Appendix 1: Selective Literature Review of Innovation Indicators

This appendix provides 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.

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 national innovation capacity (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 (see Exhibit 1A). She notes that this perspective warns against looking at statistical indicators individually to assess the performance of national innovation 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.

But the challenge of the NIC approach is to approximate empirically the different NIC frameworks across countries and the knowledge distribution of power. To be sure, an understanding of these different frameworks can shed light on the relative effectiveness of different systems of innovation (e.g. EU versus US), if not quantitatively, at least qualitatively. For example, it has been documented that the key areas of weakness of innovation in the EU lie in "market pull conditions" and knowledge networks. The EU generates a great deal of knowledge in its universities and research institutes and produces large numbers of skilled personnel. But it does not exploit this knowledge and expertise for social and economic needs.

In contrast, Veugelers points out that the United States does a better job in this area for a number of reasons. It has a more competitive environment; better linkages between science and industry; a higher quality research base due to an openly competitive system of private and public universities and government-subsidized peer-reviewed research grants; a large, unified market unencumbered by differences in language, customs, and standards; stronger intellectual property rights; more flexible financial markets making available venture capital to innovating firms; and more flexible labour markets promoting internal migration and the immigration of highly skilled persons.

Exhibit 1A: National Innovation Capacity: An Integrative Framework

- Common Innovation Infrastructure: cross-cutting institutions, resources, and policies
    - Existing stock of technological know-how
    - Supporting basic research and higher education
    - Overall science and technology policy

- Technology/Cluster Specific Conditions
    - Technology specific know-how: specialized R&D personnel
    - Incentives for innovation: lead users, appropriation (IPR) and output market competition: (local) rivalry, openness
    - Presence of related/supporting industries (clusters)

- Quality of Links between Clusters and Common Factors
    - Industry-science relationships
    - Efficient labour and capital markets

Source: Veugelers (2005:8-9).

As part of the 2000 Lisbon strategy to make the EU "the most dynamic and competitive knowledge-based economy in the world capable of sustainable economic growth with more and better jobs and greater social cohesion," a European Innovation Scoreboard (EIS) was developed to focus attention on the drivers and output of innovation (Exhibit 2A). An industry dimension can be developed for many of the indicators.

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 source 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.

Exhibit 2A: European Innovation Scoreboard

1. Human Resources

1.1 S&E graduates (‰ of 20-29 years age class)
1.2 Population with tertiary education (% of 25-64 years age class)
1.3 Participation in life-long learning (% of 25-64 years age class)
1.4 Employment in medium-high and high-tech manufacturing (% of total workforce)
1.5 Employment in high-tech services (% of total workforce)

2. Knowledge Creation

2.1 Public R&D expenditures (GERD - BERD)
2.2 Business expenditures on R&D (BERD) (% of GDP)
2.3.1 EPO high-tech patent applications (per million population)
2.3.2 USPTO high-tech patent applications (per million population)
2.4.1 EPO patent applications (per million population)
2.4.2 USPTO patents granted (per million population)

3. Transmission and Application of Knowledge

3.1 SMEs innovating in-house (% of manufacturing SMEs and % of services SMEs)
3.2 SMEs involved in innovation co-operation (% of manuf. and services SMEs)
3.3 Innovation expenditures (% of all turnover in manufacturing and services)

4. Innovation Finance, Output and Markets

4.1 Share of high-tech venture capital investment
4.2 Share of early stage venture capital in GDP
4.3.1 SMEs sales of 'new to market' products (% of all turnover in manufacturing and services SMEs)
4.3.2 SME sales of 'new to firm but not new to the market' products (% of all turnover in manufacturing and services SMEs)
4.4 Internet access/use
4.5 ICT expenditures (% of GDP)
4.6 Share of manufacturing value-added in high-tech sectors
4.7 Volatility-rates of SMEs (% of manufacturing and services SMEs)

Source: Veuglers (2005:15-16).

