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Indicators of Innovation in Canadian Natural Resource Industries

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CSLS Research Report 2005-03
May, 2005

Prepared by the Centre for the Study of Living Standards
for Natural Resources Canada

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Executive Summary

It is widely recognized that innovation is the major driver of productivity growth, which in turn is the key determinant of growth in living standards. The objective of this report is to develop a set of indicators of innovation in a number of natural resource industries in Canada and use these indicators to assess trends in innovation over time in Canadian natural resource industries and to compare the innovation performance of Canadian natural resource industries to that of the all-industries average in Canada and to that of natural resource industries in other countries.

The report is divided into three major sections. Part one provides a summary of a review of the literature on innovation indicators, with particular focus on indicators of relevance to natural resource industries. The second part of the report presents a comprehensive overview of innovation indicators in natural resource industries in Canada, relative to the all-industries average for Canada and relative to natural resource industries in other OECD countries. The innovation indicators are organized into eight areas: research and development (R&D), skills, machinery and equipment, productivity, foreign direct investment, technological balance of payments, use of the internet, and incidence of innovation. The third part of the report provides an overall assessment of the innovation capacity and performance of Canadian natural resource industries.

The report finds that on most innovation indicators, Canadian natural resource industries perform either at the all-industries average or above the average. Relative to natural resource industries in other countries, Canadian natural resource industries exhibit an average performance.

It is true that R&D intensity (R&D/value added) of Canadian natural resource industries is currently (but not historically) below average: 48 per cent of the business sector average in 2004, but above the business sector average for most of the period before 1992. Some argue that this situation indicates that the innovative capacity and performance of these industries is substandard. The report argues that this is a misleading interpretation for a number of reasons, the most important being that intramural R&D spending captures only part of the multi-dimensional concept of innovation. R&D spending is by no means a sufficient or necessary condition for innovative behaviour, although it can foster such behaviour.

Reasons that intramural R&D spending by Canadian natural resource industries tell only part of the sector's overall R&D and innovation story include the following.

- Extramural R&D spending funded by natural resource industries but performed outside of the business sector, primarily by the higher education sector, is excluded, as is contracting out of R&D activities within the business sector.

- Intramural R&D spending by the paper industry may be significantly underestimated because of the exclusion of mill trials from the definition of R&D.

- The R&D undertaken by other sectors (government labs, universities) and by other industries in the business sector that supply inputs to natural resource industries (e.g. machinery producers) that is directly applicable to natural resource industries is excluded from the intramural R&D of the natural resource sector, even though this R&D contributes to productivity advance in natural resource industries.

- Since the goods produced by natural resource industries are generally homogeneous commodities requiring little if any product development, natural resource industries do not have to do as much product innovation as non-natural resource industries. Their motivation for undertaking R&D is often cost reduction. This reality manifests itself in innovation surveys in the greater proportion of process innovation in total innovation undertaken by natural resource firms.

- While R&D intensity may be below average in natural resource industries, R&D personnel per 1,000 workers is almost identical to the all-industries average. R&D personnel may in fact be more important for the innovative performance of a sector than R&D spending as it is the scientists that develop and apply ideas.

Natural resource industries do well on many innovation indicators. Probably the most important is the sector's labour productivity performance. Labour productivity levels tend to be about double the economy-wide average, reflecting in part the high capital intensity of the sector, and long-term labour productivity growth has been about 0.8 percentage points higher. Multifactor productivity growth has also been above average. This superior productivity performance is not the sign of an innovation laggard.

Other innovation indicators where natural resource industries fare favourably relative to other Canadian industries include use of the internet (above average), machinery and equipment per worker (above average), and foreign direct investment (above average). Natural resource industries fare near the average in the proportion of R&D personnel working in the sector, and slightly below average in educational attainment and in the proportion of firms that are defined as being innovative.

It is more difficult to assess the innovativeness of Canadian natural resource industries relative to natural resource industries in other OECD countries because of limited comparable data. For the four innovation indicators that are available, Canada is in the middle of the pack, with no discernible trend. Certain countries such as Sweden and Finland tend to outperform Canada on a number of indicators.

One possible area of concern in terms of the innovation performance of Canada's natural resource industries is the downward trend in R&D intensity. The current R&D intensity level of 0.64 per cent of value added is well below the 1.2 per cent level recorded in the early 1990s. The causes of this development are unclear and worthy of further study. A second concern may be the decline in the proportion of university-educated workers in the natural resource sector relative to the proportion in other industries.

Indicators of Innovation in Canadian Natural Resource Industries[1]

It is widely recognized that innovation is the major driver of productivity growth, which in turn is the key determinant of growth in living standards. The objective of this report is to develop a set of indicators of innovation in a number of natural resource industries in Canada and use these indicators to assess trends in innovation over time in Canadian natural resource industries and to compare the innovation performance of Canadian natural resource industries to that of the all-industries average in Canada and to that of natural resource industries in other countries.

The report is divided into three major sections. Part one provides a summary of a review of the literature on innovation indicators, with particular focus on indicators of relevance to natural resource industries. It looks first at general studies on innovation indicators by three organizations: the European Community, the Conference Board of Canada, and the OECD. It then discuses four specific studies on innovation trends in natural resource industries. The detailed literature review is found in Appendix 1.

The second part of the report presents a comprehensive overview of innovation indicators in natural resource industries in Canada, relative either to the all-industries or business sector average for Canada and relative to natural resource industries in other OECD countries. The innovation indicators are organized into eight areas: research and development (R&D), skills, machinery and equipment, productivity, foreign direct investment, technological balance of payments, use of the internet, and incidence of innovation. Innovation indicators for which data are not currently available are also discussed.

The third part of the report provides an assessment of the innovation capacity and performance of Canadian natural resource industries, again relative to the all-industries average in Canada and to natural resource industries in other OECD countries.

From the perspective of this report, the natural resource industries discussed roughly correspond to the industry mandate of Natural Resources Canada: logging and forestry, mining, and oil and gas extraction (and services associated with mining and oil and gas) from the primary sector; wood products, pulp and paper, primary metals (including both ferrous and non-ferrous metals), non-metallic mineral products, fabricated metal products, and petroleum and coal refining from manufacturing; and electric power from the service sector . In addition to the natural resource industries aggregate which is the sum of all natural resource industries, three sub-aggregates are used: energy, defined as oil and gas extraction, petroleum and coal refining, and electric power;[2] forest products, defined as logging and forestry, wood products and paper and allied industries; and mining and mineral-related products, defined to include mining, primary metals (including ferrous and non-ferrous metals), non-metallic mineral products, and fabricated metal products. The pipelines industry (including natural gas distribution) and the geomatics / geophysics industry are not explicitly included because of lack of a number of time series, including R&D estimates, for these industries.[3]

Canada's productivity performance, measured in terms of both labour productivity growth rates and labour productivity levels, has been inferior to that of the United States since 1990. An innovation gap with the United States is often pointed to as an important, if not the most important, factor in explaining the Canada-U.S. productivity growth and level gaps (Rao et al., 2001).[4] But the productivity gap varies greatly by industry (Rao, Tang, and Wang, 2004), which implies that the innovation gap also may vary greatly by industry. Indeed, many Canadian natural resource industries have higher productivity levels than their U.S. counterparts, which may imply that they are more innovative. From this perspective, it is important to have an understanding of innovation in Canada at the industry level as well as at the total economy level.

I. Literature Review of Innovation Indicators

Part one provides a summary of a selective review of the literature on innovation indicators, with particular focus on indicators of relevance to natural resource industries. It looks first at general studies on innovation indicators by three organizations: the European Community (EC), the Conference Board of Canada, and the OECD. It then discuses four specific studies on innovation trends in natural resource industries. The complete literature review on which this summary is based is found in Appendix 1.

A. General Innovation Studies

1) EU Approach to Innovation

Reinhilde Veugelers (2005), from the EC Commission and the Leuven Catholic University, provides a perceptive analysis of what constitute the appropriate indicators for assessing and improving innovative capacity in the context of the EU's growth challenge.

Veugelers uses the concept of National Innovative Capacity (NIC), defined as the ability of a nation to not only produce new ideas, but also to commercialize a flow of innovative technologies over the longer term. Veugelers points out that in the NIC perspective, country differences with respect to innovation and growth reflect not just differences in endowments of labour, capital, and the stock of knowledge, but also the varying degrees of the "knowledge distribution of power" or the efficiency of the innovation system. She notes that this perspective warns against looking at statistical indicators individually to assess the performance of national innovative capacity but rather advocates a systemic approach to understanding the relationships between science and technology indicators (STI) and social-economic development. The effectiveness of innovation systems depends on the balanced combination of creative capacity, diffusion capacity, and absorption capacity.

Veugelers stresses that inter-industry comparisons of innovation indicators must be interpreted with care. This is because structural differences can play a role in explaining industry differences in innovation performance. The relative importance of various sectors differs across countries. In addition, there can be significant diversity among industries in terms of innovation process and innovation inputs and outputs, linked to some of the factors outlined below.

- Technological opportunities differ, with the ICT sector for example having huge opportunities for technological advance.
- The size of the innovating unit differs across industries, which is large in certain sectors such as motor vehicles and small in others such as machinery.
- The objectives of innovation vary, with certain sectors favouring process innovations and others product innovations.
- There is diversity among the sources of innovations, with suppliers crucial in agriculture, users in software, and in-house R&D laboratories in chemicals.

Veugelers makes the case that since the systemic approach to innovation operates at the technology/sectoral level, indicators should be tracked at this level as there is a great deal to learn by analyzing innovation performance across sectors. She notes that the challenge is the lack of data at the sectoral level for many variables.

2) Conference Board of Canada Innovation Benchmarking Indicators

In 2004, the Conference Board of Canada released *Exploring Canada's Innovation Character: Benchmarking Against Global Best*, a study prepared for Industry Canada as part of the federal government's Innovation Strategy. The framework developed and used by the Conference Board to benchmark innovation is very useful. It breaks down innovation into four areas: knowledge performance; skills performance; innovation environment; and community-based innovation. Exhibit 3A in the Appendix presents the 17 indicators that make up the framework. Canada ranked a very respectable 4th (after the United States, Sweden and Finland) out of 24 OECD countries in innovation at the total economy level. The indicators developed by the Conference Board have been applied by the Conference Board to the total economy, but many of them may be applicable at the industry level.

Appendix 1 organizes the indicators into three categories: relevant and currently available, at least for Canada, at the industry level; relevant and potentially available at the industry level; and not relevant at the industry level. Out of the 17 innovation benchmarks put forward by the Conference Board of Canada, five are relevant and currently available at the industry level, seven are relevant and potentially available, and five are not relevant in an industry dimension.

3) OECD Industry Definitions of Technology Intensity

The OECD has been the leading international organization for the classification of industries by level of technology and for defining high technology.[5] An industry's classification by level of technology can give an indication of the innovative capacity of that industry. It is useful to examine how the OECD has treated natural resource industries and how this treatment has changed over time. Exhibit 4A in the Appendix, drawn from a 1986 OECD report which classified industries on the basis of the R&D-to-sales ratio,[6] found that out of seven natural resource industries, six were at a low level of technology intensity, and one was at the medium level. Exhibit 5A in the Appendix, drawn from a 1997 OECD report, presents a slightly different picture. Four of the natural resource industries now fall in the medium-low technology classification, and only two fall in the low technology classification.

This updating of the technology capability of natural resource industries between 1986 and 1997 was due to a change in the definition of technological intensity. In the more recent definition technology dissemination is now taken into account. This means that industries that use embodied technology or technology incorporated in physical capital, such as the capital intensive natural resource industries, are considered more technology-oriented and hence more innovative.

B. Studies of Innovation in Natural Resource Industries

1) Mining Association of Canada Study

Global Economics Limited produced in 2001 a study of innovation in the Canadian mining sector on behalf of the Mining Association of Canada (MAC). The report focuses on innovation trends in this sector, especially the impact of the use in recent years of information technologies. The survey results show that in general, mining firms were largely motivated to increase their R&D spending in order to reduce costs, to improve existing processes or develop new ones. Compliance with environmental regulation also was an important incentive. An interesting result is that development of new products ranks low among the reasons for mining firms to spend more on R&D. Although no data are provided, the report mentions that mining firms have found that the only important constraint on R&D is funding. In general, firms have access to sufficient amounts of personnel, facilities, and other inputs.

In terms of allocation of R&D expenditures, mining firms spend little on basic research, which is not a surprise considering it may take years before commercial applications can be derived from such activities. Development was found to represent the largest share of R&D spending. About half of those expenditures were assigned to improvements in existing processes or development of new processes while about 10 per cent of R&D expenditures were devoted to improving products or developing new ones. These results confirm the relative importance of process innovation versus product innovation in the mining industry.

The second section of the MAC report is devoted to an overview of various indicators of innovation. Based on the MAC innovation survey, mining firms usually spend the equivalent of one per cent of their revenue on R&D. This is an average and includes the one quarter of mining firms that have no R&D expenditures. The survey also found that 42 per cent of Canadian mining firms have a center dedicated specifically to R&D activities. As well, most research is performed in-house by more than half of the firms, while only 25 per cent of firms contract out all of their research activities.

2) Statistics Canada Research Reports on Innovation in Metal Ore Mining and the Forest Sector

Statistics Canada has released two research reports, both by Susan Schaan (2002 and 2003) on innovation and the use of advanced technologies in metal ore mining and processing and in the forest sector (logging, wood and paper), based on the results of the 1999 S*urvey of Innovation*. This was the first innovation survey that included, in addition to manufacturing industries, certain natural resource industries, namely mining and logging. (Wood products and paper products had already been included in an earlier survey under manufacturing.)

The papers present results for five indicators of innovative activities: the percentage of process innovators and percentage of product innovators among innovative firms (Exhibit 6A in the Appendix); the objective of innovation, that is the motivation for innovative firms to innovate, which should be linked to the motivation for spending on R&D (Exhibit 7A in the Appendix); the role of innovation in the overall business strategy of innovative firms (Exhibit 8A in the Appendix); involvement in R&D activities (Exhibit 9A in the Appendix); percentage of highly innovative manufacturing firms that sell products to selected natural resource firms.(Exhibit 10A in the Appendix).

3) Mohnen and Therrien Study on Canada/Europe Innovation in Natural Resource Industries

Pierre Mohnen, formerly from UQAM, and Pierre Therrien (2001), of Industry Canada, examine innovation trends in Canada and Europe based on the 1999 Canadian *Survey of Innovation* and the 1997-1998 European Community innovation surveys.[7] The paper first evaluates the comparability of the surveys, all of which were inspired by the Oslo manual and meant to produce internationally comparable results. It then modifies data to improve comparability and compare Canada's position to four European countries: France, Ireland, Germany and Spain. Four innovation indicators are used to compare innovation performance across countries by industry: (1) percentage of innovators; (2) share of sales of new or improved products; (3) percentage of first-innovators; and (4) share in sales of new or improved products for first-innovators.

The percentage of innovators refers to the percentage of firms that introduced a new or improved product during the reference period (1997-99 for Canada and 1994-96 for European countries). A much greater proportion of manufacturing natural resource firms were innovators in Canada than in Europe (Exhibit 13A in the Appendix). Canada comes first in all sectors. The performance of innovative Canadian firms in terms of share of sales of new or improved products (a measure of innovation intensity) is not as outstanding as performance in terms of innovation incidence. This suggests a lower ability of Canadian firms in converting new and improved products into revenue, especially compared to firms in Spain and Germany.

II. Innovation Indicators for Natural Resource Industries

This second part of the report presents a comprehensive overview of innovation indicators in natural resource industries in Canada, relative either to the all-industries or business sector average for Canada and relative to natural resources industries in other OECD countries. The innovation indicators are organized into eight areas: research and development (R&D), skills, machinery and equipment including information and communications technologies (ICT), productivity, foreign direct investment, technological balance of payments, use of the internet, and incidence of innovation.[8] Potential innovation indicators for which data are not currently available are also discussed. (Note: the tables referred to as sources for the charts presented here can be found at the end of this document; additional data not shown here are also included in these tables.)

