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The Growth of Diamond Mining in Canada and Implications for Mining Productivity

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Abstract

Diamond mining in Canada began in 1998, with the first production from the Ekati mine in the Northwest Territories. Since then the Diavik mine has begun production, and two other mines are slated to begin production within two years. Canada's share of the world value of diamond production was 15 per cent in 2003, the third largest worldwide. These mines are all located in the northern regions of Canada, and hence contribute substantially to the growth of these regions. Diamond production accounted for 19.9 per cent of total real output in the Northwest Territories in 2002, representing a phenomenal impact, especially given that the industry did not exist five years before. Given the very high level of output per hour in the diamond mining industry – reflecting a high degree of economic rent – and the strong expected growth of the industry in the coming years, the labour productivity growth of the overall mining industry will be favourably affected. Based on a rough simulation of the growth of the Canadian diamond mining industry in the 2001-2006 period, average annual labour productivity growth in the overall mining industry will be between one and two percentage points higher than if the diamond mining industry did not exist. Although the mining of rough diamonds is lucrative in itself, there is also much value added in the manufacture and retailing of diamond jewelry. Investment by Canadian firms in each stage of the diamond pipeline could promise large returns due to the very high value added associated with the overall diamond industry.

The Growth of Diamond Mining in Canada and Implications for Mining Productivity

Executive Summary

In December 2002, the Centre for the Study of Living Standards (CSLS) delivered to Natural Resources Canada (NRCan) an overview report entitled "Productivity Trends in Natural Resource Industries in Canada." This report examined trends and drivers or determinants of labour, capital, and total factor productivity for all 20 natural resource industries in Canada over the 1961-2000 period. In February and March of 2004, CSLS prepared for NRCan in-depth analyses of the drivers of labour productivity growth for a subset of these industries, consisting of nine selected natural resource industries (coal mining, gold mining, diamond mining, electricity generation, oil and gas, logging and forestry, wood products, paper products, and earth sciences). This report is the result of the analysis undertaken for the diamond mining industry.

There are currently two diamond mines in production in Canada, both located in the Northwest Territories. The Ekati mine began production in the fall of 1998, and the Diavik mine in early 2003. Between 1997 and 2002, value added in the diamond mining industry increased from zero to nearly $550 million. The share of diamond mining in total economy real output rose from zero in 1997 to 0.05 per cent in 2002. Diamond production accounted for 19.9 per cent of total real output in the Northwest Territories in 2002, representing a phenomenal impact, especially given that the industry did not exist five years before.

The Jericho mine, in Nunavut, is expected to be in production by 2005. The Snap Lake mine, in the Northwest Territories, owned by the international diamond conglomerate De Beers, is slated to begin production in 2006. In addition, several mining companies have staked land claims in the Northwest Territories and are currently assaying these plots, and many companies are also exploring sites in Quebec, Labrador and northern Ontario. The Victor mine, on the Attawapiskat River in Ontario and also owned by De Beers, may begin production as early as 2007. Geologists have also stated that there are geological indications that suggest the possible presence of diamonds in the northern areas of the Prairie provinces.

Canada was the third largest producer of rough diamonds by value in 2003. Our share of the world value of production surged to around 15 per cent in that year, ranking Canada only behind Botswana and Russia and pulling ahead of South Africa, Angola and Namibia. It is also important to note the quality of Canadian diamonds. The average price per carat for rough diamonds, which reflects such quality indicators as size, colour and clarity, was third highest for Canadian diamonds in 2002, behind only diamonds from Namibia and Angola.

In addition to the diamond mines in production, the backward linkages to other industries supplying diamond mines and diamond exploration and development activities,

the diamond industry also includes downstream activities such as cutting and polishing rough stones, designing and manufacturing jewelry, and retailing. A small Canadian cutting and polishing industry has so far had limited success. The greater the Canadian involvement in these downstream activities, the greater will be the Canadian share of the value added of the diamond industry, from the mining of rough Canadian stones to the final sale of jewelry products.

Based on the limited data that are available, it appears that the knowledge and expertise developed by other mining industries in Canada has given the diamond mining industry a solid foundation. Labour productivity growth in diamond mining over 1998-2001 was above average, although it is difficult to make long-term predictions based on this short time period. More impressive is the very high level of labour productivity, reflecting the high degree of economic rent in the sale of rough diamonds.

Given this very high level of output per hour and the strong expected growth of the diamond mining industry in the coming years, the labour productivity growth of the overall mining industry will be favourably affected. Based on a rough simulation of the growth of the Canadian diamond mining industry in the 2001-2006 period, average annual labour productivity growth in the overall mining industry will be between one and two percentage points higher than if the diamond mining industry did not exist. For example, based on a conservative assumption on the increase in diamond output that can be expected by 2006 given planned mine openings, overall mining labour productivity growth in 2001-2006 is forecast to be 7.4 per cent per year, compared to 6.4 per cent per year in the mining industry excluding diamonds. Given a more optimistic assumption, labour productivity growth in the overall mining industry could be as high as 8.1 per cent per year.

The future of the Canadian diamond mining industry is very bright. Nonetheless, there are even more benefits that may possibly be realized through the further development of the industry. First, it is possible that the capacity for the present in-house training programs to keep up with the anticipated expansion of the industry in terms of providing skilled workers will become inadequate in the future. The further development of training programs may have large benefits, in terms of providing more individuals with access to high-paying jobs in the diamond mining industry, and in terms of allowing for further increases in diamond production.

Second, the expansion of the diamond mining industry in the Northwest Territories has provided a springboard for economic growth in this region. There may be a role for government policy in ensuring that such growth becomes more broadly based and firmly established.

