrial surveys designed to collect information from science and engineering managers.

14. We evaluated the precision of this estimator directly from Canadian census data. We compared our results for equation (1) to the actual share estimates that one obtains when these are calculated directly from earnings data that are not top coded. (These actual shares are calculated as $\frac{y_c^i}{Y_C}$, the sum of all earnings for individuals in occupational category *i* divided by the sum of employed earnings). The actual share values and the estimated values based on equation (1) are very similar, both in specific years and when compared over time. When we calculate these ratios from 2001 Canadian census data, there is a 1 percentage point difference between the actual earnings share and the estimated earnings share for S&E and S&E-related occupations obtained from equation (1). And this 1 percentage point difference also represents the divergence in the growth of these earnings ratios over the longer run, as the estimated and actual earnings shares from the 1981 Canadian census are virtually identical. These comparisons give us confidence in the reliability of the income shares reported herein.

15. An additional note on methods: Canadian estimates for 1991 are an average of the results obtained from two separate classification schemes, the 1980 Occupational Classification Codes (used for the 1981 estimates) and the 1991 Standard Occupational Classification (used for the 2001 estimates).

Chapter 4. S&E and S&E-related occupations in Canada and the United States

The shares of total employment and total earnings accounted for by scientists and engineers and workers in S&E-related occupations are reported in Table 2. These tabulations include workers in both private and public sector industries.

Table 2 Scientists and engineers and science and engineering-related employment and income shares

Employment shares	1980–1981	1990–1991	2000–2001
Canada			
Percentage of employed individuals classified as:			
Scientists and engineers	2.3	3.0	4.5
Science and engineering-related workers	7.5	8.7	9.0
Other workers	90.2	88.3	86.4
United States			
Percentage of employed individuals classified as:			
Scientists and engineers	2.6	3.3	4.5
Science and engineering-related workers	7.1	8.0	9.1
Other workers	90.4	88.7	86.4
Income shares			
Canada			
Percentage of paid earnings accounted for by:			
Scientists and engineers	4.2	5.2	7.7
Science and engineering-related workers	9.3	11.3	12.2
Other workers	86.6	83.5	80.1
United States			
Percentage of paid earnings accounted for by:			
Scientists and engineers	5.1	6.5	8.5
Science and engineering-related workers	7.3	9.0	10.7
Other workers	87.7	84.5	80.8

Note: Percentages may not add to 100 due to rounding.

Source: Tabulations based upon data from the 1981, 1991 and 2001 Canadian Censuses of Population and from the 1980, 1990 and 2000 United States Censuses of Population.

It is striking to note how similar the size of the S&E workforce is in Canada and the United States when viewed in proportional terms. In 1980 and 1981, S&E and S&E-related occupations together constituted 9.8% of paid employment in Canada and 9.7% of paid employment in the United States. Both countries have seen the relative importance of these workers increase, in virtual tandem, over time. By 1990 and 1991, S&E and S&E-related workers together accounted for 11.7% and 11.3% of paid employees in Canada and the United States, respectively. By 2000 and 2001, both countries had equivalent S&E and S&E-related shares, at 13.6% of total employment.

There are only modest differences in the proportional size of the two broad occupational classes that together comprise the science and engineering community. In 1980 and 1981 the United States had slightly more scientists and engineers than did Canada, at 2.6% and 2.3% of the workforce, respectively. By 2000 and 2001, the gap between the two countries had disappeared—scientists and engineers accounted for 4.5% of paid employees in both Canada and the United States.

Workers in the second broad occupational group of S&E-related occupations, are, on balance, far more numerous than scientists and engineers—though the relative numbers of scientists and engineers increased more dramatically in both countries during the 1990s. In earlier years, Canada had a slight edge over the United States in the proportionate size of this S&E-related workforce. In 1990 and 1991, these workers amounted to 8.7% of Canadian employment, compared to 8.0% of employment in the United States. By 2000 and 2001, these slight differences had again disappeared, with S&E-related workers amounting to 9.0% and 9.1% of the Canadian and American workforces.

Income growth within the S&E community has also followed a similar course in both countries, with gains in the S&E and S&E-related shares of paid earnings outpacing the corresponding gains in employment. From 1981 to 2001, scientists, engineers and workers in S&E-related occupations in Canada increased their share of paid earnings from 13.5% to 19.9%, while their counterparts in the United States saw their earnings share improve from 12.4% to 19.2%. Scientists and engineers generate the largest incomes in relation to their numbers. Workers in S&E-related occupations also generated income shares well in excess of their employment shares, most notably in Canada. And the difference between the income and employment shares of S&E related workers has been increasing over time in both countries.