A. Research and Development (R&D)

Research and development is an important part of the innovation process. This section of the report looks at three aspects of R&D undertaken by firms in natural resource industries in Canada and other OECD countries: R&D spending, R&D personnel, and the number of R&D performing firms.

1) R&D Expenditures

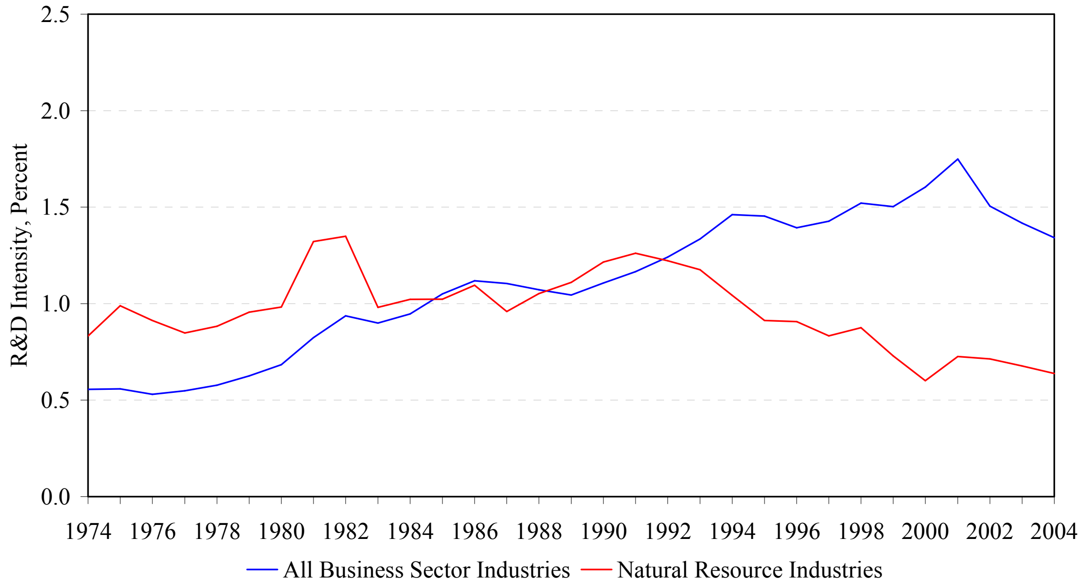
Estimates of intramural R&D expenditures are available, as a share of nominal value added,[9] for the Canadian natural resource sector, three industry aggregates (forest products, energy, and mining and mineral products), ten industries (logging and forestry, mining, petroleum and natural gas, electric power, wood, paper, primary metal, fabricated metal products, non-metallic mineral products, and refined petroleum and coal products) and the business sector average in Canada for the 1974-2004 period inclusive.[10] Charts 1-6 show trends in R&D intensity. The salient findings are:

- the natural resource sector, taken as a whole, had in 2004 a R&D/GDP ratio or R&D intensity of 0.64 per cent (Chart 1), just under one half of the business sector average of 1.34 per cent (Chart 2);

- while business sector R&D intensity more than doubled from 0.56 per cent of GDP in 1974 to 1.34 per cent in 2004, the R&D intensity for natural resource industries was actually lower in 2004 than in 1974 (0.64 per cent versus 0.83 per cent). From 1974 to 1991 the R&D intensity of natural resource industries was on average higher than the business sector average. This situation reversed itself after 1991 with the decline in R&D intensity in natural resource industries and the continued rise at the business sector level. The trough for natural resource R&D

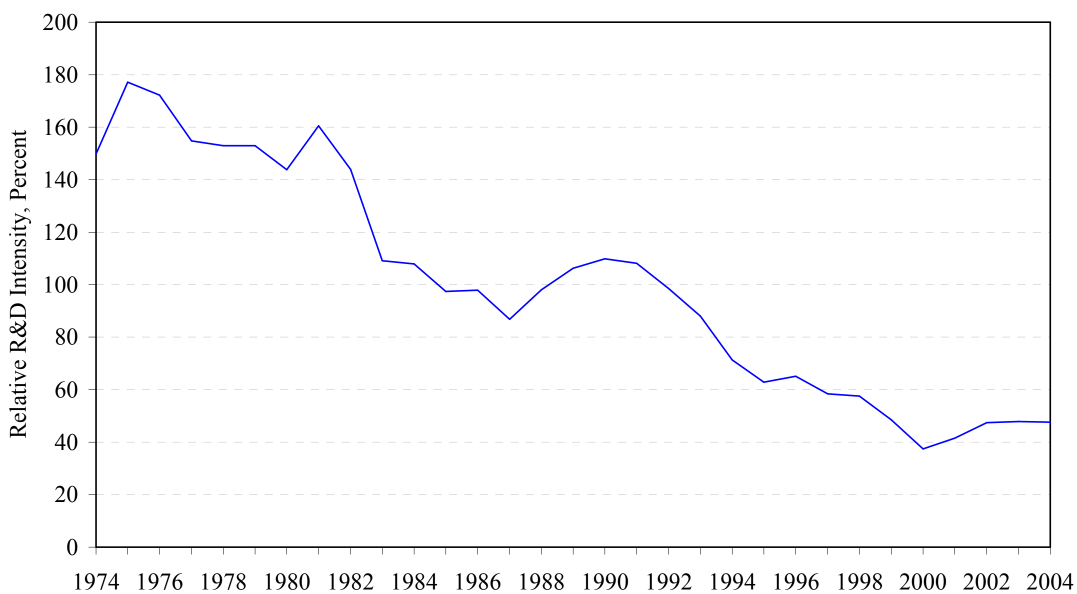
intensity relative to that of the business sector occurred in 2000 when the former was less than four tenths the latter (0.60 per cent versus 1.60 per cent);

Chart 1: R&D Intensity in Natural Resource Industries in Canada, Intramural R&D Expenditure as a Share of Value Added, 1974-2004



Source:Statistics Canada, Research and Development in Canadian Industry. CANSIM II Tables 379-0001 (SIC nominal GDP), 379-0023 (NAICS nominal GDP), 379-0017 (NAICS constant dollar GDP) and 380-0056 (GDP deflator), March 12 2005.
Notes: See Tables 1a and 1b.

Chart 2: Relative R&D Intensity in Natural Resource Industries in Canada, Natural Resource Industries R&D Intensity as a Share of Total Economy, 1974-2004



Source:Statistics Canada, Research and Development in Canadian Industry. CANSIM II Tables 379-0001 (SIC nominal GDP), 379-0023 (NAICS nominal GDP), 379-0017 (NAICS constant dollar GDP) and 380-0056 (GDP deflator), March 12 2005.
Notes: See Tables 1a and 1b.

- of the three natural resource industry aggregates (Chart 3), in 2004 forest products had the highest R&D intensity (1.00 per cent), followed by mining and mineral products (0.78 per cent), and energy (0.46). Between 1974 and 2004, the R&D intensity of the forest products industry more than doubled, mining and mineral products was virtually the same, while energy fell by more than half;

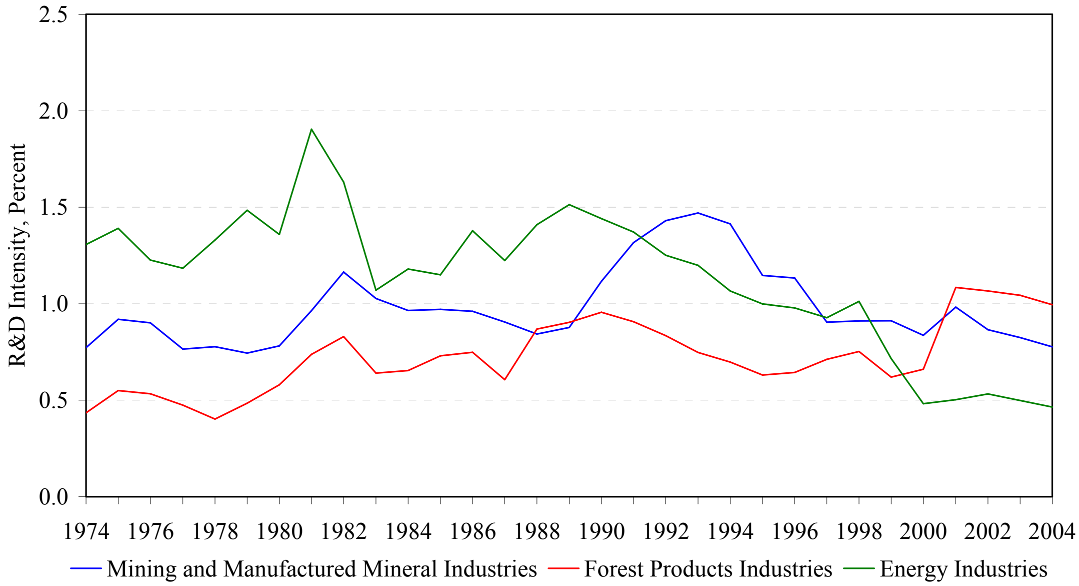
- of the ten detailed natural resource industries for which estimates are available in 2004 (Charts 4-6), only three had a ratio of R&D to value added or R&D intensity above the business sector average: paper and allied products (2.00 per cent); primary metal (1.85 per cent); and refined petroleum and coal products (1.69 per cent). These industries have consistently exhibited above average R&D intensity over the 1974-2004 period;

- in terms of the seven natural resource industries with below average R&D intensity, the lowest in 2004 was recorded in non-metallic mineral products (0.12 per cent), followed by wood (0.27 per cent), logging and forestry (0.29 per cent), mining (0.30 per cent), petroleum and natural gas extraction (0.31 per cent), electric power (0.58 per cent), and fabricated metals (0.59 per cent);

- of the ten detailed natural resource industries, four experienced an increase in R&D intensity between 1974 and 2004. The largest absolute increase was in paper and allied products (1.22 points from 0.77 per cent to 2.00 per cent),[11] followed by fabricated metal (0.34 points from 0.25 per cent to 0.59 per cent), logging and forestry (0.27 points from 0.02 per cent to 0.29 per cent), and wood (0.18 points from 0.09 per cent to 0.27 per cent); and

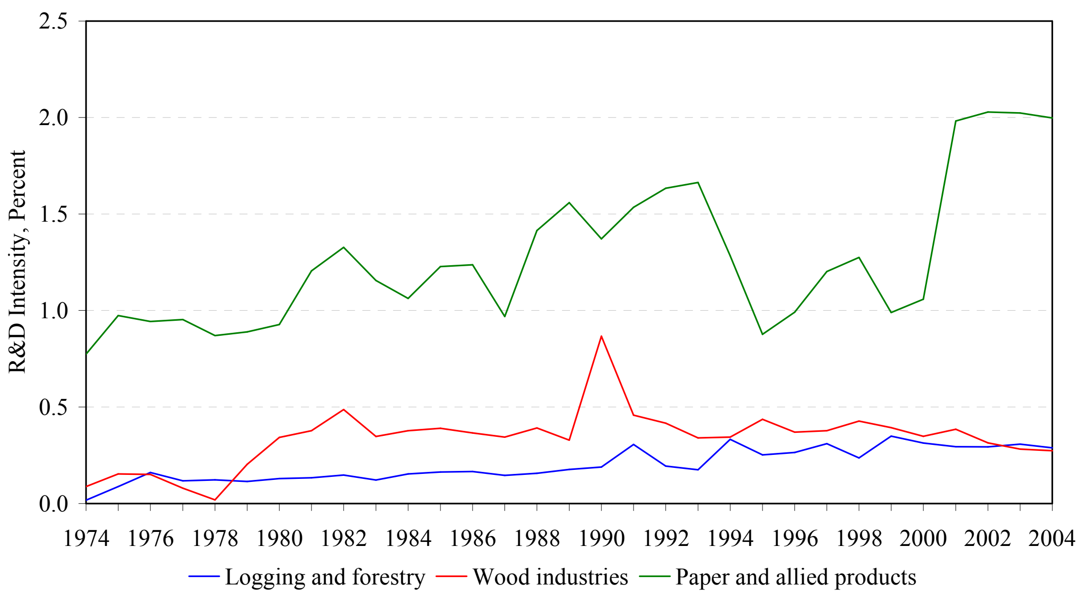
- R&D intensity fell in six natural resource industries between 1974 and 2004: 13.68 points from 15.38 per cent to 1.69 per cent in refined petroleum and coal products; 0.69 points from 1.27 per cent to 0.58 per cent in electric power; 0.37 points from 0.49 per cent to 0.12 per cent in non-metallic mineral product; 0.29 points from 2.14 per cent to 1.85 per cent in primary metal; 0.07 points from 0.37 per cent to 0.31 per cent in petroleum and natural gas; and 0.05 points from 0.36 per cent to 0.30 per cent in mining industries.

Chart 3: R&D Intensity in Natural Resource Industries in Canada, Intramural R&D Expenditure as a Share of Value Added, 1974-200



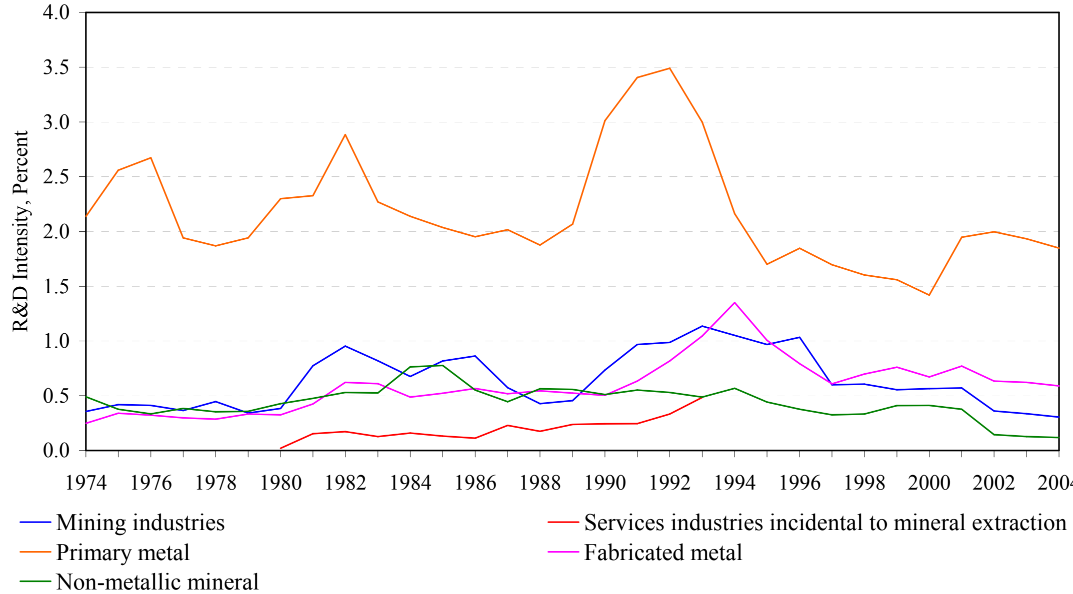
Source:Statistics Canada, Research and Development in Canadian Industry. CANSIM II Tables 379-0001 (SIC nominal GDP), 379-0023 (NAICS nominal GDP), 379-0017 (NAICS constant dollar GDP) and 380-0056 (GDP deflator), March 12 2005.
Notes: See Tables 1a and 1b.