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 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 17 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. This section of the literature review addresses this issue of the applicability of the Conference Board innovation indicators to natural resource industries. The indicators have been organized for the purposes of this report 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.

a. Innovation Indicators Relevant and Available at the Industry Level

Five of the 17 indicators fall under this category and are used to assess the innovation capacity and performance of Canadian natural resource industries later in this report.

1) The indicator of business expenditure on R&D (BERD) as a percentage of GDP is very applicable for the natural resource sector as business R&D spending is collected on an industry basis. This indicator allows comparison of R&D intensity across industries in Canada and of the R&D intensity of natural resource industries across countries. Given that R&D statistics adhere to the definitions of R&D given in the Frascati manual (OECD, 1963), the R&D estimates are in principle highly comparable, although national differences in interpretation of certain definitions may introduce some incomparability.

2) The Conference Board uses receipts plus payments from the technology balance of payments as an indicator of the diffusion of knowledge through technology transfer. It correctly argues that care must be taken in interpreting the technology balance of payments, as a negative figure does not necessarily mean a low level of competitiveness since it could reflect increased imports of foreign technology as well as declining receipts. Equally, a positive balance could indicate a high degree of technological autonomy, a low level of technology imports, or a lack of capacity to assimilate foreign technology. This variable is readily available at the industry level from the OECD's STAN database, although for a limited number of natural resource industries.

Exhibit 3A: Conference Board of Canada Innovation Benchmarking Indicators
(with Canada's ranking in parentheses, out of 12 unless otherwise specified)

<u>Knowledge Performance</u>

1) GERD as a % of GDP (7th)
2) BERD as a % of GDP (8th)
3) Publication of scientific papers per one million population (5th)
4) triadic patent families (8th)
5) university-industry collaboration in R&D (2nd of 10)
6) technology balance of payments (5th of 10)

<u>Skills Performance</u>

1) educational attainment in the labour force (1st)
2) human resources in science and technology occupations (7th)
3) adult participation in continuing training (6th out of 6)

<u>Innovation Environment</u>

1) economy-wide regulatory environment (6th)
2) total corporate tax as a per cent of GDP (3rd)
3) attractiveness of R&D tax treatment (3rd)
4) investment in venture capital (2nd)
5) World Competitiveness Ranking (4th)
6) Relocation of R&D Facilities as a treat to the economy's future (7th)
7) Foreign Direct Investment Confidence Index (7th of 9)

<u>Community-based Innovation</u>

1) Broadband subscribers per 100 population (1st).

Source: Conference Board of Canada (2004).

3) The educational attainment of the labour force affects a country's ability to both create and assimilate new technologies. While data on educational attainment by industry are readily available within Canada from the Labour Force Survey and the census, these data are less readily available internationally.

4) The proportion of workers engaged in science and technology occupations is another indicator of the labour force's ability to create and assimilate new technologies. While data on occupations by industry are readily available within Canada from the Labour Force Survey and the census, comparable data are less readily available internationally. Estimates of R&D personnel on an industry basis based on the Frascati R&D definitions are however available for Canada and for some OECD countries.

5) Innovation involves continuous or life-long learning, so the proportion of adults in continuing education and training is an indicator of innovation. The International Adult Literacy Survey provides data on literacy and may be available on an industry basis. While data on continuing education and training by industry are available

within Canada from the Adult Education and Training Survey and the Workplace and Employee Survey, these data are less readily available internationally, particularly on a detailed industry basis.

b. Innovation Indicators Relevant and Potentially Available at the Industry Level

1) The Conference Board of Canada argues that measuring patents helps to understand innovation performance as patents relate to the creation and diffusion of knowledge. A patent is a member of a triadic patent family if it is simultaneously filed at the European Patent Office, the Japanese Patent Office, and the United States Patent Office.[1] In 1999, Canada had 16.5 triadic patent families per one million population, well below the number for Sweden (102), Japan (90), Finland (79), Germany (73), the United States (52), France (35), and the United Kingdom (30). It is unclear whether Canada's general weakness in this area applies to Canadian natural resource industries, as data do not appear to be available at the industry level presently.