The aggregate tabulations presented above reveal little difference in the proportionate size of the S&E and S&E-related workforces in Canada and the United States. The incidence of these workers is similar in each analysis period (1980-1981, 1990-1991 and 2000-2001) with the growth in S&E and S&E-related employment occurring in step in both countries. The same holds true when evaluating their paid earnings.

We next present more detailed estimates of S&E employment by industry, as a means of evaluating the extent to which these aggregate similarities obscure important differences in the location of science and engineering workers across the two economies. In this exercise, we focus specifically on the core set of scientists and engineers—workers that, in 2000 and 2001, accounted for 4.5% of employment in both countries.

Table 3 reports the share of employment accounted for by scientists and engineers in 20 different industry sectors, based on data from the 2000 U.S. census and the 2001 Canadian census. It also reports the share of total employment, based on all occupations, accounted for by each sector. In parentheses, we also list the rankings of each sector, in terms of S&E intensity and employment share, within each country.[16]

Table 3 Scientists and engineers in workforce, by industry

	Percentage of workforce accounted for by scientists and engineers				Industry share of total employment (%)			
	Canada	Sector ranking	United States	Sector ranking	Canada	Sector ranking	United States	Sector ranking
Professional, scientific and technical services	25.5	1	19.9	1	6.4	6	5.8	7
Information and cultural industries	12.7	2	11.4	2	2.7	15	3.1	14
Utilities	12.2	3	9.8	4	0.8	19	0.9	18
Mining and oil and gas extraction	8.9	4	8.5	5	1.1	18	0.4	19
Public administration	8.4	5	6.9	7	5.9	7	5.6	8
Management of companies and enterprises	7.8	6	10.6	3	0.1	20	0.1	20
Finance and insurance	5.6	7	5.5	8	4.2	12	5.0	9
Manufacturing	4.8	8	8.1	6	13.8	1	14.0	1
Wholesale trade	4.3	9	2.7	10	4.5	11	3.6	12
Education services	2.5	10	2.9	9	6.7	4	8.7	4
Administrative and support, waste management and remediation services	2.1	11	1.6	12	3.8	13	3.4	13
Health care and social assistance	1.6	12	1.9	11	10.0	3	11.0	3
Construction	1.5	13	1.4	14	5.4	8	6.7	5
Other services (except public administration)	1.3	14	1.0	18	4.8	10	4.8	10
Transportation and warehousing	1.3	15	1.2	16	5.0	9	4.3	11
Real estate and rental and leasing	1.3	16	0.9	19	1.7	17	1.9	15
Arts, entertainment and recreation	1.1	17	1.1	17	1.9	16	1.8	16
Agriculture, forestry, fishing and hunting	0.9	18	1.3	15	3.5	14	1.5	17
Retail trade	0.8	19	1.5	13	11.3	2	11.6	2
Accommodation and food services	0.1	20	0.2	20	6.5	5	6.0	6

Note: Industries are sorted by descending Canadian science and engineering share.
Source: Tabulations based upon data from the 2001 Canadian Census of Population and the 2000 United States Census of Population.

Canadian and U.S. S&E-intensities are similar across many of the sectors examined. Of the five most S&E-intensive sectors in each country, four are common to both countries. Two sectors warrant particular emphasis. First, the sector with the largest share of scientists and engineers in both countries—professional, scientific and technical services industries—is more S&E-intensive in Canada than in the United States. Scientists and engineers make up one-quarter of this sector's workforce in Canada, compared to about one-fifth in the United States. This sector makes up about 6% of the aggregate workforce in both countries. The second sector worth stressing is manufacturing. At 14% of both Canadian and U.S. employment, manufacturing is the largest sector examined above. And manufacturing is more S&E-intensive in the United States than in Canada. Scientists and engineers make up 8.1% of U.S. manufacturing employment, compared to 4.8% in Canada.

Though their relative rankings are similar in both countries, there is also some slight variation in Canada/United States S&E intensities across industries with more modest employment shares. Public administration industries in Canada have a higher S&E share (8.4%) than in the United States (6.9%). In both countries, education services is less S&E intensive than public administration. But education services is both proportionately larger and slightly more S&E-intensive in the United States. This said, these and other differences are qualitatively modest.