Chart 4: R&D Intensity in Forest Products Industries in Canada, Intramural R&D Expenditure as a Share of Value Added, 1974-2004



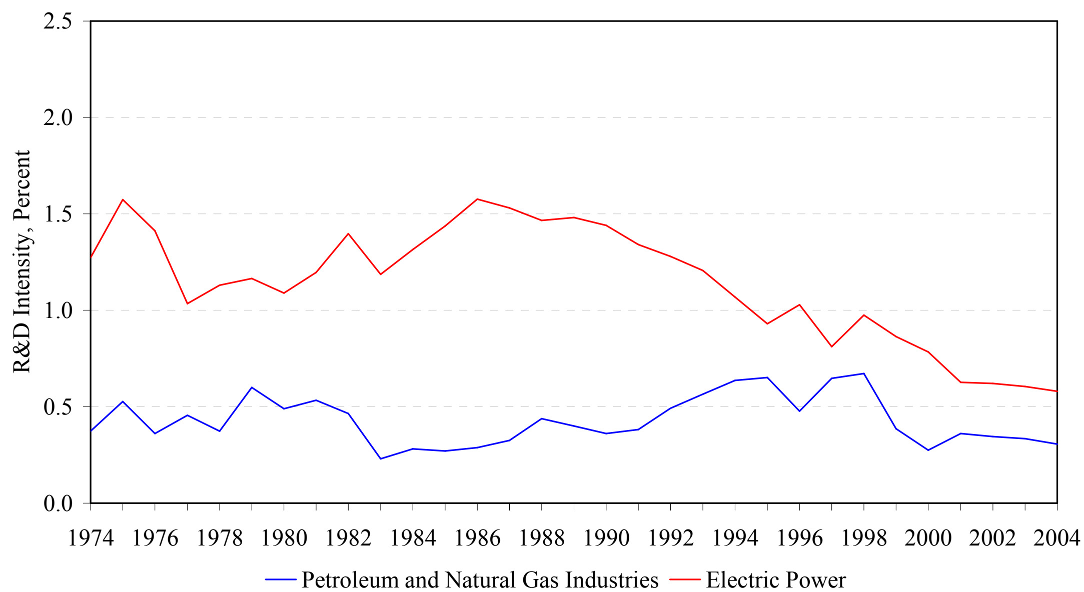
Source:Statistics Canada, Research and Development in Canadian Industry. CANSIM II Tables 379-0001 (SIC nominal GDP), 379-0023 (NAICS nominal GDP), 379-0017 (NAICS constant dollar GDP) and 380-0056 (GDP deflator), March 12 2005.
Notes: See Tables 1a and 1b.

Chart 5: R&D Intensity in Mining and Mineral Products Industries in Canada, Intramural R&D Expenditure as a Share of Value Added, 1974-2004



Source:Statistics Canada, Research and Development in Canadian Industry. CANSIM II Tables 379-0001 (SIC nominal GDP), 379-0023 (NAICS nominal GDP), 379-0017 (NAICS constant dollar GDP) and 380-0056 (GDP deflator), March 12 2005.
Notes: See Tables 1a and 1b.

Chart 6: R&D Intensity in Energy Industries in Canada, Intramural R&D Expenditure as a Share of Value Added, 1974-2004



Source:Statistics Canada, Research and Development in Canadian Industry. CANSIM II Tables 379-0001 (SIC nominal GDP), 379-0023 (NAICS nominal GDP), 379-0017 (NAICS constant dollar GDP) and 380-0056 (GDP deflator), March 12 2005.
Notes: See Tables 1a and 1b. The Refined petroleum and coal products industry was not included because of unusually high values.

Exhibit 1 provides estimates of R&D intensity (R&D/nominal value added) for seven natural resource industries in up to 13 OECD countries for selected years over the 1987-2001 period based on the OECD STAN database.[12] Overall, Canada fared poorly, with an average rank of 8.3 out of an average of 11.3 countries. In none of the seven industries was Canada in the top half of R&D performers. It is interesting to note that three countries have considerably higher R&D intensity in natural resource industries than other OECD countries: Japan, Sweden, and Finland. Perhaps surprisingly given its high total economy R&D/GDP ratio, natural resource industries in the United States generally did not exhibit above average R&D intensity.

Exhibit 1: R&D Intensity in Selected OECD Countries
(R&D expenditures as a share of value added; 2001 or most recent year)

Industry	Country												
	Australia	**Canada**	Finland	France	Germany	Italy	Japan	Korea	Norway	Spain	Sweden	United Kingdom	United States
Mining and Quarrying	1.6	0.2	1.7	NA	1.4	0.3	3.6	0.4	0.2	0.6	2.6	0.2	0.7
Wood and products of wood and cork	NA	0.3	1.6	0.2	0.3	0.1	3.0	1.4	NA	0.1	0.9	NA	0.4
Pulp, paper, paper products, printing and publishing	NA	0.4	1.2	0.3	0.3	6.7	NA	0.4	NA	0.2	1.9	NA	NA
Coke, refined petroleum products and nuclear fuel	1.1	1.6	5.8	2.4	0.8	1.9	0.6	0.7	NA	1	3.1	9.6	3.1
Other non-metallic mineral products	0.8	0.2	1.7	2.4	2.2	0.3	4.6	1.1	1.6	0.4	1.2	0.8	2.2
Basic metals	NA	1.4	2.9	3.6	1.7	0.5	4.1	1.3	4.6	1.1	6.1	1.3	1.2
Fabricated metal products	NA	0.8	4.0	0.7	1.5	0.3	1.7	1.0	0.9	0.5	0.8	0.5	1.8

Source: OECD website, Science and Technology Database, Research and Development Statistics, Total Business Expenditure on Research and Development (BERD) by Industry (Table 13), ISIC Rev.3 Vol. 2004 release 01, STAN Industry Vol. 2005 release 01 (Value Added), March 14 2005.

Box 1: The Accuracy of Official R&D Estimates in the Paper Industry: the Boundary Issue of Clinical Trials

At the March 4, 2005 workshop on perspectives on R&D expenditures in natural resource sectors organized by Natural Resources Canada, the issue arose of the possible underestimation of R&D in certain natural resource industries. Indeed, it was noted that certain representatives of the forest products sector had claimed that the actual R&D performed by the industry was three times that reported by Statistics Canada.

Dan Wicklum, Executive Director of the Canadian Forest Innovation Council, explained that about 70 per cent of the discrepancy between certain industry R&D estimates and those of Statistics Canada (and the Canadian Revenue Agency (CRA), which collects the data used by Statistics Canada to compile R&D estimates) was due to differences in the definition of R&D in the pulp and paper industry. In particular, the industry argues that spending on mill trials – that is, the shop floor testing of pulp mixes – should be included in the definition of R&D. CRA appears to currently exclude most of this type of spending from the R&D definition. Clinical trials are included in the Frascati manual definition of R&D, but what is included in the definition of clinical trials, as opposed to related scientific activities, appears to be a grey area.[13]

A trial's eligibility for the Scientific Research and Experimental Development (SR&ED) tax credit program requires the presence of "technological uncertainties". The industry complaint that their spending on mill trials is not eligible for R&D tax incentives is certainly a legitimate concern and one that is currently being examined by CRA officials.[14]

It is true that this issue only pertains to the paper industry, but this industry is an important player in R&D spending in the natural resource sector. In 2004, it spent $296.2 million on R&D, accounting for 32.2 per cent of total natural resource R&D. If the true figure were in fact three times the official figure, R&D spending in the paper industry, and in the total natural resource sector, would be $584 million higher. This would raise the R&D intensity for the natural resource sector from 0.76 per cent in 2004 to 1.25 per cent, putting the R&D intensity of natural resource industries well ahead of the all-industries average (1.02 per cent). Even a doubling of R&D spending in the paper industry based on a change in the definition of R&D would raise the R&D intensity of natural resource industries above the all-industries average. The resolution of this R&D definitional issue is obviously needed to make a definitive statement on the relative R&D intensity of the natural resource sector.

2) R&D Personnel

The proportion of the workforce in an industry that is dedicated to R&D is an important indicator of the industry's capacity to innovative. Estimates of the number of R&D personnel per 1,000 workers and in absolute terms for natural resource industries in Canada are available for the 1994-2002 period based on recently released Statistics Canada data. Charts 7-9 show the trends.

In 2002, there were 6,303 R&D personnel working in natural resource industries in Canada, 6.3 per cent of the all-industries total, down from 10.0 per cent in 1994.

In 2004, there were 6.5 R&D personnel per 1,000 workers in natural resource industries, identical to the all-industries average (Chart 7). Over 1994-2002, the proportion of R&D personnel fell from 9.0 to 6.5 per 1,000 workers for natural resource industries, but increased from 6.0 to 6.5 per 1,000 workers for all industries. Thus the R&D personnel intensity in the natural resource industries fell from one and one half of the all industries average to the all-industries average over the period (Chart8).

Within natural resource aggregates (Chart 9), mining and mineral products had the highest R&D personnel intensity in 2002 (7.4 per 1,000 workers), closely followed by energy (7.2). Both these aggregates were above the all-industries average. The R&D personnel intensity in the forest products industry was 5.0 per cent. The fall in the overall R&D personnel intensity of the natural resource sector over the 1994-2002 period was accounted for by declines in mining and mineral products and energy, with forest products unchanged.

In terms of the ten natural resource industries, petroleum and coal manufacturing had the largest proportion of R&D personnel in total employment (13.4 per 1,000 workers in 2002), followed by primary metals (11.4), paper (11.0), utilities (8.4), and fabricated metal (8.4). The importance of R&D personnel in the five other natural resource industries was below average. Forestry and logging had the lowest rate (2.2 per 1,000 workers), followed by wood products (2.5), mining (2.7), non-metallic mineral products (3.0), and oil and gas extraction (4.5).

Estimates are available, based on the OECD's STAN database, of R&D personnel per 1,000 workers, research scientists and engineers (RSE) per 1000 workers, and university graduates per 1,000 workers for nine natural resource industries (mining, wood, paper, coke, refined petroleum products and nuclear fuels, non-metallic mineral products, basic metals, non-ferrous metals, and fabricated metals) and the business sector for selected OECD countries (up to 13) over the 1987-2001 period. Unfortunately, estimates for a large number of countries and years are missing, limiting the value of the data set.

The key findings for R&D personnel per 1,000 workers and research scientists and engineers (RSE) per 1,000 workers are summarized in Exhibit 2. Overall, Canada ranked slightly above average, in contrast to the below average performance for R&D

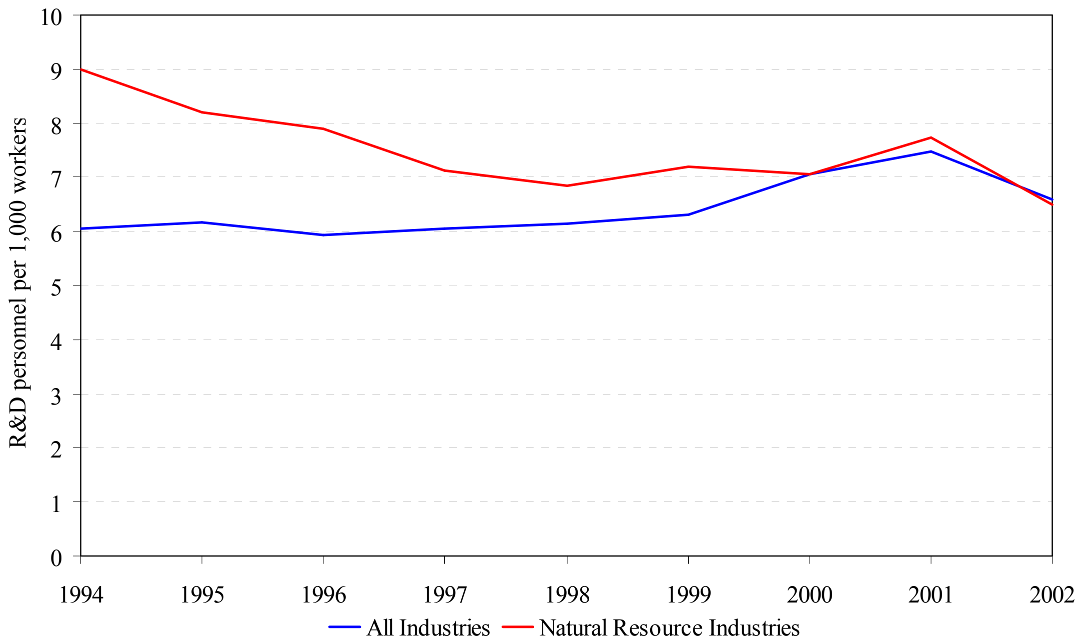
intensity. For the nine natural resource industries, Canada had an average rank of 3.6 out of an average of 10.9 countries for total R&D personnel per 1,000 workers, and of 4.4 out of an average of 10.1 countries for research scientists and engineers per 1,000 workers. In terms of total R&D personnel, Canada ranked first in fabricated metal products and second in non-ferrous metal products, wood, and paper. In terms of scientists and engineers, Canada ranked first in no industry, and second in only one industry: non-ferrous metals.

Exhibit 2: Summary of R&D Personnel in Natural Resource Industries in Selected OECD Countries

	Business Enterprise Total R&D Personnel per 1,000 workers			Business Enterprise Research Scientists and Engineers per 1,000 workers		
	Canada's Performance	Country Ranking First	Country Ranking Second	Canada's Performance	Country Ranking First	Country Ranking Second
Mining	4/11	Korea	Japan	4/10	Japan	United States
Wood Manufacturing	2/11	Japan	Canada	4/10	Japan	United States
Paper Manufacturing	2/10	Japan	Canada	3/9	United States	Japan
Coke, Refined Petroleum Products, and Nuclear Fuel Manufacturing	5/9	Japan	United Kingdom	5/9	Japan	United States
Non-Metallic Mineral Products Manufacturing	6/12	Japan	France	7/11	Japan	United States
Basic Metal Manufacturing	3/9	Japan	France	3/8	Japan	France
Ferrous Metal Manufacturing	5/9	France	Japan	4/8	Japan	United States
Non-Ferrous Metal Manufacturing	2/9	Japan	Canada	2/8	Japan	Canada
Fabricated Metal Manufacturing	1/9	Canada	Germany	4/8	United States	Japan
Business Sector	4/10	Japan	France	4/10	United States	Japan

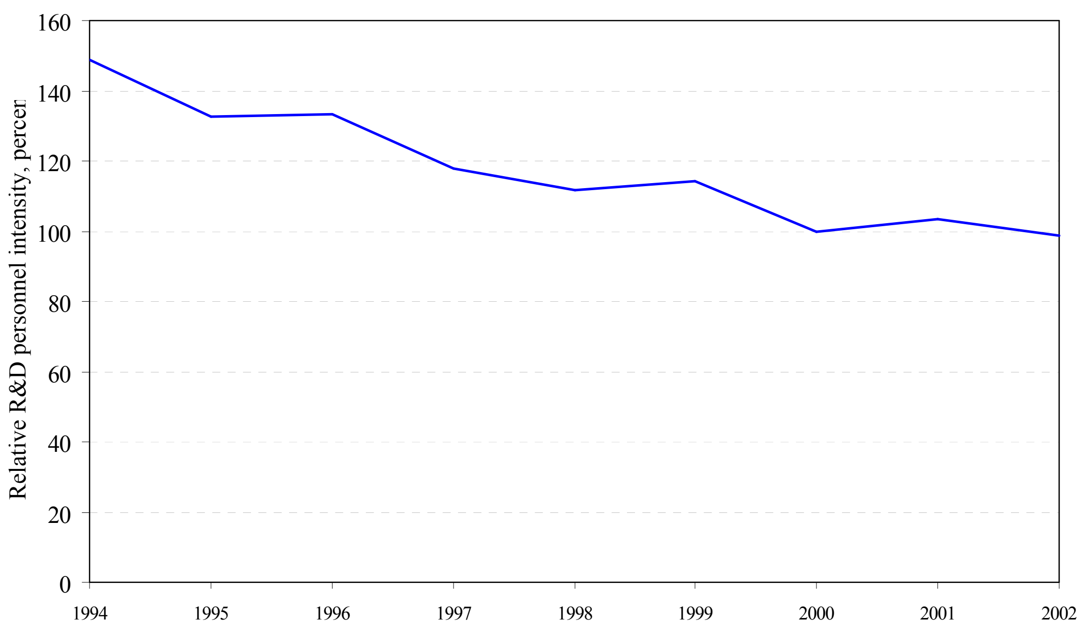
Source: Calculated from Tables 4a-4k; Note: Rankings are based on the most recent year for which data are available for a given country. This means that, for example, data for Canada in 1994 may be compared with data for Japan in 2001 in some cases. Canada's performance is expressed as Canada's rank among the countries for which data are available relative to the number of countries for which data are available.

