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Innovation in Canadian Natural Resource Industries: A Systems-Based Analysis of Performance, Policy and Emerging Challenges

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Abstract

Innovation is an important driver of productivity growth, which in turn is a major source of improvement in living standards. Given the growing importance of the natural resources sector in the Canadian economy, innovation in this sector is particularly relevant. This report, using a systems-of-innovation approach, analyzes the innovation performance of the Canadian natural resources sector by comparing it to that of the Canadian business sector as a whole. Among the many indicators discussed, the report looks at R&D expenditures, workers' education and skills, machinery and equipment investment, and the use of information and communication technologies. The key conclusion of the report is that the overall innovation performance of the Canadian natural resources sector is strong and has improved in recent years. However, there is still room for improvement, especially in terms of R&D intensity and labour force skills.

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Executive Summary

Innovation is an important driver of productivity growth, which in turn is a major source of improvements in living standards. Given the growing importance of the natural resources sector in the Canadian economy, innovation in this sector is particularly relevant. The objective of this report is to broaden and deepen our understanding of innovation in Canadian natural resource industries, and to identify strengths and weaknesses of the sector in terms of innovative capacity.

The report adopts a systems of innovation approach guided by the concept of National Innovative Capacity (NIC) as developed by Porter and Stern (2001). A systems approach to innovation looks at a variety of indicators that represent the innovative efforts of firms. These indicators include: research and development (R&D) expenditures, workers education and skills, machinery and equipment (M&E) investment, and the use of information and communication technologies (ICTs), among others. By comparing these indicators for the Canadian natural resources sector with those for the business sector, we are in essence comparing the innovative capacity of the natural resource sector to that of the economy as a whole.

The executive summary is divided into four parts. Parts one, two, and three look at the innovation performance of the three major subgroups in the natural resources sector – namely, energy, metals and minerals, and forest products. Part four provides an overview of the innovation performance of the Canadian natural resources sector as a whole.

Innovation in the Metals and Minerals Subsector

The metals and minerals subsector was the strongest innovator among the three natural resources groupings. In most of the innovation inputs indicators, this subsector had above-average performance when compared to the Canadian business sector as a whole. The only exceptions are those related to R&D intensity and average years of schooling, which were also areas that the natural resources sector struggled as a whole. On the other hand, the metals and minerals subsector was the only natural resources subsector with an above-average performance in terms of M&E capital intensity growth.

The subsector's excellent performance in terms of innovation inputs translated into stronger innovation outcomes. Growth in labour productivity between 1961 and 2007 for the metals and minerals subsector was higher than that of the Canadian business sector as a whole, reinforcing the high labour productivity levels typically seen in that subsector.

Innovation in the Energy Subsector

The energy subsector was also an innovation leader in Canada, particularly in terms of R&D personnel and educational attainment levels. The educational quality of the labour force can impact innovation performance through a variety of channels. First, educational quality of the labour force affects not only productivity, but also potential quality of R&D. Second, a highly qualified labour force can incorporate new technologies to the existing production processes more effectively. Third, regardless of whether innovation takes place in the field or the laboratory, the subsector is dependent upon highly-educated individuals to keep management abreast of technologies which may become firm or industry-first innovations in the future.

Other areas in which the energy subsector performed above the Canadian average include real M&E capital intensity and internet use, though this was also the case in all of the other natural resources subsectors. A potential area of concern is that, while the indicators in the subsector had above average levels, growth rates were generally below the Canadian average. In particular, labour productivity growth in the oil and gas industry has been extremely poor, mainly due to high oil prices, which make the exploitation of more marginal resources such as the oil sands profitable. While profitable, more hours are required to produce a given barrel of oil, resulting in falling labour productivity in the industry as a whole.

Innovation in the Forest Products Subsector

The one exception to the overall above-average innovation performance of the natural resources sector is the forest products subsector, which has experienced negative developments related to a downward shift in demand for its output. In particular, the subsector had a poor performance in terms of educational attainment and M&E investment.

Innovation in the Natural Resources Sector

The key conclusion of the report is that the overall innovation performance of the Canadian natural resources sector is strong and has improved in recent years. The strongest piece of evidence to collaborate this finding is the expert assessment of the science and technology of Canadian industries conducted by the Council of Canadian Academies in 2006 (CCA, 2006). It found that out of 197 sub-areas of science and technology the top ten industries were all natural resource industries, with the Alberta oil sands ranking number one.

An assessment of the innovative capacity of natural resource industries using the broader systems approach suggests that the sector's innovation performance is grounded on a diverse set of public support programs, a novel stock of technologies and the consistent collaborative efforts of firms.

The implication of this overall positive assessment of the innovative performance of the natural resources sector (or at least the mining and energy parts of the sector) is that Canada's system of innovation for natural resource industries is working quite well. The innovation performance of Canadian natural resource industries is strong as measured by most indicators. For example, natural resource industries outperform the Canadian business sector in terms of productivity levels, M&E intensity, adoption of new technologies, collaboration efforts between firms, and R&D personnel. In fact, R&D personnel intensity (R&D personnel per thousand workers) in the natural resource sector was almost double that of the total economy in 2008 (16.2. vs. 9.3, respectively).

Despite the overall above-average innovation performance of the Canadian natural resources sector, there is still room for improvement. In particular, the natural resources sector performed poorly in terms of: 1) R&D intensity; 2) labour force skills; and 3) in the case of the oil and gas industry, labour productivity growth. While part of the poor performance in these indicators can be attributed to structural factors specific to natural resources industries, they also reflect areas that could be improved.

In the case of R&D intensity, for example, part of the below-average performance can be attributed to two structural characteristics of the natural resources sector as a whole: 1) process innovation tends to be more important in natural resources industries than product innovation; 2) innovation in natural resources industries frequently takes the form of new M&E, which are produced by other industries. However, the fact that R&D intensity in some of the industries in the natural resources sector has fallen over the past twenty years is a source of concern.

Innovation in Canadian Natural Resource Industries: A System-Based Analysis of Performance, Policy and Emerging Challenges[1]

I. Introduction

The most important source of long-term improvements in living standards is productivity growth. One of the main drivers of productivity growth is innovation, in products, production processes, organizational structures, and management techniques. Similarly, negative externalities that have an adverse impact on living standards, such as environmental degradation, can be reduced through innovation. Additionally, it is important to keep in mind that the social benefits of innovation outweigh the private benefits. The bottom line is that innovation is crucial to the economic performance and social progress of Canada.

Innovation in the natural resources sector is of particular relevance given the growing importance[2] of natural resources to the Canadian economy. In recent years, the natural resources sector has faced an array of issues which threaten its international competitiveness such as shortages of skilled labour and a strong Canadian dollar. The innovation performance of Canadian natural resource industries will be a crucial determinant of their future viability. Adopting new technologies and practices and acquiring the latest vintage of capital goods will ensure that Canadian resource firms remain strong in the face of emerging international competition while improving energy efficiency and environmental performance. This sector has traditionally had an adverse effect on the environment and in recent years has made strides to reduce its carbon footprint, implement modern resource-management practices, and expand the scope of its operations to address ecological concerns.

The objective of this report is to broaden and deepen our understanding of innovation in Canadian natural resource industries and identify strengths and weaknesses of the sector in terms of innovative capacity.[3] Thus, the focus of this report is on innovation indicators from the perspective of a systems-based approach. Although measures of the overall economic performance of the Canadian natural resources sector (such as profitability and employment) are also important to understand the sector as a whole, the reader should keep in mind that these measures are outside of the scope of the report.

The natural resources sector (or natural resources industries) can be divided into three subsectors: energy, forest products, and metals and minerals. Exhibit 1 provides the detailed

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[1] This research report was prepared by Andrew Sharpe and Blair Long. It represents the views of the Centre for the Study of Living Standards (CSLS). The CSLS would like to thank Natural Resources Canada for the financial support. For comments, Andrew Sharpe can be reached at andrew.sharpe@csls.ca.

[2] Nominal value added GDP growth for natural resource industries in Canada has outpaced that of the business sector between 2000 and 2008, averaging annual growth of 5.7 per cent versus 4.4 per cent, respectively (CANSIM table 379-0024).

[3] This report builds on and extends previous CSLS studies on the performance of the Canadian natural resource sector. See Sharpe and Guilbaud (2005), Bradley and Sharpe (2009a, 2009b), and Harrison and Sharpe (2009).

breakdown of each of those subsectors by NAICS (North American Industry Classification System) code. For the most part, the report follows this breakdown. It should be noted, however, that for some of the indicators, data on specific industries might not be available.

Exhibit 1: The Natural Resources Sector (NAICS codes)

Natural Resources Sector	Energy	Oil and gas extraction (211) Support activities related to oil and gas and mining (213) Electric power transmission and distribution (2211) Natural gas distribution (2212) Petroleum and coal products (324) Pipeline transportation (486)
	Forest Products	Logging and forestry (113) Wood products (321) Paper products (322)
	Metals and Minerals	Mining (212) Non-metallic mineral products (327) Primary metals (331) Fabricated metals (322)

Source: Natural Resources Canada.

In principle, the indicators chosen quantify the main components of a system of innovation, guided by the concept of National Innovative Capacity (NIC) as developed in Porter and Stern (2001). These indicators span innovative efforts by firms such as research and development (R&D) expenditures, worker education and skills, machinery and equipment (M&E) investment and the use of information and communications technology (ICT) but also efforts by government, in terms of the scale and scope of innovation support programs as well as taxation policies and research infrastructure in university research centres. By comparing these indicators for natural resource industries to the Canadian business and manufacturing sectors, we are in essence comparing the innovative capacity of the Canadian natural resource sector to that of the economy as a whole.

A complete assessment of all aspects of the national system of innovation as it is realized in natural resource industries is beyond the scope of this report. This represents a first attempt at a global assessment of innovation in natural resource industries using a system-oriented approach. It should be noted that the innovative performance of the 14 natural resource industries covered by this report can vary significantly.

Section II of this report outlines conceptual means of assessing innovation. Innovation is defined and distinctions are drawn between individual innovation initiatives and the broader environment in a country in which innovation takes place. Section III identifies unique characteristics of natural resource industries that affect their incentives to innovate, both positively and negatively. Section IV describes the innovation environment facing Canadian natural resource industries, focusing on public support programs and collaborative efforts between government, industry and academia. Additionally, a system process map describing how innovation occurs in natural resource industries is presented. Section V presents innovation indicators and evaluates the performance of Canadian natural resource industries in terms of innovation. International benchmarking is also conducted by comparing Canada's innovation performance to selected OECD peers and other relevant countries. Section VI identifies emerging challenges that may restrict or stimulate the natural resource sector's capacity to innovate. Section VII provides an overall assessment of the innovative performance of Canadian natural resource industries. Section VIII concludes.

II. Perspectives on Innovation

This section provides a conceptual overview of innovation. It details definitions of innovation and outlines perspectives on how innovation occurs. This section also discusses some of the main indicators of innovation performance, including not only aggregate measures, but also firm or industry-specific indicators.

A. Defining Innovation

From a historical perspective, Schumpeter (1934) defines innovation as any of the following: the introduction of a new product or qualitative change in an existing product; new production processes that lead firms to restructure their operations; the opening of a new market; the development of new sources for raw materials or other outputs; and changes in industrial organization. It is interesting to note that each of these types of innovation has been observed in natural resource industries in Canada. Although more practical and narrow definitions of innovation have arisen over the past century, this insightful definition is useful to identify innovative activity as being a broader phenomenon than laboratory based R&D or product development.

The standard definition of innovation used by the OECD is from the Oslo Manual (OECD, 2005) which characterizes innovation as "the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations". Similarly, Canada's Federal Science, Technology and Innovation Council (2011) defines innovation as: "the process by which individuals, companies and organizations develop, master and use new products, designs, processes and other business methods. These can be new to them, if not to their sector, their nation or to the world. The components of innovation include research and development, invention, capital investment and training and development." It is also noteworthy that innovation can be said to occur outside the firm, as many firms engage in co-innovation endeavors with their counterparts or rivals, and also draw upon government and academic support. The natural resources sector in Canada has traditionally conducted less intramural R&D than the overall business sector. As a result, many technologies the sector acquires as a means of increasing productivity or decreasing ecological footprints are not developed in-house.

B. The "Systems" Approach to Innovation and Clusters

A popular conceptual measure of innovation is National Innovative Capacity (NIC), defined by Porter and Stern (2001) as "a country's potential – as both a political and economic entity – to produce a stream of commercially relevant ideas". NIC depends on the technological sophistication of an economy, as well as the size of the scientific and technological labour force. Additionally, NIC reflects the array of investments and policy choices of the public and private sector that determines the incentives for and productivity of a nation's R&D. The main elements of NIC are common innovation infrastructure, firm-specific conditions and the quality of the linkages between them. Innovation infrastructure includes human, financial and technological capital as well as the policy environment surrounding them. Additionally, it includes basic research, which has no immediate application at any given time. Relevant policies include the degree of antitrust regulation, the protection of intellectual property and the extent of tax-based incentives. These factors combined, constitute an overarching system of innovation for a country. That is, a country's capacity to innovate, as measured by NIC is the direct outcome of the interdependence between industry, government and academia. This report adopts the systems approach to innovation and assesses not only the role of firms in the innovation process but also the role of government, universities and research institutes.

Traditionally, the agents involved in innovative activity are "clusters", as opposed to individual firms. Clusters are geographic concentrations of interconnected companies and institutions in a particular field. The rationale for thinking of innovation as emerging from clusters is that the product or geographic market structure can affect innovative capacity, as individual firms vie for market share. Cluster-specific conditions that influence innovative capacity include: conditions surrounding firm strategy and rivalry; sufficient anticipatory demand in local markets; the quality of related and supporting industries; and functioning input markets for human resources, capital and basic research. An innovative cluster for example could be a group of firms competing for local market share by responding to demand from sophisticated local customers, using high quality human and technical resources supplied by a reliable, competitive upstream industry. The quality of linkages between innovation infrastructure and clusters is reciprocal. Strong innovation clusters fuel resources in the overall innovation environment and vice-versa. Additionally, demand conditions, in both output and input markets, shape innovation policy and create incentives for clusters to perform R&D, adopt state of the art technologies or implement innovative management practices. Many conventional indicators of innovation measure firm-specific attributes such as R&D expenditures or the skill sets of workers. Combined, innovation infrastructure, policy, firm behaviour and linkages between these factors constitute an overarching system of innovation.

Though this framework is conventionally applied to the manufacturing sector, it is relevant to natural resource industries for several reasons. First, many natural resource industries are manufacturing industries. These include manufacturers of wood products, paper, petrochemical products and metal products. Second, natural resource industries are typically constrained geographically to cluster near the resource they are extracting. For example, a number of firms will tend to operate near a mine. A further example of a cluster in natural resource industries, unique to Canada, is the collection of firms operating in the Alberta oil sands.

The systemic nature of NIC is also stressed by Veugelers (2005), noting that individual innovation indicators should be interpreted with caution, as the effectiveness of the overall system is not well-defined by a handful of indicators. Additionally, she warns about the limitations of inter-industry comparisons of innovation performance as structural differences can account for differences in innovation performance. Some factors that influence such discrepancies are outlined below.

- Technological opportunities differ across industries, 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 innovation, with suppliers being crucial in agriculture, users in software, and in-house R&D laboratories in chemicals.

These types of structural characteristics are particularly relevant in evaluating the innovation performance of Canada's natural resource sector, as will be discussed later in this report.

The Science, Technology and Innovation Council (2011) also advocates measuring innovation using a complete innovation system/environment, laying emphasis on human capital, basic research, public and private sector institutions creating value from existing research, systems for knowledge transfer and application and commercialization of private sector R&D. Canada as a whole is seen as lagging behind in mobilizing knowledge from universities and government to the marketplace. The need for an all-encompassing framework of analysis has also been highlighted by the OECD (2010), which stresses that innovation should be understood in terms of inputs, outputs and social impacts.

C. Composite Measures of National Innovative Capacity

There is also a distinction to be made between measuring NIC using a composite indicator or simply as a set of its components. Though this report focuses on a set of indicators which in principle indicate the quality of Canada's NIC, some studies have focused on measuring innovation using indexes which aggregate and weight component parts. In principle, the indicators used in this study could be compiled into an aggregate indicator.

An example of a composite indicator is that used by The Economist magazine which takes a comprehensive approach in ranking countries by innovativeness. The study builds both an index for innovation inputs as well as an index for the overall innovation environment in a country. Components of the inputs index include R&D expenditure, quality of research, ICT infrastructure, education and technical skills of the workforce, and broadband penetration, all of which enter the index equally weighted. The innovation environment index includes political and macroeconomic stability, institutional variables, measures of the quality of regulatory environment, protection of intellectual property, access to capital, flexibility of the labour market, openness to FDI, and taxation data. The weights used for the indicators in the environment index are not equal by definition. For example, political stability and protection of intellectual property are weighted more heavily than others popular attitudes towards scientific advancements.

Since 2000, the European Innovation Scoreboard (EIS) has been used for cross-country innovation comparisons within the EU. Conceptually, the EIS offers a composite indicator, the Summary Innovation Index, which also focuses on innovation as a system. The original EIS methodology included 25 indicators ranging across human capital, access to physical capital, firm R&D expenditures, industry entries/exits, patents and other measures of investment, linkages and entrepreneurship. After 2008, several changes were made to the EIS in response to numerous criticisms. In particular, the use of a composite indicator has been criticized for abstracting from the complexity of the process that generates it. Additional criticisms include not accounting for structural differences between countries and not capturing every dimension of the innovation process. The 2008 updated version of the EIS was expanded to include indicators such as private credit as a percentage of GDP, firm renewal as a percentage of SMEs, public-private co-publications per million people, the technological balance of payments, technological innovators as a per cent of SMEs, resource efficiency innovators and knowledge-intensive services exports.

D. "Demand-Pull" vs. "Supply-Push" Innovation

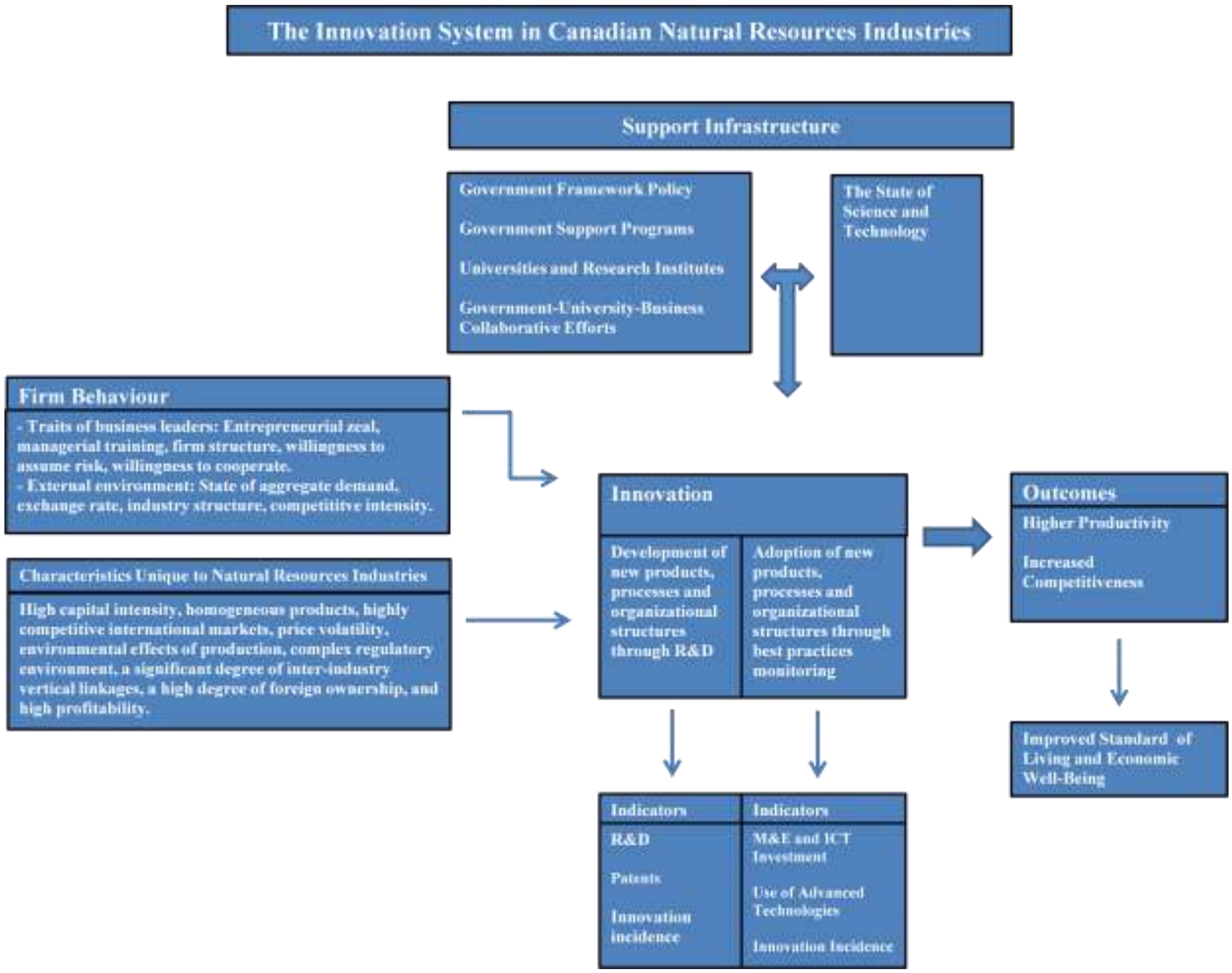
An additional consideration needed to develop an appropriate measure of innovation is the model of innovation on which indicators are premised. There are two different, but not mutually exclusive, perspectives on what drives innovation. The supply-push approach sees innovation arising from the development of inputs such as basic research and knowledge and R&D, relatively independent of the demand for innovation. The demand-pull approach sees innovation arising from the demand for new goods and services by consumers and consequently a demand by firms for new technologies and products to produce these goods and services.

Salazar and Holbrook (2003) draw attention to the fact that many innovation surveys focus on R&D inputs to innovation, a supply-side perspective. Innovation systems can be seen as also having a demand-side component, where factors such as linkages between firms and other technology-related agents, knowledge diffusion, and human capital are needed to fully characterize the environment in which innovation occurs. This is not limited to end-use demand, as industries such as mining, logging and forestry and oil and gas extraction are typically users of product innovation from other manufacturing sectors. The Public Policy Forum (2011) finds that while the supply of innovative ideas has grown, Canada has been slow generally to bolster sufficient demand to stimulate innovation at a significant scale. Boothe and Roy (2008) highlight that the determinants of Canada's poor innovation performance are not well understood, and that low demand for innovation in the business sector is a significant factor.

E. An Analytical Framework for Assessing the Canadian Innovation System for Natural Resources Industries

The Centre for the Study of Living Standards has developed an analytical framework for assessing Canada's innovation system for natural resource industries (Exhibit 2). Innovation or innovative industries are defined as those that develop new products, processes, organization structures, and business practices including marketing through R&D and/or those that adopt new products, processes, organization structures, and business practices including marketing by monitoring best practices in other sectors or countries. The outcomes arising from innovative industries are higher productivity levels and a higher degree of international competitiveness, which in turn ensure that the industry prospers and the living standards and economic well-being of the population improves.

Exhibit 2: The Innovation System in Canadian Natural Resources Industries



Source: CSLS.

Innovation in natural resources industries in Canada is influenced by the characteristics of the natural resource industries and by firm behaviour. The natural resources industries have a number of unique characteristics, including high capital intensity, homogeneous products, highly competitive international markets, output price volatility, environmental effects of production, a complex regulatory environment, a high degree of foreign ownership and control, a significant degree of inter-industry vertical linkages, and above-average profitability.

Firm behavior related to innovation is affected by both the environment external to the firm and the characteristics of the business leadership. The former include the state of aggregate demand, the exchange rate, environmental and social concerns, industry structure and competitive intensity, among others. The latter include ownership and control structures affecting decision making, entrepreneurial drive and willingness to assume risks, managerial training, business strategy, and willingness to cooperate with others. These factors influence innovation in all industries, not just natural resource industries.

The support infrastructure for innovation in natural resource industries includes the overall state of sciences and technology relevant for natural resource industries from both a basic research and applied research perspective in both Canada and abroad. Innovation draws upon this knowledge base.

This infrastructure also encompasses government framework policies, including macroeconomic policies such as fiscal policy and microeconomic policies such as tax policy and intellectual property (IP) policy and government policies directing targeting innovation in natural resource industries, including R&D tax credits and grants for business R&D, financial support for high education R&D, and research in government labs. The universities represent an additional component of this support infrastructure for innovation in natural resource industries, both undertaking basic and applied research and educating skilled personnel. Collaborative efforts related to innovation between government and business, universities and business, and among all three players represent a final element of this support infrastructure.

F. The Games Approach to Innovation

In a recent book Roger Miller and Marcel Côté (2012a) have developed a highly original framework for understanding innovation called "games of innovation".[4] This approach may have considerable relevance for the natural resources sector. They argue that it is market conditions, not R&D, that shape innovations and drive innovators' strategies. Indeed, the pattern of innovation reflects the conditions of the market where they occur.

They first make a distinction between two dimensions of the business context, namely innovations taking place in emerging markets and those occurring in mature markets. For each type of market there are three types of products or systems: autonomous products, platform-based products and closed systems. There are in turn six games of innovations, one associated with each type of market and product (Exhibit 3).

Exhibit 3: The Six Games of Innovation

	Autonomous Products	Platform-Based Products	Closed Systems
Innovations in Emerging Markets	Eureka!	Battles of Architecture	System Breakthroughs
Innovations within Mature Markets	New & Improved	Mass Customization	Pushing the Envelope

Source: Miller, Roger and Marcel Côté (2012).

The two games or strategies most relevant for natural resource industries are "new and improved" and "pushing the envelope" The first game is characterized by continuous development of an edge in the marketplace through product differentiation and cost reduction. The development of new types of paper products in the paper industry and the new production processes to reduce costs in raw material transformation industries are examples of this type of game. The second game is characterized by redefining the state of the art in the field to create a new production process or product. The development of technologies for the extractive of oil from bitumen would be an example of pushing the envelope.

[4] See Miller and Côté (2012b) for a synthesis of their main arguments.

III. Unique Characteristics of Natural Resource Industries that Influence Innovative Capacity and Incentives to Innovate

The particular characteristics of a sector or industry can influence the capacity and incentives to innovate of that sector or industry. The natural resources sector in Canada has a number of characteristics that distinguish it from other sectors and hence influence its innovative performance. This section outlines these unique characteristics and discusses the implications for innovation. These characteristics include high capital intensity, the production of homogenous goods, highly competitive international markets, output price volatility, a growing demand for technical skills, adverse environmental impacts that arise from the production process, a high degree of regulation, the prevalence of vertical linkages, a high degree of foreign ownership, and high profitability. Some of these characteristics serve as a hindrance to innovation performance, while others actually create added incentives for natural resource firms to engage in innovative activities.

A. High Capital Intensity

The natural resource sector is by nature capital-intensive (in terms of capital-labour ratios). In 2010, the combined capital stock of natural resource industries in Canada accounted for approximately 35 per cent of the total capital stock in Canada; 28 per cent of this was attributable to energy industries. This is a significant proportion, as natural resource industries account for approximately 20 per cent of nominal value added. Enormous, expensive and immobile capital structures pose several obstacles to the innovative performance of firms, including increasing the risks associated with project success and whether an innovation will find its way into the market. Among these are the sheer cost of developing and adopting new capital goods and the risk associated with engaging in R&D. Because capital goods require significant financing, there is a barrier for firms to adapt production to incorporate innovative practices. The opportunity cost of R&D initiatives in the natural resources sector is foregoing current production.

A large portion of the risk associated with natural resource development is related to capital intensity. The greater importance of structures (immobile capital) compared to machinery and equipment (mobile capital) in the total physical capital stock of all three natural resource sectors implies a higher production cost than in sectors where capital is mobile. If the return on a project is plagued by uncertainty, firms are unwilling to invest the significant amount of capital required for most natural resource development projects. Lonmo and Schaan (2005) highlight the role of economic barriers to innovation such as a lack of financial resources in industries which serve the mining and forestry sectors using the 2003 Statistics Canada Survey of Innovation.[5] In contract drilling (except oil and gas) and other support activities for mining, a high degree of risk reducing the feasibility of capital intensive innovative projects is the main obstacle that slowed down innovation. The risk associated with large-scale investment in capital goods consequently creates a disincentive for innovation activity in many natural resource industries.

[5] These industries are "Support activities for forestry", "Contract drilling", "Other support activities for mining" and "Environmental consultants."

B. Homogenous Products

Natural resource firms typically produce commodities such as gold, oil, natural gas, pulp and lumber. Commodities are by definition homogeneous and there is little room for competition via product differentiation in natural resource industries. These industries are already sensitive to international market conditions, in which they are price takers and must prioritize cost effectiveness as a chief means of staying competitive as opposed to developing new products. For example, Natural Resources Canada (2011) stresses that Canadian natural resource firms have minimal influence on world markets even with the uniqueness of mega-projects such as the oil sands. This bias towards cost savings suggests that natural resource firms tend to engage in process innovation more than manufacturing or service industries. It is because of this bias that improved process innovation performance will be a pivotal factor in the future viability and performance of the Canadian natural resources sector.