2) Collaboration between industry and higher education fosters the transfer of ideas, knowledge and expertise from the university sector to industry and promotes innovation. The Conference Board evaluates this variable by calculating the proportion of higher education R&D funded by industry. An alternative indicator would be the proportion of industry-funded R&D that is undertaken by higher education. Absolute values of both of these types of expenditures could also be used. This indicator could in principle be available at the industry level as data are gathered at this level of disaggregation.

3) The Conference Board of Canada innovation benchmarking report identified the economy-wide regulatory environment as a factor that can foster or impede innovation. This benchmark includes barriers to trade and investment (trade and foreign direct investment restrictions), economic regulation (barriers to competition and state control), and administrative regulations (administrative burden and red tape). Based on the OECD Regulatory Indicators Questionnaire, Canada in 1998 ranked 6th of 11 countries in terms of having a regulatory environment that is favourable to innovation. Canada fared extremely well in terms of having a favourable administrative regulatory environment. It also did well in terms of the economic regulatory environment, but much less well for barriers to trade (last of the 11 countries). Certainly data on the regulatory environment can be gathered on an industry basis both within Canada and across countries, but such data do not appear to be currently available.

4) The Conference Board considers total corporate tax as a per cent of GDP as an innovation indicator, as lower taxes give industries more resources to pursue innovative activities, although it recognizes that higher corporate taxes is not a negative feature per se. What counts is that the tax revenues are used effectively. Canada in 2001 did well on this indicator, with the third lowest ratio of corporate taxes (income and employers' social security contributions, and a portion of property and goods and services tax) to GDP out of 11 countries. Certainly data on corporate taxes can be compiled on an

[1] Stead (2001) points out that most Canadian patents are granted for foreign inventions and more Canadian inventions are patented in the United States than in Canada.

industry basis both within Canada and across countries, but such data do not appear to be currently available.

5) Research and development spending, a key component of innovation, can be influenced by R&D tax incentives. The Conference Board of Canada consequently considers the attractiveness of R&D tax incentives as a innovation benchmark. It finds that in 2001 Canada had the third most generous national tax treatment of R&D among 11 countries. If sub-national (i.e. provincial) tax incentives were included, Canada's ranking would likely be even better. There are no sector-specific tax incentives for R&D in Canada,[2] but this might not be true in other countries. Thus the overall national R&D tax treatment may not apply on an industry basis across countries. Internationally comparable data on the tax treatment of R&D by industry could potentially be compiled, but they do not appear to be currently available.

6) Venture capital is an essential ingredient for the growth of new innovative firms. Consequently, the Conference Board of Canada identified the availability of venture capital, defined as venture capital as a proportion of GDP, as an innovation benchmark. Over the 1998-2001 period, Canada ranked second out of 11 countries on this variable. Data on venture capital by industry are available for Canada, as such data are gathered on an industry basis. It is unclear, however, whether internationally comparable estimates of venture capital by industry are available. If venture capital is receptive to attractive investment opportunities in any industry and hence is indifferent to which industry it is allocated to, the national venture capital picture may apply to all industries, making an industry breakdown unnecessary from the perspective of venture capital availability (but not from the perspective of which industries offer opportunities for venture capital).

7) A.T. Kearney has developed a Foreign Direct Investment (FDI) Confidence Index based on the perception of business leaders regarding the attractiveness of a country for investment over the next one to three years. The Conference Board of Canada includes this variable as an innovation benchmark because it believes this perception is an indicator of the overall innovation environment. Canada ranked seventh out of nine countries on this indicator in 2002. A. T. Kearny collects responses from the world's 1,000 largest companies from 42 countries and 23 industries, but it is unclear if the industry data are publicly available.

c. Innovation Indicators Not Relevant at the Industry Level

1) The most widely used indicator of innovation is undoubtedly gross expenditure on research and development (GERD) as a proportion of GDP, and the Conference Board appropriately includes this measure as one of its innovation benchmarks. The GERD/GDP ratio applies to all sectors of the economy (business enterprise, higher education, government, non-profit) and consequently cannot be applied to one industry within the business sector. But its sister measure, business expenditures of R&D (BERD), can apply at the industry level.