Finally, there may also be benefits in the further development of downstream diamond industries in Canada, such as the cutting and polishing of rough stones and the manufacture and retailing of jewelry products. Investment by Canadian firms in each stage of the diamond pipeline could promise large returns due to the very high value added associated with the overall diamond industry.

The Growth of Diamond Mining in Canada and Implications for Mining Productivity

In December 2002, the Centre for the Study of Living Standards (CSLS) delivered to Natural Resources Canada (NRCan) an overview report entitled "Productivity Trends in Natural Resource Industries in Canada" (CSLS, 2003). This report examined trends and drivers or determinants of labour, capital, and total factor productivity for all 20 natural resource industries in Canada over the 1961-2000 period. In February and March of 2004, CSLS prepared for NRCan in-depth analyses of the drivers of labour productivity growth for a subset of these industries, consisting of nine selected natural resource industries (coal mining, gold mining, diamond mining, electricity generation, oil and gas, logging and forestry, wood products, paper products, and earth sciences). A summary of these analyses is found in CSLS (2004). The present report is the result of the analysis undertaken for the diamond mining industry.[1]

The Canadian diamond mining industry has only existed since 1998. Since then, growth in the industry has been extraordinary. But the early stage of development of the industry makes a detailed analysis of some of its aspects difficult. This report is hence meant as more of an introduction to and description of the industry than as a detailed examination of its productivity performance, which would require a longer term perspective than is possible with the data that are presently available. The report is divided into three sections. The first discusses the general characteristics of the diamond mining industry in Canada upon which some data are available, makes observations on other mining industries that likely apply to the diamond mining industry as well, and attempts to quantify the broader impacts of the diamond mining industry on the Canadian economy.

I. Description and Characteristics of the Canadian Diamond Industry

A. The Rise of Diamond Mining in Canada

There are currently two diamond mines in production in Canada, both located in the Northwest Territories. The Ekati mine began production in the fall of 1998, and the Diavik mine in early 2003. Between 1997 and 2002, value added in the diamond mining industry increased from zero to nearly $550 million (Table 1). The share of diamond mining in total economy real output rose from zero in 1997 to 0.05 per cent in 2002. Diamond production accounted for 19.9 per cent of total real output in the Northwest

[1] CSLS would like to thank NRCan for financial support to undertake this research. The author would like to thank NRCan officials for comments on earlier drafts and Andrew Sharpe for comments and guidance. Comments can be directed to the author at jeremy.smith@csls.ca. The reports on coal mining (Smith, 2004b) and gold mining (Smith, 2004a) are available as CSLS Research Reports 2004-07 and 2004-08 respectively at www.csls.ca under Publications and Research Reports, and the reports on the remaining six industries are available upon request from info@csls.ca.

Territories in 2002, representing a phenomenal impact, especially given that the industry did not exist five years before.

Table 1: Output, Employment, Hours Worked and Labour Compensation in Diamond Mining in Canada, 1997-2002

	Real Value Added, millions of 1997 dollars at basic prices	Employment	Hours Worked, thousands	Average Compensation per Worker, current dollars	Average Compensation per Hour Worked, current dollars
1997	0	0	0	0	0
1998	$52.0	93	206.7	$67,462	$30.35
1999	428.3	387	826.5	67,791	31.74
2000	303.9	634	1,343.4	54,144	25.55
2001	446.2	731	1,627.1	56,967	25.59
2002	545.4	na	na	na	na

Sources: GDP from unpublished GDP by Industry data from Statistics Canada. Hours paid by production workers, total employees and total labour compensation from *General Review of the Minerals Industries*, 2001 edition, Statistics Canada catalogue number 26-201. Hours paid for total employees calculated by applying average hours for production workers to total employees. Hours paid converted to hours worked by applying the ratio of total hours worked by all workers in overall non-metal mining (from the Productivity Program Database) to hours paid of employees in all metal mining, from the *General Review of the Minerals Industries*. Note that statistics refer to the Ekati mine only, as the Diavik mine did not start production until 2003.

There were no employees in diamond mining in Canada in 1997 and 93 in 1998, the first year of production (Chart 1). This rose to 731 in 2001. This represents an increase in the share of diamond mining in total mining employment, from zero in 1997 to 1.49 per cent in 2001.[2] Santarossa (2004) estimates that by early 2004 there were as many as 2,200 jobs related to diamond mining in Canada.[3]

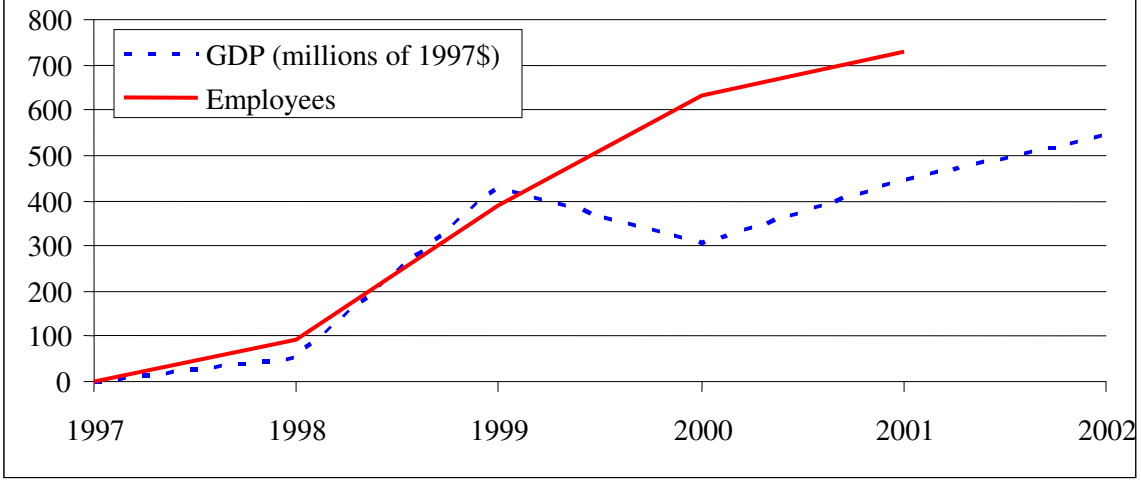
These figures understate the extent of diamond-related activities taking place in Canada. First of all, they do not include the significant exploration activity that is taking place on many other sites across most Canadian provinces, as well as the development activities associated with mines slated to begin production in the next few years. Second, there are backward linkages between the diamond mining industry and other industries engaged in supplying goods and services to diamond mines, such as transportation services. And third, diamond mining creates economic spin-offs downstream from the