C. Highly Competitive International Markets

Competition is a key driver of innovation (Sharpe and Currie, 2008). Canadian natural resource industries have faced increased competitive pressure from the international marketplace over the past decade. The 2009 Survey of Business Strategy and Innovation (SIBS) shows that Canadian natural resource industries are more exposed to international competition than Canadian industry as a whole. Data from SIBS also indicates that natural resource firms are more likely to compete with multinationals, which creates a competitive disadvantage, as multinationals tend to be large and resourceful. This trend is most visible for paper manufacturers and mining, quarrying and oil and gas extraction, in which over 80 per cent of respondent firms claimed competition from multinationals in their principle markets.

The forestry sector is perhaps the best example of waning performance due to international competition. In addition to a strong Canadian dollar and high energy costs, Wernerheim and Long (2011) note that competition from state of the art paper mills in Europe, China and the tropics has fueled the decline of Canadian forestry.[6] The share of forestry products of Canada's total exports has fallen from a peak of 15.9 per cent in 1995 to 5.7 per cent in 2010. In spite of such a weak performance in recent years, the Canadian forest sector has a great deal of innovative potential.

D. Price Volatility

Commodity prices are volatile. This can be clearly seen by comparing Statistics Canada's raw materials price index – which includes prices of several goods such as: wood, metals, mineral fuels, etc. – with the CPI. Between 1981 and 2012, the standard deviation of annual price changes in raw materials was 9.5 per cent, significantly higher than the standard deviation of the CPI during the same period, 2.1 per cent. Because commodity prices tend to be volatile, natural resource firms have difficulty planning their future, and tend to be biased towards producing (as

[6] Another factor that has played an important role in the decline of the Canadian forestry industry is the falling demand for newsprint.

opposed to innovating) in periods where prices are high and hesitant to do anything when prices are low (for fear the trend continues).

The Centre for Innovation Studies (2008) highlights this variant of the “resource curse” as an obstacle for innovation and diversification in the Canadian natural resource sector. It notes that a “rip-and-ship” mentality, characterized by the desire to capitalize on presently high commodity prices without consideration of longer-term development is a hindrance to innovative practices in the sector. Such an attitude inevitably diverts resources away from R&D, investment in better technologies and other means of increasing productivity in favour of production in the short-term.

E. Environmental Effects of Production

Due to the extractive nature of the natural resources sector, there are negative externalities in production. Sustainability and environmental considerations have increased the pressure on natural resource industries to “clean up” the production process. Climate change is one of the most controversial policy issues of the past few decades. The extractive nature of most natural resource industries comes with an environmental burden which has been seen as affecting the public image of mining, energy and forest industries in Canada. In addition to concerns about public image, there is an added incentive for the Canadian natural resource industry to adopt innovative environmental and sustainability practices. The increasingly competitive international market will reward clusters that enhance energy efficiency and reduce emissions intensity with substantial cost-savings.

There is evidence, however, to suggest that firms may not invest enough in environmental technologies without the right incentives. A survey conducted by Waggener Edstrom Worldwide (2009) asked 47 institutional investors, 26 brokerage analysts, 5 independent research firms and 3 other industry participants about the future of alternative energy investment. Despite clean-tech industries being shaken by the global economic downturn in 2008, respondents remained optimistic about the future of alternative energy. A majority of respondents expressed concern that alternative energy markets may not prosper on their own and government intervention may be required to bolster demand.

F. The Degree of Regulation

In contrast to most manufacturing and service industries, natural resource industries tend to be more regulated. Examples of regulation in natural resource industries include environmental assessments and standards, Aboriginal land claims and greater employee health and safety standards. Rheaume and Roberts (2007) find that “the regulatory approval processes for new mills, mines, oil and gas developments, electricity generation, pipelines and electricity transmission are slow and cumbersome.” Major projects may have to receive approval from federal, provincial and municipal companies, which implies three sets of regulations to comply with. Further complexity is identified by Rheaume and Roberts (2007) who note that “federal and provincial regulations are often overlapping and duplicative, making approval processes complex and costly”. The federal government, however, is currently attempting to address those issues.

Environmental regulation is an important issue for the natural resources sector. Certainly Boag (2009) expressed concern for what the Canadian plan would be to curb greenhouse gas production and encouraged legislators to be mindful of economic consequences if the time periods chosen for reduction are too fast, or if emissions are priced differently in Canada then in our trading partners. Ambec *et al*. (2011) summarize the empirical evidence concerning the Porter hypothesis, a prediction by Harvard economist Michael Porter which posits that properly designed environmental regulation should foster innovation as firms adopt or develop advanced technologies to offset the added cost of carbon. Evidence on the "weak" version[7] of the hypothesis is generally supportive. In the case of the strong version, empirical evidence is mixed, with the most recent evidence being largely supportive. As such, there is a case to be made that increased environmental regulation that would have once been thought of as a hindrance to the performance of natural resource industries could potentially ensure the industry's viability in the proper innovative environment.

G. The Degree of Vertical Linkages in Production Processes

An additional structural characteristic of the natural resources sector is the high degree of vertical linkages between component industries. For example, each aggregate natural resource industry is characterized by primary industries, such as logging, mineral extraction or oil and gas extraction, as well as downstream industries such as paper, mineral product manufacturing or petroleum product manufacturing. These characteristics have implications for innovation measurement in that the innovation performance of natural resource industries as assessed by conventional indicators may be weakened or strengthened depending on the industry aggregation used. For example, an upstream industry may be unwilling to engage in innovative efforts because downstream industries will share the benefits of doing so. If these industries are under independent ownership, there is an incentive in industries with this type of structure for free-riding on the innovative efforts of upstream/downstream firms. In this case where industries are not vertically integrated, innovation in one component industry constitutes a positive externality which benefits linked industries, leading to an undersupply of innovation in the sector as a whole.

Vertical linkages can also foster innovation. If the production processes of several industries are integrated, then the innovative needs of the sector as a whole are known amongst firms. In this case, collaborative efforts and co-innovation can generate innovative efforts that benefit the sector as a whole. Anderson (2006) compares the innovation performance of two Canadian forest support industries: environmental consulting and support services for forestry. The author concludes that vertical structures are a key driver of innovation in the forest sector as a whole. For example, there is a significant downstream spillover for forestry firms that purchase environmental consulting services. Additionally, innovation in support services is negligible primarily because of a strong reliance on the innovative capacity of suppliers, namely manufacturers of machinery and equipment.

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[7] The "weak" version of the Porter hypothesis suggests that stricter environmental regulation will increase innovation whereas the "strong" version suggests that stricter environmental regulation will increase overall business performance.

H. High Degree of Foreign Ownership

The degree of foreign ownership in Canadian natural resource industries is high. Foreign direct investment (FDI) stocks in all Canadian natural resource industries increased over the 1999-2010 period (Appendix Table 15),[8] with the stocks growing much faster than the all-industries total (75 per cent) in mining, oil and gas and utilities (220 per cent) and petroleum, coal and chemical manufacturing (136 per cent).

A high degree of foreign-ownership in Canadian natural resource industries is relevant to innovation performance in two ways, which are counteracting. First, foreign firms may be less interested in long-run viability than short-term profitability of resource extraction. As such, this means that there is a disincentive to invest heavily in innovation. Second, it is also possible that with foreign ownership comes a wealth of improved products and practices that the industry can employ, which spill over into the innovation environments of the home country. Multinational firms are an important vessel for technology transfer across borders. There is a vast literature on FDI and knowledge spillovers (Chen *et al*. (2010), Branstetter (2006), Todo and Miyamoto (2006)). Knowledge spillovers are positive externalities that result from the employment of innovative technologies, knowledge or practices being transferred from users to non-users. In the case of multinational firms, moving operations across borders can introduce new technologies and practices to firms in a host nation. As such, the degree of foreign direct investment in an industry is a useful indicator of an industry's potential to innovate.

I. High Profitability

Firm innovation, whether involving the undertaking of in-house R&D or the acquisition of state-of-the-art equipment, costs money. Consequently, the financial health of the firm can influence the pace at which innovation is pursued. The financial situation of the industry in which the firm operates provides information on the likely state of a firm's finance.

Natural resource industries in Canada have been very profitable in the 21st century. Operating profits tripled from $23.4 billion to $70.0 billion (a historical peak) between 1999 and 2008, before plummeting to $20.6 billion in 2009 (Appendix Table 39). Data are not yet available for 2010, but with the recovery it is likely that profits rebound significantly. From 1999 to 2009 inclusive natural resource industries accounted (on average) for 19.3 per cent of the business sector, while representing only 5 per cent of employment. From this perspective natural resources have had, at least until recently, ample financial resources to pursue an innovation agenda.

But the overall financial situation of the resource industry is misleading as it reflects very different sectoral patterns of profitability. Profits in the forest products sector are dismal while those in the energy sector have been extraordinary and those in mining between the two extremes. Annual profits in the forest products sector averaged $3.7 billion between 1999 and 2009, and were negative in both 2008 and 2009. In contrast, annual profits in the energy sector averaged $28.8 billion and peaked at $52.7 billion in 2008, before falling to $12.6 billion in

[8] The complete list of Appendix Tables can be found at http://www.csls.ca/reports/csls2012-06AppendixTables.xlsx.

2009. In the mining sector profits averaged $11.7 billion over the 1999-2009 period. This means that firms in the forest products sector have had very limited resources to innovate, while those in the energy sector have had massive resources.

Exhibit 4: The Effect of the Unique Characteristics of Natural Resource Industries on Innovation

	Effect on Innovation	Estimated Net Effect
High Capital Intensity	- The risk associated with large-scale investment in capital goods creates a disincentive for innovation activity in many natural resource industries.	-
Homogeneous Products	- Homogeneous products leave little (or no) room for competition via product differentiation. Since natural resource firms are generally price takers, they must constantly strive for cost effectiveness – which provides an important incentive to engage in process innovation.	+
Highly Competitive International Markets	- Canadian natural resource industries are more exposed to international competition than Canadian the average Canadian firm. Hence, they must innovative if they want to stay in business.	+
Price Volatility	- Commodity prices tend to be volatile. As a consequence, natural resource firms have difficulty planning ahead, and tend to be biased towards producing (as opposed to innovating) in periods where prices are high and hesitant to do anything when prices are low (for fear the trend continues).	-
Environmental Effects of Production	- The increasingly competitive international market will reward clusters that enhance energy efficiency and reduce emissions intensity with substantial cost-savings.	+
The Degree of Regulation	- In general, regulation is seen as a factor that inhibits innovation; - However, in the natural resources sector, regulation can potentially force firms to improve their production processes (Porter hypothesis).	Ambiguous
The Degree of Vertical Linkages in Production Processes	- Higher levels of vertical integration can foster innovation since the innovative needs of the sector as a whole are known amongst firms; - Conversely, low vertical integration can hinder innovation because downstream industries will share the benefits of innovation along the value chain.	Ambiguous
High Degree of Foreign Ownership	- Foreign firms may be less interested in long-run viability than short-term profitability of resource extraction; - On the other hand, foreign ownership might bring along a wealth of improved products and practices that the industry can employ, which spill over into the innovation environment of the home country.	Ambiguous
High Profitability	- High profitability guarantees that firms have enough funds to pursue R&D; - At the same time, however, high profitability may dull the incentives of firms to innovate.	Ambiguous

Source: CSLS.

IV. The Innovation Environment of Canadian Natural Resource Industries

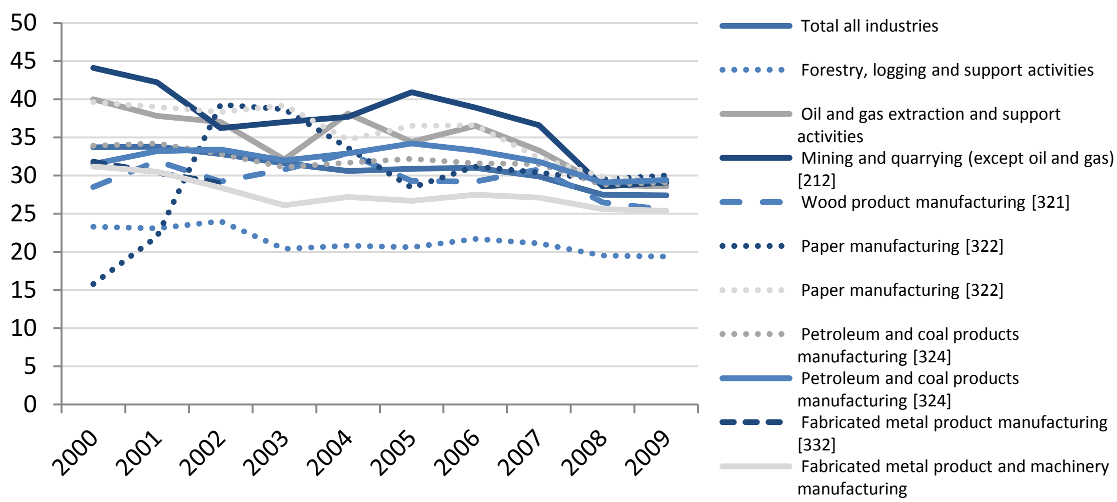
The main objective of this report is to understand the innovation performance of Canadian natural resource industries based on a systems approach to innovation. In this sense, it is essential that we have a clear picture of the innovation environment facing natural resource firms in Canada. This environment is comprised of overarching government framework policies, an array of programs in the public sector which target R&D, investment and human capital development, several initiatives from academia and collaborative efforts between the public and private sector. Business perspectives on public support programs are also summarized. These programs and initiatives form an integral part of Canada's innovative capabilities and consequently, determine in part the NIC of natural resource industries.

A. Government Framework Policy

Government policies need not target innovation specifically to affect the innovative capacity of firms. Fiscal policy can affect both firm incomes and final demand for outputs, which in turn determine the incentives facing firms to innovate. In recent years, public policy has shifted towards greater market-orientation. Policies that lead to freer trade, less business regulation and lower corporate taxes will, in principle, have a positive effect on innovation. Additionally, policies that affect the degree of FDI in an industry also determine the amount of technological and knowledge spillovers, further affecting the industry's capacity to innovate.

One important example of a government framework policy that in principle has a positive effect on the environment for innovation is falling corporate tax rates (Chart 1). Lower corporate taxes lower the cost of capital and provide businesses with greater after-tax profits, which, in turn, can contribute to increased investment and innovation. Appendix Table 20 shows that between 2000 and 2009 the ratio of corporate taxes to income (an effective tax rate) fell in 9 of 10 natural resource industries, with many industries experiencing a fall of 10 percentage points or more.

Chart 1: Effective Tax Rates, Natural Resource Industries, Percentage, 2000-2009



Source: Appendix Table 20

The Doing Business index, calculated by the World Bank, ranks countries according to how easy it is to start and conduct a business operation. Countries where the regulatory environment is more business friendly receive a higher ranking. The index is constructed based on ten broad indicators: ease of 1) starting a business; dealing with construction permits; 2) getting electricity; 3) registering property; 4) getting credit; 5) protecting investors; 6) paying taxes; 7) trading across borders; 8) enforcing contracts; 9) and resolving insolvency. In 2012, Canada was considered one of the most business friendly countries in the world, ranked at 13th place out of 183 countries.

Canada also ranks extremely high in the Heritage Foundation's Index of Economic Freedom. This index looks at ten indicators of economic freedom: 1) property rights; 2) freedom from corruption; 3) level of government spending; 4) fiscal freedom; 5) business freedom; 6) labour freedom; 7) monetary freedom; 8) trade freedom; 9) investment freedom; 10) and financial freedom. In 2012, Canada ranked at 6th place out of 179 countries.

B. Public Support Programs

This section details institutions and programs which play a role in the innovation performance of Canadian natural resource industries. Collaboration between industry, government and academia is the driving force behind the spread of knowledge in the economy. Collaboration can take the form of co-innovative efforts by firms, public funding support or a variety of initiatives from universities and research institutes.

The Canada Mining Innovation Council (CMIC) (2010) recognizes 38 federal research and innovation funding initiatives/programs as being relevant to the mining sector, though most of the programs are not specific to mining, or even specific to natural resources. Among the programs, there are five broad categories: mapping (1 program), skills development (8 programs), tax incentives (7 programs), innovation co-financing (9 programs), and government directed research and collaboration efforts between government, industry and academia (13 programs).

i. Public Support for R&D

There are two main types of public R&D support for business: tax credits and grants. Both of these mechanisms reduce the R&D cost of firms. According to the Canada Revenue Agency (2010), the Scientific Research and Experimental Development (SR&ED) Tax Incentive Program "is the largest single source of federal government support for industrial R&D. The SR&ED program gives claimants cash refunds and/or tax credits for their expenditures on eligible R&D work done in Canada". In 2010-2011, federal spending on this tax credit amounted to $3.53 billion, the largest single expenditure of all federally funded R&D support (Jenkins, 2011). By sector, 8.7 per cent of SR&ED funding in 2007 went to the mining and oil and gas sector.

Federal support for R&D comprises more than 100 programs and institutes and totaled approximately $6.44 billion in the 2010-2011 fiscal year (Jenkins, 2011). A sector breakdown reveals that of the $630 million in direct expenditures by the federal government on business R&D, mining and oil and gas received only 3.8 per cent and agriculture, forestry, fishing and hunting received 9.8 per cent. A large portion (52.7 per cent) went to the manufacturing sector.

Similarly, Jenkins (2011) notes a variety of both repayable and non-repayable grants for R&D available from the federal government. These include Strategic Network Grants, Strategic Project Grants and Collaborative Project Grants, each of which is directed at fostering R&D in key strategic areas and encouraging collaboration between industry and higher education.[9]

There is one tax credit exclusive to investment in the mining industry, the Mineral Exploration Tax Credit that encourages exploration for new mineral deposits. Data from the 2003 Statistics Canada Survey of Innovation indicate that amongst government R&D support programs, R&D tax credits are the most widely used support program by "other support activities for mining," of which, mineral exploration is a part.

Natural Resources Canada's Office of Energy Research and Development has three programs to fund energy supply research, technologies that reduce greenhouse gas emissions and clean energy initiatives. The program of Energy Research and Development funds research by universities, other levels of government, and industry to ensure a sustainable energy future for Canada. The Clean Energy Fund finances research and development of clean energy production and technologies like carbon sequestration that mitigate the environmental damage done by producing energy. There is also an initiative called ecoENERGY Technology Initiative, which is outlined in Box 1 alongside other notable federal investment support initiatives.

Federal support also takes the form of funding to universities through the creation of research chairs. The NSERC (Natural Sciences and Engineering Research Council) Chairs Programs in industrial research, engineering and environmental engineering foster greater research and also allow for better education of graduate students. The Canada Global Excellence Research Chairs endeavors to attract world-class academics to Canada that specialize in the environment, natural resources and energy, health, and information and communications technology.

A final vessel of support for R&D from the federal government is via its own laboratories, which engage in R&D in key areas, often with a regional focus. For example, Natural Resources Canada engages directly in research and development through three laboratories: CANMET-MMSL (Mining and Mineral Sciences Laboratory), CANMET-MTL (Materials Technology Laboratory), and CANMET-Energy. These laboratories conduct research on mining extraction, metallurgical processing, environmental issues related to mining, technological improvements on the use and production of metal and mineral products, and sustainable production and use of Canada's energy supply.

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[9] The objective of Strategic Network, Strategic Project, and Collaborative Project Grants is to increase research and training in targeted areas that could strongly enhance Canada's economy, society and/or environment.

ii. Public Support for Investment

Public efforts that enhance innovative capacity also take the form of funding for investment. Similar to R&D, several investment support programs take the form of tax credits. Additionally, there are a number of programs aimed at co-financing investment in new technologies.

Tax credits (as mentioned previously) reduce the costs associated with their targeted objective. In the case of investment, tax credits make acquiring new technologies and other capital goods less costly for firms. An especially important tax credit that is applicable for almost every industry is the Capital Cost Allowance (CCA). This allows for a business to claim the depreciation on investment assets as an expense, which encourages investment. The tax credit has had some temporary enhancement recently, with a 100% CCA rate for computers and software acquired between January 2009 and February 2011, which likely served to increase investment in high-return information and communication technologies. Similarly, there was a temporary 50 per cent straight-line depreciation on manufacturing and processing machinery and equipment.

Box 1: Federal Investment Support Programs for the Natural Resources Sector

Sustainable Technology Development Canada (SDTC) (http://www.sdtc.ca/): SDTC is a non-profit organization that funds and supports the development of technologies that provide solutions to issues related to climate change, clean air and water and soil quality. It operates two funds aimed at the development as well as the demonstration of innovative solutions: the SD Tech Fund and the NextGen Biofuels Fund. The SD Tech Fund is a $590 million initiative that supports projects that address climate change, air quality, soil quality and water quality. The NextGen Biofuels fund is a $500 million initiative which supports the development of novel facilities for the production of next generation renewable fuels.

Natural Resources Canada's Clean Energy Fund (http://www.nrcan.gc.ca/energy/science/programs-funding/1482): The Clean Energy Fund has committed approximately $612 million to the development of large-scale carbon capture and storage projects as well as smaller scale demonstration projects of renewable and alternative energy technologies. To date, three of these projects have been implemented in Alberta, receiving $466 million from the fund. These three projects are the Shell Canada Energy Quest project, the Transalta project pioneer and the Alberta Carbon Trunk Line Carbon Capture and Storage Project. In the coming five years, the fund has committed $146 million to various projects across Canada that include geothermal heating projects, tidal turbine projects, heat generation from biomass gasification and solar energy.

ecoENERGY Technologies Initiative (http://www.nrcan.gc.ca/energy/science/1335): The ecoENERGY technologies initiative is a group of programs implemented by the Government of Canada for both consumers and organizations to aid the acquisition of energy efficient technologies. On the consumer end, the ecoENERGY retrofit program provides up to $5,000 to consumers to retrofit their homes with energy efficient technologies. The program also provides a tax credit of 15.25 per cent of the cost of a monthly transit pass to consumers who regularly use public transit. For organizations, the program offers an array of programs ranging from grants for the construction or expansion of transportation biofuel production facilities in the agricultural sector to the development of energy efficient technologies to funds to reduce the dependence on fossil fuels of Aboriginal communities.

Pulp and Paper Green Transformation Program (http://cfs.nrcan.gc.ca/pages/231): This program has been implemented by Natural Resources Canada to encourage innovation and investment in areas such as energy efficiency and renewable energy production. It is aimed at helping pulp and paper mills reduce their environmental impact while remaining competitive through diversification into the production of renewable energy via biomass. The program is capped at $1 billion.

In addition to tax credits, several federal support programs take the form of co-financing. There are a number of initiatives aimed at co-financing investments of which the natural resources industry may take advantage. Some programs aim to create a more environmentally friendly industry, such as Natural Resources Canada's Office of Energy Efficiency and Sustainable Development Technology Canada (which is funded by the Government of Canada). The aim of these programs/initiatives is to develop clean energy, promote energy efficiency, and support projects for clean water, air, and soil. While not explicitly for the resource industry, the National Research Council Industrial Research Assistance Program was assigned $220 million over the next two years (Government of Canada, 2012: 82) to assist firms at all stages to build their innovation capacity.

Beyond the environmentally-geared co-financing strategies, there is also a system of community and regional development programs that can be used to promote innovation in natural resource industries. The Community Adjustment Fund (Western Economic Diversification Canada) and the Business and Regional Growth Program (Canada Economic Development for Quebec Regions) serve to diversify local economies and encourage innovation and technology transfers. There are additional regional economic development agencies (such as the Atlantic Canada Opportunities Agency, Northern Ontario Development Program, and the Canadian Northern Economic Development Agency) that have innovation funds, and all help encourage business investment and innovation.

A co-financing initiative that aides the mining industry is the Geo-mapping for Energy and Minerals program. This program is a five-year $100 million dollar initiative by the Government of Canada, which aims to provide information to industries that will guide investment decisions for exploration and developments of mines and energy resources. About three quarters of the funding focuses on Northern exploration and one quarter in the provinces. There is also a funding provision for the development of new exploration methods for deep mineral deposits.

iii. Public Support for Human Capital Development

There are a number of general federal programs that are aimed at increasing human capital in the labour force that benefit the natural resources sector. A majority of these aims to lower the costs of obtaining an education. There are four federal programs that encourage university attendance. The Canada Student Grant Program, Canada Student Loans Program, Canada Graduate Scholarships, and Canada Graduate Scholarships Abroad programs will collectively represent a federal investment in skill acquisition of $1.755 billion over the 2009-2012 fiscal years. Registered Education Savings Plans (RESPs) encourage postsecondary education through encouraging savings for future education.

The federal government has recognized the importance of apprenticeship programs in recent years, having introduced a number of initiatives for support of these programs. This is particularly relevant to the natural resources sector as a disproportionate number of occupations in the natural resource sector are apprenticeable trades. Apprenticeships are important to the natural resources sector as there is high demand for trades people who are needed to implement innovative technologies. Education and apprenticeships are encouraged through the Trade Persons Tool Expenses Credit, Textbook Tax Credit and Tax exemption for Scholarships and Bursaries which encourage investment in tools, textbooks and tuition. There is also an Apprenticeship Job Creation Tax Credit ($80 million investment annually) that encourages employers to hire new apprentices and. Human Resources and Skills Development Canada offers an Apprenticeship Incentive Grant, budgeted at $100 million over 2 years, that encourages individuals to undertake apprenticeships by covering some of the expenses.

Natural resources extraction very often takes place near Aboriginal land holdings. Companies are happy to engage the local Aboriginal population if it has the needed skills. The Aboriginal Skills and Employment Partnership (ASEP) and the Aboriginal Skills and Training Strategic Investment Fund will together provide $180 million in funding over a five year period to facilitate the acquisition of skill sets and employment experience.

iv. Business Perspectives on Public Support Programs to R&D

It is important to evaluate how natural resource industries have taken advantage of public support and whether it has proven useful. As part of the consultation exercise of the Federal Taskforce on R&D (Review of Federal Support to R&D, 2011), a set of consultation questions were put to Canadian industries in order to obtain their perspectives on the effectiveness of government R&D programs. The natural resource sector was well-represented among respondents. This section provides a summary of the response to these consultation questions, by three key business associations in the natural resources sector – the Forest Products Association of Canada (FPAC), the Canada Mining Innovation Council (CMIC), and the Canadian Association of Petroleum Producers (CAPP).

Two initiatives highlighted by FPAC (2011) are the Transformative Technologies Pilot Scale Demonstration (TT-PSD) and the Investments in Forest Industry Transformation (IFIT) programs. The two-year TT-PSD program, from Federal budget 2009, provided support via FPInnovations to forest products companies to help them demonstrate at the pilot scale technologies related to the industry's transformation. The funding of $100 million over four years for the IFIT program was announced in the 2010 federal budget. The IFIT program provides direct support to individual forest products companies to help them implement new technologies leading to non-traditional high-value forest products and renewable energies at the pilot to commercial scale. The program received one hundred and seven applications over its two calls for proposal rounds and the total value of projects submitted exceeded $2 billion. Forest industries have also taken advantage of the SR&ED tax credit, which is cited by FPAC (2011) as the single most important program in terms of supporting the sector. FPAC's recommendations to improve federal R&D support are summarized below:

- Commitment to longer-term funding for FPInnovations so it can focus on longer-term priorities critical to the future of the industry

- Further investment in programs that target piloting and implementation of promising technologies

- Implementation of tax reforms that allow unprofitable companies immediate access to their accumulated tax credits, in order to aggressively stimulate private sector investment in capital and R&D

The CMIC (2010) notes several concerns regarding federal R&D funding to date. Suggested changes include encouraging the efforts of NSERC to reflect in its funding decisions what CMIC would consider a more equitable contribution to mining R&D, the federal government implementing mining specific funding programs, further support to Natural Resources Canada to implement its mining mandate, encouraging more federal-provincial cooperation in meeting the research funding needs of the mining sector, further support for mining-related university research facilities and implementing tax measures specifically designed to support mining-related research. Similar to FPAC (2011), CMIC(2011) recommends changing the SR&ED to a tax refund as opposed to a tax credit.

CAPP (2011) also cites eligibility concerns and the length of the bureaucratic process as obstacles to upstream petroleum producers applying for the SR&ED tax credit. Firms have expressed dissatisfaction with the inconsistent availability of the tax credit and as such, there is added uncertainty in long-run planning in an industry that is already sensitive to commodity and business cycles. A potential solution to this problem is suggested in the form of a streamlined and binding pre-approvals process.

Globalization and the rapid dissemination of technologies also pose an incentive problem for Canadian petroleum producers with respect to R&D. Producers are unlikely to invest in R&D if there is a degree of certainty that a particular needed technology is in development elsewhere. CAPP (2011) thus recommends that the federal government adapt R&D funding programs to attract international researchers. CAPP (2011) observes that better indicators are needed to assess the true innovation performance of natural resource industries which incorporate field research.

C. Initiatives from Academia

The stock of basic knowledge is an essential component of a national system of innovation. A country's aptitude for generating scientific research drives NIC by providing industry with the knowledge and technologies it needs to innovate. Graduates from university programs in science, engineering and other disciplines relevant to natural resources also become valuable human capital assets for natural resource firms.

A crucial contribution of universities to the Canadian innovation environment is the training of students. Canada is fortunate to have a considerable number of world-class universities with experts in areas such as geology, geophysics, geography, chemistry, engineering and other disciplines that are needed in natural resource industries. As more graduates emerge from these institutions, they prove to be a valuable resource for the natural resources industry. Graduate programs tailored to agriculture, natural resources and conservation have increased by about 37 per cent since 2000. Similarly, graduates from graduate programs in the physical and life sciences and technologies have grown by 43.3 per cent.