Chart 7: Research and Development Personnel Intensity (R&D personnel per thousand workers) in Natural Resource Industries in Canada, 1994-2002



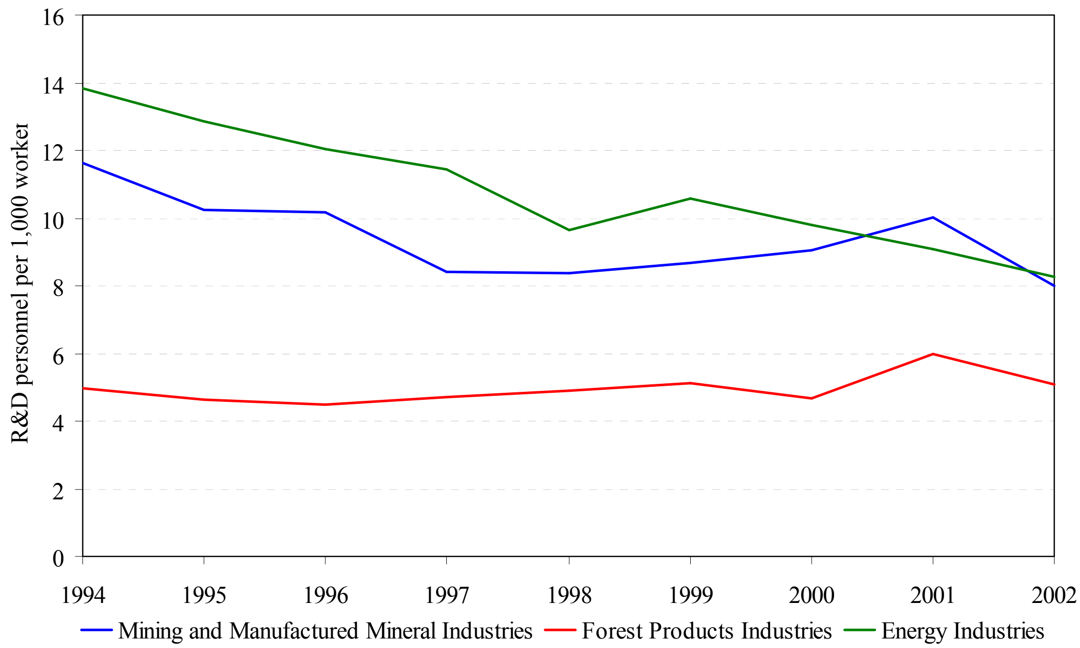
Source: Statistics Canada, CANSIM II Table 358-0024 (R&D personnel), March 23, 2005, and LFS special run (employment).

Chart 8: Relative Research and Development Personnel Intensity (R&D personnel per thousand workers) in Natural Resource Industries, as a Share of Total Economy in Canada, 1994-2002



Source: Statistics Canada, CANSIM II Table 358-0024 (R&D personnel), March 23, 2005, and LFS special run (employment).

Chart 9: Research and Development Personnel Intensity (R&D personnel per thousand workers) in Natural Resource Industries in Canada, 1994-2002



Source: Statistics Canada, CANSIM II Table 358-0024 (R&D personnel), March 23, 2005, and LFS special run (employment).

3) Number of R&D Performers in Natural Resource Industries

In addition to the amount of R&D spending, the number of R&D performers is a measure of innovation in itself. This is because the receptor capacity of industries to assimilate new technologies is positively influenced by a firm's ability to undertake R&D.

Estimates of the number of firms that performed R&D in natural resource industries (excluding utilities) in Canada are available over the 1994-2000 period. The data were released by the Impact Group consultancy based on data from Statistics Canada and the Canada Revenue Agency drawn from the Scientific Research and Experimental Development (SR&ED) tax credit program.

A number of observations stand out. First, the number of R&D performers in most natural resource industries that undertake R&D is very small. Excluding fabricated metal products, which is much further downstream or removed from natural resource extracting and processing than other natural resource industries, there were in 2000 only 353 R&D performers in natural resource industries (238 excluding non-metallic mineral products). These firms represented 3.4 per cent of total business sector R&D performers, even though the R&D performed by these industries accounted for 6.6 per cent of total business sector R&D.

The second observation is the fall in the number of R&D performers between 1994 and 2000, a trend that manifested itself for almost all natural resource industries as well as for all industries. The number of R&D performers in natural resource industries fell 10.8 per cent from 1,139 in 2004 to 1,016 in 2000, which is consistent with the fall in the R&D intensity from 1.03 per cent to 0.57 per cent over the same period. This development manifested itself in 8 of the 10 natural resource industries and in the other two industries there was no change or virtually no change.

Freedman (2005a and 2005b) has expressed concern about the declining number of R&D performers in Canada in general, and in the natural resource sector in particular.[15] He argues that the capacity of natural resource industries in Canada to assimilate new technologies is being negatively affected by this decline in the number of firms in the sector that are performing R&D.

B. Skills in Natural Resource Industries

Estimates of different measures of educational attainment (average years of schooling, percentage of workers with a university degree, percentage of workers with completed post-secondary education, and percentage of workers with less than a high school diploma) of workers in natural resource industries and the all- industries average in Canada are available for the 1976-2003 period inclusive based on data from the Labour Force Survey. Charts 10-12 plot average years of schooling for natural resource industries while Charts 13-16 plot the percentage of workers with a university degree.

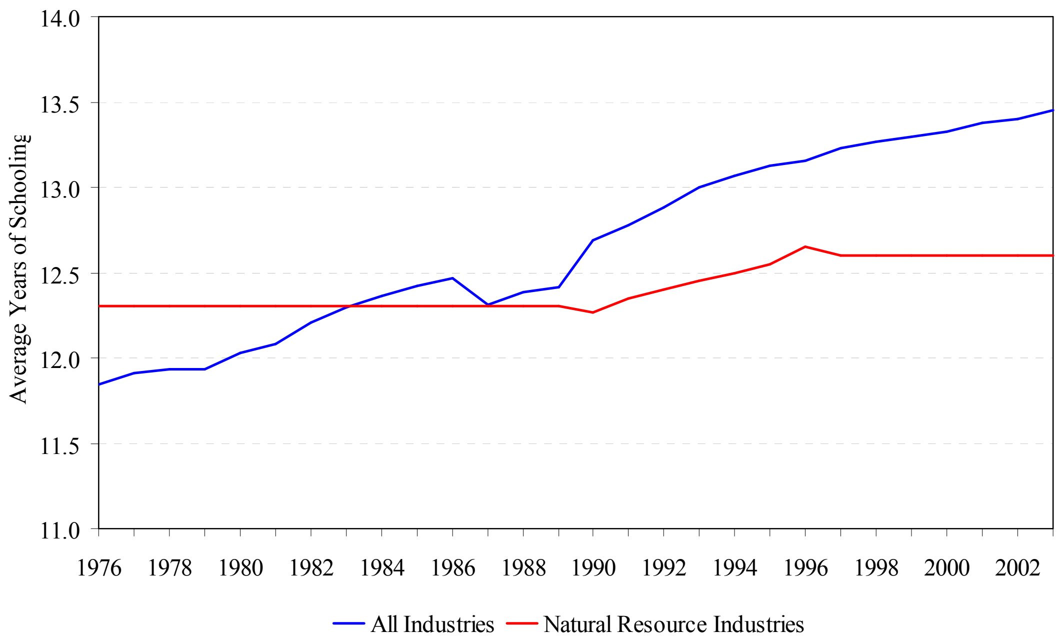
In terms of years of schooling, workers in natural resource industries on average are below the all-industries figure: 12.6 years versus 13.5 years in 2003 (Chart 10). The rate of growth of average years of educational attainment over the 1976-2003 period was slower on average for natural resource industries than for all industries (0.10 per cent per year versus 0.47 per cent). Consequently, there was a deterioration in the relative average educational attainment of workers in natural resource industries, from 104 per cent of the all-industries average in 1976 to 94 per cent in 2003 (Chart 11).

In terms of the three natural resource industry aggregates (Chart 12), workers in the energy sector had the highest average educational attainment at 13.7 years in 2003, slightly above the all-industries average, followed by workers in mining and mineral products (12.9 years, and forest products (12.5 years).

Out of the 14 natural resource industries, in 2003 only two had average years of schooling above the all-industries average – electric power (14.2 years) and oil and gas extraction (14.1 years); and two industries – petroleum and coal manufacturing and support activities for forestry – had average years equal to the all-industries average.

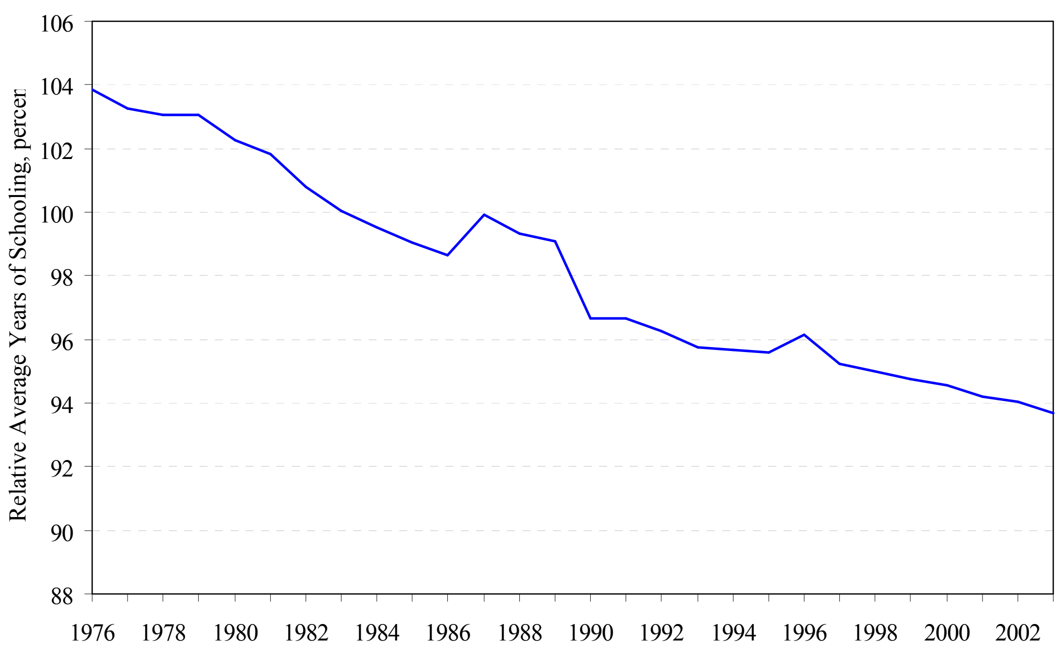
The lowest level of average years of schooling in natural resource industries in 2003 was found in forestry and logging (11.9 years), followed by wood products (12.2 years) and non-metallic mineral products (12.3 years). All other industries were within one year of the all-industries average. The lowest rate of improvement in educational attainment over the 1976-2003 period in natural resource industries was in petroleum and coal manufacturing, with growth of only 0.21 per cent per year, although from a high base level.

Chart 10: Average Years of Schooling in Natural Resource Industries, Canada, 1976-2003



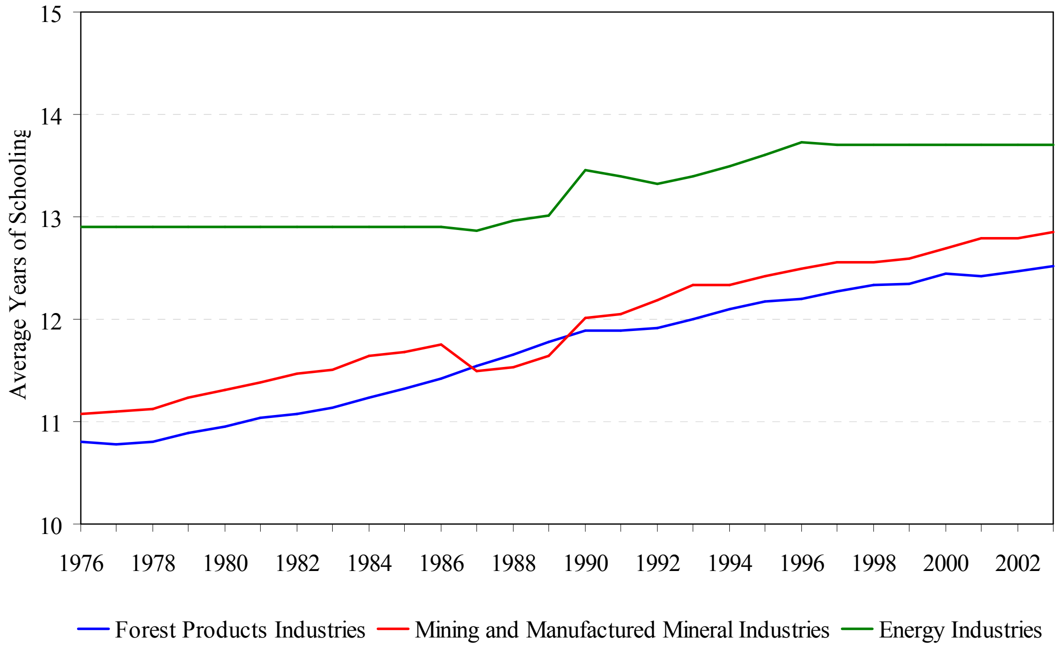
Source: Statistics Canada, Labour Force Survey. See Appendix on Educational Attainment

Chart 11: Relative Average Years of Schooling in Natural Resource Industries, as a Share of Total Economy, Canada, 1976-2003



Source: Statistics Canada, Labour Force Survey. See Appendix on Educational Attainment

Chart 12: Average Years of Schooling in Natural Resource Industries, Canada, 1976-2003



Source: Statistics Canada, Labour Force Survey. See Appendix on Educational Attainment

Historically, a high school education was not necessary to work in many jobs in natural resource industries. In 1976, about one third of workers in all industries did not have a high school diploma, but the proportion was near or over one half in many natural resource industries (for example, 64 per cent in forestry and logging, 49 per cent in metal ore mining, 52 per cent in wood products, 50 per cent in primary metals and in non-metallic mineral products). The proportion of workers without a high school diploma has fallen at the all-industries level and in natural resource industries over the 1976-2003 period, but most natural resources industries still have an above average proportion of their workers without a high school diploma (Chart 13).

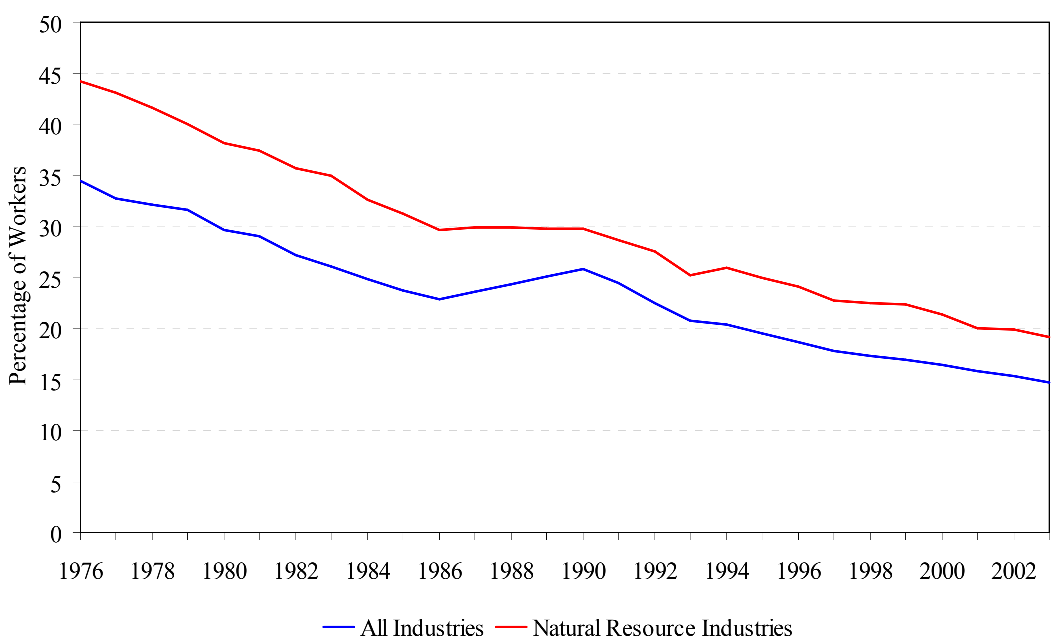
Just as natural resource industries have had a disproportionately high percentage of workers without a high school diploma, they have historically had a disproportionately low percentage of workers with a university degree. In 2003, only 11.8 per cent of workers in the natural resource sector had a university degree, compared to 20.4 per cent at the all-industries level (Chart 14). Since 1976, the growth of the workforce share of the university-educated in the natural resource sector has been only one quarter that of all industries. This resulted in a doubling of the proportion of university-educated workers at the all-industries level from 10.2 per cent to 20.4 per cent, compared to only a 2.6 point increase from 9.2 per cent to 11.8 per cent for natural resource industries. While natural resource industries had 90 per cent of the average level of university-educated workers in 1976, by 2003 this ratio had dropped to 58 per cent (Chart 15). To the degree that skills acquired at the university level are needed for innovation, the failure of natural resource industries to keep pace with other sectors in hiring university-educated workers may be cause for concern.