[2] Data are from *Non-Metallic Mineral Mining and Quarrying*, Statistics Canada catalogue number 26-226. The share of mining employment in total economy employment was 0.48 per cent in 1998 and 0.39 per cent in 2001.

[3] This estimate refers to employment at the Ekati and Diavik mines as well as workers currently engaged in the development of the Snap Lake mine. It is not clear if this figure also includes employees of companies on contract work for diamond mines, such as transportation and supply companies.

actual mining of the diamonds, such as the cutting and polishing of rough stones, the manufacture of abrasives and other products using industrial-quality stones, and the making and retailing of jewelry with finished gem-quality stones. With the recent success of diamond mining, all of these activities may begin to establish a firm hold in Canada as well. The diamond industry is therefore poised to be a boon to the Canadian economy for many years to come.[4]

Chart 1: Output and Employment in the Canadian Diamond Mining Industry, 1998-2002



The Jericho mine, in Nunavut, is expected to be in production by 2005. The Snap Lake mine, in the Northwest Territories, owned by the international diamond conglomerate De Beers, is slated to begin production in 2006. In addition, several mining companies have staked land claims in the Northwest Territories and are currently assaying these plots, and many companies are also exploring sites in Quebec, Labrador and northern Ontario. The Victor mine, on the Attawapiskat River in Ontario and also owned by De Beers, may begin production as early as 2007. Geologists have also stated that there are geological indications that suggest the possible presence of diamonds in the northern areas of the Prairie provinces (Starnes, 2004). About 23 per cent of all metal and mineral exploration activity was accounted for by diamond exploration over the 1998-2002 period. About 40 per cent of diamond exploration in 2002 was undertaken in the Northwest Territories, with 20 per cent each taking place in Nunavut and Ontario, and smaller shares in other provinces (Santarossa, 2004).

The cutting and polishing industry is in a nascent state in Canada, with activity primarily centered around Yellowknife, and firms in Vancouver and Matane, Quebec as well (Chamber of Mines of the Northwest Territories and Nunavut, Mining Association of Canada and Prospectors and Developers Association of Canada, 2004). Canadian

[4] These downstream activities related to diamond mining are classified within very detailed miscellaneous manufacturing industries, and there are no data available on their output or employment. Neither has it been possible to estimate the extent to which the activities of the transportation and other upstream industries are related to diamond mining.

diamonds are initially sorted at the mine, and at this stage are valued for the purposes of royalty payments. They are then sent to Antwerp, Belgium or London, England for final sorting and sale to buyers of rough diamonds. Aber Diamond Mines has established sorting operations in Toronto, from which sales of the sorted rough diamonds are made, typically through Antwerp. Through an agreement with the owners of the Ekati mine, some diamonds from this mine are returned to the cutting and polishing firms in Yellowknife. Canadian cutting and polishing firms can also import rough diamonds from other countries.[5] There are signs that this industry may become more important in coming years. Sirius Diamonds of Yellowknife, the first cutting firm in Canada, was founded by an expert in the industry from South Africa and employs several master cutters from Armenia. Sirius was also the firm that first used the laser-engraved polar bear marking to distinguish Canadian diamonds. Arslanian Cutting Works of Yellowknife also employs recognized master cutters, and both firms have heavily invested in training Canadian workers.[6]

In 2001, the value of Canadian production of rough diamonds from mines accounted for just over 5 per cent of the value of world production. Production increased in 2002, and stood at nearly 5 millions carats, worth $800 million (current dollars). Santarossa (2004) states that our share of the world value of production may have surged to 15 per cent in 2003, ranking Canada only behind Botswana and Russia and pulling ahead of South Africa, Angola and Namibia.

It is also important to note the quality of Canadian diamonds.[7] The price of rough diamonds reflects their quality, and is included in the value of production but not in the raw quantity of production. In terms of quantity of production, as measured by carats, Canada ranked 7th in 2002, behind Botswana, Russia, South Africa, Angola, the Democratic Republic of Congo and Australia, these latter two with very large quantities of mined diamonds of low value, reflecting low quality and hence price. This discrepancy between Canada's ranking in value and quantity suggests a high price for Canadian diamonds. Indeed, the average price per carat for rough diamonds, which reflects such quality indicators as size, colour and clarity, was third highest for Canadian diamonds in 2002, behind only diamonds from Namibia and Angola.

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[5] Canada is a founding member of the Kimberly Process for trade in rough diamonds. Member countries agree to import and export diamonds to and from other member countries only, and each traded diamond is individually certified under the process. The effort was initially chaired by South Africa on behalf of interests of other African countries and with the support of the United Nations and other countries. The process is designed to break the observed link between the illicit trade in diamonds and the funding of armed conflict in several African civil wars.