Universities can also play an important role in determining NIC via experts identifying necessary objectives for industry. In recent years, a lack of research veered towards natural resource industries has posed a major challenge to the natural resources sector, as research efforts have not been effectively steered towards industry needs. Lynch (2010) finds that universities in general have had a very poor record on commercializing innovation in general due to the lack of addressing industry needs, noting that this does not need to be the case. A counterexample is that of the University of Alberta, which has put forth great efforts over the last decade-and-a-half establishing university-industry-government collaboration on oil sands research issues ranging from environmental impact to welding techniques.

D. Collaborative Efforts

Collaborative efforts between various players in the economy are another key driver of NIC via strengthening the linkages between basic research, industry objectives and government support. Jenkins (2011) highlights the role of collaboration, noting that linkages enable innovation partners to "pool staff and resources, and to share information, risks and costs". The CMIC (2008a) identifies collaboration between industry, government and academia as a means of enhancing research efficiency suggesting that the sharing of research and perspectives, across sectors, will eliminate regional barriers and create an awareness of "who does what and where." The Public Policy Forum (2010, 2012) similarly notes the importance of linkages between industry, government and research institutions, citing the CMIC as an example of the network type that should be adopted in all resource industries. The expected outcome is more integrated and focused research. Collaboration can also apply to access to research funding. A stronger network between industry, government, and universities would help the mining sector to better access mining programs. This is not unique to the mining sector: greater collaboration is a pivotal component of a national innovation system.

There are several projects that aim to foster networking between industry, government, and academia. One program is the Natural Sciences and Engineering Research Council (NSERC) Partnerships Programs which attempts to create collaboration between industry, government, and universities as a way of promoting expertise in Canadian organizations. Similarly, the National Research Council's Regional Innovation Clusters create clustered areas of specialty that facilitate innovation through creating partnerships and aims to give regions competitive advantages through innovation. Networks of Centres of Excellence Canada have operated for over two decades and are generally regarded as having been very successful at allowing for collaborative efforts that allow industrial know-how and academic expertise to meet.

As previously mentioned, another R&D oriented collaborative effort is FPInnovations, a public-private partnership between the federal government and the forest products sector that works towards optimizing the forest sector's value chain. It capitalizes on Canada's fibre attributes and develops new products and market opportunities within a framework of environmental sustainability. The federal government provides support to FPInnovations of approximately $30 million each year. This funding contributes to research in paper and pulp mills and academic institutions across Canada. FPInnovations is a unique organization that is flexible in terms of research capabilities, with researchers exhibiting broad skill sets and expertise. FPAC (2011) cites this flexibility as a source of FPInnovations' continued research output such as cellulose-based nanomaterials and solutions to suppress and manage wildfires. This flexibility would be greatly diminished without federal support.

Diversification is an additional issue addressed via collaboration. The Biopathways Project is an investigation of the opportunities to produce bio-based products from wood fibre created by a partnership between Natural Resources Canada, FPInnovations, several provincial governments and many scientific experts from across Canada. Findings indicate that integrating bio-technologies into the traditional forest products industry is the most economically viable way to diversify the sector.

Collaboration is not limited to direct R&D initiatives; it can also be a vessel for implementing modern resource management practices. An interesting collaborative effort between industry and stakeholders is the Canadian Boreal Forest Agreement (CBFA). In 2010, the Forest Products Association of Canada and nine environmental and sustainability organizations[10] came together to address a number of ecological issues facing the forest sector. The commitments of the signatories of the agreement are primarily based around revamping forest management policies to incorporate "world-leading, on-the-ground sustainable forest management practices that best reflect the principles of ecosystem based management." Other initiatives under the banner of the CBFA include caribou habitat preservation and identifying areas of climate and energy policy that intersect with forest management and conservation. The CBFA also establishes an independent science advisory team so that the signing parties are privy to the most recent and accurate scientific information.

[10] The nine organizations were: the Canadian Boreal Initiative, Canadian Parks and Wilderness Society, the David Suzuki Foundation, ForestEthics, Greenpeace, Canopy, the Nature Conservancy, Pew Environment Group International Boreal Conservation Campaign, and the Ivey Foundation.

V. Innovation Indicators in Canadian Natural Resource Industries

This section presents an overview of innovation indicators for natural resource industries in Canada. The innovation performance of natural resource industries is analyzed via comparison to the all industries or business sector averages for Canada and relative to the natural resource industries of selected OECD countries. Indicators are organized into the following categories: the state of technological prowess in Canadian natural resource industries; innovation inputs such as research and development (R&D), skills, investment and capital stock and intangibles; innovation outcomes such as productivity, energy efficiency and patents; incidence of innovation indicators such as plant innovativeness and the novelty of innovations; and other indicators spanning co-innovation, public support, competitiveness and business strategy and improved organizational structures. These indicators are individual measures that summarize the innovation environment in a country. Though these indicators are not aggregated into an overall composite indicator that describes the innovation environment in which Canada's natural resource industries operate, analyzing them individually does point towards the quality of the innovation system in Canada's natural resource industry.

A. State of Technological Prowess in Canadian Natural Resource Industries

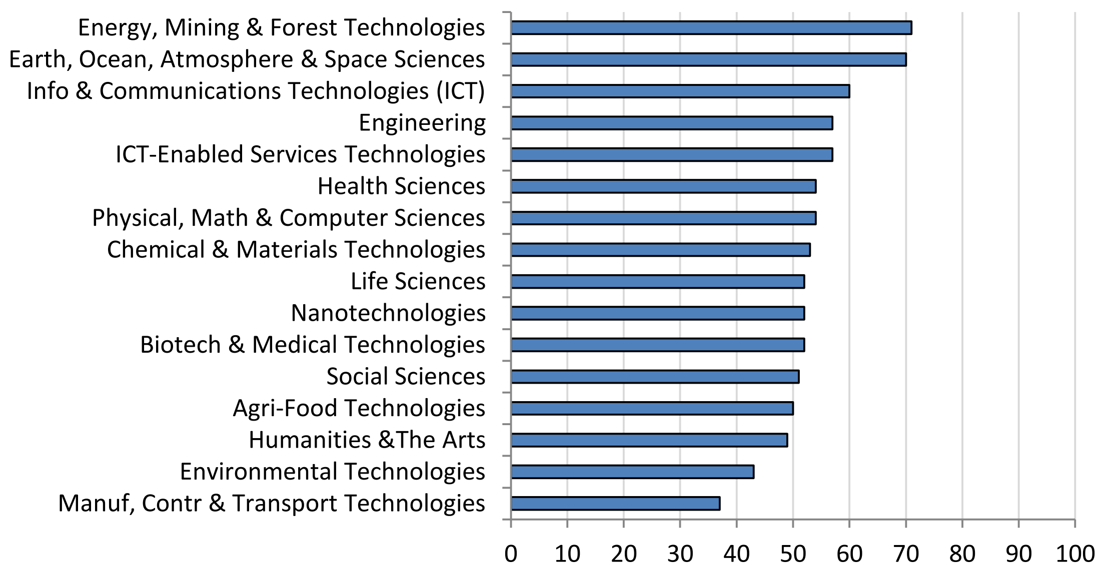
This section provides a breakdown of the technological performance of Canadian natural resource industries. The state of technology in natural resource industries is a vital complement to firm characteristics such as R&D expenditure and worker skills and education in determining innovative capacity. Given the diversity of industries that comprise the natural resources sector, there is little research that deal(s) with innovation in the sector as an aggregate. Rather, there is a wide body of literature analyzing innovation in a subset of the natural resource sector.

The Council of Canadian Academies (2006) rated 16 broad areas of science and technology and 197 more specific sub-areas in terms of technological standing. The methodology used was a survey of knowledgeable people asked to compare the direction and state of science and technology in Canada compared to other advanced countries. Chart 2 depicts an important result from this study, the per cent of respondents rating broad S&T areas in Canada as strong in terms of their technological standing. Of the 16 broad areas, energy, mining and forest technologies were deemed to be in a strong technological position relative to other countries by the highest proportion of respondents, at 71 per cent, while only 8 per cent considered the area weak. This can be compared to the fact that most other areas were rated as strong by 53 per cent of respondents (or less). While the natural resource area is in a strong technological position, for energy, mining and forest technologies, the trend compared to other countries was deemed as upwards by 29 per cent of respondents (the 6th highest out of 16 areas) while 56 per cent thought it stable and 15 per cent deemed it as having a downward trend. Alternative energy sources, such as wind, solar and biofuels, were not included in the natural resources area, but rather in the environmental technologies area. The environmental technologies area had a positive trend (30 per cent thought the relative position was improving), but was second lowest in terms of its current technology level.

The assessment of the sub-areas also demonstrates a very positive assessment of the state of technology in the natural resources sector. There were 26 sub-areas in the natural resources sector out of 197 sub-areas in the 16 broad areas of science and technology, and the top 10 in terms of state of technology were all in natural resources. The oil sands had the highest proportion of respondents deeming the sub-area to be strong compared to that of other countries, and also the area which was most perceived as having an upward trend. Also in the top 10 were: conventional oil and gas exploration and extraction; hydroelectric; resource production in cold climates; geology, mining exploration; mineral extraction and primary processing; aluminum production; physical geography; and petroleum and polymer engineering.

The difference between the number of respondents that rank an industry as having an upward trend of technological progress and those that rank an industry as having a negative trend is a reasonable measure of the consensus opinion regarding industry trends. Using this measure, three natural resources industries were in the top 10 sub-areas (oil sands and related, conventional oil & gas exploration/extraction, and petroleum/polymer engineering), and only one in the bottom 10 (pulp and paper). While 35 per cent of all sub-areas (69 out of 197 sub-areas) were perceived as having a downward trend relative to other advanced countries, the rate was only 30.8 per cent among natural resource industries.

Chart 2: Strong Rating for Broad S&T Areas (Per cent of Respondents)



Source: Council of Canadian Academies (2006)

Laverdure and Fecteau (2004) finds that there have been large advances in Canadian mining such as the development of paste backfill techniques along with the use of electronic detonators and hoisting systems. These advances have led to increased productivity and longevity of mining locations. Furthermore, Canada is deemed to have global expertise in mining methods along with workplace environment, engineering aspects such as ventilation, diesel research, dust and gas control, ergonomics, and the use of alternative fuels for mining vehicles.

Negeri (2008) finds that Canada has many areas of expertise within mineral processing and extractive metallurgy. These include both hydrometallurgy and pyrometalurgy, in which Canada has globally recognized expertise. Within ore preparation, Canada has a global expertise in crushing and Semi-Autogenous (SAG) milling, grinding, and modeling and wear simulation. Canada also has a recognized expertise in mineralogical characterization research, mineral chemistry, processing and leeching and separation processing techniques.

Box 2: Hydraulic Fracturing

Hydraulic fracturing (or "fracking") is a process innovation in natural gas extraction that has become widely used in some regions/countries. This innovation is a means of accessing natural gas deposits which are otherwise trapped in rock formations. The process involves blasting sand, water and chemicals into rock formations such as shale, coal beds and tight sands, cracking the rock and allowing the gas to flow up the well. An average fracking operation requires approximately 3-9 million gallons of water, of which about 1-2 per cent contains various chemicals and products to control fluid flow and facilitate fracturing. Fracking is a significant development in the natural gas industry as it can drastically increase yields of natural gas at a time when energy-intensive oil is being phased out wherever possible.

Though it is widespread across the United States— it was first used in Texas in the 1940s— the use of fracking is in its infancy in Canada. Shale gas producers have set their sights on expansion and vast reserves have been identified. To date, fracking has been employed mainly in Western Canada. Drilling is currently underway in the Horn River Basin in British Columbia and coal bed methane fracking has been in Alberta for many years. Additionally, drilling is already underway in Penobsquis and Elgin, New Brunswick. Exploration is also ongoing in Saskatchewan, Manitoba, Ontario, Quebec, Nova Scotia and Prince Edward Island.

Fracking is not, however, without its controversy. Despite the enormous efficiencies it generates in the extraction of natural gas at a time when natural gas is pegged to replace oil as an energy source in many sectors, the use of chemicals has raised concerns regarding overuse of water resources, human health and environmental impacts.

The Canadian forestry industry can also be very innovative. More recently, much of the focus has been on the creation of bio-fuels and burning waste to improve efficiency, which is outlined in the next section. Lessard *et al*. (2010) notes that CERFO (Centre d'enseignement et de recherché en foresterie de Sainte-Foy Inc.) has made important contributions to wood pre-drying methodology, and has also developed a new wood preserving treatment. CERFO has also started research in the area of agroforestry with the aim of combining fast growing hybrid poplar and the quality hardwood of black walnut. According to the Forest Products Association of Canada (2011), research has been done on using wood fibres for bulletproof vests and other clothing, biodegradable plastics and paper towels that indicate contamination, among other products.

The forestry industry has also made great efforts at achieving sustainability and creating eco-friendly products. Lessard *et al*. (2010) outline some major accomplishments of CERFO in these areas. Major accomplishments include the development of software indicating the allowable cut in an area and the development of operations management and decision making techniques. CERFO also offers support forest planning and prescription techniques to preserve local ecology. Industry Canada (2006) outlines areas of research in the area of biofuels. Some firms have experimented with producing bio-fuels for on-site use, and displacing fuel that would otherwise need to be purchased. One bio-fuel technology that remains in the early stages of development is pyrolysis, a prominent example of which is a Dynamotive plant that processes 100 tonnes of biomass a day, and the bio-oil is burned in a turbine developed by Orenda. Natural Resources Canada (2009) notes that the Technology and Innovation Research and Development

Initiative developed willow clones and improved cultivation practices for bio-fuel production and databases that would help conversion facilities in estimating supply costs.

Another example of innovative activity in the forest products industry is the emerging wood fibre industry, which is not yet recognized under an individual NAICS code. This industry produces, among other things, nanocrystalline cellulose, wood pellets, and ethanol. The Canadian Wood Fibre Centre documents several innovation projects related to the wood fibre industry, such as projects for enhanced forest inventory, somatic embryogenesis, etc.

The energy sector has undertaken enormous innovation, due in part to the recent demand for more environmentally friendly energy sources and in part to the rapidly expanding oil and gas sector. Natural Resources Canada (2008) notes that several processes have been developed for separating oil sands bitumen from other elements in order for it to be upgraded to oil. These processes were developed due to over 95 per cent of Canada's established oil reserves being in the oil sands. There has also been a large amount of engineering work done on proposals to expand pipeline networks, and there have been two proposals for new refineries. Natural Resources Canada (2009) outlines several initiatives from the Technology and Innovation Research and Development Initiative for cleaner fossil fuel and decentralized energy production. Among the initiatives were the first field gas hydrate production test in the world, research on deep sea drilling, integration of solar heat and electricity production. The natural gas industry in Canada has recently adopted hydraulic fracking, a means of accessing gas trapped inside rock formations (see Box 2).

Natural resource industries have also been innovative in finding ways to mitigate environmental impacts. Vance (2008) notes that mining firms have done extensive research in minimizing "acidic drainage, heavy metal contamination, release of tailings or other wastes into natural waters and the general issue of environmental footprint". Vance (2008) deems Canada to have world-class expertise in waste management, process, surface and mine water treatment, mine closure and reclamation, and prediction of metal behaviour under different site conditions.[11] Canadian firms have made great advances, over the last two decades in handling the treatment of cyanide waste solution and the disposal of thiosalts. New mines now generally require closure strategies, which has increased research in minimizing environmental damage at the initial stage of mining. One field that has gained particular attention is the revegetation of mine sites which allows for the preservation of ecosystems.

A particularly innovative technology that has recently been adopted in the oil sands is toe-to-heel air injection (THAI). THAI is a configuration for in situ combustion which relies on using less steam to heat bitumen and vertical air injection to initiate a combustion reaction. THAI and the innovation environment in which it was adopted are summarized in Box 3.

[11] Prediction of metal behaviour under different site conditions is an important consideration in determining the best way to mitigate environmental risks at the mining and processing stage.

Box 3: Adoption of THAI in the Alberta Oil Sands

Bloomer, Jacoda and Landry (2010) study the case of adopting toe-to-heel air injection (THAI) technology in the oil sands. The authors assess a systemic innovation framework in the context of the firm Petrobank. The adoption of this technology allowed Petrobank to reduce GHG emissions by 50 per cent, which shows promise for reducing the environmental footprint of the oil sands as a whole.

THAI is a configuration for in situ combustion that relies on significantly less energy than previous methods. THAI works by only heating bitumen around the well bore, whereas most in situ processes heat the entire well. With THAI, air is injected into the well once it reaches optimal temperature. The air injection initiates a combustion reaction which partially upgrades the quality of the oil, making it less viscous and allowing for a more efficient flow towards the surface.

The innovation system which allowed for the diffusion of THAI is characterized by the incorporation of environmental factors, economic conditions, policy support, support infrastructure, technology demand and end product demand. Bloomer, Jacoda and Landry (2010) posit that environmental issues such as GHG emissions influence economic conditions such as oil prices, which becomes a production incentive for firms. Additionally, community members such as citizens and special interest groups create pressure to reduce the environmental impacts of production.

The innovation process is also fostered by supportive policies from government and research councils. The diffusion of an innovation is dependent upon technology demand as well as end-product demand, each of which shapes existing environmental factors. For example, firm demand for innovative technology reduces GHG emissions and consumer demand for oil and gas products creates further incentives to innovate. The results of Bloomer, Jacoda and Landry (2010) demonstrate that the adoption of THAI by Petrobank fits this framework. Additional factors that facilitated the adoption of THAI include a decline in oil prices (which created pressure to reduce production costs), a grant from the Government of Alberta, a general awareness about the environmental impact of the oil sands, and R&D funding. Despite the success of this diffusion, there were also several inhibiting factors worth noting. First, government support for such innovations is essential and a lengthy government approval process in Alberta delayed the expansion of THAI. Second, Petrobank is a relatively small company and had to make extra efforts to gain project financing.

Source: Bloomer, Jacoda and Landry (2010).

Climate change has also drawn attention to carbon sequestration technology. Natural Resources Canada (2009) notes that research has been done in injecting carbon dioxide into the ground where there are reserves of both natural gas and bitumen such that the carbon dioxide displaces natural gas and maintains a constant pressure level in the reservoir. Not only does this have the potential to increase natural gas and bitumen extraction, but the carbon sequestration ensures that there is a reduced environmental impact. Another project involved demonstrating that more water could be recovered from fluid-fine tailings such that less water waste and pond storage would be required; Syncrude Canada has committed to undertaking a large pilot test.

B. Inputs to Innovation

This section analyzes trends of inputs to innovation in natural resource industries. It first looks at expenditures in research and development. Next, human capital indicators are discussed. This is followed by a discussion of capital formation in the sector. Finally, we look at the contribution of intangible assets to natural resource industries.

i. Research and Development (R&D)

R&D involves the creation of new knowledge and is pivotal to the innovation performance of any industry. R&D activity demonstrates the extent to which natural resource firms are committed to the development of production processes. Three aspects of R&D performance are analyzed in this section: R&D spending, R&D personnel, and the number of firms engaged in R&D activities.

a. R&D Expenditures

R&D expenditure data can be analyzed in several ways. In this report, R&D spending is analyzed using total expenditure as a share of value added, or R&D intensity. R&D expenditure data is available up to 2010. Because of a three-year lag in the release of nominal value added data by industry from Statistics Canada, R&D expenditure as a share of value added only goes up to 2008.

Among natural resource industries, oil and gas extraction spent the most on R&D in 2008 (Table 1), with total expenditure reaching $994 million. This was followed by primary metal manufacturing ($331 million) and fabricated metal manufacturing ($236 million). Industries with lower R&D expenditures included forestry and logging ($6 million), mining industries ($41 million) and non-metallic metals ($60 million).

R&D intensity data (summarized in Table 1) are available for the Canadian natural resources sector, aggregates (forestry product, energy and mining and manufactured minerals), ten industries[12] and the business sector average for the 1974-2008 period inclusive. Chart 3-8 depict the trends in R&D intensity. The most prominent and telling findings are summarized below:

- The natural resources sector had an R&D intensity of 0.93 per cent (Chart 3) in 2008, three quarters of the business sector average (1.25 per cent);

- From 1974 to 2008, business sector R&D intensity more than doubled from 0.56 to 1.25. In contrast[13] R&D intensity for natural resource industries saw less impressive growth during this period, increasing from 0.82 (above the business sector average) to 0.93 (below the business sector average) in 2008. Natural resource sector R&D intensity has been lower than that of the business sector since 1992, with the greatest discrepancy occurring in 2000, when R&D intensities were 1.61 per cent and 0.70 per cent, respectively (Chart 4);

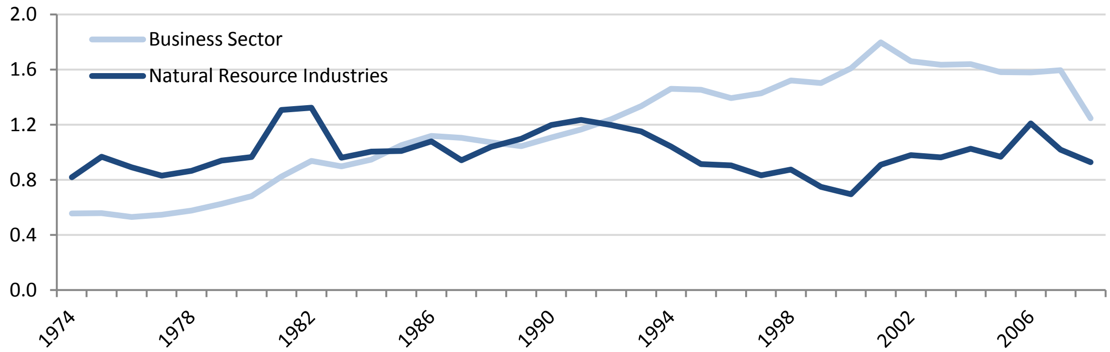
- Of the three natural resource industry aggregates, forest products had the highest R&D intensity in 2008 (1.53 per cent) – reflecting the low value added growth in that sector –, followed by mining and mineral products (1.09 per cent), and energy (0.85 per cent) (Chart 5). Between 1974 and 2008, the R&D intensity of the forest products industry

[12]These ten industries are 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.

[13] Business sector R&D expenditure was divided by business sector nominal GDP, not total economy nominal GDP.

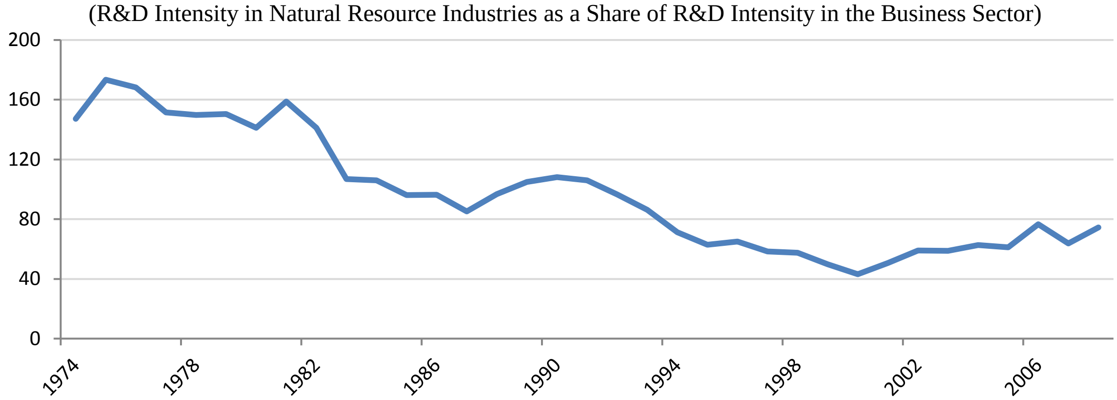
more than triple in forestry than, mining and mineral products was up by about 40.0 per cent, while energy fell by about one third (as the denominator rose faster than the numerator). Note that R&D in the forestry products sector grew slower than in the other two natural resources sectors;

Chart 3: R&D Intensity in Natural Resource Industries in Canada, 1974-2008
(Intramural R&D Expenditure as a Share of NominalValue Added)



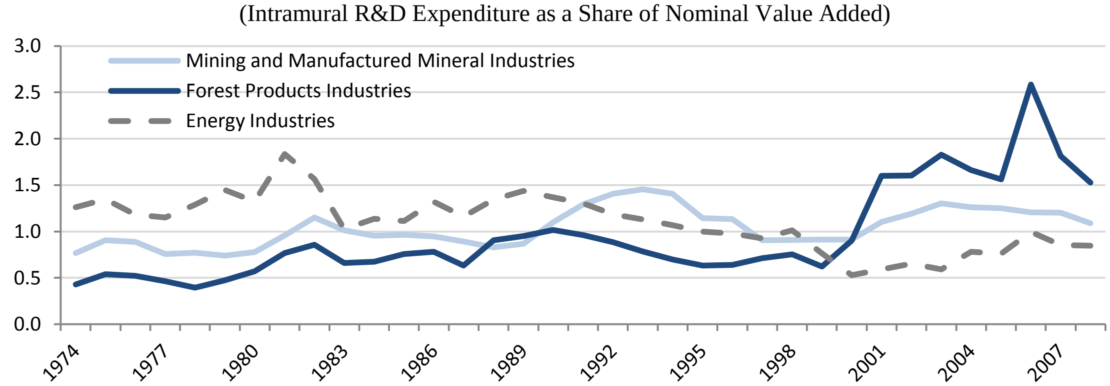
Source: Appendix Table 1a

Chart 4: Relative R&D Intensity in Natural Resource Industries, Canada, 1974-2008
(R&D Intensity in Natural Resource Industries as a Share of R&D Intensity in the Business Sector)



Source: Appendix Table 1a

Chart 5: R&D Intensity in Natural Resource Subsectors in Canada, 1974-2008
(Intramural R&D Expenditure as a Share of Nominal Value Added)



Source: Appendix Table 1a

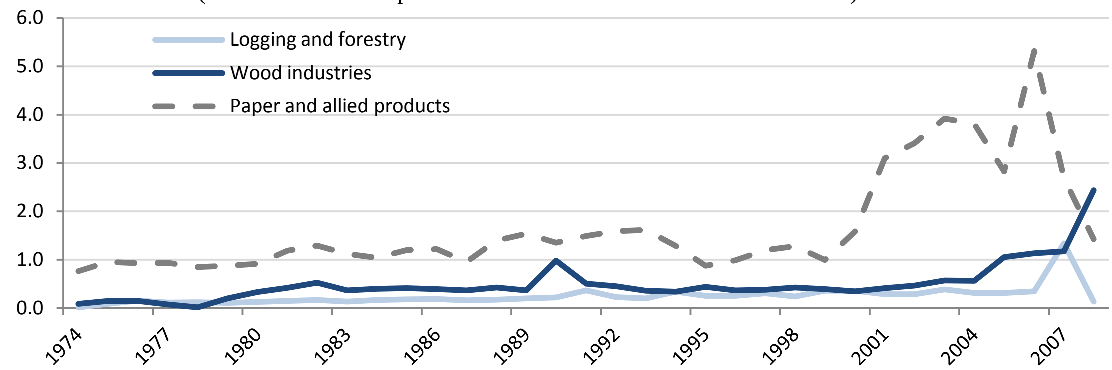
Table 1: Nominal GDP and R&D Intensity for Natural Resources Industries in Canada, 1990 and 2008

	R&D (in millions)				Nominal GDP at Basic Prices (in millions)				R&D Intensity (%)		
	1990	2008	% change	% contribution to change in Business Sector R&D	1990	2008	% change	% contribution to Change in Business Sector GDP	1990	2008	% change
Business Sector Industries	5,169	15,792	205.5	100.0	466,916	1,266,612	171.3	100.0	1.11	1.25	12.6
Natural Resource Industries	931	2,311	148.2	13.0	77,759	249,082	220.3	21.4	1.2	0.93	-22.5
Mining and Manufactured Mineral Industries	308	668	116.8	3.4	28,024	61,435	119.2	4.2	1.1	1.09	-1.1
Mining (except oil and gas)	63	41	-35.4	-0.2	9,562	25,246	164.0	2.0	0.66	0.16	-75.5
Support activities for mining and oil and gas extraction	5	..	..	..	1,968	11,404	479.5	1.2	0.24	..	..
Primary metal manufacturing	185	331	79.0	1.4	6,482	14,864	129.3	1.0	2.85	2.23	-21.9
Fabricated metal product manufacturing	38	236	515.9	1.9	6,589	14,964	127.1	1.0	0.58	1.58	171.2
Non-metallic mineral product manufacturing	17	60	258.4	0.4	3,423	6,361	85.8	0.4	0.49	0.94	92.9
Forest Products Industries	164	334	103.8	1.6	16,155	21,866	35.4	0.7	1.01	1.53	50.6
Forestry and logging	8	6	-20.1	-0.1	3,416	4,528	32.6	0.1	0.22	0.13	-39.7
Wood product manufacturing	42	195	367.9	1.4	4,244	7,996	88.4	0.5	0.98	2.44	148.3
Paper manufacturing	115	133	15.9	0.2	8,495	9,342	10.0	0.1	1.35	1.42	5.4
Energy Industries	459	1,309	185.2	8.0	33,580	154,377	359.7	15.1	1.37	0.85	-38
Electric power generation, transmission and distribution	221	167	-24.5	-0.5	16,369	30,330	85.3	1.7	1.35	0.55	-59.3
Petroleum and coal products manufacturing	181	148	-18.4	-0.3	1,289	5,939	360.7	0.6	14.08	2.49	-82.3
Oil and gas extraction	56	994	1,665.70	8.8	15,922	118,108	641.8	12.8	0.35	0.84	138.0