There are very large differences within the natural resource sector in terms of the importance of university-educated workers. In the energy sector nearly one quarter of workers (24.5 per cent) in 2003 had a university degree compared to only one twelfth in forest products (8.1 per cent), and one eleventh (9.0 per cent) in mining and mineral products (Chart 16).

At the level of the 14 natural resource industries only three natural resource industries matched the all-industries average for workers with a university degree: oil and gas extraction (27.1 per cent), electric power (24.4 per cent), and gas distribution (21.7 per cent). In six natural resource industries less than one tenth of workers had a university degree: wood products (5.0 per cent), forestry and logging (5.3 per cent), non-metallic mineral products (7.2 per cent), support activities for mining and oil and gas extraction (8.6 per cent), primary metals (9.1 per cent), and fabricated metal products (9.1 per cent).

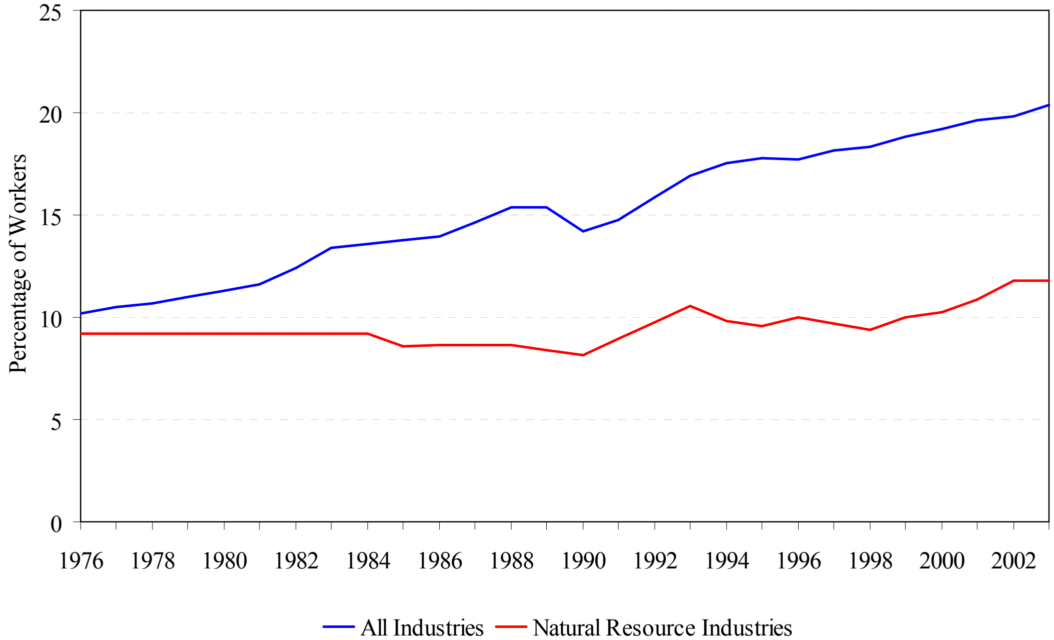
When other forms of post-secondary education such as community college certificates and diplomas and apprenticeship certification are taken into account, the gap in educational attainment between natural resource industries and the all-industries average is reduced, as many workers in natural resource industries have these qualifications. In 2003, 51.0 per cent of workers in natural resource industries had completed some form of post-secondary education, compared to 54.5 per cent for all industries (Chart 17). Unlike attainment of a university degree, there has been no deterioration in the proportion of workers in natural resource industries with some form of post-secondary qualification relative to the all-industries average (Chart 18).

Chart 13: Percentage of Workers with Less than High School Diploma in Natural Resource Industries, Canada, 1976-2003



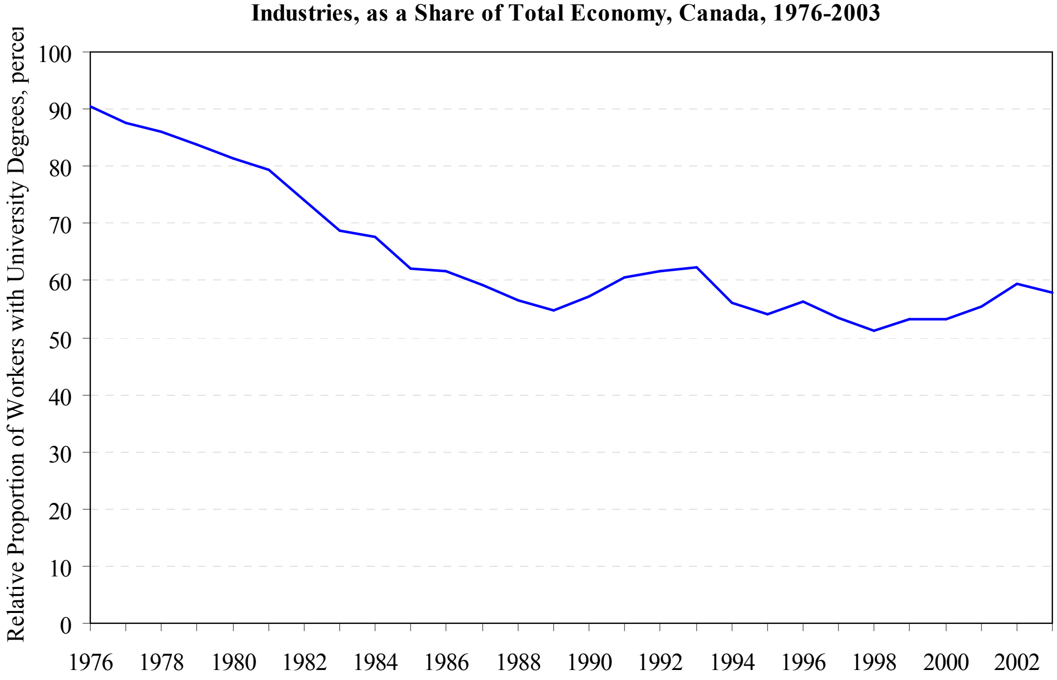
Source: Statistics Canada, Labour Force Survey. See Appendix on Educational Attainment

Chart 14: Percentage of Workers with a University Degree in Natural Resource Industries, Canada, 1976-2003



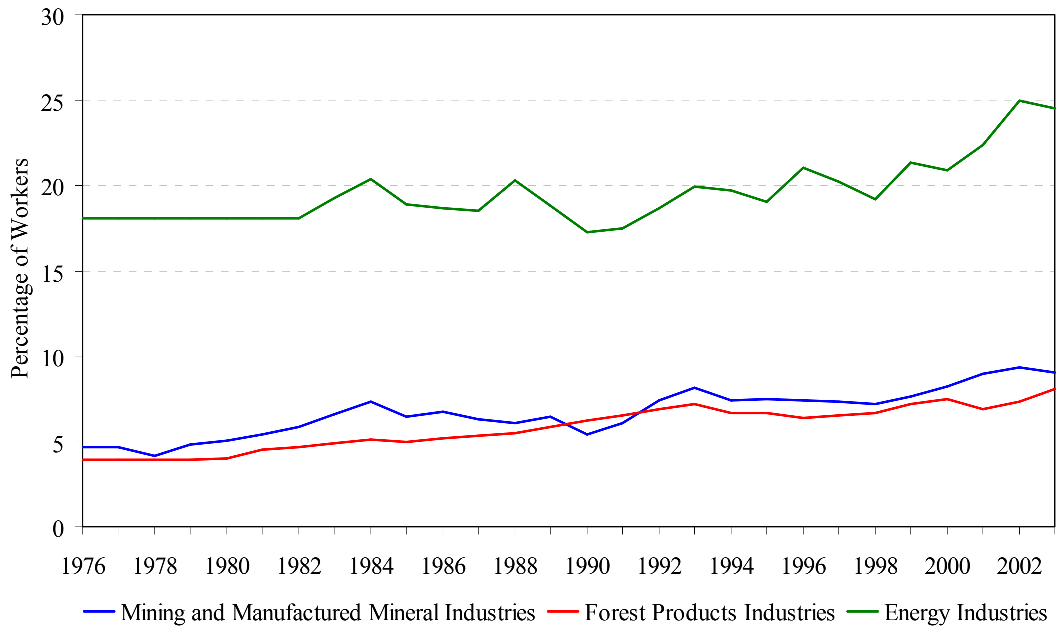
Source: Statistics Canada, Labour Force Survey. See Appendix on Educational Attainment

Chart 15: Proportion of Workers with a University Degree in Natural Resource Industries, as a Share of Total Economy, Canada, 1976-2003



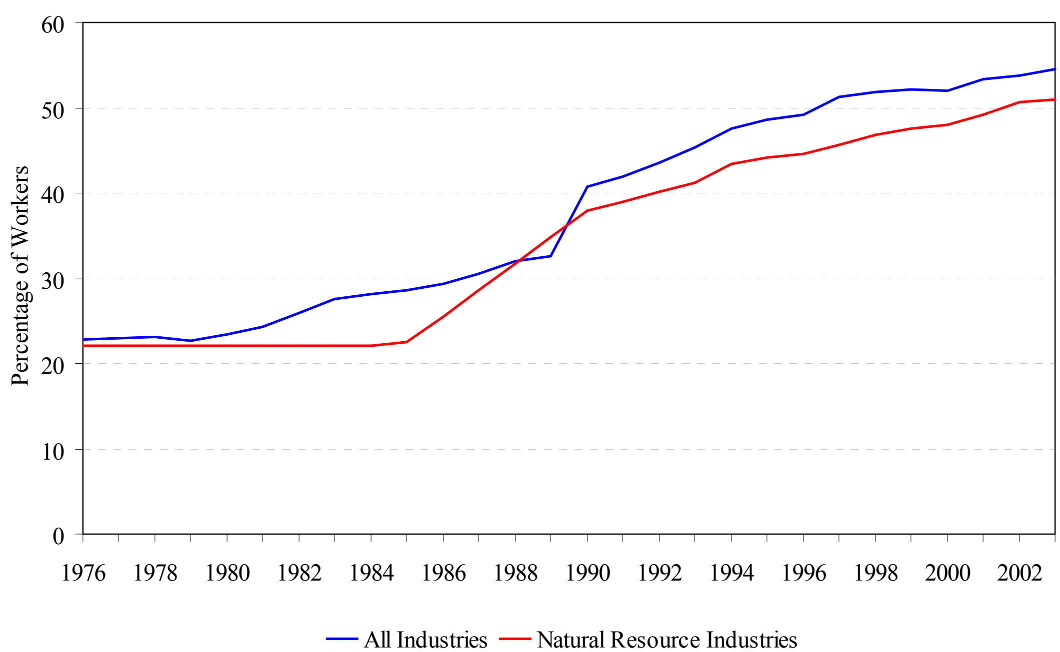
Source: Statistics Canada, Labour Force Survey. See Appendix on Educational Attainment

Chart 16: Percentage of Workers with a University Degree in Natural Resource Industries, Canada, 1976-2003



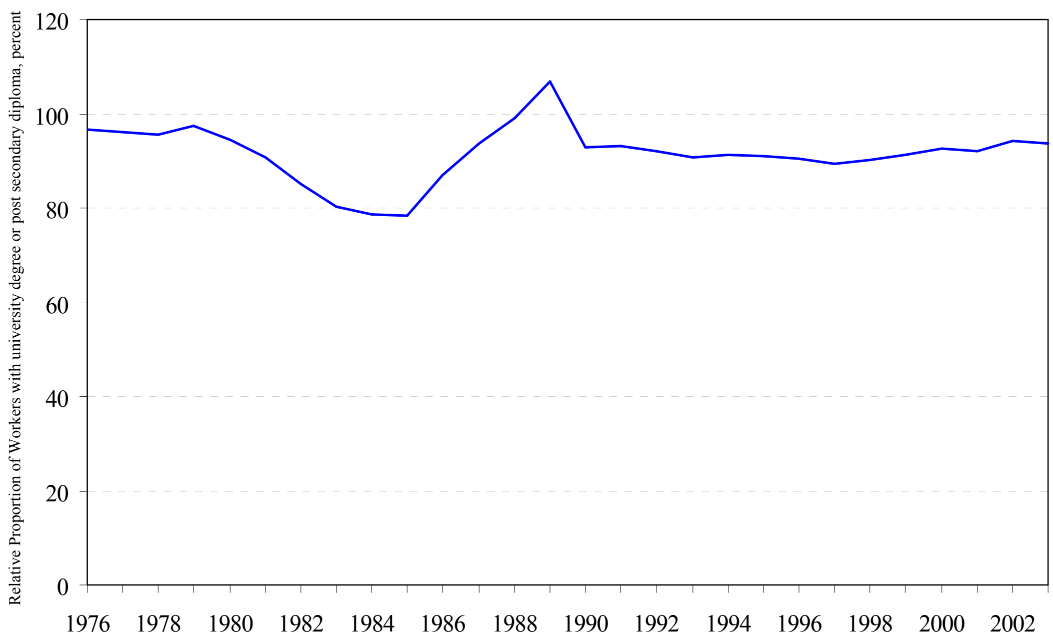
Source: Statistics Canada, Labour Force Survey. See Appendix on Educational Attainment

Chart 17: Percentage of Workers with a University Degree or Post Secondary Diploma in Natural Resource Industries, Canada, 1976-2003



Source: Statistics Canada, Labour Force Survey. See Appendix on Educational Attainment

Chart 18: Proportion of Workers with a University Degree or Post Secondary Diploma in Natural Resource Industries, as a Share of Total Economy, Canada, 1976-2003



Source: Statistics Canada, Labour Force Survey. See Appendix on Educational Attainment

C. Machinery and Equipment in Natural Resource Industries

New technologies are often embodied in machinery and equipment (M&E) and introduced into the production process through M&E investment. Thus the ratio of M&E investment to an industry's value added, the relative importance of M&E in the total capital stock, and the M&E capital stock/labour ratio may be useful indicators of an industry's innovativeness. The higher the value of the indicator, the more important M&E and hence the greater the possibility that new technologies can be assimilated into the production process.[16]

1) M&E Investment

Estimates of nominal M&E investment as a share of nominal value added, or the M&E investment rate, for 12 natural resource industries, three natural resource aggregates, all natural resource industries and all industries are available from 1961 to 2004 inclusive.[17] In 2004, M&E investment represented 7.6 per cent of GDP at the total economy level. The average for the natural resource industries aggregate was somewhat higher at 9.3 per cent (Chart 19). While the investment rate is cyclical, since 1961 there has been a downward trend in the investment rate for natural resource industries, and an upward trend for all industries. This has resulted in a fall in the investment rate for natural resource industries relative to all industries from 141 per cent in 1961 (and over 200 per cent during the early 1970s, early 1980s, and early 1990s) to 122 per cent in 2004 (Chart 20).

Both mining and mineral products and energy had above average M&E investment ratios, at 9.3 per cent and 9.9 per cent respectively, while forest products was average at 7.7 per cent (Chart 21). Seven natural resource industries were above the all-industries average: petroleum and coal products (45.0 per cent), primary metals (18.6 per cent), paper products (12.2 per cent), electric power (11.4 per cent), mining excluding oil and gas extraction (9.4 per cent), support activities for mining and oil and gas extraction (9.1 per cent), and non-metallic mineral products (7.8 per cent).