[2] This is not true for government financial assistance (grants and loans) related to the development of new productsm as certain industries such as aerospace and pharmaceuticals receive some special treatment.

2) Data on the per capita publication of scientific papers are available by subject area or academic discipline, but not on an industry basis. Indeed, relatively few scientific publications are based on research undertaken in the business sector. Most of the scientific research that is published in leading international journals takes place in universities, government and non-profit research institutes.

3) The Institute for Management Development (IMD) in Switzerland publishes an annual report entitled *World Competitiveness Yearbook (WCY)* that ranks the countries of the world on the basis of a multitude of variables in four areas: economic performance, government efficiency, business efficiency, and infrastructure. The Conference Board of Canada uses the overall rankings from this report as an innovation benchmark because it believes that the four factors that comprise this benchmark make up the environment in which innovation takes place and hence shape both domestic and international perceptions regarding Canada as a place to live work and invest. Canada ranked fourth out of 11 countries in 2002. Since WCY data are not collected on an industry basis, this indicator cannot be applied at the industry level.

4) One variable in the IMD's World Competitiveness Yearbook is an executive survey question on whether the relocation of R&D facilities is a threat to the economy's future. The Conference Board of Canada includes this variable as an innovation benchmark because it believes concern over relocation is strongly linked to issues of leadership, business confidence, and culture, thereby making this concern an important aspect of the environment. Canada ranked seventh out of 11 countries in 2002. Since WCY data are not collected on an industry basis, this indicator cannot be applied at the industry level.

5) The Conference Board of Canada includes one community-based innovation indicator, namely broadband subscribers per 100 population. It is argued that this technology, which fosters the development and delivery of advanced applications and services, will bring new economic and social opportunities to communities across Canada. Canada ranked first out of 11 countries in 2003 on this variable. Since this variable is community or household-based, there is no industry dimension or disaggregation.

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.[3] 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, drawn from a 1986

[3] 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.

OECD report which classified industries on the basis of R&D-to-sales ratio,[4] 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, 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.

Exhibit 4A: OECD Technology Intensity Levels, 1986

High	Medium	Low
Aerospace	Automobiles	Stone, clay, glass
Office machines, computers	Chemicals	Food, beverage, tobacco
Electronics and components	Other manufacturing	Shipbuilding
Drugs	Non-electrical machinery	Petroleum refineries
Instruments	Rubber, plastics	Ferrous metals
Electrical machinery	Non-ferrous metals	Fabricated metal products
		Paper, printing
		Wood, cork, furniture
		Textiles, footwear, leather

Source: *Science and Technology Indicators*, OECD, 1986 taken from Godin (2004: no.25:18).

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 first section of the report is partly devoted to the results from the 1999 MAC survey on innovation, conducted by the Impact Group. The survey asked, among other questions, the reasons why mining companies had increased R&D spending in the past, and how the expenditures were allocated.

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

[4] See Godin (2004a:15-16) for details on the definition.

reports 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.

Exhibit 5A: OECD List of Technology Industries, 1997

High

Aircraft and spacecraft
Pharmaceuticals
Office, accounting and computing machinery
Radio, TV and communications equipment
Medical, precision and optical instruments

Medium-High

Electrical machinery and apparatus
Motor vehicles, trailers and semi-trailers
Chemicals excluding pharmaceuticals
Railroad equipment and transport equipment
Machinery and equipment

Medium-Low

Coke, refined petroleum products and nuclear fuel
Rubber and plastic products
Other non-metallic mineral products
Building and repairing of ships and boats
Basic metals
Fabricated metal products, except machinery and equipment

Low

Manufacturing: Recycling
Wood and products of wood and cork
Pulp, paper, paper products, printing, and publishing
Food products, beverages, and tobacco
Textiles, textile products, leather and footwear

Source: OECD taken from Godin (2004:no 25:21).