[6] However, Chamber of Mines of the Northwest Territories and Nunavut, Mining Association of Canada and Prospectors and Developers Association of Canada (2004) are pessimistic about the prospects for a large and successful Canadian cutting and polishing industry, noting that many of the employees in the Yellowknife firms are foreign workers on temporary work visas, and that employment has been subject to high turnover. Also, at least one Yellowknife cutting and polishing firm has faced financial difficulties in meeting loan repayment obligations.

[7] The Voluntary Code of Conduct For Authenticating Canadian Diamond Claims defines a Canadian diamond as one that has been mined in Canada. Therefore, not all Canadian diamonds are necessarily cut and polished in Canada. There is, however, a movement to define a Canadian diamond more narrowly, as one that is both mined and cut and polished in Canada.

Foreign ownership in the diamond mining industry is high. The Ekati mine is 20 per cent owned by the two Canadian geologists who made the initial discoveries – Charles Fipke and Stewart Blusson – with the remaining 80 per cent owned by the Australian mining company BHP Billiton Diamonds. The Diavik mine is 40 per cent owned by Aber Diamond Mines, a Canadian company, and 60 per cent owned by the British Rio Tinto. As mentioned previously, De Beers is the owner of the Snap Lake mine, and has other diamond interests in Canada as well. The Jericho mine is wholly owned by Tahera, a Canadian corporation. It appears, in contrast, that most exploration activity is undertaken by Canadian 'junior' companies. Once promising finds are made, however, the large capital costs required to begin operation are usually financed by major international companies with expertise in the area.[8]

B. Observations on the Diamond Mining Industry in Canada, and Inferences Based on Other Mining Industries

Diamond mining resembles other mineral mining operations in several respects, such as workplace safety concerns, environmental regulations, the capital intensity of production, average wages, and the technology of production. Discussions of these factors for the Canadian gold mining and coal mining industries are available in Smith (2004a and 2004b). Given that data on some of these aspects are not available for diamond mining specifically, the following comments are based on those discussions.

- Average annual salaries in diamond mining were about $57,000 in 2001 (Table 1), about 15 per cent higher than other non-mineral mining workers, and so about 40 per cent above average annual salaries for all workers. Similarly consistent with the above-average earnings in mining industries, average hourly compensation was $25.59 in 2001.

- The actual extraction process for diamonds is based on conventional open-pit mining methods. Deep open-pit mines are drilled and blasted, and deposits (of kimberlite in the case of diamonds) are harvested. The diamonds themselves are then removed from these ores, pre-sorted, and transported from the mine for dispatch to international sorting centres (i.e. Antwerp and London). The process of removing diamonds from the kimberlite ores once they have been mined may be somewhat less capital intensive than the chemical and crushing processes required for metal mining, and the volume of kimberlite removed using heavy hauling vehicles may be less than that of ores removed for metal mining. Nonetheless, the nature of the equipment required for mine construction and kimberlite extraction likely implies that diamond mining is a highly capital intensive operation, like other mines. The absence of official estimates of capital stock for diamond mining prevents confirmation of this hypothesis.

[8] The exploration phase of development is attracting increased foreign involvement as well. Stueck (2004) reports that 42 per cent of the 1,518 prospecting claims authorized by Nunavut in 2003 were by De Beers, and 26 per cent were by BHP Billiton. Stornoway, a Canadian company, claimed 10 per cent of the permits, and other smaller companies (probably mostly Canadian) the remaining 22 per cent.

- Given that the capital requirements and mining processes for diamonds resemble those for other types of mining, technological development available to the mining industry in general will also be beneficial to diamond mining. There have been several basic improvements in mining processes in the past several decades, especially in the continually increasing capacity of large machinery for extracting ores. Perhaps most importantly in the past decade, the control of many operations has been computerized, along with pre-mining planning and site design. The relatively new Canadian diamond mining industry has the advantage of being able to rapidly adopt new technologies that have been developed over several years in response to the needs of other mines and diamond mines in other countries.

- At least one challenge faced by diamond mines that is not generally faced by other mining operations is transportation. The Ekati and Diavik mines are located about 300 kilometers northeast of Yellowknife, and ground transportation to Yellowknife is only possible via ice roads for about four months every year. However, the rough diamonds produced at these mines do not require large scale truck transportation. Still, the cost of air transportation for bringing in supplies when ice roads are not available and for transporting employees imposes a cost on diamond mines that is not present for most other mines.

C. Indirect Benefits of Diamond Mining

The potential role of the Canadian diamond mining industry in the development of complementary upstream and downstream industries have already been mentioned. However, two more important benefits derived from the recent take-off of the diamond mining industry in Canada are increased government revenues and well-paying work in areas of typically limited employment opportunities, particularly for aboriginal people.

The federal government has royalty claims to resource extraction in the territories, and provincial governments will stand to realize these same gains when diamond mining commences in the provinces.[9] As well, there are increased revenues from income and business taxes when new businesses and jobs are created. Santarossa (2004) states that "Indian and Northern Affairs Canada estimates that over the life of the mines, the Ekati, Diavik and Snap Lake projects will collectively generate royalties of $1.6 billion, federal business taxes of $2.6 billion, territorial business taxes of $1.3 billion, and employee and other business income taxes of $4.7 billion." These revenues could be used to invest in northern communities contributing to these mines, or in other programs aiming to improve economic and social progress.

The well-paying diamond mining jobs are potentially a boon to northern communities, where employment alternatives of any sort are sparse and jobs requiring specific skills usually require the importation of workers from other provinces. The challenge in making these jobs beneficial for the north is to ensure that northern residents have access to them. There is evidence that there has been success thus far in this area.