The sector-specific S&E tabulations noted here warrant comparison to a recent analysis of Canada's R&D effort which focused on the underlying importance of structural differences between the two economies. ab Iorwerth (2005) reports that a sizable portion of Canada's R&D gap, relative to the United States, stems from lower R&D spending in a small number of industries—industries that are heavily weighted in the derivation of Canadian GERD-to-GDP ratios. His study also noted that Canada is home to several research-intensive industries that perform proportionately more R&D than their American counterparts, but these are smaller industries that count less towards aggregate R&D comparisons. The tabulations presented herein suggest that these types of distributional factors that structurally disadvantage perceptions of Canada's R&D performance do not carry over to comparisons of S&E workers. Areas of the economy for which the United States is more S&E-intensive are offset by higher Canadian S&E intensities in other sectors. The employment weighting associated with these patterns of higher and lower S&E intensity generates an equivalent S&E share in the aggregate.

The sector-level comparisons presented in Table 3 provide a starting point for more detailed analyses of the structural and technological factors that contribute to sector-specific differences in S&E intensity between Canada and the United States. For the two sectors for which large differences in S&E intensity exist—manufacturing and professional, scientific and technical (PST) services—we can decompose the portion of this difference that is due to underlying variation in industry structure and underlying variation in technology skills. The first of these effects, variation in industrial structure, refers to the portion of the difference in S&E intensity in either manufacturing or PST services that stems from underlying differences between the two countries in the relative size of the industries that make up either sector. The second effect, variation in technology skills, refers to the portion of the difference in S&E intensity in either manufacturing or PST services that arises because of underlying differences in the intensity with which scientists and engineers are employed in these specific industries, after compositional effects are taken into account. (We present the mathematics of this decomposition in Appendix C.)

The Canadian manufacturing sector is 3.3 percentage points less S&E-intensive than its American counterpart. About half of this difference is due to underlying differences in the industrial composition of manufacturing between the two countries, after technological differences are taken into account; the remainder is due to differences in technological intensity after controlling for the effects of industrial composition. Within manufacturing, automotive and aerospace industries account for much of the difference in industrial structure leading to a higher S&E intensity in the United States. High-tech equipment industries[17] account for much of the difference in technological intensity after controlling for variation in the industry mix.

Canada's professional, scientific and technical services sector is 5.6 percentage points more S&E-intensive than its U.S counterpart. Here about two-thirds of the difference is driven by underlying variation in the industrial composition of this sector between the two countries. The computer systems design and related services industry accounts for much of the observed difference, in terms of both industry and technology effects.

Endnotes

16. We report the distribution of scientists and engineers across industries in Appendix B.
17. Computer and peripheral equipment manufacturing, communications, audio and video equipment manufacturing, and electronic components and products manufacturing.

Chapter 5. Conclusion

There is a considerable interest in empirical studies that investigate how the innovation capabilities of national economies differ. Canada's innovation system is sometimes characterized as disadvantaged, because Canadian businesses devote proportionately fewer resources to research and development than do businesses in many other countries. Canada's R&D gap with the United States has received particular attention.

R&D-intensity is only one measure of an economy's innovative capacity. This paper focuses on a different input measure, the share of science and engineering occupations within the employed labour force. Scientists and engineers have long been regarded as important sources of technological innovation and economic growth. Many of these workers engage in R&D activities. Others engage in labour market activities that fall outside the boundaries of formal R&D.

Our tabulations use Census of Population data for Canada and the United States to estimate the size of the S&E workforce in both countries. While Canada may lag behind the United States in terms of its domestic expenditures on R&D, Canada does not look comparatively disadvantaged in terms of the size of its S&E workforce. In the aggregate, the portion of individuals employed in S&E and S&E-related occupations in the two countries is remarkably similar. These shares were similar 20 years ago, and have since grown in tandem.

Appendix A. Notes on the measurement of S&E and S&E-related occupations

The taxonomy used herein for quantifying the size of the S&E and S&E-related workforce is based on the occupational structure developed by the National Science Foundation (NSF). Several of the challenges involved in producing these estimates were noted in Section 2. In this appendix, we offer a more detailed discussion of data issues.

The main data development task for this study centered on operationalizing the NSF's occupational S&E framework in what could be termed as "census context"—both for Canada and the United States. This involved linking the detailed occupational structure used by the NSF to the occupational codes that are used to classify workers in the Canadian and U.S. censuses. Those census occupational codes change over time in each country, because of revisions to the occupational standards that occur periodically to reflect the changing occupational characteristics of the workforce. The challenge then was to identify a consistent set of S&E and S&E-related occupations for each country, and render these comparable between countries, both cross-sectionally (for a given census period) and over time (across all census periods under study). This process involved a reasonable amount of subjective evaluation as to the appropriateness of specific occupational codes and how to harmonize these code sets over time. However, we are confident that, in the main, the occupational codes used herein accord well with the substance of the NSF's science and engineering framework. (The detailed census occupational codes that are used are available from the authors upon request.)

