SOCIAL INDICATORS FOR ARCTIC MINING

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Abstract

This paper reviews and assesses the state of the data to describe and monitor mining trends in the pan-Arctic. It constructs a mining index and discusses its value as a social impact indicator and discusses drivers of change in Arctic mining. The widely available measures of mineral production and value are poor proxies for economic effects on Arctic communities. Trends in mining activity can be characterized as stasis or decline in mature regions of the Arctic, with strong growth in the frontier regions. World prices and the availability of large, undiscovered and untapped resources with favorable access and low political risk are the biggest drivers for Arctic mining, while climate change is a minor and locally variable factor. Historical data on mineral production and value is unavailable in electronic format for much of the Arctic, specifically Scandinavia and Russia; completing the historical record back to 1980 will require work with paper archives. The most critically needed improvement in data collection and reporting is to develop comparable measures of employment: the eight Arctic countries each use different definitions of employment, and different methodologies to collect the data. Furthermore, many countries do not report employment by county and industry, so the Arctic share of mining employment cannot be identified. More work needs to be done to develop indicator measures for ecosystem service flows. More work also needs to be done developing conceptual models of effects of mining activities on fate control, cultural continuity and ties to nature for local Arctic communities.

Key Words

Social indicators; mining; mining life cycle; economic effects indicators; mining employment; mining production index; ecosystem service indicators; drivers of change; climate change.

Overview

This analysis is a component of a larger project known as the Arctic Observations Network Social Indicators Project (AON-SIP), which in turn is part of a science initiative known as the Study of Environmental Arctic Change (SEARCH).[1] The goal of SEARCH is to understand the nature, extent and future development of the system-scale changes presently seen in the Arctic. The SEARCH program of research is focused on climate change in the context of other global changes underway, with the intent to identify knowledge that will help people respond to environmental change. The SEARCH Implementation Plan identifies initial priorities of SEARCH, including:

1. Develop an integrated pan-Arctic human dimension observation system based on existing data;
2. Develop stakeholder networks to identify relevant observations and predictions, and to help understand the dynamics of the Arctic system; and,
3. Develop and apply models to a pan-Arctic database to advance our understanding of environmental change and to identify data gaps that could be filled in subsequent research or agency initiative.

As part of SEARCH, AON-SIP is intended to contribute to the long term goal of identifying adaptive strategies based on an understanding of the dynamics of change in the Arctic. A top SEARCH priority is to ensure that the Arctic Observation Network (AON) includes the measures necessary to an analysis of Arctic change. AON-SIP is a first step. We are compiling existing data for components of the Arctic system that are likely to involve climate-human interactions. Our objectives are to assess the adequacy of existing data and to recommend additions to the Arctic observation network where necessary to fill critical gaps.

Figure 1 shows the relationship between this project and three major science initiatives: the Study of Arctic Environmental Change (SEARCH), the Arctic Observation Network (AON), and the Arctic Social Indicators initiative (ASI).