Note: Although business sector R&D intensity is often calculated as business sector R&D expenditures divided by nominal GDP in the total economy, here, for consistency, it was calculated as business sector R&D expenditures divided by business sector nominal GDP.
Source: Appendix Table 1b

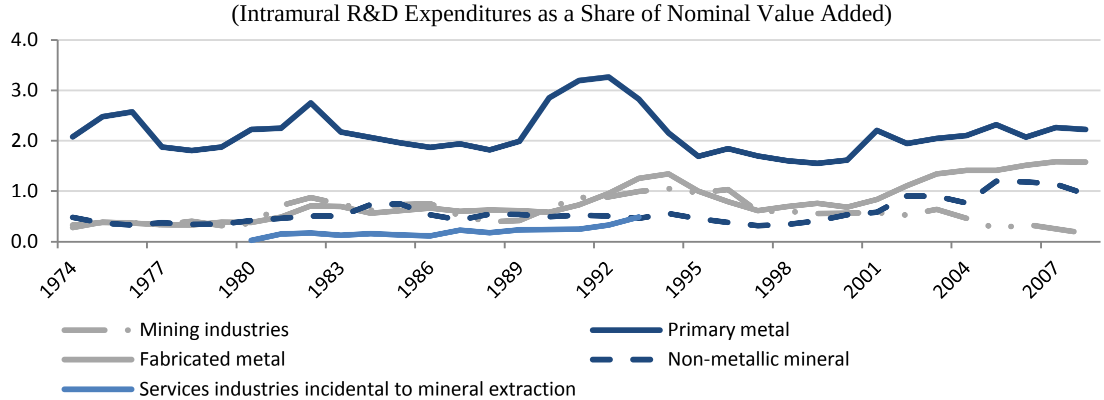
- Of the ten detailed natural resource industries for which estimates are available in 2008 (Charts 6-8), five had a ratio of R&D to value added or R&D intensity above the business sector average: refined petroleum and coal products (2.49 per cent); paper and allied products (1.42 per cent); wood industries (2.44 per cent); fabricated metals (1.58); and primary metal (2.26 per cent). These industries have consistently exhibited above average R&D intensity over the 1974-2008 period;

Chart 6: R&D Intensity in Forest Products Industries in Canada, 1974-2008
(Intramural R&D Expenditures as a Share of Nominal Value Added)



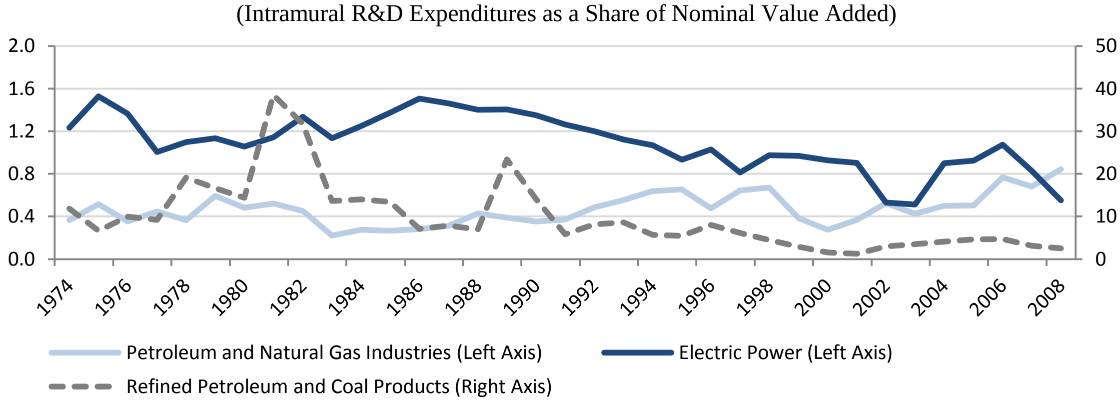
Source: Appendix Table 1a

Chart 7: R&D Intensity in Mining and Mineral Products Industries in Canada, 1974-2008
(Intramural R&D Expenditures as a Share of Nominal Value Added)



Source: Appendix Table 1a

Chart 8: R&D Intensity in Energy Industries in Canada, 1974-2008
(Intramural R&D Expenditures as a Share of Nominal Value Added)



Source: Appendix Table 1a.

- The natural resource industries with below average R&D intensity were: logging and forestry (0.13 per cent), mining (0.16 per cent), electric power (0.55 per cent), petroleum and natural gas industries (0.83 per cent), and non-metallic minerals (0.94 per cent).

- Of the ten detailed natural resource industries, seven experienced an increase in R&D intensity between 1974 and 2008. The largest absolute increase was in wood industries (2.35 percentage points from 0.09 per cent to 2.44 per cent), fabricated metal (1.30 points from 0.28 per cent to 1.58 per cent), followed by paper and allied products (0.65 percentage points from 0.77 per cent to 1.42 per cent), petroleum and natural gas industries (0.47 points from 0.37 per cent to 0.84 per cent), non-metallic minerals (0.46 points from 0.48 per cent to 0.94 per cent), primary metal (0.15 points from 2.08 per cent to 2.23 per cent), and logging and forestry (0.11 points from 0.02 per cent to 0.13 per cent);

- R&D intensity fell in three natural resource industries between 1974 and 2008. The largest decline was in refined petroleum and coal products (down 9.31 points from 11.8 per cent to 2.49 per cent), followed by electric power (down 0.68 points from 1.23 per cent to 0.55 per cent), and mining industries (down 0.17 points from 0.33 per cent to 0.16 per cent).

- The sharp increase in R&D intensity for paper and allied products in the post-1999 period (from 0.99 per cent in 1999 to 2.69 per cent in 2007) largely reflects the substantial decrease in value added in the industry (Chart 6).

Table 2: R&D Intensity in Selected OECD Countries, Natural Resource Industries (R&D expenditures as a share of value added; 2009 or Most Recent Year)

	Industry							
	Mining and Quarrying	Wood and products of wood and cork	Pulp, paper, paper products, printing and publishing	Coke, refined petroleum products and nuclear fuel	Other non-metallic mineral products	Basic metals	Fabricated metal products	Unweighted Average
Country								
Australia	NA	2.0	1.5	5.3	1.9	4.8	1.3	2.8
Canada	NA	0.6	3.8	3.1	0.8	1.7	1.2	1.9
Denmark	NA	1.2	1.0	0.0	0.6	1.6	0.9	0.9
Finland	NA	0.7	1.9	4.8	1.7	1.6	3.1	2.3
France	NA	0.4	0.4	5.6	3.4	3.7	0.9	2.4
Germany	0.4	0.3	0.6	3.5	1.9	1.8	1.2	1.4
Italy	3.5	0.2	0.4	0.8	0.8	1.5	0.6	1.1
Japan	NA	0.9	1.3	0.9	4.2	3.5	2.3	2.2
Korea	0.3	0.5	0.4	1.7	1.7	1.7	1.6	1.1
Norway	0.3	0.8	1.4	NA	1.1	6.2	1.3	1.9
Spain	1.1	0.7	0.7	2.3	0.9	1.1	1.1	1.1
Sweden	NA	0.4	2.3	2.6	2.2	3.7	1.8	2.2
United Kingdom	NA	NA	NA	13.2	0.9	1.4	0.5	4.0
United States	NA	0.9	1.6	1.1	3.8	1.1	1.8	1.7
Average	1.8	1.9	2.1	2.2	1.9	2.0	1.7	1.9
Canada's Rank	NA	8/14	1/14	6/14	12/14	7/14	8/14	7/14

Source: Appendix Table 2a

Table 2 shows estimates of R&D intensity for Canada and selected OECD counterparts for seven natural resource industries. These data are for 2009 or the most recent available year (the furthest back being 2005) and were taken from the OECD STAN database. Canada ranks below average in four of the seven industries: wood and products of wood and cork; other non-metallic minerals; basic metals; and fabricated metal products. Canada ranks first in pulp, paper, paper products, printing and publishing with an intensity of 3.8 per cent versus the industry average of 2.1. Additionally, Canada fares well in coke, refined petroleum products and nuclear fuel with an intensity of 3.1 per cent versus the industry average of 2.2 percent. A comparison of countries (averaging industry performances) reveals that Canada is exactly on par with average R&D intensity across industries (1.9 percent).

b. R&D Personnel

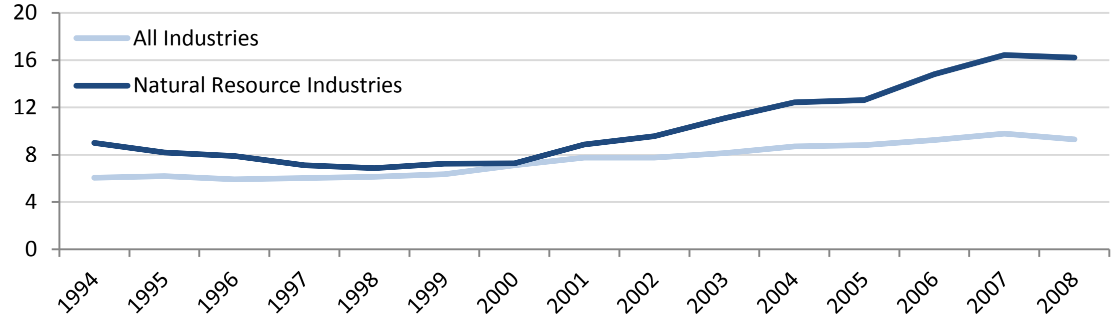
The proportion of the workforce in an industry that is dedicated to R&D, or R&D intensity, is an important indicator of the industry's capacity to innovate (Table 3). Estimates of the number of R&D personnel per 1,000 workers and in absolute terms for natural resource industries in Canada are available for the 1994-2008 period based on recently released Statistics Canada data (Appendix Table 3b). Charts 9 and 10 show the trends. In 2008, there were 14,314 R&D personnel working in natural resource industries in Canada, 9.0 per cent of the all-industries total.

From 1994 to 2008, the proportion of R&D personnel increased from 9.0 to 16.2 per 1,000 workers for natural resource industries (a change of 60 per cent), while increasing from 6.0 to 9.3 per 1,000 workers in all industries (Chart 9). Thus the R&D personnel intensity in the natural resource industries was about 150 per cent at the beginning of the period, and one-and-three-quarters at the end of the period, though the intensity was virtually the same in 2000 (Chart 10).

Within natural resource aggregates (Chart 11), mining and mineral products had the highest R&D personnel intensity in 2008 (22.6 per 1,000 workers). While both above the all industry average (9.3), forest products industries (11.4) and energy industries (10.9) were far below the mining and manufactured mineral industries average. During the 1994-2008 period, mining and manufactured mineral industries experienced the largest increase in R&D personnel per 1,000 workers, with an increase of 7.15 per thousand workers, followed closely by forest products industries with an increase of 6.44 per thousand workers. Energy industries in contrast, actually experienced a decline of 2.85 per thousand workers.

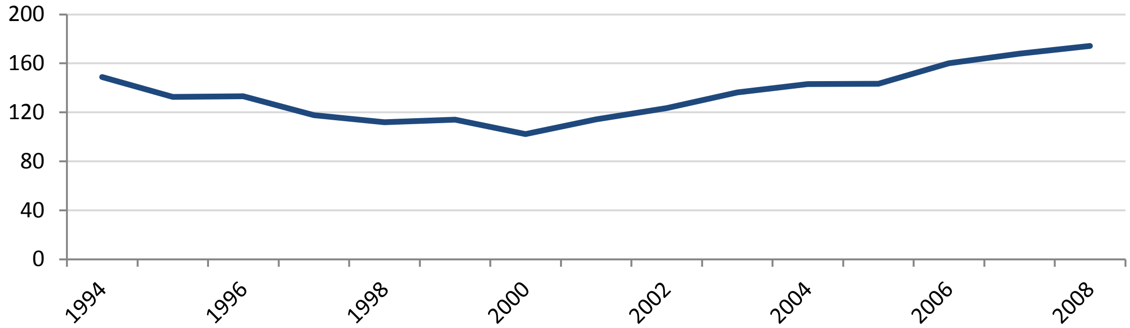
In terms of the ten natural resource industries, fabricated metal product manufacturing had the largest proportion of R&D personnel in total employment (32.9 per 1,000 workers in 2008), followed by non-metallic mineral manufacturing (19.4), primary metal manufacturing (19.3), paper manufacturing (17.8). The importance of R&D personnel in the six other natural resource industries was below the natural resource industries average. Mining and related support activities had the lowest rate (4.1 per 1,000 workers in 2008), followed by forestry, logging and support activities for forestry (4.5), wood product manufacturing (9.9), oil & gas extraction contract drilling and related services (12.5), and petroleum and coal manufacturing (15.3).

Chart 9: R&D Personnel Intensity in Natural Resource Industries in Canada, 1994-2008
(R&D Personnel per Thousand Workers)



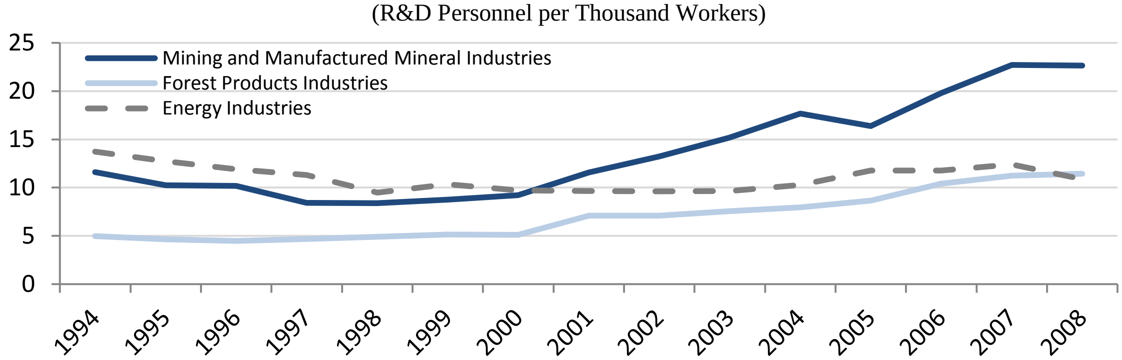
Source: Appendix Table 3a

Chart 10: Relative R&D Personnel Intensity in Natural Resource Industries in Canada, 1994-2008
(R&D personnel intensity in natural resources industries as a share of R&D personnel intensity in the business sector)



Source: Appendix Table 3a

Chart 11: R&D Personnel Intensity in Natural Resources Subsectors in Canada, 1994-2008
(R&D Personnel per Thousand Workers)



Source: Appendix Table 3a

Estimates are available from the OECD's STAN database of R&D workers in seven natural resource industries for 11 selected countries. Using employment share data from the same database and overall employment figures, R&D personnel intensity can be calculated for selected OECD countries. These intensities are shown in Tables 3 and 4. Canada fares relatively well in some industries (agriculture, hunting and forestry; wood and products of wood and cork; and fabricated metal products) and poor in others (coke, refined petroleum products and nuclear fuel; and basic metals). Canada's performance is approximately average in mining and quarrying, and non-metallic mineral products. Canada's average performance across industries (13.2 per cent) is slightly above the average of all countries (12.3 per cent).

Table 3: R&D Personnel, Employment and R&D Personnel Intensity for Natural Resources Industries in Canada, 1990 and 2008

	R&D Personnel (Persons)				Employment (Thousands of Persons)				R&D Personnel Intensity (number of R&D personnel per thousand workers)		
	1990	2008	% change	% contribution to change in Business Sector	1990	2008	% change	% contribution to change in Business Sector	1990	2008	% change
Business Sector Industries	78,883	158,926	101.5	100.0	13,059	17,087	30.9	100.0	6.0	9.3	54.0
Natural Resource Industries	7,912	14,314	80.9	4.2	880	883	0.3	0.1	9.0	16.2	80.3
Mining and Manufactured Mineral Industries	3,961	8,766	121.3	3.1	341	387	13.5	1.1	11.6	22.6	94.9
Mining (except oil and gas)	683	298	-56.4	-0.2	69	73	5.6	0.1	9.8	4.1	-58.7
Primary metal manufacturing	1,510	1,499	-0.7	0.0	98	78	-20.9	-0.5	15.4	19.3	25.5
Fabricated metal product manufacturing	1,497	5,852	290.9	2.8	122	177	45.1	1.4	12.3	33.0	169.4
Non-metallic mineral product manufacturing	271	1,144	322.1	0.6	51	59	15.0	0.2	5.3	19.4	267.0
Forest Products Industries	1,671	3,129	87.3	0.9	335	274	-18.3	-1.5	5.0	11.4	129.2
Forestry and logging	165	245	48.5	0.1	84	54	-35.2	-0.7	2.0	4.5	129.3
Wood product manufacturing	447	1,269	183.9	0.5	127	128	1.3	0.0	3.5	9.9	180.4
Paper manufacturing	1,059	1,615	52.5	0.4	124	91	-26.8	-0.8	8.5	17.8	108.4
Energy Industries	2,280	2,419	6.1	0.1	166	222	33.9	1.4	13.7	10.9	-20.8
Electric power generation, transmission and distribution	1,296	1,029	-20.6	-0.2	99	116	17.0	0.4	13.1	8.9	-32.2
Petroleum and coal products manufacturing	480	292	-39.2	-0.1	17	19	15.8	0.1	29.1	15.3	-47.4
Oil and gas extraction	504	1,098	117.9	0.4	51	88	72.5	0.9	9.9	12.5	26.3

Note: Includes researchers, technicians, and support staff.
Source: Appendix Table 3a

Table 4: R&D Personnel Intensity in Natural Resources Industries in Selected OECD Countries, 2008 or most recent year

(R&D personnel per thousand workers)

	Industry									
	Agriculture, hunting and forestry	Mining and Quarrying	Wood and products of wood and cork	Pulp, paper and paper products	Coke, refined petroleum products and nuclear fuel	Other non-metallic mineral products	Basic metals	Fabricated metal products	Unweighted Average	Overall Ranking
Country										
Canada	4.4	6.1	8.4	17.7	15.9	15.1	14.0	24.2	13.2	4
Finland	0.0	8.1	3.9	23.7	NA	12.7	24.2	5.5	11.2	5
France	4.1	NA	16.4	8.4	55.2	18.0	24.4	6.1	18.9	2
Germany	1.4	2.3	1.7	4.4	17.9	9.5	13.4	7.0	7.2	8
Italy	0.0	20.3	1.6	6.6	4.6	4.8	8.7	4.2	6.4	9
Japan	0.4	10.3	5.1	19.8	77.4	24.2	32.9	7.0	22.1	1
Korea	0.1	3.6	NA	1.3	NA	8.9	7.8	4.8	4.4	11
Norway	2.8	17.3	3.8	29.0	NA	5.8	27.2	8.9	13.5	3
Spain	1.2	3.5	2.1	4.8	50.3	5.8	6.4	6.1	10.0	6
Sweden	1.3	1.3	1.1	23.2	7.5	5.2	31.1	5.1	9.5	7
United Kingdom	2.9	7.1	NA	NA	NA	7.7	NA	NA	5.9	10
Unweighted Average	1.7	8.0	4.9	13.9	32.7	10.7	19.0	7.9	12.3	
Canada's Ranking	1/11	5/11	2/11	5/11	5/11	3/11	6/11	1/11		

Source: Appendix Table 6a

ii. Skills in Natural Resource Industries

Estimates of educational attainment in Canada for natural resource industries as well as the all-industries total are available from Statistics Canada's Labour Force Survey. Relevant measures include 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 education.

As noted previously, the educational characteristics of the natural resource sector's labour force is but one cog in the overarching innovation system of a country/sector. That being said, educational indicators are important for several reasons. First, the educational quality of the labour force affects not only productivity but also potential quality of R&D. Second, if firms in natural resource industries are to implement new technologies, a skilled labour force is essential. Third, regardless of whether R&D takes place in the field or the laboratory, natural resource industries are dependent upon highly-educated individuals to keep management abreast of technologies which may become firm or industry-first innovations in the future.

a. Educational Attainment

Data on educational attainment are available by natural resource industries and the all-industries average in Canada for the 1976 to 2010 period.[14] Charts 12-14 depict the average years of schooling for natural resource industries, Charts 15-20 demonstrate the specific educational attainment levels for natural resource industries in terms of high school, university or post-secondary education. Estimates on average years of schooling across natural resource industries in Canada are summarized in Table 5.

Historically, workers in natural resource industries have been below the all-industries average education level (Chart 12). In 2010, workers in the natural resources sector had, on average, 13.3 years of schooling, while workers in all industries had, on average, 14.0 years of schooling. The average annual growth rate of educational attainment in natural resource industries was higher than that of all industries from 1990-2010, at 0.44 per cent versus 0.39 per cent.

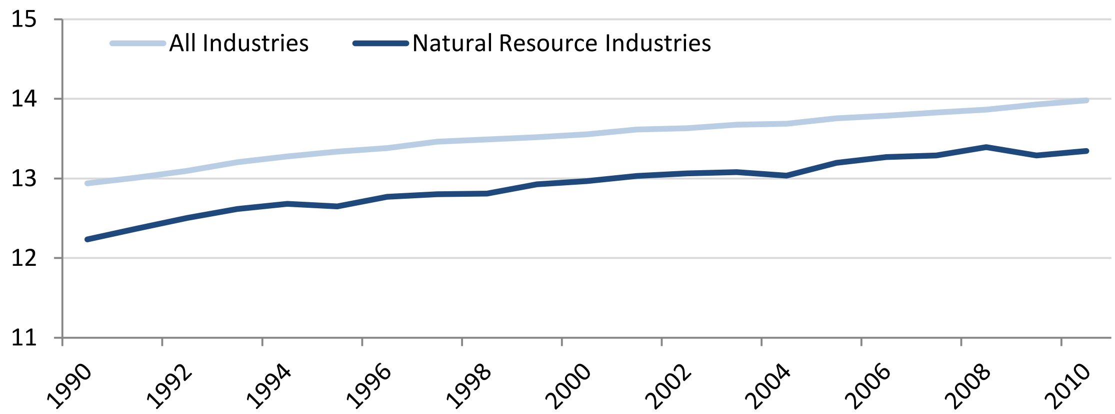
[14] Time profiles in this report only go as far back as 1990, as LFS educational attainment data from 1976 to 1990 are inconsistent with post-1990 data. Sharpe and Guilbaud (2005) previously analyzed data back to 1976.

Table 5: Average Years of Schooling of Workers in Natural Resource Industries, Canada, 1990 and 2010

	Average Years of Educational Attainment			% All Industries		
	1990	2010	% change	1990	2010	% change
	1	2	(3)=[(2)/(1)-1]*100	(4)=(1)/12.94	(5)=(2)/13.98	(6)=[(5)/(4)-1]*100
Mining	12.24	13.34	9.05	94.6	95.4	0.93
Mining (except Oil and Gas)	12.05	13.44	11.51	93.1	96.1	3.21
Support Activities for Mining & Oil & Gas Extraction	12.21	13.34	9.25	94.4	95.4	1.11
Non-Metallic Mineral Manufacturing	12.00	12.78	6.50	92.7	91.4	-1.43
Primary Metal Manufacturing	12.41	13.49	8.69	95.9	96.5	0.60
Fabricated Metal Product Manufacturing	12.30	13.41	9.01	95.1	95.9	0.90
Forestry	12.01	12.91	7.48	92.8	92.3	-0.52
Forestry and Logging	10.89	12.50	14.84	84.1	89.4	6.29
Support Activities for Forestry	12.36	11.80	-4.53	95.5	84.4	-11.64
Wood Product Manufacturing	11.93	12.78	7.14	92.2	91.4	-0.84
Paper Manufacturing	12.46	13.58	9.00	96.3	97.2	0.89
Energy	13.39	14.36	7.29	103.5	102.7	-0.70
Electric Power Generation, Transmission & Distribution	13.69	14.57	6.46	105.8	104.3	-1.47
Petroleum and Coal Manufacturing	12.69	13.87	9.33	98.1	99.2	1.19
Oil & Gas Extraction	13.88	14.47	4.23	107.3	103.5	-3.53
Natural Resources	12.24	13.34	9.05	94.6	95.4	0.93
All Industries	12.94	13.98	8.04	100.0	100.0	0.00

Source: Appendix Table 6a.

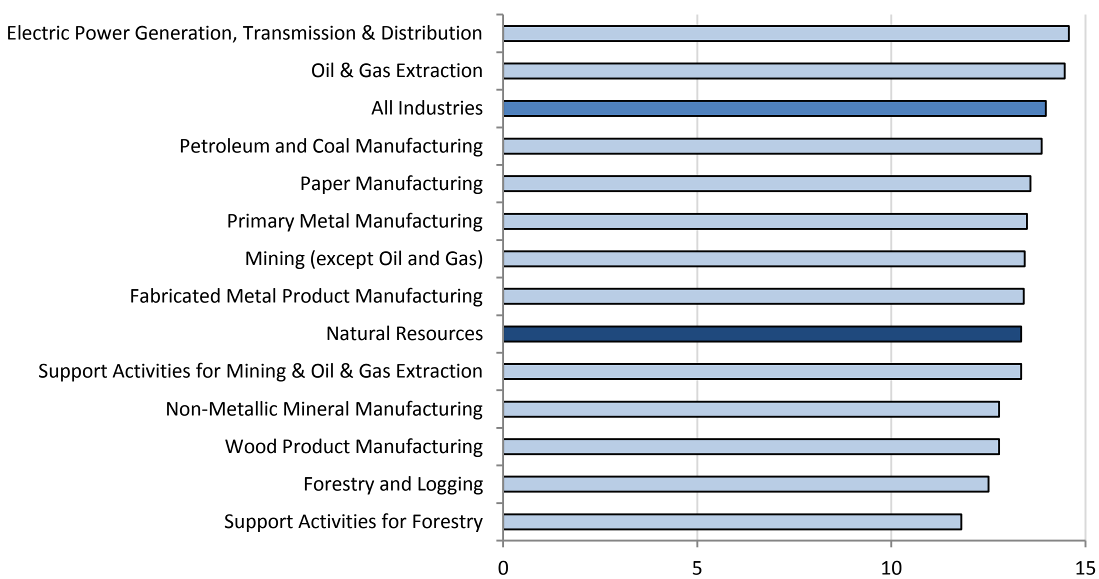
Chart 12: Average Years of Schooling in Natural Resource Industries, Canada, 1990-2010



Source: Appendix Table 6a

In 2010, the workers in the majority of natural resource industries averaged fewer years of education than most industries (Chart 13). Only oil and gas extraction and electric power generation, transmission and distribution fare better than the average for all industries.

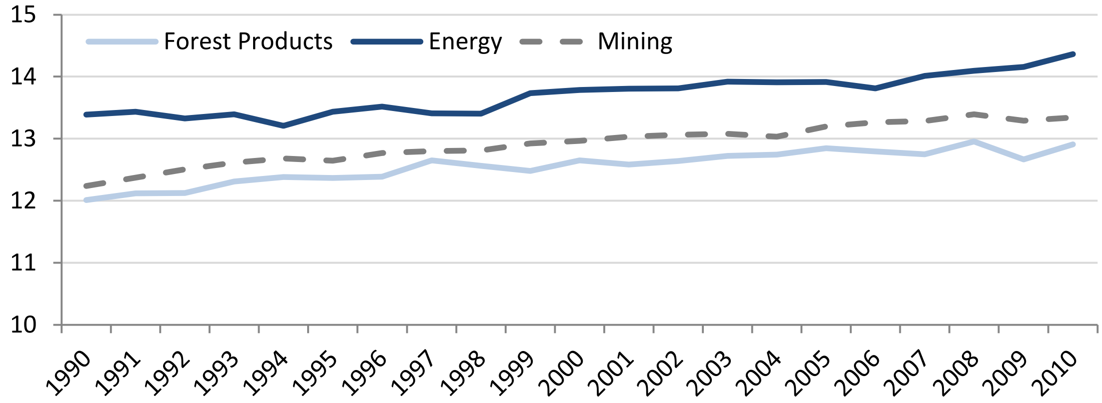
Chart 13: Average Years of Schooling, Natural Resource Industries, Canada, 2010



Source: Appendix Table 6a

A comparison of the levels of average years of schooling across natural resource industries (Chart 14) demonstrates that the energy sector has traditionally been a leader in this regard, outperforming both the forest products and mining and manufactured metals industries as well as the all-industries average. Despite this, average years of schooling in energy industries averaged annual growth of only 0.36 per cent, slightly below that of all industries. Average years of schooling in mining and manufactured minerals saw average annual growth of 0.44 percent during this period, which was higher than the all-industries average.