Though discussed in Section 2, the key element of our occupational approach is worth stressing again here. Individuals are classified as scientists and engineers and S&E-related workers regardless of the nature of their formal education. In other words, some scientists and engineers—albeit a small minority—do not possess science, engineering or S&E-related degrees. This said, this occupation-based approach provides for a much more restrictive estimate of the S&E and S&E-related population than one obtains when using an education-based approach.

There are a number of detailed issues concerning the treatment of specific occupations that, for reasons of transparency, warrant mention. We note these below.

The NSF includes post-secondary teaching occupations in relevant S&E fields in its S&E definition. However, the Canadian census data do not classify post-secondary teachers by their subject matter (e.g., physics, chemistry, mathematics). Consequently, we allocate a portion of this post-secondary group to a single separate S&E-related category (based on share of degree holders educated in S&E and S&E-related fields). To ensure comparability with the U.S. census data, detail on the subject matter of post-secondary educators is ignored.

Though the NSF creates a separate category for pre-college teachers in computer science, mathematics, science and social science, secondary teachers are not classified by subject matter in either country via the census. These educators are not included in the S&E and S&E-related classifications used in this research.

The NSF includes health diagnosing and treating professionals in their Life Sciences category if they have received a PhD (earned doctorate). In the United States census micro-data files, degree attainment is available for the 1990 and the 2000 censuses but not for the 1980 census. As a result, all health diagnosing and treating professionals are grouped together in the Health Occupations category.

Sales Engineers are identified by distinct codes in the U.S. census micro-data files. However, in Canada, this occupation is not identified on census files (or in occupational classification systems). It is assumed that these individuals are classified to “other engineering occupations” as opposed to “technical sales specialists”.

Some of the tabulations reported in this paper are derived using the 1980 Occupational Standard. This standard groups computer programmers together with computer systems analysts. To ensure continuity over time, we classify both sets of occupations to the Mathematics and Computer Science group within the main S&E category. The NSF allocates this occupation to its S&E-related group.

In the NSF framework, the Other S&E-related category includes actuaries and architects. Because of the occupational classification standards used in Canada, actuaries are grouped with mathematical occupations. Consequently, for both countries, we assign actuaries to the mathematics and computer science category in the main S&E group. Hence, in this study, architects (including landscape architects) are the only occupation included in the Other S&E related category.

Scientists and engineers in the Armed Forces are classified on an occupational basis in the Census (in both Canada and the United States) to an armed forces occupation. These workers can only be classified as scientists and engineers via the application of the NSF’s degree-based taxonomy. Though this could be done in the Canadian context using major field-of-study data available from the Census, there is no corresponding data available from the U.S. micro-data census files. Consequently, these workers are excluded from the S&E and S&E-related definitions used herein.

S&E managers are measured reasonably well in the 2000 Standard Occupational Classification, but considerably less well in earlier classification systems. These classification systems assign managers in engineering, mathematics and natural sciences and managers in social sciences and related fields to higher-level occupational aggregates. Consequently, this study uses a more restrictive definition of S&E managers in the 1980-1981 and 1990-1991 analysis periods (based on managers in health and medicine-related occupations).

Appendix B. The distribution of S&E and S&E-related occupations across industrial sectors

Table 3 in Section 4 reports on the percentage of employment accounted for by scientists and engineers in 20 different sectors, as a means of comparing the intensity of S&E employment across Canadian and U.S. industries. The following table outlines how the total stock of scientists and engineers in each country is distributed across these industries, in order to gauge the extent to which scientists and engineers are more heavily concentrated in certain sectors in one or the other country. As in Table 3, we also report the distribution of total paid employment across these industries in both Canada and the United States.