One component of M&E investment is information and communications technologies (ICT), which in recent years has been driving productivity growth in certain industries. Unfortunately, Statistics Canada only releases data on ICT investment at the two-digit NAICS level, which means in terms of natural resource industries covered by this report, only data for mining and oil and gas extraction are available (forestry is included with agriculture, forestry, fishing and hunting, and there is no breakdown for manufacturing). In this sector, ICT investment was very small. In 2004, it represented only 0.5 per cent of total investment (both M&E and structures), compared to 18.1 per cent at the total economy level (and 47 per cent in wholesale trade and 70 per cent in information and cultural industries). This low ICT investment intensity may reflect the limited ICT applications for the sector as well as the high overall investment rate, particularly when structures are included. It should not necessarily be interpreted as an indication of lack of innovation in natural resource industries. In addition, it is important to note that some equipment specific to natural resource industries with ICT embodied in it, such as computer-assisted operating systems in mining, may not be included as separate ICT investment, thus underestimating the use of ICT in natural resource industries relative to other industries.

ICT investment per worker in mining and oil and gas extraction in 2004 was $1,145 (chained 1997 dollars), about one third of the all industries average of $3,196. Again, this may not be a sign of lack of innovative effort by natural resource industries to the degree that ICT has less applications in these industries than elsewhere in the economy.

2) M&E Capital Stock

Estimates of M&E capital stock as a proportion of the total capital stock (M&E and structures) for 13 natural resource industries, three natural resource aggregates, all natural resource industries and all industries in Canada are available for the 1987-2004 period. In 2004, the M&E capital stock in natural resource industries represented 18.7 per cent of the capital stock, compared to 21.1 per cent for all industries. This below average share reflects the very large structures component of the capital stock in oil and gas extraction (93.8 per cent of the total capital stock) and mining (89.2 per cent).

In contrast, the manufacturing-related natural resource industries have well above average shares of M&E in their capital stock. The natural resource industry with the highest share of M&E in its capital stock in 2004 was paper products at 64.4 per cent, followed by wood products (56.9 per cent), non-metallic mineral products (54.8 per cent), primary metals (51.3 per cent), and fabricated metals (45.5 per cent). These industries thus have great potential to assimilate the latest technologies through M&E investment, although they do not differ greatly from manufacturing industries unrelated to natural resources in this regard.

The ICT component of the capital stock for mining and oil and gas extraction, the only industry for which estimates are available, was a miniscule 0.1 per cent of the total capital stock in 2004, well below the total economy share of 4.4 per cent.

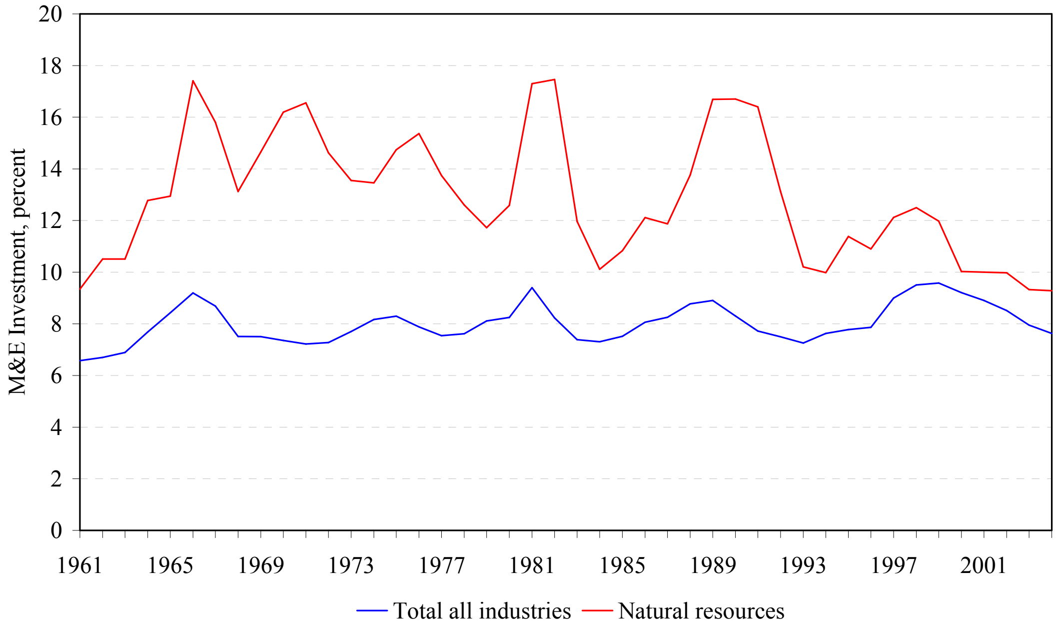
3) M&E Capital Intensity

Estimates of M&E capital intensity, defined as the M&E capital stock per worker for 13 natural resource industries, three natural resource aggregates, all natural resource industries and all industries in Canada are available for the 1987-2004 period. The aggregate for natural resource industries in 2004, at $131,959 (chained 1997 dollars) per worker, was over four times the all-industries average.[18] There was great variation in M&E capital intensity across natural resource industry aggregates, from 13 times the all industries average in energy to 3 times in forest products, to twice the average in mining and mineral products.

At the 13 industry level, there was even greater variation in M&E capital intensity, ranging from a high of 19.6 times the all-industries average in pipelines transport to a low of 0.5 times in logging and forestry and fabricated metal. Other natural resource industries with high M&E capital intensity are electric power (16.4 times), petroleum and coal products (11.9), oil and gas extraction (7.8), paper products (7.0), primary metals (5.5), and mining (3.1).

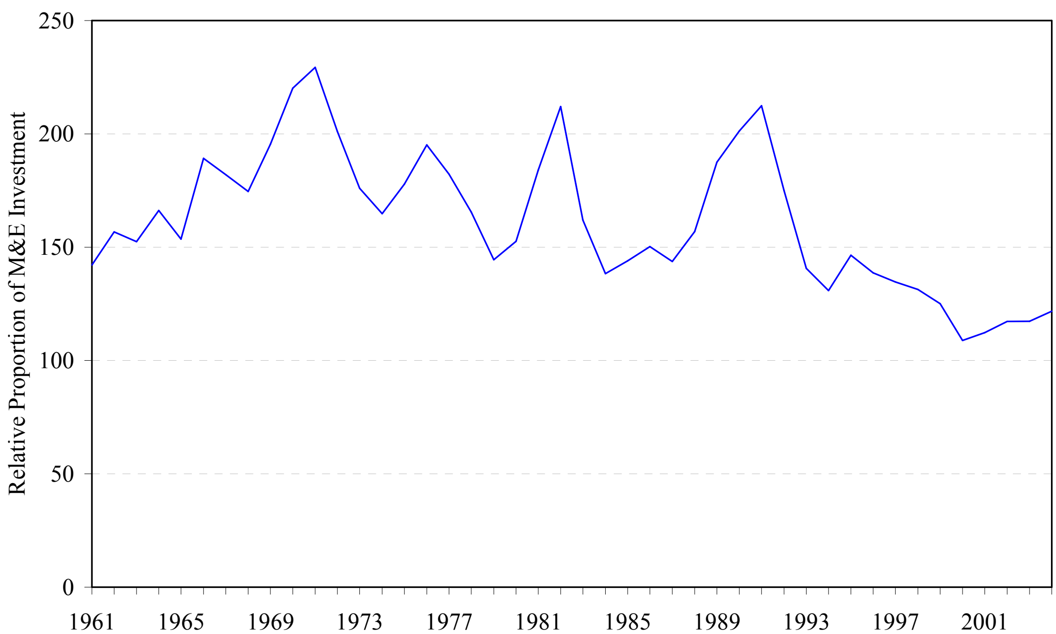
ICT net capital stock per worker in mining and oil and gas extraction in 2004 was $2,042 (chained 1997 dollars), one quarter of the all industries average of $8,235. Again, this may not be a sign of lack of innovative effort by natural resource industries to the degree that ICT has less applications in these industries than elsewhere in the economy.

Chart 19: Machinery and Equipment Investment as a Share of Value Added in Natural Resource Industries in Canada, 1961-2004



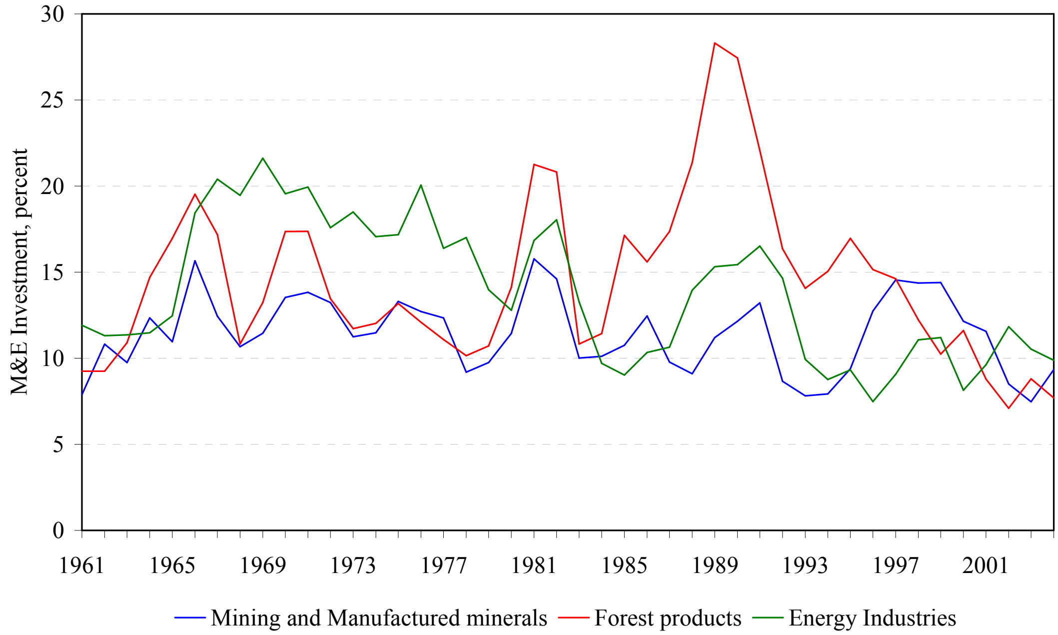
Source: Statistics Canada, CANSIM II, Table 031-0002 (investment in M&E) and Table 379-0023 (current GDP), March 12 2005.

Chart 20: Relative Machinery and Equipment Investment Share of Value Added in Natural Resource Industries, as a Share of Total Economy, in Canada, 1961-2004



Source: Statistics Canada, CANSIM II, Table 031-0002 (investment in M&E) and Table 379-0023 (current GDP), March 12 2005.

Chart 21: Machinery and Equipment Investment as a Share of Value Added in Natural Resource Industries in Canada, 1961-2004



Source: Statistics Canada, CANSIM II, Table 031-0002 (investment in M&E) and Table 379-0023 (current GDP), March 12 2005.

D. Productivity

1) Labour Productivity

Labour productivity, defined as output per hour worked, is more an outcome of the innovation process than an indicator of innovation capacity. Industries with high levels of labour productivity have by definition a large capacity to generate income and wealth, and it is likely that this capacity is directly related to their innovate capacity. Equally, industries with strong labour productivity growth rates have a greater capacity to generate increases in income and wealth and it is again likely that this capacity is related to their pace of innovation.

Data is available from CSLS (2003) presenting absolute and relative levels of labour productivity (output per hour) for natural resource industries in Canada in 2000 and labour productivity growth rates for the 1961-89, 1989-2000, and 1961-2000 periods. Average annual labour productivity growth rates for the 1989-2002 period for seven natural resource industries in 20 OECD countries based on the OECD's STAN database are also available. Chart 22 presents official Statistics Canada estimates of output per hour for natural resource industries in Canada for the 1997-2001 period. Two observations are salient:

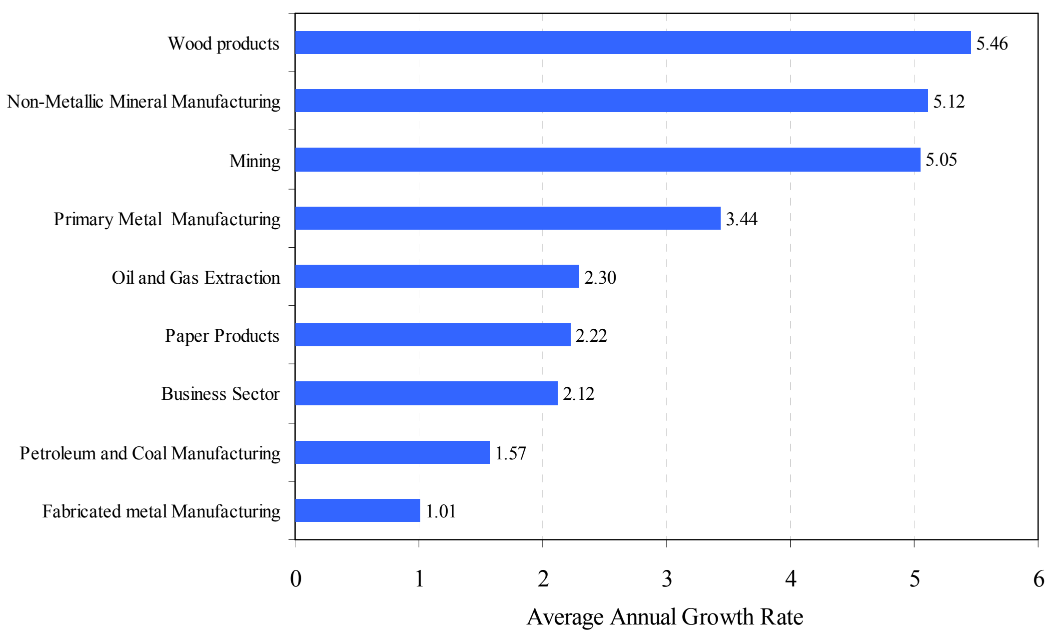
- the well above average labour productivity levels and growth rates in natural resource industries in Canada; and

- the average nature of the labour productivity growth performance of Canadian natural resource industries compared to those of other OECD countries.

According to the CSLS report on productivity in natural resource industries prepared for Natural Resources Canada in 2003, out of the 17 Canadian natural resource industries for which data are presented, in 2000 15 industries had labour productivity levels above the all-industries average, with many far above average. The average level of labour productivity in natural resource industries was about twice the all-industries average. The average labour productivity growth rate in natural resource industries was around 0.8 percentage points faster than the all industries average in all three of the periods for which data are presented. Indeed, over 1961-2000 13 of 17 natural resource industries had labour productivity growth rates superior to the all-industries average.

According to official Statistics Canada productivity estimates, output per hour growth over the 1997-2003 period exceeded the business sector average in six of eight natural resource industries for which data are available (Chart 22), and advanced at more than twice the business sector rate in three industries (mining, wood products, and non-metallic mineral products).

Chart 22: Average Annual Growth Rates in Labour Productivity in Natural Resource Industries in Canada, 1997-2003



Sources: Statistics Canada, CANSIM II Table 383-0013 , April 9, 2005.

According to OECD data, Canada fared well in terms of international comparisons of productivity growth performance (productivity level comparisons are not possible because of the absence of industry purchasing power parities) in wood products (third of 11 countries) and in non-metallic mineral products (second of 14), but did very poorly in mining and quarrying (17^{th} of 19). In the other four industries, Canada exhibited an average performance. Overall, Canada's labour productivity growth in natural resource industries in the 1990s relative to that of other countries could be considered respectable, but certainly not impressive.

Another perspective on Canada's labour productivity performance in natural resource industries can be obtained from a comparison of labour productivity levels in these industries between Canada and the United States. A recent Industry Canada study (Rao, Tang, and Wang, 2004), based on industry purchasing power parities, found that even though output per hour in Canada's business sector in 2001 was 81 per cent of its U.S. counterpart, equivalent to a 19 percentage point productivity gap, the gap in most natural resource industries was much smaller or non-existent. For example, the gap in mining was only 2 percentage points while in four industries the Canadian labour productivity level exceeded that of the United States: wood (131 per cent of the U.S. level), paper (123 per cent), primary metals (150 per cent) and non-metallic mineral products (138 per cent). It should however be noted that in two natural resource industries the Canada-U.S. labour productivity gap greatly exceeded the business sector average: petroleum and coal products (with a labour productivity level just 61 per cent of the U.S. level) and fabricated metal products (52 per cent of the U.S. level).