[9] Aboriginal groups with land treaty claims on mined land also receive a share of the royalties.

Chamber of Mines of the Northwest Territories and Nunavut, Mining Association of Canada and Prospectors and Developers Association of Canada (2004) state that DeBeers and the Chamber of Mines of the Northwest Territories and Nunavut have both been involved with local mine training programs. According to their own statistics, the Ekati mine employs 320 northern residents[10] out of 800 direct employees, with an unknown proportion of a further 800 contract workers from the north. The Diavik mine employs northern residents in 457 out of 625 positions. About one third of total employment in both mines consists of aboriginals, amongst whom unemployment has been typically severe (Santarossa, 2004). Starnes (2004) states that the unemployment rate in the Northwest Territories in 2003 was 6.6 per cent, lower than the Canadian average, reflecting increased employment opportunities arising from the development of the diamond industry.

II. Productivity Performance of the Canadian Diamond Mining Industry, and Implications for the Overall Mining Industry

A. Productivity Performance

Data on output, hours and labour productivity are shown in Table 2 below. Output per hour has been on a broad upward trend over the 1998-2001 period, with a large jump in 1999 and a large decline in 2000, but a rebound in growth in 2001.[11] Labour productivity in diamond mining in Canada grew by 9.0 per cent between 1998 and 2001, or 2.9 per cent per year. This compares with output per hour growth of 1.5 per cent per year at the total economy level.

More important than labour productivity growth is the level of labour productivity, which is very high in diamond mining relative to other industries. Output per hour in diamond mining in 2001 was $274.24 (1997 constant dollars), 3.4 times and 7.6 times the mining and total economy averages respectively of $80.74 and $36.33. It therefore appears that diamond mining is a very high-productivity level industry. This is of course explained by the high degree of economic rent in diamond mining, and the capital intensive nature of operations. Although firm conclusions on trend productivity growth in diamond mining are not possible due to the limited number of years for which data are available and the recent nature of the industry, it also appears that there is potential for strong labour productivity growth. Unfortunately, estimates of output and employment are not available for downstream diamond-related activities such as cutting and polishing, although the productivity level and growth in these industries are likely closer to the economy-wide average due to the more limited economic rents. Nor are there any estimates of capital stock or investment available for diamond mining.

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[10] The precise definition of a northern resident is unclear in these statistics.

[11] These estimates are not necessarily robust, as they are based on a single firm. The drop in output in 2000 was likely driven by the first production of smaller diamonds from a new site at the Ekati mine. This drove the average price of Ekati diamonds downwards as sales included both higher-quality large stones and small stones (Santarossa, 2004). As production of the smaller stones increased and production shifted back towards larger stones, overall output increased after 2000.

Table 2: Output, Hours Worked and Output per Hour in Diamond Mining in Canada, 1998-2002

	Real GDP, millions of 1997$ at basic prices	Hours Worked, thousands	Output per hour, 1997$
1997	0	0	na
1998	52.0	206.7	251.57
1999	428.3	826.5	518.19
2000	303.9	1,343.4	226.22
2001	446.2	1,627.1	274.24
2002	545.4	na	na

Sources: GDP from unpublished GDP by Industry data from Statistics Canada. Hours paid by production workers from *General Review of the Minerals Industries*, 2001 edition, Statistics Canada catalogue number 26-201. Hours paid for total employees calculated by applying average hours for production workers to total employees. Hours paid converted to hours worked by applying the ratio of total hours worked by all workers in overall non-metal mining (from the Productivity Program Database) to hours paid of employees in all metal mining, from the *General Review of the Minerals Industries*. Data in this table refer only to the Ekati mine, as the Diavik mine did not start production until 2003.

B. Impact on Overall Mining Industry Productivity

Given the well above-average level of labour productivity in diamond mining and the expectation of expanding diamond mining activity as new mines are opened, it can be expected that the labour productivity growth of the overall mining industry will accelerate in coming years due to a composition effect (i.e. as the high-productivity diamond sector continues to grow in importance). This can be illustrated with an exploratory simulation exercise, the details of which follow.

- Diamond mining value added was $446 million (1997 constant dollars, for all real output values in this simulation) in 2001. Since then the Diavik mine has begun production, and the Jericho and Snap Lake mines are scheduled to begin production in the next couple of years. Assuming all four mines are producing, on average, at about the 2001 production level of the Ekati mine by 2006, diamond mining output will be $1,789 million in 2006.[12]

[12] Forecasting diamond mining output is difficult, since the size and other characteristics of diamonds on one site are different from those on other sites, and because the abundance of a given deposit is subject to uncertainty. This assumption of a quadrupling of output is hence not intended to be an accurate forecast, but it can be partially supported with information on the expected quantity of production from each of the four mines. Santarossa (2004) reports that average expected output per year over the life of the mine is 4 to 5 million carats at Ekati, 8 million carats at Diavik, 0.4 million carats at Jericho, and 1.5 million carats at Snap Lake. Assuming that each of the four mines reaches this expected average by 2006, there will be 13.9 million carats of diamonds produced in that year. This is about 3.7 times the 3.8 million carats produced in 2001. Unfortunately it is not known how output in carats will translate into real value added. However, as

- There were 1,637 thousand hours worked in the diamond industry in 2001. Assuming that the growth rate of output per hour in diamond mining maintains its 1998-2001 rate of 2.9 per cent per year until 2006 (and hence that output per hour will be $316.37 in 2006), hours worked in diamond mining will be 5,641 thousand in 2006 (also using the projected 2006 output level for diamond mining).