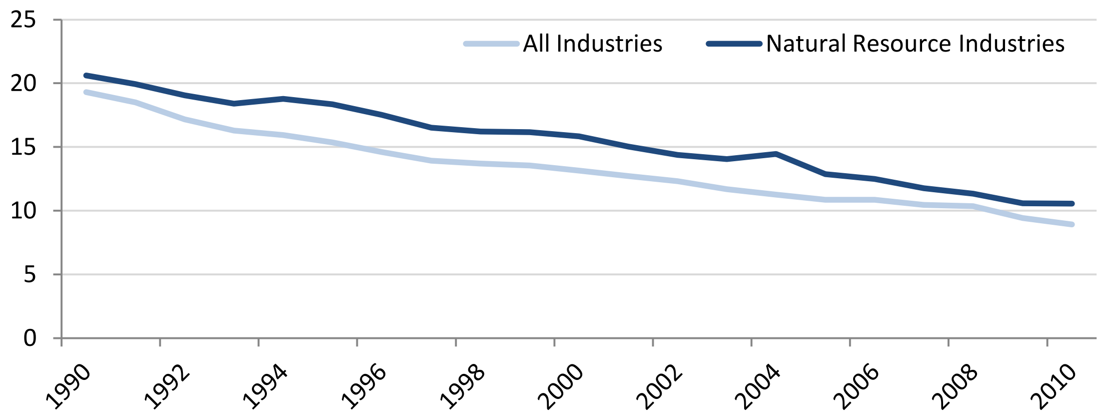
Chart 14: Average Years of Schooling in Main Natural Resource Sectors, Canada, 1990-2010



Source: Appendix Table 6a

Chart 15 depicts the trend of the proportion of workers in natural resource industries with less than a high school diploma, compared to the all-industries average. Historically, many jobs within the natural resources industry—contract logging or other support services, for instance—did not require a high school diploma. In 1990, natural resource industries had a larger proportion of workers with less than a high school diploma than the all-industries average, 20.6 per cent versus 19.3 per cent. The proportion of workers with less than a high school diploma has fallen substantially in natural resource industries (and for the all-industries average) since 1990, with the 2010 figures being 10.60 per cent and 8.92 per cent, respectively. The fact that this gap has slightly increased over time suggests natural resource industries have drifted slightly from other Canadian industries in terms of acquiring skilled workers.

Chart 15: Percentage of Workers with Less than High School Diploma in Natural Resources, Canada, 1990-2010



Source: Appendix Table 6c

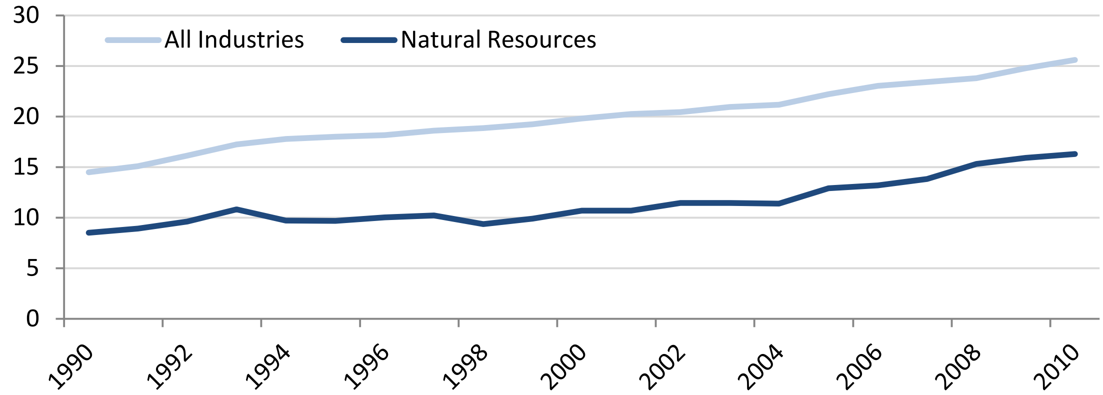
Charts 16-19 report the proportion of workers with post-secondary education in natural resource industries. Indicators used are the proportion of workers with a university degree and the proportion of workers with a university degree or post-secondary diploma. The salient findings are:

- The proportion of workers in natural resource industries with a university degree has almost doubled from 8.5 per cent in 1990 to 16.3 per cent in 2010 but it is still well below the all industries average, which rose over this same period from 14.5 to 25.6 per cent (Chart 16). The all-industries average grew at an annual rate of 2.9 percent (vs. 3.3 per cent per year in the natural resources sector). Despite this faster growth, the gap between the natural resource sector and the all-industries average has increased from 6.0 percentage points to 9.8 percentage points;

- Relative to the all-industries average, the proportion of workers with a university degree in the natural resources sector has grown between 1990 and 2010 (Chart 17), increasing from 59.2 per cent to 63.6 per cent;

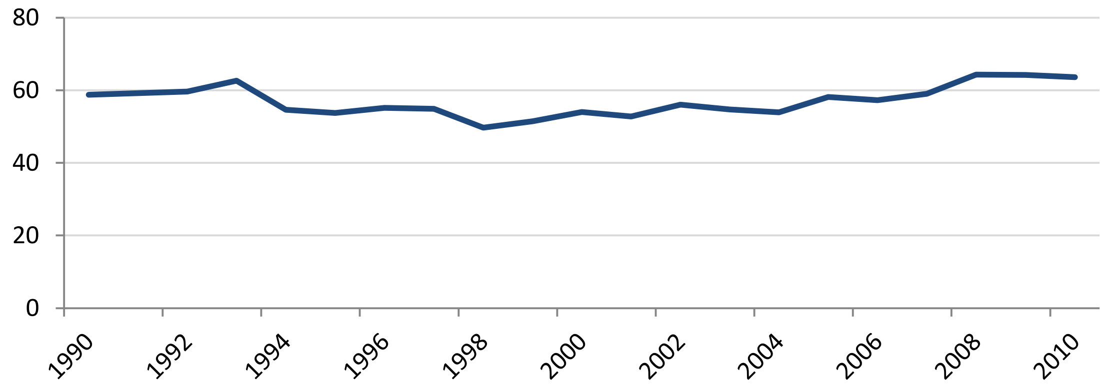
- The percentage of workers in energy industries with a university degree is higher than the all-industries average (Chart 16) and significantly higher than that of the forest products and mining and manufactured metals industries (Chart 18). In 2010, these figures were 29.7 per cent and 25.6 per cent for energy products and the all-industries average, respectively. Of workers in the forest products and mining and manufactured metals industries, 11.8 and 11.4 per cent (respectively) had university degrees;

Chart 16: Percentage of Workers with a University Degree in Natural Resources Industries, Canada, 1990-2010



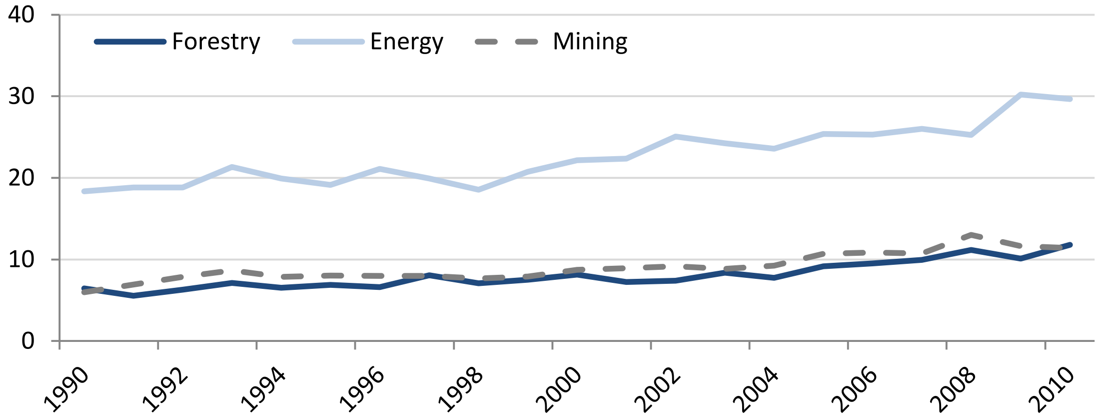
Source: Appendix Table 6b

Chart 17: Proportion of Workers with a University Degree in Natural Resource Industries, as a Proportion of Total Economy Canada 1990-2010



Source: Appendix Table 6b

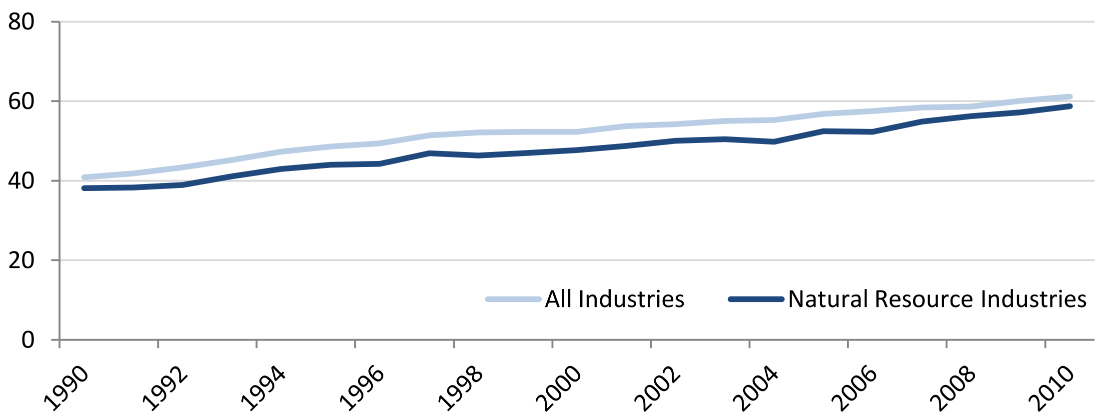
Chart 18: Percentage of Workers with a University Degree in Natural Resource Industries, Canada, 1990-2010



Source: Appendix Table 6b

- When non-university post-secondary education programs are reflected, the gap between the natural resources sector and the all-industries average greatly diminishes (Chart 19). This gap was only 2.3 percentage points in 2010. it is likely that this reflects the increased effort of non-university post-secondary institutions establishing programs to address the needs of the natural resources sector;

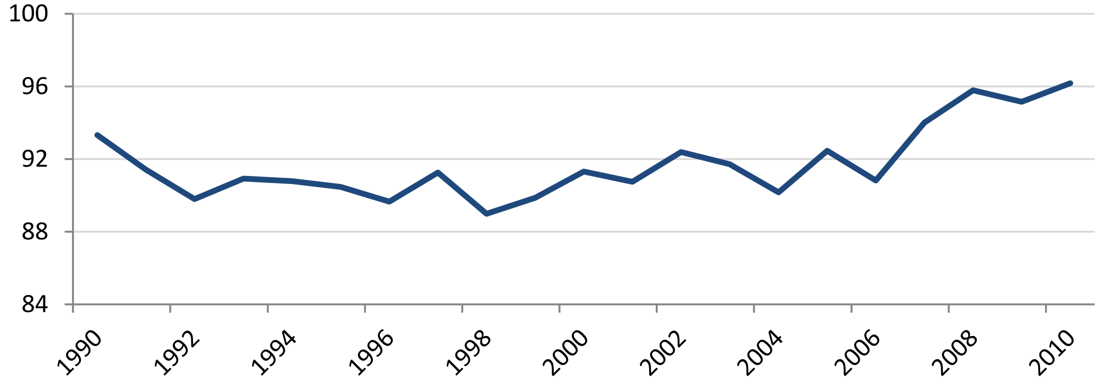
Chart 19: Percentage of Workers with a University Degree or Post-Secondary Diploma in Natural Resource Industries, Canada, 1990-2010



Source: Appendix Table 6d

- Relative to the total economy, the proportion of workers with a university degree or post-secondary diploma in natural resource industries has increased substantially from 93.3 per cent to 96.2 percent of the all-industries average over the 1990-2010 period (Chart 20). Though this is a positive sign, the sector still lags.

Chart 20: Proportion of Workers with a University Degree or Post-Secondary Diploma in Natural-Resource Industries, as a Share of Total Economy, Canada, 1990-2010



Source: Appendix Table 6d

b. Post-secondary graduates

Natural resource industries, like all industries, require a growing supply of post-secondary graduates both to undertake R&D and to effectively use new machinery and equipment, including ICT. Canadian post-secondary institutions have greatly increased the number of graduates in recent years, especially in programs that have relevance for natural resource industries (Appendix Table 24a and 24b).

In 2008, Canadian universities granted degrees, diplomas or certificates to 244,380 persons, up 44.7 per cent from 168,870 in 1992 and 38.4 per cent from 176,556 in 2000. The growth was particularly impressive at the graduate level, with a 88.6 per cent increase in graduates at the master's level and a 77.9 per cent rise in graduates at the doctorate level between 1992 and 2008.

The program area most relevant for natural resource industries is agriculture, natural resources and related technologies. The number of graduates in this program area rose 77.8 per cent from 2,283 in 1992 to 4,059 in 2008, with a 90.2 per cent rise at the graduate level. However, the number of graduates in this area is limited.

The number of graduates in two other program areas related to the education and skill requirements of natural resource industries – architecture, engineering, and related technologies and physical and life sciences and technologies – also have experienced above-average growth. The number of graduates in the first program area rose 69.3 per cent from 11,895 in 1992 to 20,142 in 2008 while the number in the second program area advanced 61.5 per cent from 11.535 in 1992 to 18, 627 in 2008. The absolute number of graduates in each of these program areas is four times that of the number of graduates in agriculture, natural resources and conservation programs.

In 2008, Canadian colleges granted degrees, diplomas or certificates to 159,444 persons, up a very impressive 137.8 per cent from 67,062 in 1992 and 12.7 per cent from 141,426 in 2000. The number of graduates in agricultural natural resources and conservation rose 78.3 per cent from 1,536 in 1992 to 2,739 in 2008, representing around 2 per cent of total graduates. The number of college graduates in architecture, engineering and related technologies rose 99.0 per cent from 10,752 in 1992 to 21,396 in 2008, and accounted for 13 per cent of graduates that year. The number of college graduates in physical and life sciences and technologies increased only 5.0 per cent from 954 in 1992 to 1,002 in 2008.

Overall Canada's post-secondary education system has performed well in producing graduates with the training and skills relevant for positions in natural resources industries. There appears to be no general supply-side constraints on the human capital needed for innovation in the sector.

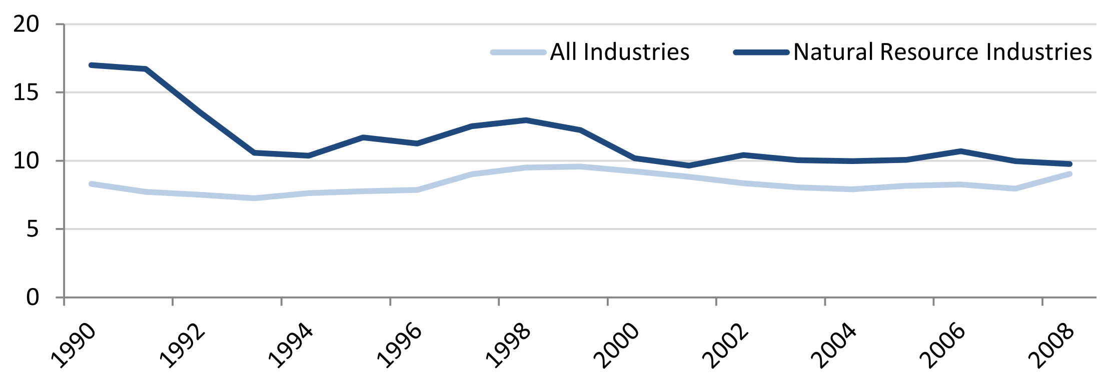
iii. Investment and Capital Stock in Natural Resource Industries

Investment and capital stock, which includes both ICT and non-ICT components, is an essential indicator of innovative capacity. Because a great deal of innovation in natural resource industries is related to adopting leading-edge capital goods which improve the efficiency of the production process, or mitigate environmental damage, M&E investment is particularly relevant for evaluating the innovation performance of the natural resources sector. A higher level of M&E investment suggests that firms in an industry are more likely to be "up to date" as far as innovative technologies are concerned.

a. Total M&E Investment

Estimates of nominal and real M&E investment are available up to 2010. Nominal value added for thirteen natural resource industries, three natural resource aggregates, all natural resource industries and all industries are available from 1961 to 2008 inclusive. M&E investment as a share of nominal value added or the M&E investment rate is thus available from 1961-2008, inclusive (a 1990-2008 summary is shown in Table 6). While the M&E investment rate average for all-industries has remained steady around 8 percent historically, the M&E investment rate for the natural resources sector has typically been impressively higher (Chart 21). In 1990, natural resources sector M&E investment amounted to approximately 17 per cent of value added. While this proportion has since declined, M&E investment comprised approximately 10 per cent of value added in 2008.

Chart 21: Machinery and Equipment Investment as a Proportion of Nominal Value Added in Natural Resource Industries in Canada, 1990-2008



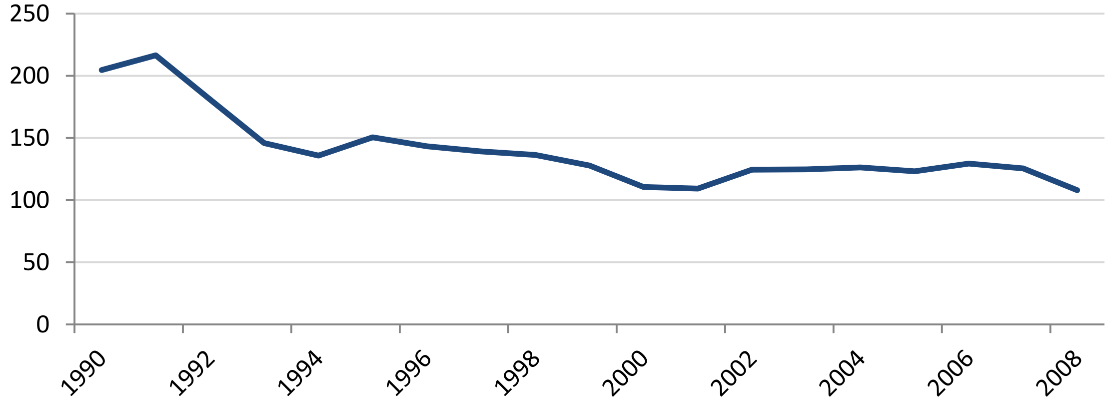
Source: Appendix Table 10a

Table 6: Machinery and Equipment Investment as a Share of Nominal Value Added in Natural Resource Industries in Canada, 1990 and 2008

	Nominal M&E Investment				Share of Value Added			% All Industries		
	1990	2008	% Change	% contribution to change in All Industries	1990	2008	% change	1990	2008	% change
Total all industries	52,418	114,915	119.2	100.0	8.3	9.03	8.8	100.0	100.0	0.0
Natural resources	13,381	23,565	76.1	16.3	16.99	9.75	-42.6	204.6	108.0	-47.2
Mining	3,405	8,276	143.1	7.8	12.15	13.64	12.2	146.4	151.0	3.2
Mining (except oil and gas)	717	2,789	289.0	3.3	7.5	11.11	48.2	90.3	123.0	36.2
Support activities for mining and oil and gas extraction	43	2,597	5,911.3	4.1	2.2	23.3	961.3	26.4	257.9	875.4
Non-metallic mineral product manufacturing	488	627	28.6	0.2	14.26	9.96	-30.1	171.7	110.3	-35.8
Primary metal manufacturing	1,908	1,552	-18.6	-0.6	29.44	10.56	-64.1	354.6	116.9	-67.0
Fabricated metal product manufacturing.	249	711	185.8	0.7	3.78	4.77	26.2	45.5	52.8	16.0
Forest products	4,433	1,935	-56.3	-4.0	27.44	9.01	-67.2	330.5	99.7	-69.8
Forestry and logging	128	181	42.0	0.1	3.74	4.07	9	45.0	45.1	0.1
Wood product manufacturing	657	712	8.2	0.1	15.49	9.05	-41.6	186.6	100.2	-46.3
Paper manufacturing	3,648	1,042	-71.4	-4.2	42.94	11.37	-73.5	517.3	125.8	-75.7
Energy Industries	5,542	13,353	140.9	12.5	16.06	9.03	-43.8	193.4	100.0	-48.3
Electric Power	4,551	3,745	-17.7	-1.3	27.8	12.44	-55.3	334.9	137.7	-58.9
Petroleum and coal products manufacturing	371	2,628	608.2	3.6	28.79	45.22	57.1	346.8	500.7	44.4
Oil and gas extraction	309	6,373	1,959.9	9.7	1.94	5.55	185.5	23.4	61.4	162.4
Pipeline Transport	311	607	95.4	0.5	13.31	..	..	160.3	..	..

Source: Table 10a

Chart 22: M&E Investment Share of Value Added in Natural Resource Industries, as a Proportion of Total Economy, in Canada, 1990-2008



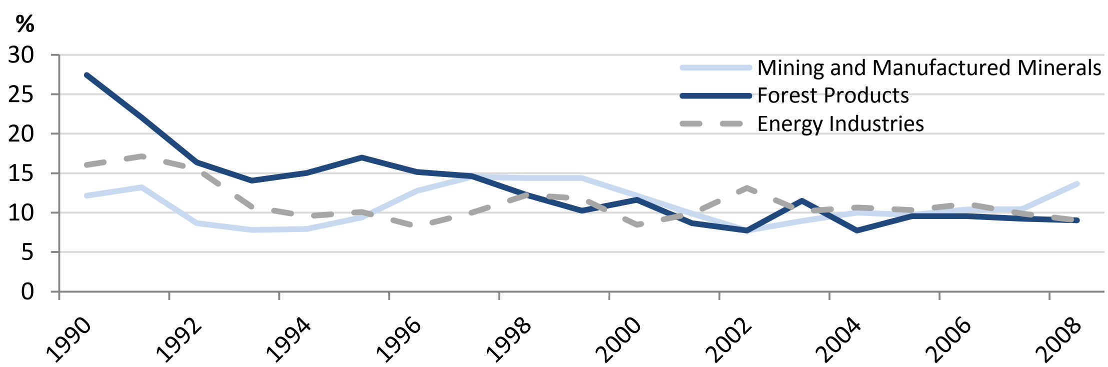
Source: Appendix Table 10a

Mining and manufactured metals saw an increase in M&E investment from 12.2 per cent in 1990 to 13.6 percent of value added in 2008. For energy industries, the M&E investment rate fell from 16.1 per cent in 1990 to 9.0 per cent in 2008. The forest products industry saw the largest proportional decline in its M&E investment rate between 1990 and 2008. M&E investment as a share of value added for the Canadian forest sector fell from an impressive 27.4 per cent to 9.0 per cent. Despite the persistent decline of the M&E investment rates in each natural resource industry, in 2008 all three industries were individually higher than the all-industries average.

b. M&E Capital Intensity

M&E capital stock data (in both current and constant prices) are available from Statistics Canada for the period 1955 to 2010, inclusive, for ten natural resource industries, three industry aggregates, natural resource industries as a whole and the total for all industries. In 2010, M&E comprised 16.5 per cent of the capital stock for natural resource industries, compared to 22.4 per cent for all industries (Chart 23 and Appendix Table 10). This is understandable, as the majority of capital investment in natural industries reflects structures.

Chart 23: Machinery and Equipment Investment as a Share of Nominal Value Added in Natural Resource Industries in Canada, 1990-2008

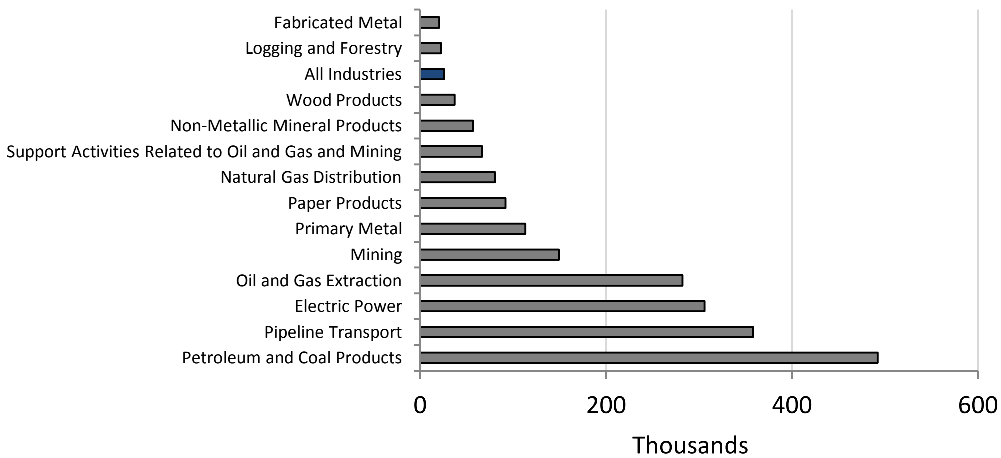


Source: Appendix Table 10a

M&E intensity is defined as the M&E capital stock per worker in an industry. Estimates are available for thirteen natural resource industries, three natural resource aggregates, the natural resources sector and all industries in Canada from 1987 through 2010. At the level of natural resource aggregates, the capital-intensiveness of natural resource industries is clear, as the M&E intensities for mining and manufactured mineral products, forest products and energy were $69,128, $53,869 and $298,285 per worker, respectively, whereas the average M&E intensity for all industries was $25,826 per worker (Table 7).

The level of capital intensiveness for natural resource industries varies tremendously, ranging from $20,751 dollars per worker in fabricated metal product manufacturing to $492,429 per worker in petroleum and coal products manufacturing (Chart 24). The majority of natural resource industries had higher capital intensity than the all industries average for this indicator. In some cases, natural resource industries outperformed the all industries average by a factor of more than ten. These include petroleum and coal products (19.1 times), pipeline transport (13.9 times), electric power (11.9 times) and oil and gas extraction (10.9 times).

Chart 24: M&E Capital Intensity, Natural Resources, Canada, 2010



Source: Appendix Table 10c

Fabricated metal product manufacturing and logging and forestry had lower M&E intensities than the all-industries average ($22,959 and $20,751 per worker, respectively). This reflects the fact that these industries are less capital intensive than their natural resource industry counterparts. Fabricated metal products, for example, has the largest number of workers in natural resource industries (Appendix Table 3) despite having below average value-added for natural resource industries (Appendix Table 1).

Table 7: M&E Capital Intensity (M&E capital stock/employment), 1990 and 2010 (chained 2002 dollars)

	M&E Capital Stock per worker			% All Industries		
	1990	2010	% change	1990	2010	% change
	1	2	(3)=[(2)/(1)-1]*100	(4)=(1)/18,750	(5)=(2)/25,826	(6)=[(5)/(4)-1]*100
Mining	46,562	69,128	48.5	248.3	267.7	7.8
Mining (except oil and gas)	53,901	149,628	177.6	287.5	579.4	101.5
Support activities for mining and oil and gas extraction	12,092	67,098	454.9	64.5	259.8	302.9
Non-metallic mineral product manufacturing	42,542	57,169	34.4	226.9	221.4	-2.4
Primary metal manufacturing	87,205	113,302	29.9	465.1	438.7	-5.7
Fabricated metal product manufacturing	16,747	20,751	23.9	89.3	80.3	-10.0
Forest products	82,318	53,869	-34.6	439.0	208.6	-52.5
Forestry and logging	12,897	22,959	78.0	68.8	88.9	29.2
Wood product manufacturing	37,584	37,449	-0.4	200.5	145.0	-27.7
Paper manufacturing.	147,985	92,102	-37.8	789.3	356.6	-54.8
Energy Industries	251,746	298,285	18.5	1,342.7	1,155.0	-14.0
Electric Power	390,520	306,086	-21.6	2,082.8	1,185.2	-43.1
Petroleum and coal products manufacturing	75,917	492,429	548.6	404.9	1,906.7	370.9
Oil and gas extraction	94,142	282,527	200.1	502.1	1,094.0	117.9
Pipeline Transport	172,819	358,492	107.4	921.7	1,388.1	50.6
Natural resources	100,630	129,704	28.9	536.7	502.2	-6.4
Total all industries	18,750	25,826	37.7	100.0	100.0	0.0

Source: Appendix Table 10c

Box 4: The Impact of Depreciation Rates on Measured Capital Intensity

Official estimates from Statistics Canada and the US Bureau of Economic Analysis (BEA) show that the level of capital intensity in Canada is below that of the United States, both at the business sector level and for natural resource industries. Appendix Table 5, based on Tang, Rao and Li (2011), shows that, using national depreciation rates (i.e. Statistics Canada rates for Canada and BEA rates for the United States), business sector capital intensity in Canada in 2007 was 67.1 per cent of the US level and that all natural resources industries in Canada were below the US level, many of them well below.