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.

Patent ownership can be an indicator of output from R&D spending. The MAC survey indicated that more than one third of R&D performers had applied for patents in 1999 and that mining firms hold on average 30 patents, although some large firms possess most of the patents. Two thirds of mining firms were involved in licensing other firms' technology, which allowed them to make use of the best available technology without holding a patent.

A highly skilled workforce is also conducive to more innovative activities. The report points out that mining and mining related industries have higher proportions of workers with a post secondary degree than manufacturing as a whole, and that the mining industry comes only behind finance and government in terms of proportion of workers in knowledge and management occupations.

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 on innovation in the forest and mining sectors present results for five indicators of innovative activities. The first one is the percentage of process innovators and percentage of product innovators among innovative firms (Exhibit 6A). Among the five forest sector industries reviewed, all have percentages of process innovators that equal or exceed 84 per cent, which is better than the 82 per cent innovation rate for manufacturing in general. But the surveyed forest sector industries have a lower percentage of product innovative firms, and this is especially true in logging. The percentage of product innovators is higher in wood products and paper manufacturing.

As is the case with forest sector firms, innovative firms in mineral sector industries are much more likely to be process innovators than product innovators. Innovative fabricated metal firms are process innovators 86 per cent of the time while all metal ore mining innovative firms are process innovators (compared to 82 per cent in manufacturing). While 85 per cent of innovative manufacturing firms are product innovators, the range for innovative mining firms goes from 46 per cent for metal ore mining to 78 per cent in fabricated metals. Schaan notes that the gap between product innovators and process innovators narrows as the ore extracted by mining firms is processed by manufactured metal firms.

Exhibit 6A: Percentage of Product and Process Innovators for Selected Forest Sector and Mineral Sector Industries and Manufacturing as a Whole, 1999 *Survey of Innovation*

	per cent of innovating firms	
	product innovators	process innovators
Logging	54	85
Sawmills and Wood Preservation	70	89
Veneer, Plywood and Engineered Wood Product Manufacturing	72	86
Other Wood Product Manufacturing	79	84
Paper Manufacturing	77	84
Metal Ore Mining	46	100
Primary Metal Manufacturing	77	89
Fabricated Metal Product Manufacturing	78	86
Total Manufacturing Industries	85	82

Source: Schaan (2002) and Schaan (2003).

The second indicator of innovative activity is 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. Improving product quality is by far the most frequently cited reason for a firm to be innovative, irrespective of the industry. Results for forest sector industries (Exhibit 7A) are comparable to those for manufacturing as a whole (with the percentages ranging from 79 per cent in “other wood products” to 91 per cent in logging, and manufacturing at 83 per cent). Improving production flexibility is a frequent motivation as well, in the forest sector and manufacturing. It also appears that more firms innovate in the forest sector to reduce environmental damage compared to manufacturing industries in general.

The most important motivation for innovation is the same in mining sector industries as it is in forest sector industries, namely to improve product quality, but with the exception of metal ore mining. In that industry, only 31 per cent of firms cite this as a motivation, compared to 80 and 83 per cent in primary metals and fabricated metal industries respectively. Extending product range is also not frequently cited by metal ore mining firms while it is frequently mentioned by firms in the other two mining sector industries. The motivation for metal ore mining firms seems to be increasing production capacity. (This is also an important motivation in the other two mining sector industries surveyed).

The third indicator is the role of innovation in the overall business strategy of innovative firms. Results from the 1999 survey (Exhibit 8A) indicate that “developing new products and processes” is not the most important strategic tool in achieving firm success for innovative firms, “satisfying existing clients” being the most important one.