- Value added in the overall mining industry excluding diamond mining was $9,131 million in 2001. Assuming that the growth in output of mining excluding diamonds remains constant at the 1998-2001 rate of 1.3 per cent per year between 2001 and 2006, output in mining excluding diamonds will be $9,740 million in 2006.

- There were 137,524 thousand hours worked in the mining industry excluding diamonds in 2001. Assuming output per hour growth remains constant at the 1998-2001 rate of 6.4 per cent per year[13] in mining excluding diamonds until 2006 (and hence that output per hour will be $90.54 in mining excluding diamonds in 2006, up from $66.39 in 2001), there will be 107,577 thousand hours worked in the mining industry excluding diamonds in 2006.

- Diamond mining in this scenario hence accounts for 4.7 per cent of total mining value added in 2001 and 15.5 per cent in 2006. Diamond mining's share of total mining hours worked is 1.2 per cent in 2001 and 5.0 per cent in 2006.

- These assumptions and observations provide output and hours estimates for diamond mining and mining excluding diamonds for 2001 and 2006. Putting these estimates together gives output per hour levels for mining (including diamond mining) of $68.82 in 2001 and $101.79 in 2006.

- These levels of output per hour imply labour productivity growth of 8.1 per cent per year in mining (including diamonds) over 2001-2006. This is 1.7 percentage points higher than the rate of growth of labour productivity of 6.4 per cent per year that would have obtained under these assumptions had there been no diamond mining. These results are shown in Table 3.

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will be discussed below, it is also possible, as a sensitivity test, to undertake the simulation with a more conservative assumption on diamond mining output growth.

[13] Output per hour growth in the mining industry accelerated in the second half of the 1990s, with the growth rate for the entire 1989-2000 period only 2.3 per cent per year. For the overall 1961-2000 period the rate of growth of output per hour in mining was 2.9 per cent per year. The growth rate of 6.4 per cent per year for 1998-2001 therefore may not represent the long-term trend rate of mining excluding diamonds productivity growth. However, the result of the simulation, in terms of the percentage point impact of diamond mining on overall mining labour productivity growth, is largely invariant to the assumption about mining excluding diamonds productivity growth. For a wide range of growth rates, the forecast average annual growth from 2001 to 2006 of the mining industry inclusive of diamonds is about two percentage points higher than that for mining excluding diamonds.

- Even though labour productivity growth in diamond mining is lower than in mining excluding diamonds, the relative productivity level in diamond mining is so high that overall mining labour productivity growth increases through a composition effect as the relative importance of diamond mining increases.

Table 3: Forecast of the Diamond Mining Industry's Contribution to Mining Industry Productivity Growth, 2001-2006

	Diamond Mining			Mining Excluding Diamonds			Total Mining (Including Diamonds)		
	Output 1997$	Hours thous.	Output per Hour	Output 1997$	Hours thous.	Output per Hour	Output 1997$	Hours thous.	Output per Hour
2001	446.2	1,627.1	274.24	9,130.6	137,524	66.39	9,576.8	139,151	68.82
2006 (est.)	1,784.8	5,641.4	316.37	9,739.7	107,577	90.54	11,525	113,218	101.79
	compound average annual growth rates, per cent								
01-06	32.0	28.2	2.9	1.3	-4.8	6.4	3.8	-4.0	8.1

This projection of output per hour trends in the mining and diamond mining industries, although quite non-rigorous in its assumptions, clearly demonstrates the impact that the emerging diamond industry will have on the overall mining industry, and hence total economy. Both the level and growth rate of mining labour productivity will be higher in the future through a composition effect, as the diamond industry expands.[14]

C. Prospects for Future Productivity Growth in the Canadian Diamond Mining Industry

There are three primary factors typically associated with productivity levels and growth in mining industries, which have also been identified as important to different degrees for gold and coal mining in Smith (2004a and 2004b). These are the price of the commodity, capital intensity of production, and technological advance.

The price of a commodity has two effects on the average productivity level, in value terms, of the industry that mines that commodity. The first is by determining the degree of economic rent, i.e. the rate of return above and beyond that consistent with a normal rate of profit. The higher is the price, the greater will be the economic rent and hence current dollar productivity level. The second is by determining the grades of ore that are profitable to be mined, and so the level of mining activity and hence output. For

[14] Instead of assuming that diamond mining output will increase by four times between 2001 and 2006, an alternative assumption is that output only increases by 2.5 times. This alternative simulation leads to an impact of about one percentage point in terms of the higher growth rate in total mining compared to mining excluding diamonds for the 2001-2006 period, compared to the nearly two percentage point impact observed with the original assumption, still a considerable effect. Preliminary mineral production statistics for 2003 from the Minerals and Metals Division of NRCan, along with anecdotal evidence on expected output increases and mine openings, suggest that the original assumption may be somewhat optimistic but that the alternative assumption is quite conservative.

example, when the real price of gold increased sharply in the early 1970s, mining sites with ores of low grade became profitable to mine since the resulting gold could be sold for such a high price. This encouraged the exploitation of these low-quality sites, which entailed high labour effort for the small amount of additional output produced. When these low-productivity mines produced alongside the established higher-productivity mines, the average productivity of the overall industry suffered.