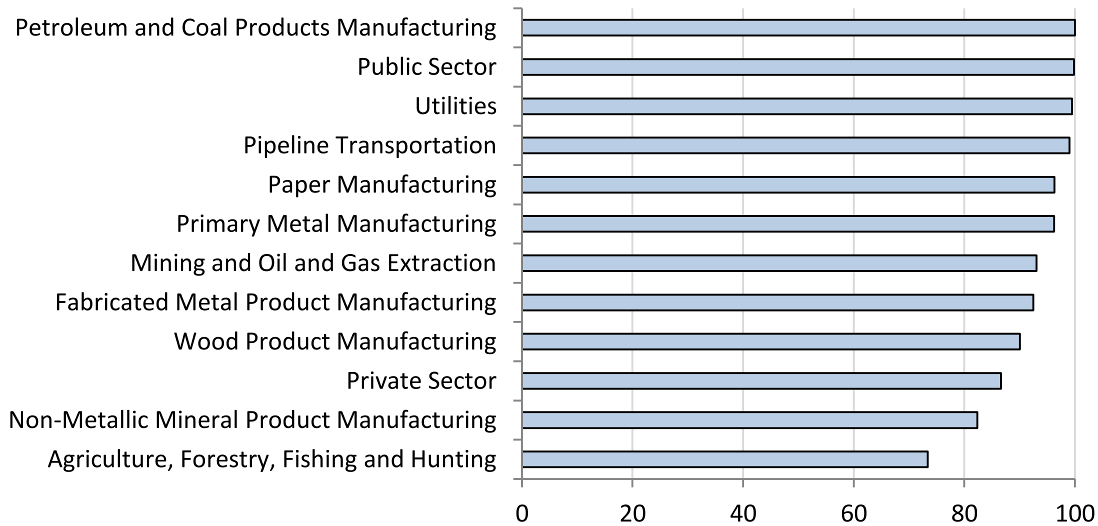
But as explained in Tang, Rao and Li (2011), Statistics Canada and the Bureau of Economic Analysis uses different depreciation rates, with Canada's rates higher for all asset classes. This means that, strictly speaking, the official capital stock estimates based on national depreciation rates are not comparable. When Tang, Rao and Li (2011) simulate what relative capital intensity would be when the same depreciation rates are used in the two countries, they find that Canada's capital intensity increases markedly relative to the United States. Business sector capital intensity rises to 113.1 per cent of the US level when Statistics Canada depreciation rates are used in both countries and to 109.1 per cent when BEA rates are used. All natural resource industries have much higher levels of capital intensity relative to their American counterparts when the same depreciation rates are used in the two countries (Appendix Table 5). Indeed, when the Statistics Canada rates are used, six of the nine natural resources industries in 2007 had higher capital intensity in Canada than in the United States.

Source: Tang, Rao and Li (2011).

c. Internet Use

Internet usage, in particular, is an important determinant of firm success. Internet usage data are available from Statistics Canada for ten natural resource industries for the period 2000 to 2007.[15] Internet usage in 2007 for natural resource firms is compared to the public and private sector averages in Chart 25 and Chart 26. The most striking observations are summarized below:

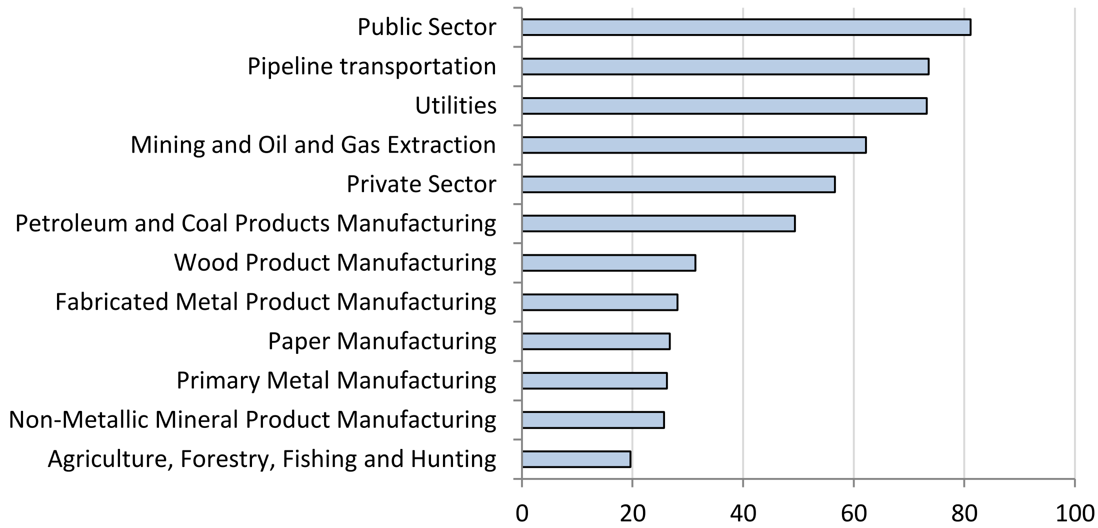
Chart 25: Internet Use in Natural Resource Industries in Canada, per cent of firms, 2007



Source: Appendix Table 17a

[15] Internet use has expanded greatly since 2007, therefore the 2007 information could be dated.

Chart 26: Internet Use in Natural Resource Industries in Canada, per cent of employees, 2007



Source: Appendix Table 17b

- internet usage for firms in natural resource industries increased almost unanimously between 2000 and 2007, with the exception of paper and wood manufacturing, in which the proportion of firms with internet access declined (Appendix Table 17a);

- the only natural resource industry to report that 100 per cent of firms had internet access was petroleum and coal products manufacturing (Chart 25);

- in terms of employees within firms having access to the internet, natural resource industries fared poorly (Chart 25), with some industries experiencing a decrease between 2000 and 2007. For example, paper manufacturing and petroleum and coal products manufacturing fell 11 per cent and 18 per cent, respectively. This indicator, however, may reflect the nature of work in natural resource industries, where many workers in the field do not have or require computer access.

iv. Intangible Assets

In addition to refining the concept innovation to refer to a highly integrated system, there is also a need to increase the range of individual indicators used. The OECD (2011) calls for the incorporation of broader measures of innovation into existing accounts. Ideally, existing indicators would be supplemented by measures of assets such as ICT, human capital and new organizational structures. The majority of these have already been discussed in the report. An additional dimension in which firms may innovate is intangible assets The OECD (2011) notes that intangible assets may explain a large proportion of multi-factor productivity growth, which cannot be observed. Baldwin, Gu, Lafrance and Macdonald (2009) estimate investment in intangible assets for Canada over the period 1981 to 2001. Intangible assets in this report include advertising, mineral exploration, purchased science and engineering and software in addition to normal R&D spending. The use of R&D as an innovation indicator can lead to underestimates of scientific activity as it does not account for efforts being made to adapt existing technologies for usage in new contexts. Findings suggest that in current dollar terms, intangible investments are greater than tangible investments.

When broken down by industry, agriculture and forestry represent only a marginal share of total intangible investment in the business sector.[16] Mineral exploration[17] accounted for a small proportion of total intangible investment in each industry (4.3 per cent of intangible asset investment from 1981-2001) (Appendix Table 32a). In the mining and oil and gas sector, mineral exploration comprised 77.5 per cent of total intangible asset investment and research and development comprised 9.2 per cent (Appendix Table 32a). It is also noteworthy that average annual growth of intangible investments in the mining and oil and gas sector was larger than that of the business sector for research and development (15.5 vs. 10.8 per cent) and purchased science and engineering (12.8 vs. 7.5 per cent).

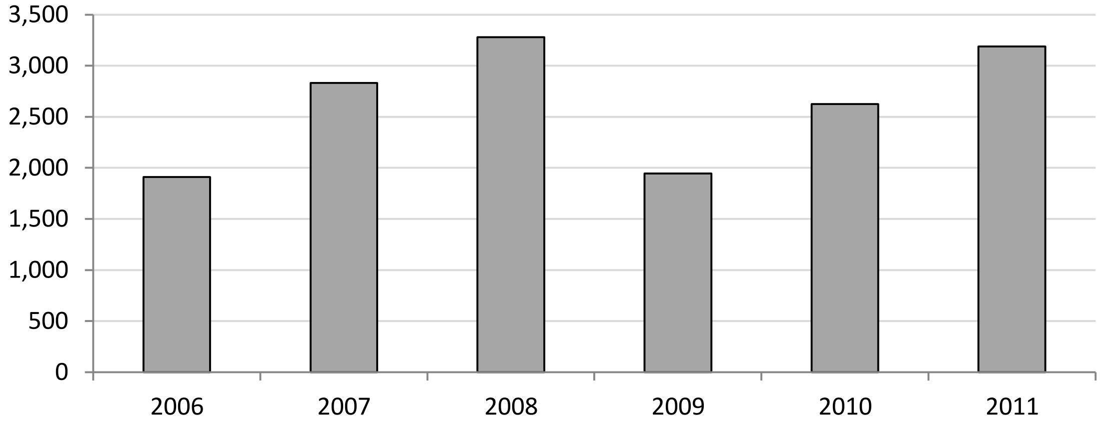
Rheaume and Roberts (2007) argue that "exploration is equivalent to scientific R&D in other businesses," a point that seems quite defensible given that it is a non-production stage meant to increase production. Canadian firms are globally recognized experts in mineral exploration owing to a multitude of junior companies, world-class technology and a well developed finance network. Canadian firms dominate exploration in Canada, the United States, South America, Central America, Europe and Africa (Rheume and Roberts 2007). Canada attracted 19 per cent of global exploration investment in 2005, more than any other country. Similarly, Canada was responsible for 47 per cent of global equity financing in the sector from 1999 to 2004. Natural Resources Canada (2010) finds that Canadian exploration expenditures grew by more than 400 per cent from 1998 to 2008.

Chart 27 depicts mineral exploration expenditures in Canada from 2006 to 2011 inclusive. The data for 2011 represents planned expenditures, which are expected to reach $3.2 billion. It is immediately clear that exploration expenditures are highly cyclical. This cyclicality is not so much due to depletion of reserves (i.e. firms increasing exploration when current resources are close to depletion), as it is due to shifts in expected future profits (driven, for instance, by high commodity prices).

[16] These include purchased science and engineering (0.6 percent), research and development (0.3), software (0.5) and own-account other science (0.6)

[17] Baldwin *et al.* (2009) define mineral exploration as the following activates: exploration and deposit appraisal, mine site equipment, geological and geophysical, drilling expenditures, pre-mining, research and other, and exploration drilling.

Chart 27: Mineral Exploration Expenditure, Canada ($ millions)



Source: Appendix Table 25

C. Innovation Outcomes

Many indicators of innovation are related to the outcomes of firm innovative efforts themselves. These include productivity indicators such as labour and multifactor productivity, as well as energy efficiency. Patents are also related to innovation outcomes, in that they directly reflect the fruit of R&D. Industries with high levels of productivity and patents are thus more likely to have high innovative capacity.

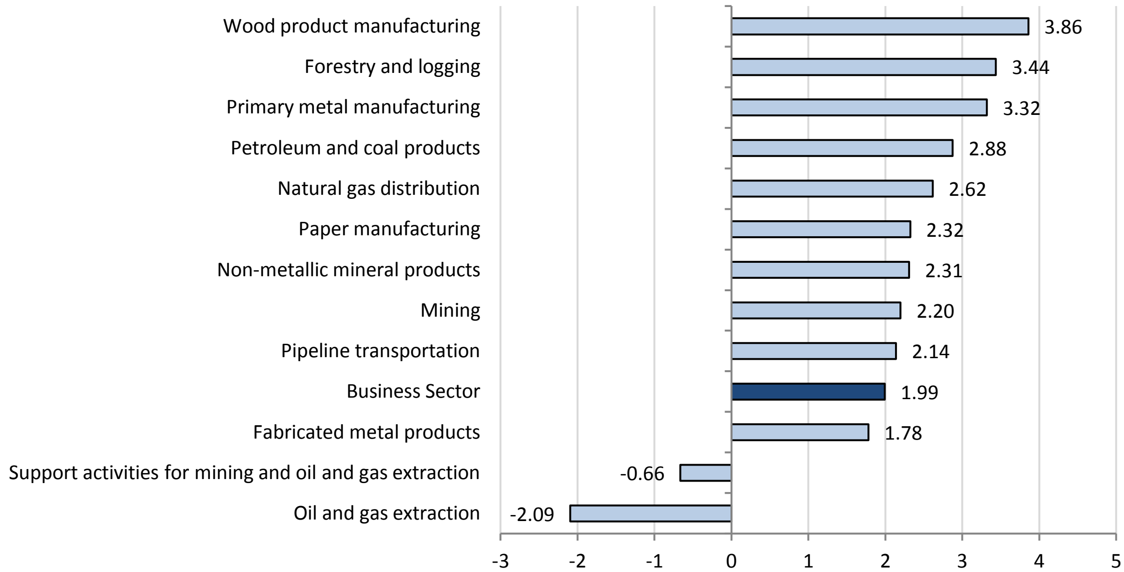
i. Productivity

Productivity is an important indicator of innovation performance. Innovations frequently translate into productivity gains, i.e. the ability to combine inputs more efficiently in order to produce output. This is no different in the natural resources sector; it may even be more pronounced. As noted above, the homogeneity of output in natural resource industries restricts the grounds on which firms can compete, which leads to emphasizing process innovation to improve productivity. Productive firms tend to be innovative firms, and vice versa.

a. Labour Productivity

Labour productivity is defined as output per hour worked and has implications for the capacity of an industry to generate wealth. This capacity in turn reflects an industry's innovative capacity. Chart 28 demonstrates that, in terms of labour productivity growth, nine out of 12 Canadian natural resource industries performed better than the business sector as a whole over the 1961-2008 period.

Chart 28: Labour Productivity (Real GDP per hour worked), Natural Resource Industries, Canada, 1961-2008
(compound annual growth rates, per cent)

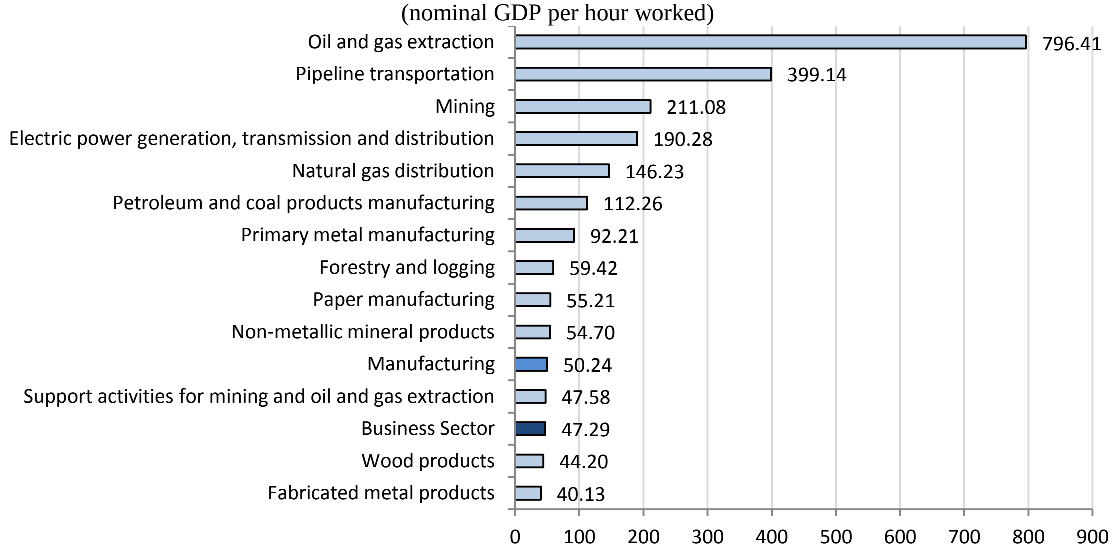


Source: Appendix Table 13

The only three natural resource industries which experienced below average labour productivity growth during the period were fabricated metal products (1.78 per cent per year), support activities for mining and oil and gas extraction (-0.66 per cent per year), and oil and gas extraction (-2.09 per cent per year). In the case oil and gas activities, it is clear that the prioritization of profit over productivity has driven this trend. When output prices are high, firms will access more costly deposits, pushing production to the extensive margin.

Chart 29 depicts labour productivity levels in 2008 for selected natural resource industries. Only fabricated metal manufacturing and wood products had levels below that of the business sector as a whole. Primary metal manufacturing, petroleum and coal products manufacturing, and paper manufacturing all outperform the manufacturing sector. Despite the decline in labour productivity in oil and gas extraction, the industry still had a significantly higher level than all other natural resources industries as well as the overall business sector. This is explained primarily by the surge in output prices seen in recent years.

Chart 29: Labour Productivity Levels, Natural Resource Industries, Canada, 2008
(nominal GDP per hour worked)



Source: Appendix Table 11

Table 8 depicts the average annual growth rates of labour productivity for selected natural resource industries and the business sector as a whole for both Canada and the United States. Between 1987 and 2007, 9 of 12 natural resource industries performed below the United States. The remaining industries, agriculture, forestry, fishing and hunting; wood products; and primary metals, performed above their American counterparts in terms of labour productivity growth.

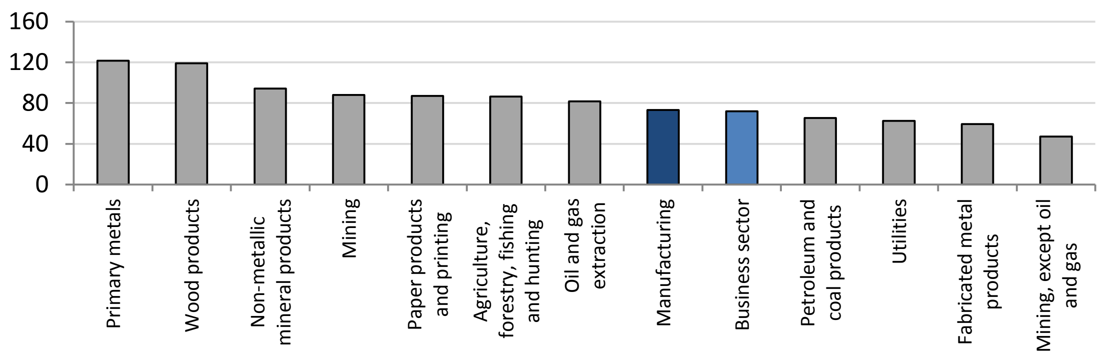
Table 8: Labour Productivity Growth in Natural Resource Industries, Canada/U.S., 1987-2008

Average Annual Growth	Year					
	1987-2000		2000-2008		1987-2008	
	Canada	United States	Canada	United States	Canada	United States
Agriculture, forestry fishing and hunting	3.4	4.0	2.9	1.7	3.2	3.1
Mining	2.1	3.0	-3.9	-5.3	-0.3	-0.3
Oil and gas extraction	4.8	3.3	-7.9	-3.9	-0.2	0.7
Mining, except oil and gas	0.4	4.6	-1.4	-2.8	-0.3	2.0
Utilities	0.3	3.7	-0.7	1.7	-0.1	2.9
Manufacturing	3.2	4.0	0.9	4.4	2.3	4.1
Wood products	2.0	-1.3	1.1	3.2	1.7	0.2
Non-metallic mineral products	1.4	3.0	0.1	0.5	0.9	2.1
Primary metals	4.7	2.8	4.0	2.6	4.4	2.8
Fabricated metal products	1.2	1.4	0.1	1.8	0.8	1.5
Paper products and printing	1.7	0.2	-0.6	2.9	0.8	1.1
Petroleum and coal products	3.0	2.1	-3.4	-1.8	0.5	0.7
Business sector	1.2	1.8	0.8	2.2	1.0	2.0

Source: Appendix Table 5b

It is well known that the level of labour productivity in the Canadian business and manufacturing sectors is significantly below that of its American counterparts. Chart 30 shows that in 2007, output per hour in the Canadian business sector was 72.1 per cent of the US and in manufacturing, 73.2 per cent. In natural resource industries, however, Canada had a better performance. Of 11 natural resource industries, 7 had higher labour productivity levels than their US counterparts and the business sector.

Chart 30: Labour Productivity (U.S.=100), Natural Resource Industries, Canada, 2007



Source: Appendix Table 5d

Table 9: Labour Productivity Growth in Natural Resource Industries for Selected OECD Countries, 1989-2009 (Average Annual Growth Rates)

	Industry						
	Mining and Quarrying	Wood Products	Paper Products, Printing and Publishing	Coke, Refined Petroleum, and Nuclear Fuel	Non-Metallic Mineral Products	Basic Metals	Fabricated Metal Products
Australia**	1.3	NA	NA	NA	3.6	NA	NA
Austria	2.3	1.5	4.0	19.8	0.9	0.9	1.8
Belgium	6.0	0.6	2.8	-1.5	1.5	NA	NA
Canada***	-0.4	1.6	1.4	0.0	1.7	4.7	1.5
Denmark	4.4	-1.4	1.8	NA	-0.3	NA	NA
Finland	3.5	3.5	3.3	6.6	1.2	4.5	1.5
France***	NA	3.0	1.8	3.1	1.9	0.1	1.2
Germany***	0.7	2.2	2.9	-4.1	1.8	NA	NA
Italy	1.9	0.5	0.5	-3.0	-0.1	NA	NA
Japan	-1.9	NA	NA	0.5	0.1	-1.6	-0.1
Korea*	8.5	7.2	4.7	10.2	7.2	7.0	2.6
Luxembourg***	0.8	NA	0.1	NA	1.4	4.6	0.1
Mexico***	0.2	NA	NA	NA	NA	NA	NA
Netherlands	1.6	0.7	2.2	1.0	0.5	2.1	2.1
New Zealand***	3.4	NA	NA	NA	NA	NA	NA
Norway	0.3	0.4	1.9	NA	0.6	-1.7	NA
Spain	1.8	-0.1	-0.2	-1.7	1.2	0.1	0.6
Sweden***	-0.1	3.5	2.5	20.8	4.2	2.3	2.0
United Kingdom***	4.2	0.6	1.3	0.2	3.4	NA	NA
Average	2.1	1.6	2.1	4.2	1.8	2.1	1.2
Canada's Rank	16/18	6/14	11/15	9/14	7/17	2/11	5/10

Source: OECD STAN Indicators Database

* Growth rates are for 1989-2006; ** Growth rates are for 1989-2007; ***Growth rates are for 1989-2008;

Table 9 depicts average annual growth rates for natural resource industries in selected OECD countries between 1989 and 2009. Canada's performance relative to its OECD peers is generally mediocre, performing below or exactly average in five out of seven industries. Canada saw above average growth in fabricated metal product manufacturing, though this gap is modest. Canadian basic metal manufacturing experienced growth at more than twice the average pace of other countries, however.

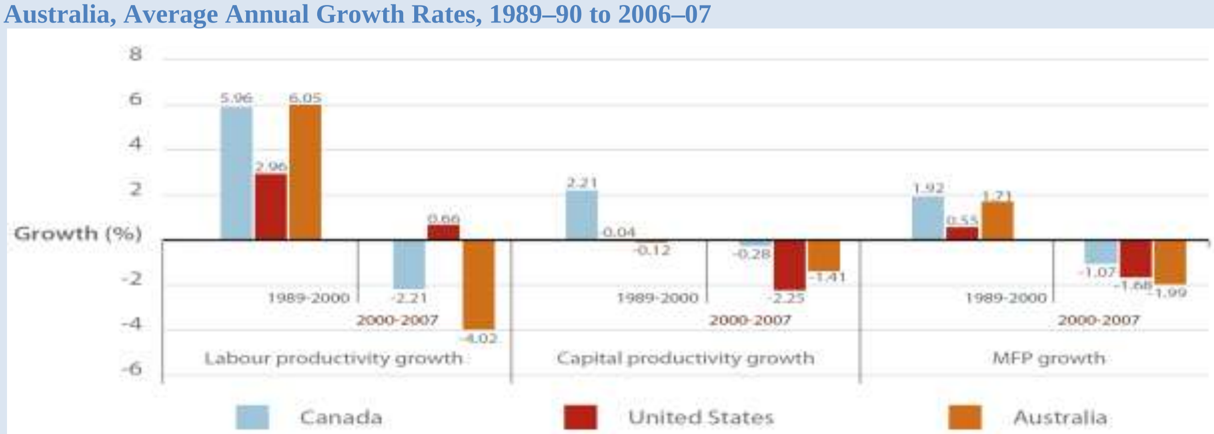
Box 4: Mining Productivity in Canada and Australia

One of Canada's biggest competitors in the mining sector is Australia. Topp *et al.* (2008) reported that mining represented approximately 5.8 per cent of Australia's nominal market sector GDP in 2006-07. On the other hand, the share of mining in Canada's business sector nominal GDP was 1.9 per cent in 2007. Therefore, both in absolute terms and as a share of GDP, the mining industry in Australia was larger than in Canada in 2007.

The value-added production of each subsector covered in the Topp *et al.* report (i.e. coal mining, iron ore, copper ore, gold ore, mineral sand mining, silver-lead-zinc ore mining, bauxite mining, and nickel ore mining) was also higher in Australia than in Canada. In particular, as the world's largest coal exporter, the value-added production of coal mining in Australia in 2006-07 was $13.9 billion (2007 CAD), much larger than in Canada, which was $1.7 billion (2007 CAD) in 2007. Australia also accounted for a significant share of the world's lead production (18 per cent) in 2007, as well as global iron ore production (19 per cent) and uranium production (22 per cent). However, all of the other types of mining not covered in the report (e.g. diamonds and potash) combined for only $1.7 billion (2007 CAD) of value-added production in Australia in 2007, much less than the $6.0 billion (2007 CAD) in Canada.

Labour productivity, capital productivity, and MFP in mining declined in both Canada and Australia between 2000 and 2007 (Figure 1). Furthermore, in all three productivity measures, Australia performed significantly worse than Canada. Part of the decline in productivity can be explained by the exploitation of lower quality resources. High quality minerals are usually mined first because they produce the largest profit. Due to the non-renewable nature of these resources, this results in poorer quality natural resources being exploited in response to increased demand. Long lags between capital investment and production of output also have a negative effect on MFP. Topp *et al.* (2008) find that these two factors are the main drivers of the situation in Australia. While these factors are also present in Canada, Bradley and Sharpe (2009a:2) also include "declining capital intensity; higher mining output prices; compositional shifts within the industry; deterioration of the average quality of the workforce; greater environmental regulation; labour relations; and taxation" as important drivers.

Figure 1: Labour Productivity, Capital Productivity and MFP Growth in Mining, Canada, the US and Australia, Average Annual Growth Rates, 1989–90 to 2006–07



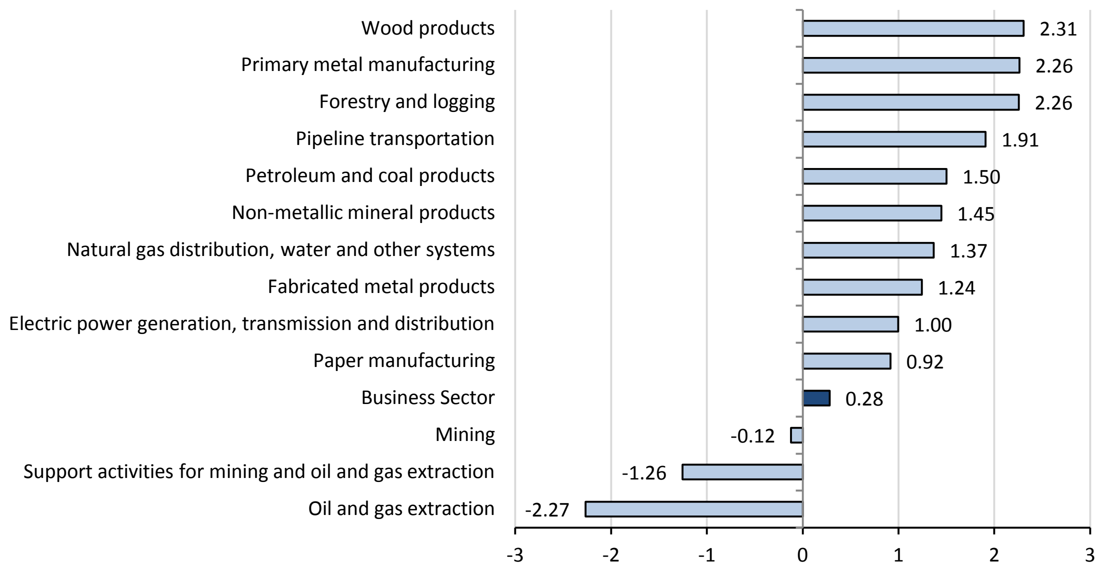
Source: Figure 5 in Syed and Grafton (2011)

b. Multifactor Productivity

Multifactor productivity measures the residual growth of productivity that cannot be explained by the change in combined inputs. It accounts for interactions between factors, economies of scale and perhaps most importantly, new technologies. Multifactor productivity indexes are available from Statistics Canada for thirteen natural resource industries for the 1961 to 2008 inclusive.

Chart 31 depicts multifactor productivity growth for Canadian natural resource industries. Similar to labour productivity, eight out of 11 Canadian natural resource industries performed better than the business sector average. Like the case of labour productivity, only oil and gas extraction and support activities for oil and gas extraction saw negative growth between 1961 and 2007. Mining also fared worse than the business sector, averaging annual growth of only 0.05 per cent.

Chart 31: Multifactor Productivity Growth, Natural Resource Industries, Canada, 1961-2008
(compound annual growth rates, per cent)



Source: Appendix Table 14

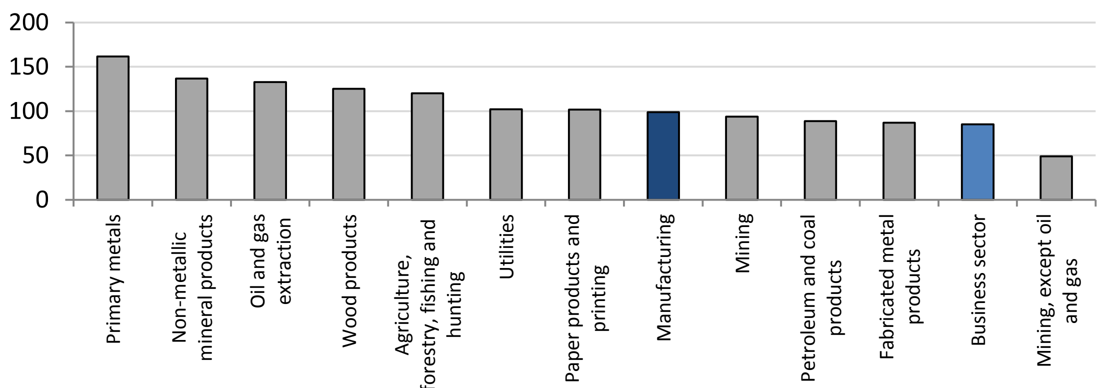
Compared to the multifactor productivity growth performance of the United States, Canada's natural resource industries performed slightly worse than they did for labour productivity growth, with 6 of 10 industries faring better than their US counterparts (Table 10). It should be noted that this performance is robust across depreciation rates.