Table B1 Distribution of employment across industrial sectors

	Industry share of scientists and engineers (% of total)		Industry share of total employment (% of total)	
	Canada	United States	Canada	United States
Professional, scientific and technical services	35.9	25.9	6.4	5.8
Information and cultural industries	7.5	7.8	2.7	3.1
Utilities	2.1	2.0	0.8	0.9
Mining and oil and gas extraction	2.1	0.7	1.1	0.4
Public administration	10.9	8.6	5.9	5.6
Management of companies and enterprises	0.2	0.1	0.1	0.1
Finance and insurance	5.2	6.0	4.2	5.0
Manufacturing	14.8	25.4	13.8	14.0
Wholesale trade	4.2	2.2	4.5	3.6
Education services	3.6	5.6	6.7	8.7
Administrative and support, waste management and remediation services	1.7	1.2	3.8	3.4
Health care and social assistance	3.5	4.7	10.0	11.0
Construction	1.8	2.1	5.4	6.7
Other services (except public administration)	1.4	1.1	4.8	4.8
Transportation and warehousing	1.4	1.2	5.0	4.3
Real estate and rental and leasing	0.5	0.4	1.7	1.9
Arts, entertainment and recreation	0.4	0.4	1.9	1.8
Agriculture, forestry, fishing and hunting	0.7	0.4	3.5	1.5
Retail trade	2.0	4.0	11.3	11.6
Accommodation and food services	0.2	0.2	6.5	6.0

Note: Industies are sorted by descending Canadian science and engineering share, as reported in Table 3.
Source: Tabulations based upon data from the 2001 Canadian Census of Population and the 2000 United States Census of Population.

The industry examples discussed in Section 4 warrant emphasis here. As noted earlier, manufacturing accounts for 14% of total paid employment in both Canada and the United States. And, as reported in Table 3, Canada's manufacturing sector is less S&E intensive than its U.S. counterpart. The above data portray these differences in a new light—in Canada, only 15% of all scientists and engineers are employed in manufacturing, compared to about 25% of all U.S scientists and engineers. In a similar vein, we also noted earlier that Canada's professional, scientific and technical services sector is more S&E-intensive than its U.S. counterpart. While these industries account for roughly the same share of total employment in both countries, they are home to 36% of all Canadian scientists and engineers, compared to 26% of all scientists and engineers in the United States.

Appendix C. Decomposing Canada/U.S. sectoral differences in S&E employment intensity

The decomposition analysis discussed in Section 4 is described in detail below. This decomposition exercise focuses on the extent to which observed differences in the S&E employment intensity of a particular sector (e.g., manufacturing in Canada versus manufacturing in the United States) is due to (1) underlying variation between the two countries in the relative size of the industries that make up the sector, and (2) underlying variation in the intensity of S&E employment within these more detailed industries. The first of these factors evaluates the role of industry composition; the second examines technological differences within these more detailed industries, as proxied by variation in the relative emphasis given to scientists and engineers.

Mathematically, this decomposition takes the following form. Let $E^{SE}_{C,i(s)}$ denote the Canadian S&E employment in sub-sector *i* (e.g., aerospace manufacturing) within sector *s* (e.g., manufacturing). The share of employed workers that are scientists and engineers in sub-sector *i* is

$$S^{SE}_{C,i(s)} = E^{SE}_{C,i(s)} / E_{C,i(s)}$$

The difference in S&E employment intensity between sector *s* in Canada and sector *s* in the United States, $S^{SE}_{C,s} - S^{SE}_{US,s}$, is denoted in the equation below as D, the sum of three terms (A, B, and C):

D = A + B + C.

Term A evaluates the impact of industry structure, holding the impact of technological skills constant. This is accomplished by setting Canada's S&E shares equivalent to the United States (observed) S&E shares:

$$[\sum_{i(s)} S_{C,i(s)} * S^{SE}_{US,i(s)}] - S^{SE}_{US,s}$$

Term B evaluates the impact of technology, holding the impact of industry structure constant. This is done by setting Canada's industry employment shares equivalent to the United States industry employment shares:

$$[\sum_{i(s)} S_{US,i(s)} * S^{SE}_{C,i(s)}] - S^{SE}_{US,s}$$

Term C represents the covariance term, which captures the interaction between term A (the industry effect) and term B (the technology effect). This takes the forms:

$$\sum_{i(s)} (S^{SE}_{C,i(s)} - S^{SE}_{US,i(s)})(S_{C,i(s)} - S_{US,i(s)}).$$

The results of this decomposition for two sectors—manufacturing and professional, scientific and technical services—are presented below.

Table C1 Results of decomposition analysis

Industry	Percentage point difference in S&E[1] employment share (Canada–U.S.) (Term D)	Difference due to underlying industry structure, controlling for technology (Term A)	Difference due to underlying S&E[1] intensity, controlling for industry (Term B)	Covariance term (Term C)
Manufacturing	-3.30	-1.81	-1.89	0.40
Professional, scientific and technical services	5.59	3.30	2.02	0.26

1. Science and engineering
Source: Tabulations based upon data from the 2001 Canadian Census of Population and the 2000 United States Census of Population.

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