Since all Canadian diamond operations already have a very high degree of economic rent, an increase in the average price[15] of diamonds may not encourage much additional mining activity, although may spur exploration by existing firms, whose profits are increased. In other words, wherever diamonds are likely to exist in Canada, it would appear that they are abundant enough and of high enough quality that they are already profitable to be mined. A price increase would make diamonds *more* profitable to be mined; but it does not appear that there are any diamond deposits in Canada that are not currently profitable to be mined and that a price increase would make profitable. Likewise, any foreseeable drop in the average price of diamonds is not expected to squeeze the profits of existing operations enough to force them out of business. However, price changes will affect the measured value of production and current dollar productivity levels of diamond mines. The point is that the price of diamonds – at least of the quality and size of which Canada appears to have an abundance – is generally high enough to cover the costs of excavation as well as provide a wide margin of profit.[16] In this sense, the existence of diamond deposits and the ability to mine them are the most important things for the diamond industry, not the average labour productivity at those mines.

Capital intensity growth is important for mining productivity growth not only because it implies that larger machines are being used for large-scale tasks that would take workers and smaller machines much longer to accomplish, but also because new capital investment embodies the latest technology. Formal decompositions of labour productivity growth for gold mining and coal mining in Smith (2004a and 2004b) found capital intensity growth to be moderately important for the most part, but not always the most important source of labour productivity growth in each period. However, Romer (1987) casts much doubt on the precision of the type of decomposition technique utilized there, and states that such methods probably underestimate the role of capital to a large degree. Therefore, the importance of the intensive use of large machinery, as well as of detailed site development and exploration/assaying (which are included in the measurement of the engineering component of the capital stock), should not be understated for diamond mining, nor for that matter for other mining industries.

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[15] As has been mentioned previously, the price of a diamond is very sensitive to its characteristics. Thus, the concept of average price refers to the expected price for diamonds of the size, colour and clarity that geologic testing indicates are present on a given site.

[16] This is in part due to the ability of De Beers to ensure high monopoly prices of diamonds. Their marketing campaign has been tremendously successful in establishing the image that a "diamond is forever" and a touchstone for romance. Some might consider this an artificial basis for an industry, since without such an ingrained institution of diamond wedding bands, for example, the price of diamonds would likely be much lower due to lower demand.

The final important driver of productivity growth in mining industries is technical advance, part of which is disembodied technological change. Although little direct research and development is done within the mining industry, much innovation occurs by using new technologies and adopting new processes. The implementation of computerized mine control systems, dispatch systems, and site development programs all show up in capital investment, but the novelty of these new techniques is not captured simply by the amount spent on these investments. The rapid rise in computer power in the 1990s made detailed three-dimensional computer assisted design of mining pits feasible, and allowed the seamless integration of mine control and transportation systems. Investments in these new computer systems caused only a slight lift in the capital stock due to relatively small importance in overall investment in machinery and structures. But with their implementation the technical capacity of mining industries took a large step forward.

Complementary to capital intensity and technical progress is the skills level of the workforce. New machinery and equipment, and especially that representing new technologies with high technical requirements, necessitates a workforce competent in its operation. However, the importance lies in the appropriateness of skills rather than some measure of the absolute quantity of skill. While average years of education are close to the average for the total economy in mining industries, this is driven by a large share of workers with a post-secondary certificate or diploma, rather than a moderate share of workers with a university degree as in all industries on average. More years of schooling do not necessarily translate into a higher competency with a given computer application. Rather, such specific skills are formed through past experience or through programs teaching that specific skill – more often found within colleges and trade schools than at universities.

In terms of these broad determinants of productivity in mining industries in general, the Canadian diamond mining industry would appear to have a solid foundation from which to grow. Several new mines are likely to begin production in coming years, and they have the strong performances of the first diamond mines and of the overall Canadian mining industry to learn from. One potential weakness mentioned by Chamber of Mines of the Northwest Territories and Nunavut, Mining Association of Canada and Prospectors and Developers Association of Canada (2004) is a possible shortage of skilled workers. Given the remote locations of Canada's diamond mines, it has proven difficult to attract skilled workers. To this point most workers have hence had to be trained as they work. Groups providing this training have stated that their capacity to continue to do so is likely to be outstripped by the demand for skilled workers as new mines open and diamond mining output continues to expand.

III. Conclusions and Outlook for the Diamond Industry in Canada

Based on the limited time series available on the young diamond mining industry in Canada, as well as observations on mining industries in general, the future of the diamond industry in Canada looks very bright. Output and employment in the diamond

mining industry have grown substantially in the first five years of mining activity, with several new mines in development stages and several slated to begin production in coming years. Moreover, reserves of diamonds in Canada appear to be vast and of high quality, ensuring profitable enterprise for years to come.

The growth of the Canadian diamond mining industry and its very high productivity level have important implications for the productivity growth of the overall Canadian mining industry. Simulations suggest that by 2006 the labour productivity growth rate of the Canadian mining industry will be one to two percentage points higher per year than would be the case if the diamond mining industry did not exist. Total economy productivity growth will thus also benefit from the growth of the diamond mining industry.

Three indirect benefits of diamond mining have also been addressed. First of all, industries related to diamonds, such as mine site developers, transportation companies serving mines, and cutting and polishing firms, have developed and have an opportunity to expand as diamond mining expands. Not only does this imply a multiplier effect in terms of the number of jobs created by diamond mining, but with respect to the downstream industries it also means that a higher proportion of the total value added of the diamond trade can remain in Canada. Although the sale of rough diamonds is in itself quite lucrative, much value is added through the cutting and polishing of stones, the assembly of a final jewelry product, and the retailing of that product. Therefore, the higher the Canadian involvement in these types of industry, the larger will be the wealth created by the mining of diamonds in Canada. Aber Diamond Mines, co-owner of the Diavik mine, has already shown interest in such further involvement by pursuing agreements with retailers in order to capture revenues from the downstream aspects of the diamond industry.[17]