Table 10: Average Annual Growth Rates, Multi-factor Productivity in Natural Resource Industries in Canada, 1987-2007

	Statistics Canada Depreciation Rates				BEA Depreciation Rates			
	1987-2000		2000-2007		1987-00		2000-07	
	Canada	United States	Canada	United States	Canada	United States	Canada	United States
Agriculture, forestry fishing and hunting	3.5	3.4	1.7	0.7	3.1	3.2	1.5	1.0
Mining	0.7	2.6	-5.3	-4.8	0.7	2.2	-4.5	-4.1
Oil and gas extraction	0.4	1.4	-6.6	-5.8	0.4	0.9	-6.0	-5.0
Mining, except oil and gas	1.1	4.5	-1.8	-2.7	0.7	4.2	-0.9	-2.0
Utilities	1.2	2.7	0.7	-0.3	0.5	2.0	0.8	0.2
Manufacturing	2.9	3.0	1.1	4.4	2.9	3.2	0.8	4.0
Wood products	1.4	-1.3	2.3	2.7	1.5	-1.3	2.0	2.5
Non-metallic mineral products	0.9	2.8	0.8	0	1.0	3.0	1.0	-0.1
Primary metals	4.2	3.1	4.2	2.5	4.2	3.0	3.4	2.1
Fabricated metal products	1.7	1.1	0.8	1.8	1.7	1.2	0.6	1.5
Paper products and printing	0.9	-0.1	1.1	2.4	0.9	-0.3	0.4	2.0
Petroleum and coal products	3.6	1.5	-4.7	-5.1	3.5	1.1	-4.2	-3.6
Business sector	1.0	1.2	0.4	2	1.1	1.3	0.6	1.9

Source: Appendix Table 5c

Chart 32: Multifactor Productivity Level (U.S.=100), Natural Resource Industries, Canada, 2007 (Statistics Canada Depreciation Rates for Canada and BEA Depreciation Rates for US)



Source: Appendix Table 5d

ii. Energy Intensity

Decreasing the energy intensity of production has become an important concern for natural resource industries, both as a means of cutting costs but also as a response to changing social values. Less-intensive use of energy reflects innovative efforts by firms, in terms of investment in cleaner technologies. Energy intensity is defined as the amount of energy used per unit of output. Data are available from Natural Resources Canada's Office of Energy Efficiency for the period 1990 to 2008, inclusive. The units are megajoules per dollar of GDP (constant 2002 dollars). Table 11 depicts the 2008 levels and percentage change.

Energy intensity in Canadian industries varies greatly. It ranges from 3.35 MJ per unit of output in the fabricated metal products industry to 81.94 MJ per unit of output in the petrochemical industry (Table 11). It is immediately clear that energy intensity has risen drastically in some industries while it has declined in others. Paper mills have made the most progress between 2000 and 2008, with energy intensity falling 28.3 per cent: the only natural resource industry to outperform the all industries average, which fell by 14.7 per cent. The largest change was seen in the petrochemical industry—the most energy-intensive industry in Canada — which increased energy intensity between 2000 and 2008 by 162 per cent. Both iron and steel and non-ferrous metal smelting and refining saw progress, with energy intensity declining 12.9 per cent and 11.6 per cent, respectively. Upstream mining and fabricated metal products industries both experienced a rise in energy intensity, increasing 54.4 and 46.3 per cent, respectively

Table 11: Energy Intensity in Selected Natural Resource Industries, Canada, 2000-2008

	Energy Intensity 2008 (MJ/$2002 GDP)	Change 2000-08 (%)
Industry		
Upstream Mining	14.1	54.4
Wood Products Industries	9.8	5.4
Paper Mills	37.0	-28.3
Fabricated Metal Products Industries	3.4	46.3
Iron and Steel	53.8	-12.9
Other Non-Ferrous Smelting and Refining	41.1	-11.6
Petrochemical Industry	81.9	162.0
All Industries	10.5	-14.7

Source: Appendix Table 22

The Mining Association of Canada (2009) highlights the sustainability advancements of the Canadian mining industry. Energy use and greenhouse gas (GHG) emissions management are measured using six indicators: energy use and management systems, energy use reporting systems, energy intensity performance targets, GHG emissions management systems, GHG emissions reporting systems and GHG emissions intensity performance targets. Performance on energy use and GHG emissions is among the weakest of all sustainability elements considered. In spite of a weak performance in terms of levels, systems and procedures for improving sustainability performance have been established for five of the six indicators since 2007. More than half of the facilities surveyed report established energy use report systems. Additionally, six companies— BHP Billiton Diamonds Inc., Diavik Diamond Mines Inc., Hudbay Minerals Inc., Syncrude Canada Ltd., Teck Resources Limited, and Xstrata Nickel— had established systems for all six indicators. This figure increased from four companies in 2007. It is uncertain whether these advancements and initiatives have positively affected energy intensity in the sector, as data is only available up to 2008.

iii. Patents

Patents assign intellectual property rights to innovations, be they products or processes. In the natural resources sector, the most relevant patents include those related to chemistry, metallurgy, textiles, and paper. Obtaining a patent requires an innovation to be novel, non-obvious and useful in industrial application. As such, patents are the most frequently used indicator of technology output (Dernis and Guellec, 2001). Though they are an indirect and incomplete measure of innovative capacity, patent data are useful to proxy the innovation activities of firms.

There are several caveats on the use of patent data for measuring the overall level of innovation in a country, however. First, firms are often unwilling to unveil innovations that are commercially sensitive. Second, the cost of patenting may defer firms from unveiling innovations that are not directly useful in the short-term. Third, an innovation may serve no commercial purpose and thus never be patented. Fourth, patent data are derived from administrative databases which are subject to changes in definition over time. As such, patent data can be irrelevant or at least inconsistent for time series analysis. Finally, innovations differ in value and a simple count of patents awarded does not account for differences in value or relevance. Each of these issues is detailed further in Dernis and Guellec (2001).

Data are available from the OECD for patent applications filed under the Patent Cooperation Treaty (PCT) for the period 1999 to 2009, inclusive. The PCT applies internationally to 144 countries and is administered by the World Intellectual Property Organization (WIPO); hence the root source of PCT data as well as all other patent data is the WIPO. The PCT organizes patent applications from member states under a single unifying procedure in which a single international application is required to obtain a patent in all participating countries.

The PCT reduces the administrative costs of filing for patents in multiple countries and thus facilitates the approval process, leading to the disclosure of more innovations than under a system of national or regional patent offices. It should be noted that the PCT does not render existing regional and national patent offices obsolete, as there is no such thing as an international patent (Oxonica Energy Ltd v Neuftec Ltd, 2008); it merely allows applicants to apply to all participating offices at once.

Briefly, the PCT application process consists of two stages (WIPO, 2011). In the first stage of the process (known as the international stage), the applicant files for patent protection with either a national or regional office or the WIPO's international bureau. This application is not a direct application for an international patent (international patents are nonexistent), but instead, simply designates all PCT state patent offices as recipients. The second stage (known as the national stage) occurs after 30 months and marks the beginning of the patent application process in each designated state. Applicants can opt not to pursue their applications for individual states at this stage. The national stage resembles the respective national application processes though many are simplified as part of the PCT application. National patent offices still require national application fees though these fees can be exempted, reduced or refunded in some circumstances, depending on the national patent office in question. For example, the Canadian application fee is reduced by 75 per cent once the Canadian Intellectual Property Office has conducted an international search for prior art.

Table 12: Patent Applications per Million People Filed Under the Patent Cooperation Treaty, by Inventor's Country of Residence and International Patent Classification (IPC), Priority Date

	IPC A: Human Necessities	IPC B: Performing Operations; Transporting	IPC C: Chemistry; Metallurgy	IPC D: Textiles; Paper	IPC E: Fixed Constructions	IPC F: Mechanical Engineering; Lighting; Heating; Weapons; Blasting	IPC G: Physics	IPC H: Electricity	Total Patents
Levels, 2009									
Australia	14.1	8.9	6.7	0.1	6.6	4.9	9.9	5.2	56.4
Canada	10.4	6.8	6.7	0.4	2.8	3.8	9.2	11.8	51.9
Denmark	37.8	16.0	17.9	0.8	6.4	15.9	15.4	16.0	126.2
Finland	11.2	23.8	16.9	9.2	7.4	11.5	35.6	60.0	175.6
France	13.1	13.5	11.6	0.6	2.2	7.7	11.6	11.8	72.2
Germany	18.3	28.6	19.9	1.8	3.5	21.2	17.5	21.7	132.4
Italy	7.8	8.6	4.5	0.9	1.9	3.9	3.0	3.5	34.0
Japan	16.1	20.2	22.4	1.0	1.4	11.1	26.3	37.5	135.9
Korea	18.5	12.2	11.5	2.5	3.4	9.6	18.0	40.9	116.5
Norway	18.4	16.6	11.0	0.1	17.4	13.7	15.7	7.2	100.0
Spain	5.6	3.8	3.5	0.3	1.2	2.5	2.7	2.6	22.2
Sweden	29.7	31.7	12.1	3.3	5.8	20.0	32.0	66.7	201.4
United Kingdom	14.6	7.5	8.8	0.4	3.2	5.4	11.6	10.3	61.9
United States	22.8	9.5	13.3	0.6	2.9	5.6	19.1	18.9	92.7
14-Country Average	17.0	14.8	11.9	1.6	4.7	9.8	16.2	22.4	98.5
Average Annual Growth, 1999-2009									
Australia	-2.8	-6.4	-3.5	-8.9	1.1	-2.9	-5.1	-4.2	-3.8
Canada	-2.9	-1.7	-5.1	-3.1	3.1	-0.6	-2.5	2.1	-1.7
Denmark	-0.8	-2.3	-4.5	-7.4	0.4	2.5	-2.7	-0.1	-1.4
Finland	-7.0	-2.3	-2.9	-8.6	2.4	0.3	1.1	-7.0	-4.2
France	-1.4	1.4	-0.4	-5.6	2.4	3.8	0.4	2.2	0.6
Germany	-1.3	0.1	-2.4	-2.4	-0.8	1.4	-1.6	-2.2	-1.0
Italy	0.1	2.3	1.7	1.5	5.0	7.3	2.3	4.0	2.4
Japan	5.3	9.5	3.7	-0.6	8.1	12.0	8.0	10.0	7.6
Korea	13.3	14.9	11.7	24.7	14.8	20.0	14.1	22.9	16.7
Norway	-3.5	-2.8	-2.3	-16.5	2.7	0.4	-1.6	-2.1	-1.5
Spain	4.6	1.3	4.9	2.3	5.7	9.5	7.1	3.9	4.6
Sweden	-5.2	-4.6	-5.2	-9.2	-5.3	-1.5	-2.3	-3.2	-3.8
United Kingdom	-3.5	-5.2	-5.9	-11.2	-1.1	0.3	-3.4	-1.7	-3.5
United States	-2.3	-3.5	-5.1	-8.1	2.0	1.4	-4.4	-2.0	-3.1
14-Country Average	-0.5	0.0	-1.1	-3.8	2.9	3.8	0.7	1.6	0.6

Source: OCED Patents Database (patents), OECD Employment and Labour Market Statistics (population), author calculations

Patent data are categorized by International Patent Classification (IPC). A number of IPC categories are relevant for the natural resource sector, ranging from those that encompass basic research, science and technology (chemistry/metallurgy; mechanical engineering, lighting, heating, weapons, blasting) to those that apply to novel products (textiles, paper).

Table 12 depicts levels and growth rates for patent applications per million people filed under the PCT for selected OECD countries. In terms of levels, Canada's performance compared to its OECD peers was poor. But in terms of growth, Canada shows promise in key areas.

Canada performs well below the 14-country average in all ICP categories in terms of levels and fares better than average in textiles and paper, and electricity in terms of growth. For total patent applications per capita, Canada compares favorably to only 2 of its 13 OECD peers; Spain and Italy. When growth rates are considered, only patent applications from Australia, Finland and Sweden have declined faster than those of Canada.

In specific IPC categories, there were 6.7 patent applications per million people in chemistry and metallurgy in Canada in 2009. Canada ranked 11 of 14 in this category, outperforming only Italy and Spain, while tying Australia. In textiles and paper (0.4 applications), Canada ranked 10 of 14 countries, faring better than Australia, Norway, Spain and the United Kingdom.

In the mechanical engineering, lighting, heating, weapons and blasting category (3.8 applications), Canada ranked 13 out of 14 countries, only ahead of Spain. Canada's best performance in terms of levels was in electricity (11.8 applications), in which it ranked eighth out of 13 countries, outperforming Australia, France, Italy, Norway and Spain.

In terms of growth, Canada fared reasonably well, particularly in textiles and paper, and electricity, in which it ranked 5 of 14 in both categories. It is also noteworthy that patents per million people for electricity grew faster in Canada than in Germany between 1999 and 2009.

D. Incidence of Innovation

Innovation at the firm and plant level is an important indicator. Survey data allows for the characterization of how innovative firms are, how novel innovations are, and the market conditions that motivate innovation. Additionally, factors that are identified as being obstacles to the innovative performance of clusters are telling with regard to other components of the system, such as government support for R&D or the degree of innovation/information sharing amongst firms.

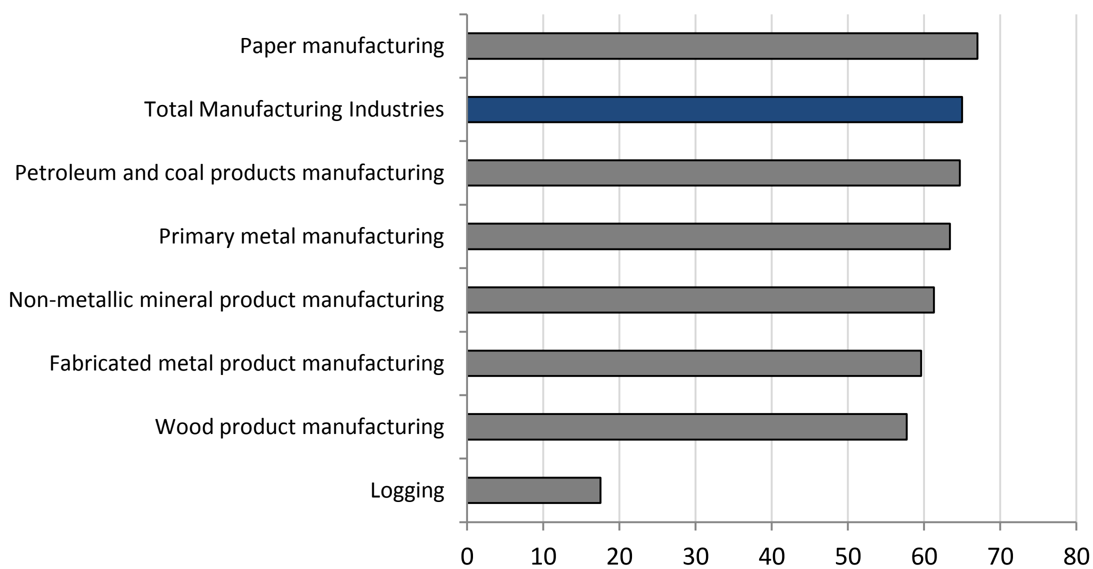
Three occasional Statistics Canada surveys related to innovation provide a variety of insights into what constitutes innovation and how innovation is measured. Each of these has been conducted relatively recently. The first is the Survey of Innovation, last conducted in 2005, which surveyed manufacturing and logging industries over the period 2002 to 2004. Conceptually, this survey addresses the degree of innovation via the novelty of new or significantly improved processes, the extent of collaboration between firms and the use of government programs designed to foster innovation. As such, data from this survey is particularly useful for assessing quality of linkages between clusters and innovation support infrastructure.

The second survey is the Survey of Advanced Technologies, conducted in 2007. This survey is an additional step in developing a set of innovation indicators for Canada, inquiring about the acquisition and integration of advanced technologies in manufacturing industries.

The third is the Survey of Innovation and Business Strategy (SIBS), a joint venture of Industry Canada, Foreign Affairs and International Trade Canada and Statistics Canada, conducted in 2010.[18] SIBS was undertaken to provide useful statistical information on strategic decisions, innovation activities and operational tactics used by Canadian firms. This section highlights the key results of these surveys related to the incidence of innovation, broadly defined.

Chart 33, based on the 2002-2004 Survey of Innovation, depicts the percentage of plants that are considered innovative in manufacturing natural resource industries. Compared to the manufacturing industries average, the performance of natural resource industries is relatively poor. Of the 7 natural resource industries, only paper manufacturing fares better than the manufacturing sector. Both converted paper product manufacturing and petroleum and coal products manufacturing perform at approximately the manufacturing sector average for this indicator. Wood product manufacturing fares well below the manufacturing sector average (by 7.3 percentage points). While it cannot be compared directly to manufacturing sectors, the logging sector has the lowest percentage of innovative plants.

Chart 33: Percentage of Innovative Plants in Manufacturing Natural Resource Industries, 2002-2004



Source: Appendix Table 18a

SIBS differs from the Survey of Advanced Technology and the Survey of Innovation in that it accounts for industries beyond manufacturing. Table 13 presents the percentage of firms

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[18] SIBS surveyed 6,233 enterprises, randomly selected from a population of 37,216 in Statistics Canada's Business Register.

by industry that introduced a product or process innovation during the 2007-2009 period. Focusing on process innovation, each natural resource industry outperforms the all-industries average for methods of manufacturing or producing (as expected), ranging from a difference of 38.8 percentage points for primary metal manufacturing to 1.9 percentage points for mining, quarrying and oil and gas extraction.

Table 13: Percentage of Enterprises Indicating they Introduced Product or Process Innovations, Natural Resource Industries, 2007-2009

2007-2009	Product Innovation		Process Innovation		
	Goods	Services	Methods of Manufacturing or Producing	Logistics, Delivery or Distribution Methods	Supporting activities for processes
All surveyed industries	18.1	24.5	17.3	12.0	25.5
Mining, quarrying, and oil and gas extraction	18.1	18.3	19.2	8.0	19.1
Manufacturing	42.6	21.7	49.7	15.7	31.4
Wood product	34.3	21.7	51.6	13.8	27.0
Paper	33.8	17.8	50.7	15.4	32.9
Petroleum and coal product	50.1	11.6	26.9	11.6	23.0
Non-metallic mineral product	37.6	14.8	46.8	14.0	26.8
Primary metal	41.9	22.5	56.1	16.5	34.1
Fabricated metal product	30.0	23.4	50.1	14.1	34.4

Source: Appendix Table 19b

In the manufacturing sector, four of six natural resource manufacturing firms fare better than the manufacturing industries average. In logistics, delivery or distribution methods, natural resource industries outperform the all industries total with the exception of mining, quarrying and oil and gas extraction. In the case of the manufacturing sector, all natural resource industries perform above the manufacturing sector average. For supporting activities and processes, only mining, quarrying and oil and gas extraction and petroleum and coal product manufacturing perform below the all industries average. In the manufacturing sector, paper, primary metals and fabricated metals perform above the sector average while wood products, petroleum and coal products and non-metallic mineral products perform below.

As stressed throughout this report, natural resource firms have traditionally been innovators in terms of processes, rather than products. Table 14 outlines the degree of novelty associated with innovations at the plant level across logging and manufacturing natural resource industries. It is immediately clear that world-first innovations are less common than country- and continent-first innovations in Canadian logging and natural resource manufacturing industries. It is noteworthy that a number of manufacturing natural resource industries outperform the manufacturing sector as a whole in all three types of innovation.

Table 14: Novelty of New or Significantly Improved Process, percentage of firms, Logging and Manufacturing Natural Resource Industries, Canada, 2002-2004

2002-2004	Degree of Novelty		
	At least one process was a first in Canada	At least one process was a first in North America	At least one process was a world first
Logging	0.6	0.6	0.0
Wood product manufacturing	3.7	2.3	1.2
Sawmills and wood preservation	1.5	1.0	0.8
Veneer, plywood and engineered wood product manufacturing	7.1	4.5	2.6
Other wood product manufacturing	4.2	2.5	1.1
Paper manufacturing	17.2	9.0	6.7
Pulp, paper and paperboard mills	33.1	19.3	12.5
Converted paper product manufacturing	10.4	4.6	4.3
Petroleum and coal products manufacturing	10.1	7.7	6.0
Non-metallic mineral product manufacturing	12.0	6.5	1.9
Primary metal manufacturing	16.5	9.0	1.8
Fabricated metal product manufacturing	6.8	3.1	0.7
Total Manufacturing Industries	9.1	5.4	2.4

Source: Appendix Table 18b

In Canada-first innovations, four out of seven three-digit natural resource industries outperformed the manufacturing sector average. At the four-digit level, pulp, paper and paperboard mills have a substantially higher proportion of innovations than the manufacturing sector average.

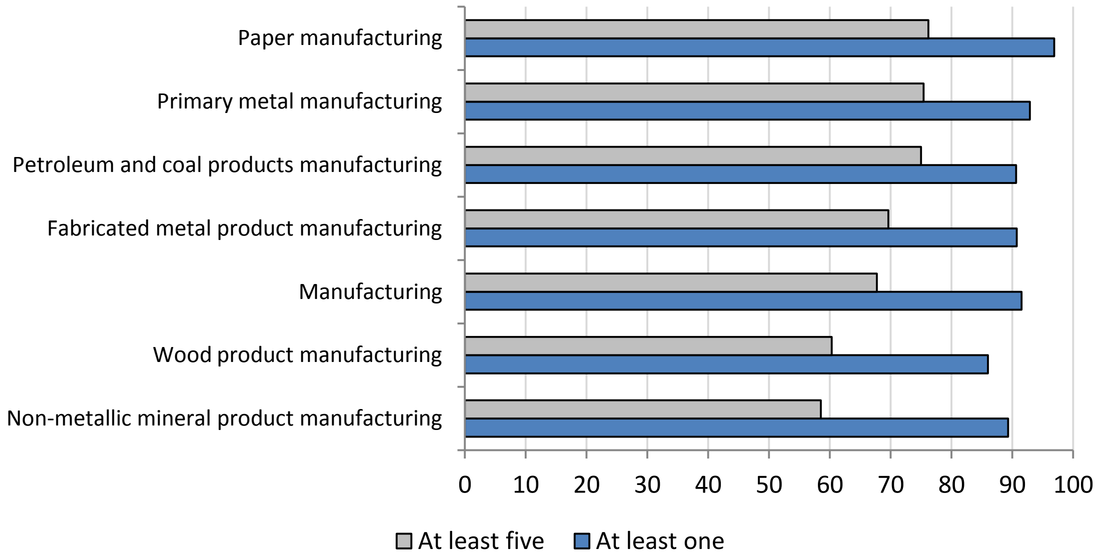
For North America-first innovations, four out of six three-digit natural resource industries outperformed the manufacturing sector. At the four-digit level, again, pulp, paper and paperboard mills had a higher proportion of firms with at least one North America-first innovation than the manufacturing sector as a whole.

For world-first innovations, two out of six natural resource industries outperformed the manufacturing sector at the three-digit level. At the four-digit level, respondents from the Canadian manufacturing sector (2.4 per cent) reported at least one world-first innovation less than respondents from pulp, paper and paperboard mills (12.5 per cent), veneer, plywood and engineered wood product manufacturing (6.7 per cent) and converted paper product manufacturing (4.3 per cent).

The Statistics Canada Survey of Advanced Technology was conducted in 2007, inquiring as to the extent that firms in manufacturing adopted advanced technologies. Chart 34 depicts the percentage of respondents in natural resource manufacturing industries that have adopted at least one or at least 5 advanced technologies in comparison to the overall manufacturing sector. In each of the 6 natural resource industries identified, over 80 per cent of respondents had adopted at least one advanced technology, with no natural resource industries falling significantly below the manufacturing average. In the case of adopting five or more advanced technologies, only two of the six natural resource industries identified are below the manufacturing sector average (67.7

per cent): wood products manufacturing (60.3 per cent) and non-metallic mineral product manufacturing (58.5 per cent). Certain industries such as paper and primary metal manufacturing were well above the manufacturing sector average.

Chart 34: Percentage of Manufacturing Plants Using Advanced Technologies by Natural Resources Industry, Canada, 2007



Source: Appendix Table 19a

An additional measure of innovation incidence is the extent of design that is undertaken by firms. Design is defined by Sam-Aggrey (2010) as "the purposeful or inventive arrangement of parts or details". Results from the Statistics Canada's Survey of Advanced Technology 2007 compiled by Sam-Aggrey (2010) suggest that natural resource manufacturing industries fare well in terms of design activities. The industrial distribution of design activities in manufacturing placed fabricated metal product manufacturing at the very top, accounting for 16.0 per cent of total design activities in manufacturing. The next notable natural resource manufacturing industry was wood products manufacturing, ranking sixth with 6.4 per cent of total design activities. Approximately 52 per cent of firms in the manufacturing sector engage in design activities. Within industries, petroleum and coal product manufacturing (60.6 per cent), paper manufacturing (56.7 per cent) and fabricated metal product manufacturing (53.9 per cent) fare better than the manufacturing sector as a whole. The worst performance amongst natural resource manufacturing industries was wood product manufacturing (38.8 per cent).

E. Other Indicators

i. Co-Innovation

The extent of innovative activities pursued by firms is in part determined by the availability of innovation support infrastructure such as public funding for R&D, the quality of linkages between firms, government and academia and the stock of basic research. Collaboration between firms can also fuel innovation by encouraging the sharing of knowledge and practices.

Any student of industrial organization or microeconomics should hardly be surprised by the idea that firms may cooperate in circumstances where intense competition may seem a more likely outcome. One such example of this is the cooperation over knowledge among natural resource firms and their stakeholders. It is likely that this is motivated by foresight on the part of natural resource firms, which recognize that long-term prosperity is a priority over short-term competition. Though Canadian examples are scarce, there is a wealth of evidence internationally (Higginson and Vredenburg, 2010; Noke Perrons and Hughes, 2008) that "keeping your enemies closer" is an effective means of establishing a knowledge base. Such an asset comprises an essential feature of a national innovation system.

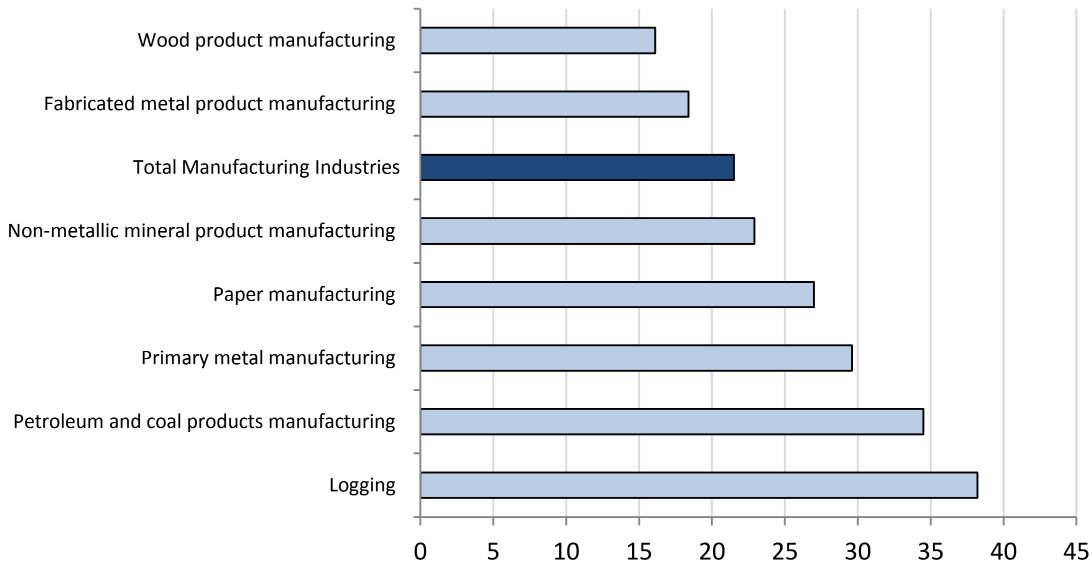
Though it has not reached the scale of collaboration between government and industry, co-innovation between firms is an important way of sharing resources and knowledge, as well as minimizing the risk associated with R&D. Lorentzen (2006) studies the cases of knowledge intensification in six resource-intensive economies (Brazil, Costa Rica, Peru, and South Africa - biopolymers, hydro-hydraulic power and humic substances). Findings indicate that in four of the six cases, the quality of linkages between firms, scientific institutes and universities matter greatly in the innovative performance of the sector.

Higginson and Vredenburg (2010) develop a model of a strategic knowledge sharing network based on collaboration between firms in Canada's west coast forest products industry. Specifically, the stakeholders in question are largely groups that have non-financial interests in the industry such as sustainability and regional development. Two pervasive trends are indentified as motivators for such collaboration: the general movement towards a knowledge economy and the re-conceptualization of the corporate role in society. The resulting knowledge sharing and engagement has led to improved forest management strategies, steering them towards sustainability, which is in the interest of both the participating firms and stakeholders. Networks such as this one generate important performance-enhancing resources that could have value for other natural resource industries. Similar engagements have taken place in the Alberta oil sands.