2) Multifactor Productivity

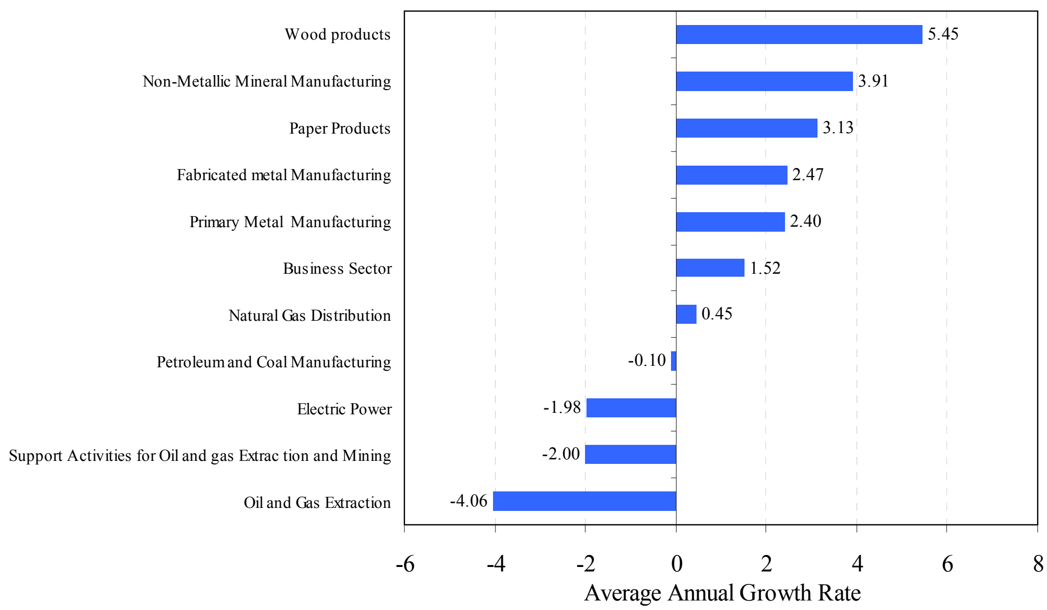
Multifactor productivity captures changes in output that are not due to increases in labour input and capital stock. It is often referred to as the "residual" and reflects the influence of many factors including economies of scale, capacity utilization, labour quality, measurement error, natural resource depletion, and underlying technological changes. Indeed, multifactor productivity is sometimes considered a proxy for the pace of technological change in a sector, although this view has been criticized (Lipsey and Carlaw, 2000 and Sargent and Rodriquez, 2000).

Indexes of multifactor productivity for natural resource industries and the business sector are available for the 1981-2003 period based on official estimates prepared by Statistics Canada. The overall performance of multifactor productivity in natural resource industries is less impressive than that of labour productivity. This reflects the fact that much of labour productivity growth in natural resource industries arises from capital deepening, that is increases in the capital-labour ratio.

For the ten natural resource industries for which data are available for the recent 1997-2003 period (Chart 23), five had multifactor productivity growth that exceeded the business sector average annual rate of change of 1.2 per cent, namely wood products, non-metallic mineral products, paper products, primary metal products, and fabricated metal products. Equally, five industries had multifactor productivity growth below the business sector average: oil and gas extraction, support activities for oil and gas extraction and mining, electric power, petroleum and coal products, and natural gas distribution. It is interesting to note that most of the industries with below average multifactor productivity growth are in the primary sector, so the poor performance may be linked to natural resource depletion. In contrast, all the natural resource industries with above average multifactor productivity growth were in manufacturing.

Based on these findings and acceptance of the view that multifactor productivity growth reflects the pace of technological change, no case can be made that the pace of innovative activities, which governs the rate of technological progress, is slower in natural resource industries than at the total economy level.

Chart 23: Average Annual Growth Rates in Multi-factor Productivity in Natural Resource Industries in Canada, 1997-2003



Source:Sources: Statistics Canada, CANSIM II Tables 383-0013 (NAICS 1997-2003), 383-0001 (SIC 1981-1997), April 9, 2005.
Note: The AAGR for Fabricated Metals is for the 1997-2002 period.

E. Foreign Direct Investment (FDI)

Multinational firms are important for their role in transferring technologies across borders, both through greenfield physical investments, implementation of more effective managerial practices, and transfer of best practice technologies from the home country (Blomstrom, 1991). Consequently, a high degree of foreign direct investment (FDI) in an industry may be a positive indicator of an industry's ability to be innovative. Based on the more current NAICS definitions, in 2003 FDI in natural resource industries totalled $96.7 billion, representing 27.0 per cent of total or all- industries FDI, well above the natural resource sector's share of output, employment, and capital stock.

In terms of the natural resource industries, mining, oil and gas, and utilities had the largest FDI at $48.3 billion in 2003, followed by petroleum and coal and chemical manufacturing ($35.1 billion), and wood products and paper manufacturing ($13.3 billion).[19] Over the 1999-2003 period, the current dollar stock of FDI in mining, oil and gas, and utilities more than doubled, while it fell slightly in wood products and paper manufacturing and increased at a rate comparable to the all-industries average in petroleum and coal and chemical manufacturing.

Estimates of FDI flows into Canada based on different definitions (total net, net long-term, net short-term, reinvested earnings, gross long-term inflows, and gross long-term outflows) for the wood and paper industry and the energy and metallic mineral industries (the only aggregates available) are available for the 1983-2004 period. Focusing on the total net flows, which is the bottom line so probably the most relevant of the six FDI measures, one sees that the energy and metallic mineral industries have been very successful in attracting significant FDI into Canada since the mid-1990s, with total net flows exceeding $52 billion in the three year period from 2000 to 2002. The wood and paper industries have also had positive total net flows over the 1994-2003 period, but at much lower levels than the energy and metallic mineral industries. These FDI flows undoubtedly contribute to ensuring that Canadian natural resource firms use best practice, world class technologies.

F. Technological Balance of Payments

The technological balance of payments can be used as an indicator of innovation, and data are produced by the OECD, although such data must be interpreted with care. Estimates of the technological balance of payments for five types of payments for two natural resource aggregates (wood and paper industries and energy and metallic minerals) and for all industries are available for the 1990-2001 period.

R&D receipts and payments are likely the most indicative of trends in innovation. Increased receipts mean that foreigners are willing to purchase more R&D services from Canada, a sign of growing technological prowess. Increased payments by Canadians to foreigners may mean that Canada is importing more R&D, which fosters domestic innovation; or it may mean that domestic R&D suppliers are not as competitive as foreign suppliers.

In wood and paper industries, R&D receipts rose from zero in 1990 to $15 million in 2001, while payments dropped from $10 million to zero, resulting in a $25 million turnaround in the R&D balance from a deficit of $10 million to a surplus of $13 million. This would appear to be a positive development from the point of view of the innovative capacity of the wood and paper industry. It may reflect greater demand abroad for wood and paper R&D done in Canada from this sector and less reliance by this sector on foreign R&D.

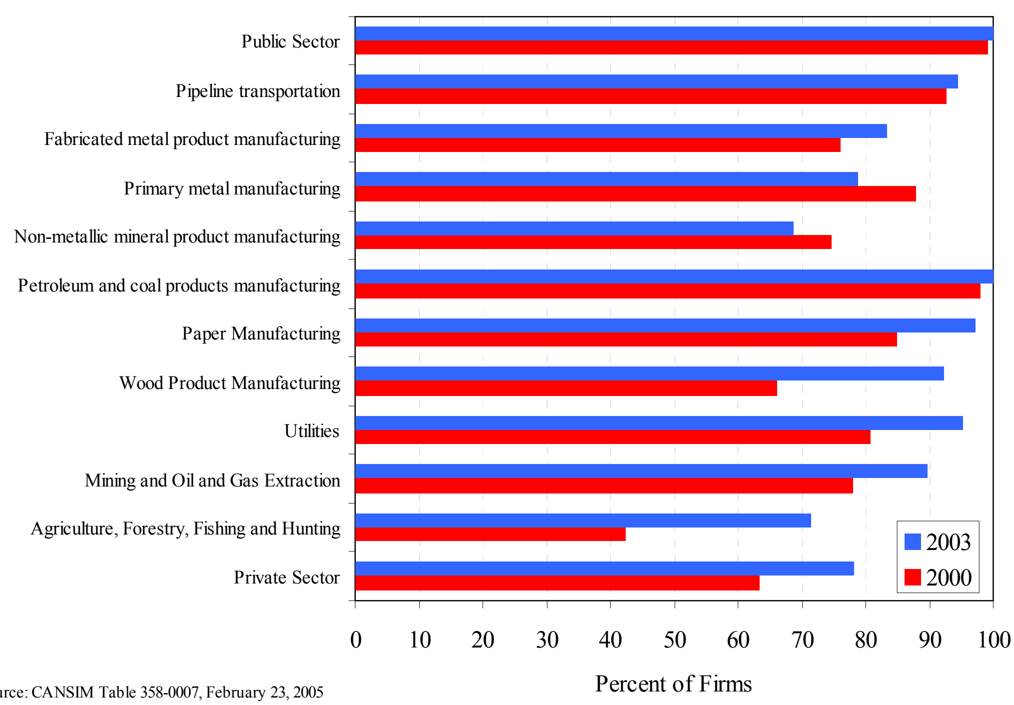
In energy and metallic minerals, R&D payments have fallen significantly, from $73 million in 1990 to $49 million in 2001. R&D payments have done the same, dropping from $119 million to $75 million. The R&D deficit of $46 million in 1990 had fallen to $26 million by 2001. Although these figures are difficult to interpret from the point of view of the innovative capacity of the industry, they are probably less positive than the developments in wood and paper industries.

G. Internet Use in Natural Resource Industries

Chart 24 provides estimates of the percentage of firms that use the internet in natural resource industries and the private and public sector averages for the 2000-2003 period based on Statistics Canada's Survey of Electronic Commerce and Technology.

In 2003, the proportion of firms using the internet was 97.1 per cent in paper manufacturing, 92.3 per cent in wood product manufacturing, and 89.7 per cent in mining and oil and gas extraction. All three natural resource industries hence made significantly greater use of the internet than the private sector average (78.2 per cent), although less than the public sector average of 100 per cent. This suggests that natural resource industries have been innovative in using the internet. Internet use in agriculture, forestry, fishing and hunting was 71.7 per cent, below the private sector average likely because of lower usage in agriculture and fishing, the most important components of this sector.

Chart 24: Internet Use in Natural Resources Industries in Canada, percent of firms



Source: CANSIM Table 358-0007, February 23, 2005

H. Incidence of Innovation

The “Oslo manual” published by the OECD/Eurostat (1997) provides a framework for the definition and measurement of innovation at the firm level. This manual has been used in the development of innovation surveys, including those conducted in Canada (Gault, 2003) and is invaluable for an understanding of what constitutes technological product and process (TPP) innovations.

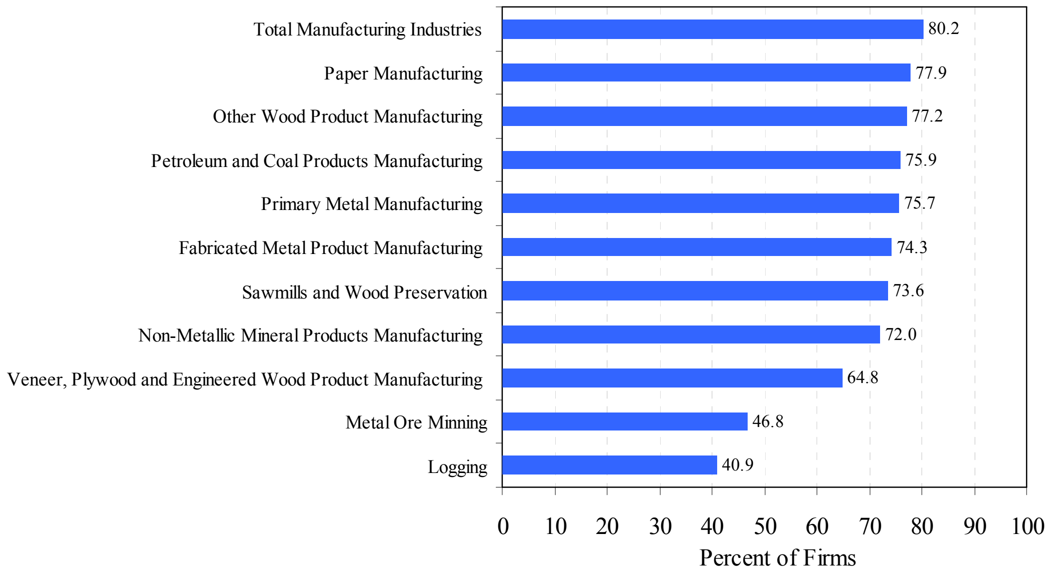
The most important indicator of innovation that has come out of innovation surveys is the proportion of firms in a country or industry that innovate. This indicator has three categories of novelty of innovation: world first, firm first, and an intermediate category between world and firm first. Additional indicators of innovation available from innovation surveys that can be used to assess industry innovation include information on active versus passive innovation patterns (creation of technologies or acquisition of disembodied or embodied technologies), the proportion of sales from new or significantly improved products, and training and marketing expenditures related to innovations.

Statistic Canada’s 1999 Innovation Survey, which for the first time extended coverage beyond manufacturing to a number of natural resource industries, generated much useful data on innovation at the industry level. The key finding was that the incidence of innovation in natural resource industries was somewhat below the all-industries average. It was also found that natural resource industries tend to do more process innovation and less product innovation in absolute terms and relative to non-natural resource industries.

These results are shown in Chart 25. The eight natural resource manufacturing industries had rates of innovation ranging from a low of 64.8 per cent in veneer, plywood and engineered wood products to a high of 77.9 per cent in paper products. The rate of innovation in all eight natural resource manufacturing industries was below the average for all manufacturing industries (80.2 per cent). The rate of innovation in logging (40.9 per cent) and metal ore mining (46.8 per cent) was well below that of natural resource manufacturing industries and overall manufacturing.

Based on the 1999 Innovation Survey, estimates of the proportion of innovative firms that had a world first innovation are available over the 1997-99 period. For overall manufacturing, 12.0 per cent of innovative firms who provided information on their most important innovation were in this category. Two natural resource manufacturing industries did even better or just as well: veneer, plywood and engineered wood products, where 19.3 per cent of such firms had a world class innovation, and non-metallic mineral products, where12.2 per cent were world class innovators.

Chart 25: Percentage of Innovative Firms in Selected Natural resource Industries, Canada, 1997-1999



Source: Statistics Canada (2002). Survey of Innovation 1999 Statistical Tables Manufacturing Industries, Canada. Cat. No. 88F0006XIE2002016, Table 3.1 pp. 125; Statistics Canada (2002). Innovation and the Use of Advanced Technologies in Canada's Mineral Sector: Metal Ore Mining. Cat. No. 88F0006XIE2002013, 26 p. Statistics Canada (2002). Innovation in the Forest Sector. Cat. No. 88F0006XIE2002011, 12 p.

I. Additional Innovation Indicators for Natural Resource Industries

In addition to the innovation indicators in natural resource industries already reviewed, there are many other possible indicators. This section outlines a number of these indicators.

The report has focused on intramural R&D undertaken by natural resource industries. In addition, the natural resource sector may engage in extramural R&D spending by financing R&D activities by other industries in the business sector, by higher education, by the federal and provincial governments (including provincial research organizations) and by the private non-profit sector. Unfortunately, data are not readily available on contracting out of R&D projects by natural resource industries to other industries within the business sector and to other sectors. Data are however available at the level of all business enterprises and indicate that extramural funding of R&D by business enterprises is not particularly important, accounting in 2002 for only 7.0 per cent of total R&D funding provided by business enterprises.[20] To the degree that the overall business enterprises pattern applies to natural resource industries, the total R&D effort of these industries would not be greatly increased by including extramural R&D spending. But to obtain a comprehensive picture of R&D performed and funded by natural resource industries, extramural R&D should be included.