Another observation from the survey results shows that developing new products and processes is more important in manufacturing than it is for forest sector firms (with the percentage of innovative firms in manufacturing that state that developing new products and processes is important at 72 per cent compared to a range of 38 per cent in logging to 64 per cent in sawmills).

Exhibit 7A: Selected Objectives of Innovation for Innovative Forest Sector and Mineral Sector Firms and Manufacturing as a Whole

	per cent of innovative firms choosing listed objective				
	Improve product quality	Reduce environ-mental damage	Improve production flexibility	Extend product range	Increase production capacity
Logging	91	57	47	na	na
Sawmills and Wood Preservation	82	35	67	na	na
Veneer, Plywood and Engineered Wood Man.	79	37	61	na	na
Other Wood Product Manufacturing	79	18	66	na	na
Paper Manufacturing	87	30	68	na	na
Metal Ore Mining	31	na	52	28	68
Primary Metal Manufacturing	80	na	63	52	80
Fabricated Metal Product Manufacturing	83	na	67	64	82
Total Manufacturing Industries	83	25	67	72	75

Source: Schaan (2002) and Schaan (2003).

Exhibit 8A: Selected Firm Success Factors for Firms in Selected Forest Sector and Mineral Sector Industries and in Manufacturing as a Whole

	per cent of firms indicating factor is important			
	All Firms		Innovative Firms	
	Satisfying existing clients	Developing new products (goods or services) and processes	Satisfying existing clients	Developing new products (goods or services) and processes
Logging	na	na	93	38
Sawmills and Wood Preservation	na	na	95	64
Veneer, Plywood and Engineered Wood Product Manufacturing	na	na	96	59
Other Wood Product Manufacturing	na	na	96	51
Paper Manufacturing	na	na	98	61
Metal Ore Mining	49	30	62	53
Primary Metal Manufacturing	99	53	98	60
Fabricated Metal Product Manufacturing	96	54	98	61
Total Manufacturing Industries	96	64	97	72

Source: Schaan (2002) and Schaan (2003).

The results for mining sector industries are again very similar to those from the forest products sector industries. The most important success factor is client satisfaction and not development of new products and processes. Developing new products and processes is also relatively less frequently cited as an important success factor than it is in manufacturing (with a range of 53 per cent in the metal ore mining industry to 61 per cent in fabricated metals, compared to 72 per cent in manufacturing). It appears that developing new products and processes is less important for a firm to remain in business in the natural resource sector than it is in manufacturing.

The fourth indicator of innovation is involvement in R&D activities (available only in the forest sector paper). Three important results come out of the 1999 survey (Exhibit 9A). First, the percentage of innovative firms in the forest products sector that undertake R&D is on average lower than in manufacturing. Only 26 per cent of innovative logging firms undertake R&D, while 69 per cent of innovative paper industries do so, compared to 68 per cent of innovative manufacturing firms. The second result is that innovative forest sector firms that undertake R&D are more likely to contract it out to other firms than manufacturing firms are. And third, of those firms that undertake R&D, there are fewer firms in the forest sector that possess a distinct R&D department compared to manufacturing, with the exception of paper manufacturing.

Exhibit 9A: R&D Activities of Innovative Firms in Selected Forest Sector Industries and in Manufacturing as a Whole

	Percentage of innovative firms undertaking given activity		
		For those firms that undertake R&D, % for whom R&D is:	
	Undertake R&D	Carried out by a separate R&D department	Contracted out to other firms
Logging	26	38	60
Sawmills and Wood Preservation	53	31	45
Veneer, Plywood and Engineered Wood Man.	64	41	46
Other Wood Product Manufacturing	55	25	27
Paper Manufacturing	69	53	37
Total Manufacturing Industries	68	45	29

Source: Schaan (2002) and Schaan (2003).