Noke, Perrons and Hughes (2008) study the impact of strategic alliances on discontinuous innovation. Using evidence from the oil and gas industry, the authors assess the role of non-committal relationships between firms as a vessel for the development of novel ideas or procedures in an industry characterized by slowly changing internal operations, finding that short-term cooperative efforts can drive the design, adoption and refinement of new technologies. Twister BV, an upstream oil and gas technology provider was created in the early 1990s to facilitate the transfer of a novel system for removing condensed gas droplets from flowing streams in air conditioning systems to the oil and gas industry, where it could be used to separate droplets from natural gas. This technology was originally designed by Noordwjik technologies for usage in air conditioners. Cooperation between Twister BV and Noordwjik allowed for the transfer of a novel technology to the oil and gas sector.

Chart 35 presents the proportion of plants in logging and natural resource manufacturing industries that have cooperated with other firms on innovation activities. Of the seven natural resource industries depicted, five perform better than the manufacturing sector in terms of co-innovation. It is very clear that there is a large degree of collaboration amongst larger-scale operations such as petroleum and coal product manufacturing, primary metal manufacturing and paper manufacturing. Industries characterized by smaller operations with many establishments such as sawmills and wood preservation and other wood product industries seldom engage with other firms.

Chart 35: Percentage of Innovative Plants that Cooperated on Innovation Activities with Other Firms, Logging and Manufacturing Natural Resource Industries, Canada, 2002-2004



Source: Appendix Table 18d

ii. Usage of Public Support Programs

As discussed earlier in the report, the federal government provides a number of support programs to foster innovation activities among firms. The use of these programs is an indicator of the innovation interests and efforts of firms. These include tax incentives and grants to conduct R&D, skills training, information programs and capital support. Table 15 summarizes the usage of these programs by firms in logging and manufacturing natural resource industries. The salient findings include:

- The most widely used support programs across industries are tax incentives for R&D, with over one-third of firms in the manufacturing sector accessing such programs between 2002 and 2004. Logging plants used these programs significantly less (4.3 per cent of respondents) than the manufacturing sector average (36.3 percent). Natural resource manufacturing firms generally accessed such programs less than the manufacturing sector as a whole, with only three industries, pulp, paper and paperboard mills (72.6 of respondents), petroleum and coal products manufacturing (42.4 per cent of respondents) and primary metal manufacturing (44.5 per cent of respondents) performing better than the manufacturing sector average;

- The second most accessed programs by the manufacturing sector were government information programs, with 8.8 per cent of respondents having used them between 2002 and 2004. Only three natural resource manufacturing firms made use of these programs more than the manufacturing sector average between 2002 and 2004: veneer, plywood and engineered wood product manufacturing (16.7 per cent of respondents), pulp, paper and paperboard mills (11.3 per cent) and fabricated metal product manufacturing (9.0 per cent of respondents). At the three-digit level, no natural resource industries accessed government information programs more than the manufacturing sector;

- Only three natural resource manufacturing industries accessed government grants for R&D more than the manufacturing sector as a whole, which had 6.3 per cent of respondents access such programs between 2002 and 2004. These were pulp, paper and paperboard mills (9.8 per cent), non-metallic mineral product manufacturing (6.8 per cent) and primary metal manufacturing (7.7 per cent);

- No natural resource industries accessed government venture capital support more than the manufacturing sector average between 2002 and 2004;

- Only paper manufacturing accessed government technology support programs and assistance programs more than the manufacturing sector as a whole;

- With skills shortages being a frequently cited hindrance to the vitality of natural resource industries in Canada, it is unsurprising that five of the ten disaggregated natural resource industries above accessed government support for training more than the manufacturing sector average (3.9 per cent of respondents) between 2002 and 2004.

Though a variety of relevant federal support programs are available, natural resource industries chiefly take advantage of tax incentives for R&D, and information and training support programs. In spite of overall program usage being low compared to the manufacturing sector average, several industries access key programs with relative frequency. Both non-metallic and primary metal manufacturing firms access R&D grants more than the manufacturing sector average.

Pulp, paper and paperboard mills use R&D tax incentives, R&D grants, technology support and assistance, information programs and training support programs more than the manufacturing sector as a whole. It is also noteworthy that petroleum and coal product manufacturing as well as primary metal manufacturing use R&D tax credits more than the manufacturing sector average.

Table 15: Percentage of Plants that Use Government Sponsored-Programs, Logging and Manufacturing Natural Resource Industries, Canada, 2002-2004

2002-2004	Type of Program						
	Research and development tax credits	Government research and development grants	Government venture capital support	Government technology support and assistance programs	Government information	Government support for training	Other government support programs
Logging	4.3	1.5	0.0	0.0	4.3	0.0	0.6
Wood product manufacturing	24.2	1.8	0.7	0.8	5.9	4.2	0.9
Sawmills and wood preservation	31.8	1.8	0.2	0.2	2.0	3.2	1.1
Veneer, plywood and engineered wood product manufacturing	29.9	1.0	1.5	2.9	16.7	6.0	0.9
Other wood product manufacturing	15.6	2.1	0.8	0.4	5.0	4.5	0.7
Paper manufacturing	45.5	4.3	0.4	3.6	4.4	3.6	0.2
Pulp, paper and paperboard mills	72.6	9.8	0.0	10.8	11.3	6.6	0
Converted paper product manufacturing	34.0	2.0	0.6	0.6	1.5	2.3	0.3
Petroleum and coal products manufacturing	42.4	2.2	0.0	1.5	5.8	0.0	1.2
Non-metallic mineral product manufacturing	29.2	6.8	0.7	1.0	4.9	2.5	0.0
Primary metal manufacturing	44.5	7.7	0.4	2.4	6.4	3.6	0.0
Fabricated metal product manufacturing	29.6	3.9	0.4	1.4	9.0	4.3	0.4
Total Manufacturing Industries	36.3	6.3	0.8	3.1	8.8	3.9	1.3

Source: Appendix Table 18e

iii. Competitiveness and Business Strategy

As noted earlier in the report, an important driver of innovation capacity is the degree of competition in an industry. Because the natural resources sector is highly competitive worldwide and the chief competitors of Canadian natural resource firms are not Canadian, there is an enhanced focus on the extent to which Canadian firms are involved in international markets and the degree of competition they face. A stronger degree of competition will foster innovation and globally active firms will be exposed to leading-edge technologies and business practices. Additionally, there is room for firms to implement novel business strategies as a means of staying competitive. The Survey of Innovation and Business Strategy has yielded useful data concerning the competitive environment and innovative practices of Canadian firms over the 2007-2009 period. Data from this survey are discussed in this section.

As discussed previously, natural resource firms largely produce homogeneous products (commodities) and there is very little room in this industry for product differentiation. Table 16 shows the percentage of enterprises indicating their most important strategy in 2009. While the vast majority of firms in all industries respond that product positioning is their focus, some natural resource firms prioritize product positioning less. Paper and petroleum and coal product manufacturing generally prioritize product positioning less than the all-industries and manufacturing sector averages, while they have a stronger focus on cost leadership. Wood product, primary metal and fabricated metal product manufacturing each focus less on product positioning than the manufacturing sector average and more on cost leadership. It is thus clear that regardless of innovation performance of the natural resources sector, their focus on innovation as a means of achieving cost leadership objectives should not be understated. It is also noteworthy that mining, quarrying and oil and gas extraction focuses more on product positioning and less on cost leadership than the all industries average, a surprising result.

Table 16: Percentage of Enterprises Indicating their Most Important Strategy in 2009

By industry	Product positioning	Cost leadership
All surveyed industries	78.6	21.4
Mining, quarrying, and oil and gas extraction	80.8	19.2
Manufacturing	86.1	13.9
Wood product	81.2	18.8
Paper	71.3	28.7
Petroleum and coal product	73.1	26.9
Non-metallic mineral product	87.6	12.4
Primary metal	84.2	15.8
Fabricated metal product	84.6	15.4

Source: Appendix Table 19c

International activities open firms up to new markets with more competition. As such, the extent to which an industry is global is a telling indicator of its incentives to innovate. Firms that are exposed internationally to more competition are more likely to be innovative, as a means of staying competitive. Table 17 summarizes the international involvement of the Canadian natural resources sector as compared to all industries and the manufacturing sector. It is immediately clear that natural resource industries are generally more involved than the all industries average and the manufacturing sector in terms of having business activities outside of Canada and exports. Additional findings include:

- Far more natural resource industries report having business activities outside of Canada than the all industries average;

- Wood products, non-metallic mineral products and fabricated mineral products have fewer business activities outside of Canada and export less than the manufacturing sector average;

- Mining, quarrying and oil and gas extraction firms have more business activities outside of Canada than the all-industries average but export slightly less.

Table 17: Percentage of Firms Indicating Their Involvement in International Markets, 2007-2009

By Industry	Had business activities outside of Canada	Relocated business activities outside of Canada	Outsourced business activities outside of Canada	Relocated business activities from another country into Canada	Exported or attempted to export
All surveyed industries	24.7	7.8	16.8	1.8	21.8
Mining, quarrying, and oil and gas extraction	34.3	8.5	18.1	2.1	21.5
Manufacturing	47.5	11.0	21.2	5.0	53.7
Wood product	28.0	1.1	13.3	0.5	44.8
Paper	56.9	9.4	16.3	6.4	64.6
Petroleum and coal product	53.7	7.1	21.4	11.5	61.6
Non-metallic mineral product	32.9	20.5	20.9	0.5	34.8
Primary metal	52.4	17.2	23.4	5.0	64.8
Fabricated metal product	45.4	5.7	18.4	3.5	44.2

Source: Appendix Table 19d

Additional findings concerning competitiveness and innovation are summarized below:

- In terms of the number of competitors facing Canadian natural resource firms (Table 18), mining, quarrying and oil and gas firms face the most competition (significantly more than the all industries average), with 43.1 per cent of firms indicating 20 or more competitors;

- The majority of natural resource firms seem to operate in markets with 4-5, 6-10 and 20+ competitors (Table 18);

- Competition is fierce in natural resource industries, with a vast majority of Canadian natural resource firms reporting competition with multinational enterprises (Chart 36);

- The response to competition via innovation in Canadian natural resource industries appears to be below average (Table 19). Generally, natural resource manufacturing firms performed below the manufacturing aggregate in terms of competing by adopting a new technology or process, introducing a new product or speeding up the introduction of a new product;

Table 18: Percentage of Enterprises Indicating the Number of Competitors for their Main Product in Their Principal Market, 2009

By industry	1	2	3	4-5	6-10	11-20	20+
All surveyed industries	3.1	5.8	13.0	12.5	27.9	16.0	21.8
Mining, quarrying, and oil and gas extraction	2.0	3.6	3.2	13.2	23.4	11.5	43.1
Manufacturing	3.9	4.9	9.0	24.4	23.2	9.8	24.8
Wood product	3.3	1.4	8.7	17.5	23.4	13.9	31.7
Paper	1.3	7.1	9.4	24.3	27.9	13	17.1
Petroleum and coal product	0.0	3.8	15.5	30.8	19.2	3.8	26.9
Non-metallic mineral product	4.6	12.2	12.0	16.1	33.0	6.7	15.3
Primary metal	5.2	6.1	10.3	26.7	31.3	4.8	15.6
Fabricated metal product	5.0	3.7	7.6	27.1	20.1	10.8	25.6

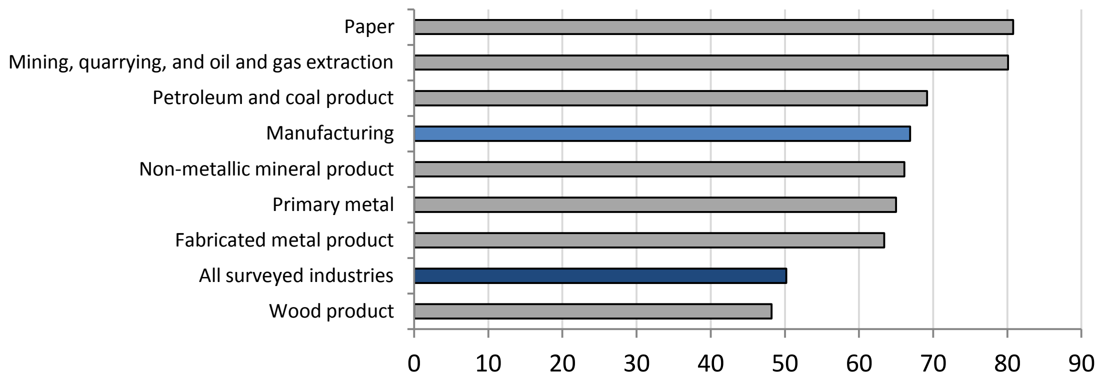
Source: Appendix Table 19e

- More firms in mining, quarrying and gas extraction competed by adopting a new technology or process than the all industries average in 2009 (Table 19);

- Only wood product and primary metal manufacturers reported competing via adopting a new technology or process more than the manufacturing sector average (Table 19);

- No natural resource industry fared better than the all-industries or manufacturing sector averages in terms of introducing new products. Only primary metal firms cited speeding up the introduction of a new product more than the manufacturing sector average as a means of competing (Table 19). Both of these findings are surprising given the recent focus of the forestry sector on diversifying towards new products;

Chart 36: Percentage of Enterprises that Competed Against Multinational Enterprises in Their Principal Market for their Main Product in 2009



Source: Appendix Table 19f

Table 19: Percentage of Enterprises Indicating Their Response to the Entry of New Competitors in their Principal Market for their Main Product in 2009

By Industry	Adopted a new technology or process	Introduced a new product	Speeded up the introduction of a new product
All surveyed industries	17.6	40.1	18.1
Mining, quarrying, and oil and gas extraction	22.7	28.5	11.4
Manufacturing	39.2	37.4	28.6
Wood product	39.3	16.7	22.0
Paper	28.3	21.5	15.1
Petroleum and coal product	33.8	33.1	16.6
Non-metallic mineral product	34.2	35.2	23.1
Primary metal	39.8	29.2	29.1
Fabricated metal product	36.3	17.6	12.4

Source: Appendix Table 19g

iv. Adoption of Improved Organizational Structures

Aside from product and process innovation, innovative activity can be seen as the adoption of new management practices, organizational structures or marketing strategies that are only indirectly related to the production process. Improvements in organizational structures help firms to find efficiencies and improve productivity. Table 20 depicts the percentage of enterprises that indicate the introduction of a novel organizational structure or means of advertising.

Table 20: Percentage of Enterprises Indicating they Introduced Organizational or Marketing Innovations in 2007–09

By Industry	Organizational Innovation			Marketing Innovation			
	Business practices for organizing procedures	Methods of organizing work responsibilities procedures	Methods of organizing external relations	Aesthetic design or packaging	Methods or techniques for promotion	Methods for product placement	Methods of pricing
All surveyed industries	23.5	27.4	15.0	11.3	23.9	14.0	15.8
Mining, quarrying, and oil and gas extraction	36.7	38.7	16.9	10.1	14.9	4.6	16.7
Manufacturing	44.9	38.6	19.8	17.0	20.4	13.6	17.5
Wood product	41.3	33.5	14.8	14.8	19.2	12.5	21.6
Paper	53.4	45.6	20.5	14.1	9.8	9.5	9.4
Petroleum and coal product	46.2	42.5	19.2	11.5	15.3	3.8	3.8
Non-metallic mineral product	41.9	43.7	17.2	12.4	22.8	15.0	18.3
Primary metal	38.6	37.9	24.9	6.8	16.3	5.9	17.8
Fabricated metal product	45.3	37.9	21.4	11.9	15.6	8.9	14.9

Source: Appendix Table 19

Out of seven natural resource industries, all introduced business practices for organizing procedures more than the all industries average between 2007 and 2009, with three out of six manufacturing natural resource industries faring better than the manufacturing sector. The introduction of methods for organizing work responsibilities was also more common in each of these natural resource industries than in all surveyed industries and half of the manufacturing natural resource industries outperformed the manufacturing sector. Only wood product manufacturing performed below the all industries average (and that of the manufacturing sector) for implementing methods of organizing external relations.

Although marketing is typically not the focus of most natural resource industries, many natural resource industries introduced novel marketing practices more than their respective benchmarking industries. The most salient finding is that the non-metallic mineral product industry outperformed the manufacturing sector in three out of the four marketing innovations listed, though it is unsurprising, given the tendency of the industry to produce consumer and luxury goods. It is also noteworthy that three out of six manufacturing natural resource industries outperformed the manufacturing sector in implementing novel methods of pricing. Additionally, mining, quarrying and oil and gas extraction introduced novel pricing methods more than the all industries average. This is surprising, given the primary nature of this industry and fact that it produces commodities, the price of which it has little control over.

VI. Emerging Challenges Related to Innovation in Natural Resource Industries

Natural resource industries in Canada face a number of emerging challenges that could serve as obstacles to innovation. This section provides an overview of key challenges that may threaten the future innovation performance of the natural resources sector in this country. These challenges include: an increasing demand for technical skills and potential inability to fulfil these skill requirements; the need to address environmental and social concerns, including the emergence of green industries and eco-innovation; the technical and financial issues associated with accessing unconventional mineral deposits; the need for natural resource industries to move up the value chain, and issues arising from increased globalization and market consolidation, including foreign direct investment in Canada and Canadian direct investment abroad.

A. Growing Demand for Skills

A commonly cited issue in Canadian natural resource industries is the need to attract and retain skilled labour. In particular, the impressive growth of the oil and gas and mining sectors in recent years has created very strong demand for workers with specialized technical skills. Several reports (e.g. Public Policy Forum (2010); Laverdure (2008); and Rheaume and Roberts (2007)) have noted that a lack of skilled workers to engage in research, identify the technological needs of natural resource industries, and most importantly to effectively use the latest technologies, represents a weakness of innovative capacity and hence is potentially a major impediment to innovation.

Evidence of the skills challenge facing natural resource industries is widespread. The 1999 Statistics Canada Survey of Innovation reported that approximately one third of metal ore mining, manufacturing and primary metal manufacturing firms found it difficult to retain skilled workers and about one quarter of metal ore mining firms believe a lack of skilled workers has had a negative effect on innovation. Schaan (2002) found that a significant threat to the innovative capacity of Canada's mining sector was the capability to attract and retain qualified workers. She noted that because most innovations in mining are related to acquiring advanced technologies, there are important complementarities between worker skills and machinery and equipment operation. Lonmo and Schaan (2005) note that 44 per cent of contract drilling (except oil and gas) firms responding to the Statistics Canada 2003 Survey of Innovation report that a lack of qualified personnel was a significant barrier to innovation.

There is broad acknowledgement that the resource sector has an aging workforce and replacing these workers is made harder by having a poor record of recruiting women, immigrants, Aboriginal peoples and youth. The Public Policy Forum (2010) suggests that a long term solution should include engaging foreign students in Canadian universities, greater promotion of science and technology from kindergarten to grade 12, and better ways to inform people of the opportunities for creativity within natural resource industries. Rheaume and Roberts (2007) suggest the solution lies in offering greater incentives for skilled workers to relocate, improving education and skills training among Aboriginals, expanding apprenticeship and internship programs, and the promotion of resource-based jobs among women and youth.

B. Addressing Environmental and Social Concerns

Due to the extractive nature of the natural resources sector, issues surrounding sustainability and the environment have increased the pressure on natural resource industries to "clean up." This has increased the importance of environmental innovation (eco-innovation) and led to the emergence of green technologies and industries.

Environmental considerations are especially important in the energy industry, and it is often criticized for contributions to global warming. Rheaume and Roberts (2007) estimate that the oil and gas industry is responsible for 18 per cent of green house gas emissions in Canada, a figure that implies reduced environmental impacts from this sector may offer a large contribution to environmental improvement. It is important to note that the increased awareness of environmental issues and the mounting pressure on governments and industries to impose and adhere to environmental regulation is likely to stimulate innovation in natural resource industries. For example, Towers *et al*. (2007) observe that there is enormous potential for the biological waste of Canada's forest products industry to be harnessed through biorefinery activities to produce many novel products.

The CMIC (2008b) identifies key areas of research in which environmental, sustainability and energy efficiency practices need improvement:

- Finding clean technologies to replace explosives in drilling and rock fragmentation;
- Using less dilution and crushing in rock fragmentation to decrease energy use;
- Cleaner engineering practices such as using alternatives to internal combustion engines and better ventilation systems;
- Improved backfill technology to lower cement usage and consequently GHG emissions;
- Increasing ore yields in rock fragmentation; and
- Reduced energy consumption in blasting, crushing and the milling process.

Objectives such as these require significant investment in science and technology. Because the benefits of these goals accrue to both firms (in the form of reduced costs, greater yields and increased employee safety) and society as a whole (in the form of reduced environmental externalities), there is a substantial case for more collaboration between industry, government, academia and research institutions.

C. Accessing Unconventional Mineral Deposits

A challenge that threatens the competitiveness of the Canadian mining and energy industries is the difficult logistics of accessing unconventional mineral and energy deposits (Natural Resources Canada (2011) and Laverdure (2008)). Canada has responded very well to this challenge in the case of the oil sands, through developing world-class technologies to extract bitumen from these deposits both through mining operations and in-situ extraction techniques. In terms of mining, there are a number of world-class mineral resources in Canada located at enormous depths and at remote locations. The challenge for firms in this industry will be to exploit these deposits in a cost-effective manner through the development of new techniques. Innovation is crucial.

D. Moving Up the Value Chain

Canada exports many natural resources, including logs, minerals and ores, and petroleum and natural gas in a raw or unprocessed state. There may be potential for Canadian firms to move up the value chain to create additional value added and employment in Canada by more processing of raw natural resources in this country.

It is largely market forces that account for the current split or distribution between the export of unprocessed resources versus their processing in Canada. One approach would be to use regulation to require firms to undertake more processing in Canada. However, a less interventionist approach may be for firms to develop new processes and products that make it cost effective to process and transform more natural resources in Canada instead of exporting them in an unprocessed state. Innovation is of course the key to the development of these new processes and products.

E. Increased Globalization and Market Consolidation

The natural resources sector has seen the emergence of a number of very large multinational firms in recent years, particularly in the mining sector and to a lesser degree the forest products sector. Unfortunately, except for the gold industry, there are no Canadian firms among these multinationals (indeed, the takeovers of Alcan and Inco contributed to the growth of these foreign mining multinationals such as Rio Tinto and Vale).

The implications of this movement toward market consolidation for innovation in natural resources industries in Canada are uncertain. On the one hand, the Canadian operations of these multinationals gain access to the technologies of these firms developed in other countries, although since Canada is already a world leader in mining technology it is unclear how valuable this access will be. On the other hand, these mining multinationals may locate or even relocate research activities in their home country, or in other countries in which they operate, resulting in less R&D being undertaken in Canada. The classic example of this type of firm behavior is the case of the Big Three auto producers (GM, Ford, and Chrysler) who historically concentrated auto industry R&D in the United States. The implications of this market consolidation for innovation in natural resource industries are consequently an important topic for further research.

VII. Overall Assessment of Canada's System of Innovation in Natural Resource Industries

This section provides an overall assessment of the innovation performance of Canadian natural resource industries based on the systems approach to innovation outlined earlier in the report (Exhibit 2). This approach sees innovative activities as dependent not only on the R&D efforts, labour quality, machinery and equipment and ICT investments of business, but also on the quality of institutional infrastructure that supports business innovation and the linkages between firms and these supportive institutions (government and universities). The basic stock of knowledge upon which natural resource industries draw for innovation as well as the degree of collaboration between firms also make up the innovation system.

McKenna (2011) asserts that "Canada's productivity performance is poor and the country suffers from a chronic innovation gap. Outside of the mining and energy sectors, the list of Canadian companies making a meaningful impact on a global stage is exceedingly short". In line with McKenna's view, the OECD (2012:58) also recognizes that "Canada is at the forefront of a number of industries, notably those that are natural resource based."

This report confirms McKenna's view that the Canadian mining and energy sectors are innovation leaders, both relative to other Canadian industries and to these sectors in other countries. Indeed, this was the finding of the previous CSLS report on innovation in natural resource industries prepared for Natural Resources Canada in 2005 (Sharpe and Guilbaud, 2005).[19]

The strongest piece of evidence to collaborate this finding that has become available since 2005 is the expert assessment of the science and technology of Canadian industries conducted by the Council of Canadian Academies in 2006 (CCA, 2006). It found that out of 197 sub-areas of science and technology the top ten industries were all natural resource industries, with the Alberta oil sands number one.[20] A second development that confirms the innovative nature of natural resource industries is the technique of fracking, which allows producers to recover natural gas from shale deposits. This innovation constitutes a massive technological shock to the natural gas industry. It has greatly increased the supply of natural gas and put downward pressure on prices.

The implication of this overall positive assessment of the innovative performance of natural resources sector (or at least the mining and energy parts of the sector) is that Canada's system of innovation for natural resource industries is working quite well. The innovation performance of Canadian natural resource industries is strong as measured by most indicators.

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[19] That report concluded "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. (Sharpe and Guilbaud, 2005:38)

[20] Rick George, CEO of Suncor, recently provided an insightful perspective on the oil sands: "In this industry, we only got a critical mass of companies involved in the last 10 years, as in-situ took off, as Shell came in and invested, and now we have all the international players come in, from the Chinese, all the European countries, including Total and Statoil. With that come very large R&D budgets. The technology changes that you are going to see in this industry in the next 10 years – both in the mining side and in the in-situ side, in the land-reclamation side – are going to be off-the-chart good" (Cattaneo, 2011).

For example, natural resource industries outperform the Canadian business sector in terms of productivity levels, M&E intensity, adoption of new technologies, collaboration efforts between firms, and R&D personnel.

The strong innovative performance of most natural resource industries has only been possible because of the effectiveness of the overall system of innovation, more specifically the infrastructure that supports these innovative efforts. Canada has one of the most generous R&D tax credit schemes in the world. Governments also provide grants for business R&D. The federal government undertakes research in its own laboratories that can be used by natural resource industries. Through its granting councils, the federal government supports research in the university sector that can be used by natural resource industries. The universities themselves are also crucial for innovation in natural resources industries, performing both basic and applied research relevant to these industries and producing graduates who will assume positions in these industries. A number of collaborative organizations have been established that bring together governments, universities and businesses to foster innovation in the natural resource sector.

Despite the overall strong innovative performance of most natural resource industries, there is always room for improvement. For example, R&D intensity in most natural resource industries (and at the natural resources aggregate level) is below the all industries average. Part of this poor performance is due to structural characteristics of the industries. Two of those structural characteristics are particularly relevant in this case: 1) process innovation tends to be more important in natural resources industries than product innovation;[21] 2) innovation in natural resources industries frequently takes the form of new machinery and equipment, which are produced by other industries in other NAICS codes. However, the fact that R&D intensity in some natural resources industries has fallen over the past twenty years is a source of concern.

A case can be made, however, that what matters in the end is innovation outcomes, not innovation inputs. Canadian natural resource industries are world leaders in innovation without directly undertaking large amounts of R&D. The system of innovation in Canada, through R&D conducted by universities, government, or capital equipment and materials providers appears to be undertaking sufficient R&D related to natural resource industries to make the sector world class. BERD is not the only driver of innovation outcomes.

Another indicator in which natural resources industries had a poor performance overall was labour force skills. Again, part of this can be attributed to structural factors specific to those industries (e.g. highly skilled workers in specific industries are not necessarily the ones with the most formal education), but part can indicate a more pervasive problem, which might hinder innovation performance in the medium-run.

Another source of concern is the poor performance of the oil and gas industry in terms of labour productivity growth. Profits trump productivity in business decision making, and high oil prices have made the exploitation of more marginal, and costly, resources such as the oil sands profitable. This results in falling productivity levels (more hours are needed to produce a given barrel of oil) despite the large amount of value added created. Despite negative productivity

[21] This process innovation takes the form of the adoption of the most advanced machinery and equipment and the R&D for these capital goods is generally performed by the equipment producers, not by natural resource industries.

growth, the Canadian oil and gas extraction sector has been a world leader in several areas of innovation.

Finally, the role of the government in promoting innovation can always be improved. In particular, a number of ways to increase the effectiveness of the SR&ED program have been put forward. Proposed changes include the reduction in red tape in support program application processes and new support programs that target innovation in specific industries.

VIII. Conclusion

This report has taken a systems-based approach to assessing the innovation performance of natural resource industries in Canada. While the discussion of innovation indicators in natural resource industries is comprehensive, the overall assessment of the various components of the innovation system as it pertains to natural resources, such as the wide range of government programs to support innovation, is less complete. Indeed, such a comprehensive assessment is beyond the scope of this contract.

The key conclusion of the report is that the overall innovation performance of the Canadian natural resources sector is strong and has improved in recent years. The one exception is the forest products sector which has experienced negative developments related to a downward shift in demand for its output. Such an unfavorable environment makes innovation difficult. An assessment of the innovative capacity of natural resource industries using the broader systems approach suggests that the sector's innovation performance is grounded on a diverse set of public support programs, a novel stock of technologies and the consistent collaborative efforts of firms.

Despite the overall above-average innovation performance of Canadian natural resources industries, there is still room for improvement. In particular, natural resources industries have performed poorly in terms of: 1) R&D intensity; 2) labour force skills; and 3) in the case of the oil and gas industry, labour productivity growth. While part of the poor performance in these indicators can be attributed to structural factors specific to natural resources industries, they also reflect areas that could be improved.

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