This leads to the next indirect benefit of the diamond industry in Canada, namely the creation of resource royalties and business and income taxes accruing to governments. The third benefit, the creation of employment opportunities in remote and often impoverished regions of Canada, is related to the second because the former gives the potential to reinforce the latter, and for that matter the first indirect benefit. With these benefits in mind, the productivity growth performance of the diamond mining industry may be secondary, given the already extremely high productivity levels of the

[17] Chamber of Mines of the Northwest Territories and Nunavut, Mining Association of Canada and Prospectors and Developers Association of Canada (2004) state that most of the value added in the diamond pipeline is in retailing. As mentioned previously, Chamber of Mines of the Northwest Territories and Nunavut, Mining Association of Canada and Prospectors and Developers Association of Canada are not optimistic on the future of the cutting and polishing industry in Canada. This is driven by concerns that government attempts to establish the cutting and polishing industry will impinge on the mining companies' ability to market their diamonds as they see fit and on the incentives to undertake diamond exploration and development. Chamber of Mines of the Northwest Territories and Nunavut, Mining Association of Canada and Prospectors and Developers Association of Canada (2004) recommend that governments support the cutting and polishing industry only out of general revenue, rather than through regulations affecting diamond mines, but also state that the use of robotic technology has made the cutting and polishing firm in Vancouver successful without government assistance.

industry. Rather, the establishment of new mines at current productivity levels will have substantial wealth-creating effects.

In terms of improving the productivity growth[18] of diamond mining, the principal factors are already in place. Capital intensity and technical change are paramount, but the fact that the diamond industry is just getting on its feet recently bodes well in both these respects. First of all, given the scale at which diamond mining takes place, large equipment is a necessity, so that mining operations will by nature be capital intensive. Secondly, given that other mining industries in Canada and the diamond mining industry in other countries are well-established, the equipment necessary for the specialized operations of large-scale open-pit mining are already available and do not need to be specially developed. Third, and probably most importantly, the late 1990s was an auspicious period to be starting production, since the use of computers in mining operations and in daily life was becoming commonplace, and because much technical advance had been built into machinery in the earlier part of the decade. In effect, the diamond mining industry was able to avoid costly experimentation with new technology and was able to start with the best technology available. In a way this is an example of technological catch-up: new comers and slow starters achieve rapid growth to catch up to the level of technology of established players since they can simply adopt the best technologies and practices immediately.

This is not necessarily a call for complacency. First of all, new technologies require a skilled workforce for their effective implementation. Given the remote location of the present and in-development diamond mines in Canada, such a skilled workforce may be difficult to attract. This suggests that a not insignificant portion of labour effort expended thus far in diamond mining may reflect the few skilled workers training other workers on the job, or simply workers learning as they work. It is possible that the capacity of in-house training programs to keep up with the anticipated expansion of the industry will become inadequate in the future. The further development of training programs may have large benefits, in terms of providing more individuals with access to high-paying jobs in the diamond mining industry, and in terms of allowing for further increases in diamond production.

Second, the diamond mines that have been established thus far have had to seek capital support from large international diamond companies for developing their sites and for meeting the rigorous core sampling requirements that investors demand. Given the good evidence provided by the diamond mines now in existence that Canada has rich and high quality diamond reserves, there may be large future benefits for Canadian companies and governments in supporting the junior companies currently in the early

[18] Of course, in terms of increasing the productivity level of diamond mining, one available method is straightforward. The more monopoly power enjoyed by firms, the higher will be the current dollar value of output per hour worked. The monopoly status is already largely secured by the marketing of De Beers over the past several decades, and the Canadian mines seem to be attempting to further strengthen the uniqueness of their brand (and hence increase the economic rent associated with it) by marketing the clarity and colour of their diamonds as unrivaled.

stages of development, in terms of keeping a larger proportion of ownership in Canadian hands.

In terms of some broader conclusions on the potential impact of diamond mining in Canada, the take-off of the diamond mining industry in Canada's northern regions provides an important opportunity to assist in the further development of these regions and to narrow the disparities between these and other regions of Canada. Such assistance could have favourable economic and social impacts for Canada as a whole. Just as the fledgling diamond mining industry is able to rapidly catch up to other Canadian mining industries in terms of technical capabilities, so too do northern regions benefit from being so far behind the rest of Canada in terms of economic development. Although the geographic isolation of these communities may preclude the agglomeration benefits of cities like Toronto and Vancouver, simply adopting the institutions that are crucial to the economic success of other Canadian regions will go a long way in ensuring that the growth recently enjoyed by the Northwest Territories will become more firmly established and broadly based. This in turn can play a role in closing the prosperity gap between the north and the south of Canada. Nor is this an area strictly for government policy. Businesses already have an opportunity to take part in the current growth of the northern regions, and such participation will in turn contribute to future growth and business opportunities.

Finally, there may also be benefits in the further development of downstream diamond industries in Canada, such as the cutting and polishing of rough stones and the manufacture and retailing of jewelry products. Although industry interests are critical of direct intervention obliging Canadian mines to supply Canadian rough diamonds to Canadian upstart cutting and polishing firms, more general support of such firms is possible through standard small business grants and incentives to adopt cost-saving technologies. Even more lucrative than supplying finished diamonds, however, would appear to be the design, manufacture and retailing of final jewelry products. Investment by Canadian firms in these stages of the diamond pipeline could promise large returns due to the very high value added associated with the overall diamond industry. To a certain degree a Canadian presence in the diamond retail market has already been established, with jewelry stores clearly advertising the exceptionally clear Canadian diamonds signed with the distinctive polar bear insignia and in some cases showing them in separate display cases.

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