The last innovation indicator is the percentage of highly innovative manufacturing firms that sell products to selected natural resource firms. This indicator shows that products from firms that innovate in manufacturing and that embody innovation are being used in forestry and logging, and mining. The percentage of firms in each highly innovative sector that sell products is comparable between logging and forestry and mining. If the goods purchased “contain” the same innovative effort in both sectors, than it appears that both sectors introduce new technologies and processes developed in other sectors of the economy at approximately the same rate. Furthermore, roughly the same percentage of innovative firms across the natural resource sector acquired M&E linked to innovation (Exhibit 10A). But since the percentage of innovative firms varies across industries, the percentage of all industries that acquired M&E linked to innovation varies across natural resource industries. It ranges from 47 per cent in logging to 79 per cent in primary metal industries.

Exhibit 10A: Industries that Indicated the Highest Percentage of Innovative Firms that Engaged in the Acquisition of Machinery, Equipment or other Technologies Linked to Innovation

	% of firms that acquired machinery, equipment or other technology linked to innovation	
	all	innovators
Logging	47	90
Sawmills and Wood Preservation	75	90
Veneer, Plywood and Engineered Wood Man.	70	94
Metal Ore Mining	60	95
Primary Metal Manufacturing	79	91

Source: Schaan (2002) and Schaan (2003).

The paper on the mining sector also contains results from the 2000 *Survey of Electronic Commerce and Technology*. One of the indicators presented is the percentage of firms that introduced new and improved technologies. The performance of the mining sector industries is on average roughly equal to that in manufacturing as a whole, but there are some differences among industries. Fifty per cent of mining industries (not just metal ore) introduced new and improved technologies, while 59 per cent of firms in primary metal industries and 39 per cent in fabricated metal industries did so, compared to 51 per cent in manufacturing. And of those firms who did introduce new and improved products, only 10 per cent in mining did so by developing the technology themselves, compared to 20 per cent in fabricated metals industries, 38 per cent in primary metals industries, and 23 per cent in manufacturing as a whole. A majority of the firms that introduced new and improved technologies did so by purchasing off-the-shelf technologies (Exhibit 11A).

Exhibit 11A: Technology Improvements of Mining, Manufacturing, and Primary Manufacturing Industries in the Mineral Sector

		% of enterprises with improved technologies, introducing new technology by:			
	% of enterprises introducing significantly improved technologies	Purchasing off-the-shelf technologies	Licensing new technologies	Customizing or significantly modifying existing technologies	Developing new technologies
Metal Ore Mining	50	68	12	46	10
Primary Metal Manufacturing	59	52	10	59	38
Fabricated Metal Product Manufacturing	39	73	20	44	20
Total Manufacturing Industries	51	71	15	51	23

Source: Schaan (2002) and Schaan (2003).

The last innovation indicators presented in the mining sector paper are the skills and training activities of mining sector firms. The 2000 survey shows that roughly 80 per cent (90 per cent in primary metal industries) of innovative firms were engaged in training linked to innovation introduction and that about the same percentage believe that training is important for firm success (Exhibit 12A). Another interesting result from the survey is that there are less innovative firms that think of hiring university graduates as an important factor to firm success than there are firms that think of hiring experienced workers as an important success factor. And finally, there does not seem to be a relative shortage of skilled workers in the mining sector since less innovative firms believe that it is difficult to hire or retain qualified workers compared to manufacturing.

Exhibit 12A: Per cent of Innovative Metal Ore Mining, Manufacturing, and Primary Manufacturing Firms with the Following Training and Skill Related Activities and Opinions

	Training employees is important to firm success	Engaged in training linked to innovation introduction	Hiring new graduates from universities is important to firm success	Hiring experienced employees is important to firm success	Lack of skilled personnel is an obstacle to innovation
Metal Ore Mining	84	80	43	57	24
Primary Metal Manufacturing	88	91	32	63	41
Fabricated Metal Product Manufacturing	79	80	18	71	45
Total Manufacturing Industries	82	81	23	70	37

Source: Schaan (2002) and Schaan (2003).

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.[5] 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 paper is not concerned specifically with innovation in natural resource industries, but information on the innovation performance of manufacturing natural resource industries is available and is compared internationally (although the European surveys did not include primary natural resource industries). To improve comparability across sectors, the authors aggregated certain industries, which limits the potential to evaluate innovation by detailed industry but allows for better international comparisons.