Estimates of the extent of collaboration between industry and higher education on an industry basis are potentially available from the R&D statistics. Indicators would be the proportion of higher education R&D funded by particular industries and the proportion of R&D funded by industries that is undertaken by higher education. Absolute values of both of these indicators could also be used.

Estimates of the quality of the workforce in natural resource industries, measured in terms of literacy and numeracy, relative to other industries in Canada and to natural resource industries in other countries, may be available from the International Adult Literacy Survey. Estimates of continuing education and training for Canada by industry are available from a special tabulation from Statistics Canada's Adult Education and Training Survey.

Data on the number of patents are in principle available from international sources on an industry basis, but have not been found. The Canadian patent office does not compile data on patents on an industry basis.

Data on the regulatory environment (trade and foreign direct investment restrictions, barriers to competition and state control, and administrative burden and red tape) can in principle be gathered on an industry basis both within Canada and across countries, but such data do not appear to be currently available.

Another approach to the measurement or quantification of innovation is the counting of the number of major new inventions in an industry. This number tends to be correlated with the success of the industry. De Bresson (1987:90), for example, identified 2,000 Canadian products or processes that became commercially successful between 1945 and 1978, and classified producers and users of the innovations by industry, highlighting inter-industry technological linkages. An update of this study from the perspective of natural resource industries would likely shed much light on the nature of the innovation process in this sector, which differs significantly from that of other sectors because of the unique characteristics of natural resource industries.

Natural resource industries could be assessed relative to other industries on their use of knowledge management practices, which are closely related to innovation behaviour. Earl (2002) identifies 22 practices under the headings leadership, knowledge capture and acquisition, training and mentoring, policies and strategies, communications, and incentives. The extent to which natural resource industries embrace these practices and undertake other forms of organizational reform could be ascertained through surveys.

III. Overall Assessment of the Innovative Performance of Canadian Natural Resource Industries

This section provides an overall assessment of the innovative performance of Canadian natural resource industries relative to the all-industries average in Canada and to natural resource industries in other OECD countries. Exhibit 3 provides a synthesis of the findings of the previous section of the report for ten innovation indicators for Canada and four indicators for other countries. The bottom line is clear. On almost all innovation indicators, Canadian natural resource industries either perform at the all-industries average or above the average. On the international indicators, Canada exhibits an average performance.

It is sometimes suggested that the below average R&D intensity of natural resource industries (48 per cent of the business sector average in 2004, but above the business sector average for most of the period before 1992) indicates that the innovative capacity and performance of these industries is substandard. This is a misleading interpretation for a number of reasons, the most important being that intramural R&D spending captures only part of the multi-dimensional concept of innovation. R&D spending is by no means a sufficient or necessary condition for innovative behaviour, although it can foster such behaviour.

Reasons that intramural R&D spending by Canadian natural resource industries tell only part of the sector's overall R&D and innovation story include the following.

- Extramural R&D spending funded by natural resource industries but performed outside of the business sector, primarily by the higher education sector, is excluded, as is contracting out of R&D activities within the business sector.

- Intramural R&D spending by the paper industry may be significantly underestimated because of the exclusion of mill trials from the definition of R&D.

- The R&D undertaken by other sectors (government labs, universities) and by other industries in the business sector that supply inputs to natural resource industries (e.g. machinery producers) that is directly applicable to natural resource industries is excluded from the intramural R&D of the natural resource sector, even though this R&D contributes to productivity advance in natural resource industries.

- Since the goods produced by natural resource industries are generally homogeneous commodities requiring little if any product development, natural resource industries do not have to do as much product innovation as non-natural resource industries. Their motivation for undertaking R&D is often cost reduction. This reality manifests itself in innovation surveys in the greater proportion of process innovation in total innovation undertaken by natural resource firms.

- While R&D intensity may be below average in natural resource industries, R&D personnel per 1,000 workers is almost identical to the all-industries average. R&D personnel may in fact be more important for the innovative performance of a sector than R&D spending as it is the scientists that develop and apply ideas.

Despite the below average R&D intensity, natural resource industries do well on many innovation indicators, as shown in Exhibit 3. Probably the most important is the sector's labour productivity performance. Labour productivity levels tend to be about double the economy-wide average, reflecting in part the high capital intensity of the sector, and long-term labour productivity growth has been about 0.8 percentage points higher. Multifactor productivity growth has also been above average. This superior productivity performance is not the sign of an innovation laggard.

Exhibit 3: Synthesis of the Relative Performance of Canadian Natural Resource Industries on Innovation Indicators

	Relative to	
	Canadian All-industries Average	Natural Resource Industries in Other Countries
R&D Intensity (level)	currently below average, but historically above average	below average
R&D Intensity (trend)	downward	NA
R&D Personnel	near average	average
Educational Attainment	slightly below average	NA
M&E Capital Intensity	above average	NA
Labour Prod. Level	above average	NA
Labour Prod. Growth	above average	average
Multifactor Prod. Growth	above average	NA
FDI	above average	NA
Internet Use	above average	NA
Incidence of Innovation	somewhat below average	average

Other innovation indicators where natural resource industries fare favourably relative to other Canadian industries include use of the internet (above average), machinery and equipment per worker (above average), and foreign direct investment (above average). Natural resource industries fare near the average in the proportion of firms that are defined as being innovative and in the proportion of R&D personnel working in the sector, and slightly below average in educational attainment.

One possible area of concern in terms of the innovation performance of Canada's natural resource industries is the downward trend in R&D intensity. The current R&D intensity level of 0.64 per cent of value added is well below the 1.2 per cent level recorded in the early 1990s. The causes of this development are unclear and worthy of further study. A second concern may be the decline in the proportion of university-educated workers in the natural resource sector relative to the proportion in other industries.

It is more difficult to assess the innovativeness of Canadian natural resource industries relative to natural resource industries in other OECD countries because of limited comparable data. For the four innovation indicators that are available, Canada is in the middle of the pack (see Exhibit 3), with no discernible trend. Certain countries such as Sweden and Finland tend to outperform Canada on a number of indicators.

IV. Conclusion

A key message of this report is that R&D spending is an imperfect guide to the innovation performance of Canadian natural resource industries, and that R&D statistics should be supplemented by other measures of innovation. The report has shown that the R&D intensity of natural resource industries is somewhat below the business sector average. But on many other indicators, natural resource industries in Canada are more innovative than the all-industries average. Most Canadian natural resource industries are highly innovative, compared to non-natural resource industries in Canada, and hold their own in terms of innovation with natural resource industries in most other countries. While there is always room for improvement, Canadian natural resource industries have done a good job in recognizing the importance of innovation and pursuing strategies to become more innovative. Of course, the competitive pressures arising from globalization have made innovation imperative for survival.

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Endnotes

[1] This report was written by Andrew Sharpe with the assistance of Olivier Guilbaud and Jeremy Smith. The Centre for the Study of Living Standards would like to thank Natural Resources Canada for the invitation to prepare this paper, Jai Persaud, Eric Sanscartier and other NRCan officials for comments on earlier drafts, and Fred Gault, Charlene Lonmo, Robert Schellings, and Janet Thompson from Statistics Canada for provision of data.
[2] Unfortunately, for most indicators it is not possible to remove coal from mining and place it in the energy aggregate.
[3] Data on R&D and innovation in this sector will be available by September 2005 when the results of the census of the geomatics industry in Canada are ready. The survey is being conducted by Statistics Canada with funding from Natural Resources Canada.
[4] There is a large economics literature that directly links innovation, and especially R&D, to productivity and economic growth. Innovation is a determinant of productivity and R&D represents an important aspect of innovation. Productivity growth, along with employment growth, constitute economic growth. For a theoretical perspective on the impact of R&D on productivity, see Bernstein (1991). For an empirical perspective, see Nicholson (2003) who presents the OECD growth project finding that a 0.1 percentage point increase in the ratio of business expenditures on R&D to GDP increases productivity growth by over 1.2 per cent.
[5] Godin (2004a:23) argues that "…High technology is the perfect example of a fuzzy concept of much value for rhetorical purposes. Officials use it constantly without any systematic definition, simply for its prestigious appeal." One criticism of high technology is that a firm may be considered technology-intensive if it conducts research, purchases or uses advanced technologies, or employs highly trained workers, leading to an overly broad definition. A second criticism is that there is not yet a standardization of terminology, so different definitions give different results.
[6] See Godin (2004a:15-16) for details on the definition.
[7] It should be noted that the different reference periods for the two surveys may limit the comparability of the results. However, it is likely that the incidence of innovation is fairly stable over short time periods.
[8] These eight areas of innovation do not cover innovation in terms of human resource, organizational or other managerial reforms. While such innovations are potentially just as integral to productivity as other forms of innovation, data on these types of reform by industry are quite limited. Some data are available from innovation surveys and the Workplace and Employee Survey (WES) in Canada, but they have not been discussed here, as much further work is required before a systematic analysis of organizational innovation can be made across industries in Canada, let alone across countries at the industry level.
[9] A case can be made that value added is a more appropriate denominator for R&D intensity calculations than gross output (also referred to as sales, revenues or value of production) because it excludes the value of intermediate inputs, whose importance varies across industries and over time.
[10] As data on current dollar value added by industry are only available to 2001, the 2002-04 estimates of R&D intensity have been based on estimates of nominal value added by industry derived from the per cent change in real value added by industry (1997 base year) plus the per cent change in the business sector GDP deflator in 2002, 2003 and 2004. In other words, it has been assumed that the implicit price deflator for each industry has grown at the rate of general inflation in the business sector as a whole for these three years. This is an unreasonable assumption for many resource-based industries, since the prices of these commodities often follow a much different path than average prices. For example, given the rapid increase in the price of oil and natural gas since 2001, it is likely that the implicit price deflator for the oil and gas industry has grown by much more than business sector inflation over this period. The method that has been used here will underestimate nominal value added (and hence overestimate the R&D to value added ratio) in the oil and gas industry, since by using the business sector deflator, the real growth rate of value added in this industry is not adjusted upward by a large enough factor. It should be noted that this method of deriving nominal GDP estimates and using them in the calculation of R&D to value added ratios is equivalent to taking R&D in 2001 dollars (defined as nominal R&D deflated by the business sector GDP deflator with 2001=100) divided by GDP in 2001 dollars (i.e. rebasing the constant dollar industry GDP series from 1997 to 2001 dollars based on the industry-specific implicit deflators in 2001). An alternative would be to divide R&D in 1997 dollars by GDP in 1997 dollars, but this is equivalent to assuming that

movements in industry deflators correspond to movements in the business sector deflator for the entire 1997-2004 period rather than just for the 2001-2004 period. In any case, the estimates of R&D as a share of value added for the 2002-04 period should be regarded as extremely uncertain due to the probable differences between industry level and business sector inflation. They will be updated as official estimates of nominal value added by industry become available for these years. It should also be mentioned here that the nominal value added series for the business sector excludes imputed rents to owner occupied dwellings.

[11] The large increase in R&D intensity in the paper industry was concentrated in 2001, when R&D in this industry increased by $112 million from $154 million in 2000 to $266 million in 2001 (and R&D intensity increased from 1.06 to 1.98 per cent). Statistics Canada officials have stated that over one half of this increase in R&D spending was due to a takeover by a paper company of a firm in another industry. This resulted in a reallocation of R&D expenditures to the paper industry from the industry of the acquired firm. R&D expenditures by industry are classified on an enterprise or firm basis rather than an establishment basis, and are assigned to industries based on the industry code of the primary activity of the enterprise.

[12] There are significant discrepancies between the R&D intensities for natural resource industries produced by Statistics Canada in Table 1 and the estimates from the STAN database, with the STAN estimates tending to be smaller. (Differences in industry definitions may explain some of these discrepancies.) For example, Statistics Canada reports R&D intensity of 1.1 per cent for paper and allied products in 2000, while the OECD reports only 0.4 per cent (although the OECD figure also includes printing and publishing).

[13] Godin (2002d:7) notes that the Frascati Manual distinguishes R&D from two other types of activities: related scientific activities and non-scientific activities (of which industrial production is perhaps the most important). Related scientific activities (RSAs) fall into four classes: 1) scientific information (including publications), 2) training and education, 3) data collection, and 4) testing and standardization (p. 15). Non-scientific activities are of three kinds: 1) legal and administrative work for patents; 2) testing and analysis; and 3) other technical services. The 1963 Manual stated that RSAs must be excluded from R&D unless they serve R&D directly (p. 16), and adds that: "It is not possible here to make a detailed standard recommendation for related scientific activities (…). The objective of this manual is to attain international comparability in the narrower field of R&D (…). Arising from this experience, further international standards can be elaborated by the OECD for related activities" (pp. 14-15). The Manual nevertheless recommended that:

> All calculation of deductions for non-research activities of research organizations, and of additions for R&D activities of non-research organizations should be made explicit, that is to say, recorded both by individual respondents and by those compiling national totals from the data furnished by individual respondents. Furthermore, whenever possible, related scientific activities such as documentation and routine testing, should be measured simultaneously with R&D and reported separately (p. 14).

The recommendation was soon abandoned. In 1967, the OECD concluded that: "these activities necessitate the formation of an *ad hoc* study group to elucidate the main problems which arise in measuring these activities." Consequently, the suggestion to measure RSA was dropped. The second edition of the Manual (1970) concentrated on R&D and no study group was ever created: "We are not concerned here with the problem of measuring R&D related activities but with the conventions to be used to exclude them when measuring R&D activities" (p. 14). The second edition of the Frascati Manual was in fact the first step in a long series of boundary work. In 1970, the list of RSAs excluded from R&D extended to seven classes (pp. 14-15): 1) scientific education; 2) scientific and technical information (itself subdivided into six subclasses, and into eight in 1976); 3) general purpose data collection; 4) testing and standardization; 5) feasibility studies for engineering projects; 6) specialized medical care; and 7) patent and license work. Policy related studies were added in the 1976 edition, and routine software development in 1993.

[14] On the debate between government and industry officials on defining R&D for tax purposes, see Hertzfeld (1988), Poterba (1997) and Warda (2003).

[15] According to Freedman's estimates (2005b) the number of R&D performers in primary industries (which differs from the definition of the natural resource sector used in the text) dropped from 414 in 1994 to 390 in 2000. As the number of R&D performers in natural resource industries in Quebec increased from 103 to

145 over the 1994-2000 period, the number of R&D performers in the rest of Canada fell by 66 or 21 per cent from 311 to 245.

[16] It should be noted, however, that in diminishing-returns natural resource industries such as oil and gas, where increasing M&E investment may be needed just to keep production constant, these M&E indicators may not be associated with productivity gains. Indeed, the opposite may be the case.

[17] Similar to the case with R&D intensity discussed in an earlier endnote, the 2002-04 estimates of M&E investment intensity have been based on estimates of nominal value added by industry derived from the per cent change in real value added by industry (1997 base year) plus the per cent change in the total economy GDP deflator in 2002, 2003 and 2004. As is the case with estimates of R&D intensity for 2002-04, the estimates of M&E investment as a share of value added for the 2002-04 period should be regarded as extremely uncertain due to the probable differences between industry level and total economy inflation. They will be updated as official estimates of nominal value added by industry become available for these years.

[18] Level comparisons of capital intensity across industries should ideally be made using current as opposed to chained dollars. If the prices of machinery and equipment capital goods have changed over time differently in different industries, comparisons of capital intensity in chained dollars may give a misleading picture of actual relative capital intensity levels.

[19] It is not possible to exclude utilities and chemical manufacturing from these aggregates.

[20] In 2002 the total value of R&D spending funded by business enterprises was $11,793 million, of which $823 million went outside the business sector (Thompson, 2003). Of this extramural component, $727 million went to higher education, $57 million to the federal government, $24 million to provincial research organizations, and $13 million to private non-profit organizations. It is interesting to note that only 1.9 per cent of the total value of R&D spending funded by foreign business enterprises went outside the business enterprises sector, compared to 9.1 per cent for domestic business enterprises.