[5] 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 incidence of innovation is fairly stable over short time periods.

Four of the ten industries for which innovation indicators are presented in the paper are relevant to this report: wood, coke, rubber, and basic metals. The first industry is an aggregate of wood product manufacturing and paper manufacturing. The second industry is an aggregate of petroleum and coal products manufacturing and chemical products manufacturing. The third industry is an aggregate of plastics and rubber products manufacturing and non-metallic mineral products manufacturing. The last industry is an aggregate of primary metal manufacturing and fabricated metal manufacturing.

Exhibit 13A: Canada-Europe Innovation Comparisons for Natural Resource-related Industries

	Canada		France		Germany		Ireland		Spain	
Percentage of Innovators (as a proportion of all firms)										
	%	# obs.	%	# obs.	%	# obs.	%	# obs.	%	# obs.
Wood	75	950	40	1,267	47	2,300	68	92	23	1,260
Coke	86	473	68	1,166	75	1,312	79	161	62	927
Rubber	80	853	49	2,273	67	4,685	79	192	31	2,450
Basic Metals	76	1,376	31	4,638	59	6,487	68	213	25	2,685
Percentage of First Innovators (as a proportion of all firms)										
	Canada		France		Germany		Ireland		Spain	
	%	# obs.	%	# obs.	%	# obs.	%	# obs.	%	# obs.
Wood	17	880	16	1,267	14	2,300	16	92	7	1,260
Coke	33	434	33	1,166	28	1,312	23	161	29	927
Rubber	31	781	26	2,273	23	4,685	25	192	9	2,450
Basic Metals	20	1,286	14	4,638	15	6,487	28	213	8	2,685
Shares in Sales of New or Improved Products (for innovators only)										
	Canada		France		Germany		Ireland		Spain	
	%	# obs.	%	# obs.	%	# obs.	%	# obs.	%	# obs.
Wood	24	535	24	505	30	1,076	20	63	47	284
Coke	20	361	23	793	39	977	28	127	34	570
Rubber	29	608	27	1,106	49	3,156	28	151	46	767
Basic Metals	23	813	20	1,428	33	3,854	34	146	38	680
Shares in Sales of New or Improved Products for First Innovators (for first innovators only)										
	Canada		France		Germany		Ireland		Spain	
	%	# obs.	%	# obs.	%	# obs.	%	# obs.	%	# obs.
Wood	28	133	25	207	32	331	22	15	56	90
Coke	22	128	26	386	34	364	39	38	34	270
Rubber	29	224	32	596	53	1,084	32	47	50	217
Basic Metals	18	236	24	645	46	963	33	59	59	216

Source: Mohnen and Therrien (2001).

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). Canada comes first in all sectors. The highest incidence on innovation was in coke (86 per cent of firms) while the lowest percentage is in wood (75 per cent). Canada's lead is not as important when first innovators are considered. First innovators are firms that sell a new or improved product which is: a "Canada first" or "world first" for Canadian firms; or a "market first" for European firms. The number of first innovators in Canada is generally comparable to numbers in other countries, but since there are fewer Canadian firms overall, the percentage of first innovators tends to be slightly larger in Canada.

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. In fact, it was below what firms in other countries achieved. In the wood, rubber and basic metal industries, Canada was second to last and was last in the coke industry. This suggests a lower ability of Canadian firms in converting new and improved products into revenue, especially compared to firms in Spain and Germany. The performance of Canadian first innovators is not better in terms of share of sales. But that is to be expected since new and improved products sold by first innovators are not necessarily “first” new and improved products (that is, new to the world or Canada) and therefore do not necessarily provide any advantage to the producer over its competitors. Depending on the innovation indicator, Canada’s relative performance might be the best or the worst among those five countries for which data are presented in the Mohnen and Therrien (2001) paper.