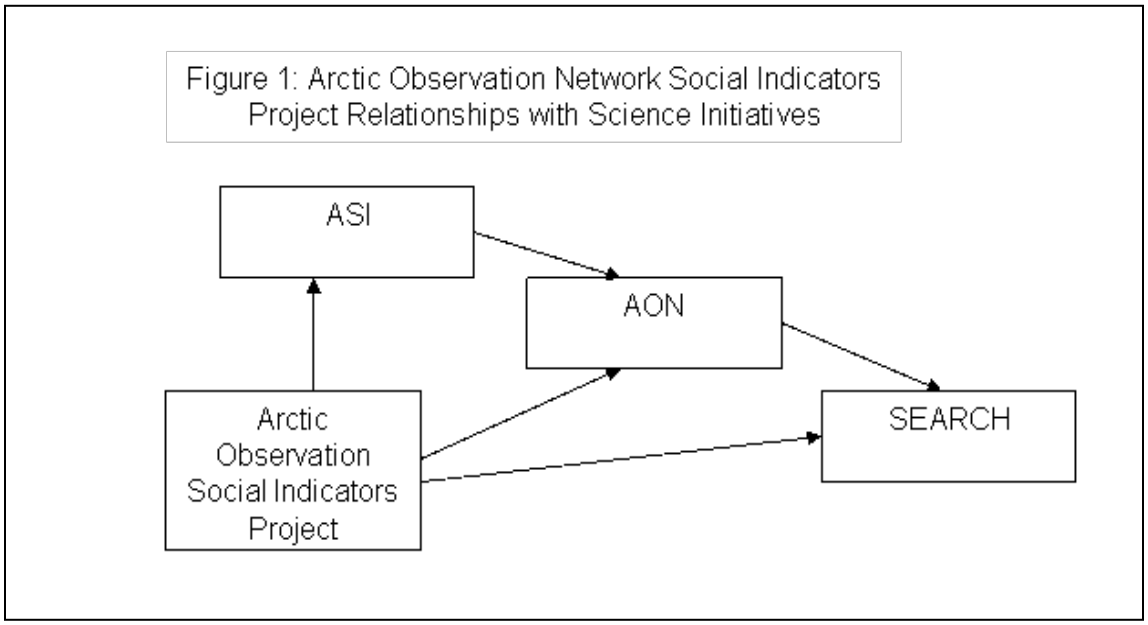
AON-SIP is funded by the National Science Foundation as part of NSF's Arctic Observation Network program. AON science priorities are largely driven by SEARCH, a federal interagency science initiative. Hence AON, and AON-SIP, are intended to contribute to the science goals of SEARCH. Arctic Social Indicators (ASI), is an initiative of the Arctic Council and a follow-up to the Arctic Human Development Report (AHDR). The goal of ASI is to recommend a small set of social indicators that could be used to monitor change in the Arctic. ASI is recommending two sets of indicators: one based on existing data, the other requiring new data collection. AON-SIP is designed to complement ASI science priorities.

AON-SIP focuses on four components of the Arctic system where climate change and people are likely to interact: (1) commercial fisheries; (2) marine mammal hunting; (3) tourism; and (4) oil, gas, mining and marine transportation. A fifth project focus is on social outcome indicators that may be affected by human interactions with environmental

[1] Project website: http://www.iser.uaa.alaska.edu/projects/search-hd/index.htm

change, and specifically the six dimensions identified in AHDR and ASI: material success, health, education, fate control, ties with nature, and cultural continuity. The complete datasets and detailed documentation are available at www.search-hd.net.

Figure 1. Arctic Observation Network Social Indicators Project Relationships with Science Initiatives



AON-SIP is part of the Arctic Observation Network. We are designing our project to foster integrated analysis across the physical, natural, and social sciences. Our database project uses the Arctic geospatial data platform, Arctic-Rapid Integrated Monitoring System (Arctic-RIMS): a database that contains a growing number of physical, biological, and social science variables. The goal of Arctic-RIMS is to make these data easily available for integrated analysis. Our project team works with other AON investigators to foster the development of Arctic-RIMS as well as other integrated databases.

This paper reports AON-SIP project analysis for one arena of Arctic change, specifically the mining component.

Background

Arctic oil and gas prospects, and the ensuing, contentious diplomatic relations that have resulted between circumpolar countries, have received widespread attention in recent years. By contrast, the expansion of Arctic mining has proceeded with little fanfare. Employment growth in Alaska's mining sector grew at six times the pace of the petroleum sector's employment growth since 1990. In Canada, the value of diamond mining has outstripped oil and gas extraction in the Northwest Territories (NWT) for the past decade (McDonald et al 2006). In Alaska, Canada and Greenland, recent regulatory changes and policies have encouraged the development of new mines (Borrell 2004;

Cope 2004; Carter 2007). And Russian mega-companies like Norilsk have extended their global reach, buying into operations in Finland and Arctic Canada (*Mining Exploration News*, 2008).

Mining, like oil and gas, has the potential to both spur economic development and create wealth, but also harm the environment and irrevocably shape the social dynamics of Arctic communities and indigenous ways of life. Mining development in the Arctic can be further complicated by an extreme environment, remote locations, and a limited labor supply. Mining's uncertain socio-economic impact is also of concern in regions where an *informal* economy – particularly subsistence hunting and herding – is a critical cultural component and essential to the quality of life of local inhabitants (*AHDR* 2004).

Within the Arctic, mining regions can be categorized as either "resource frontier regions," or "mature" regions (also known as "downward transitional areas") (Sugden,1982; Duhaime 2004). Arctic Scandinavia is a mature region. Mines in Scandinavia have operated since the 1950s and are well integrated into a national transportation network. They have generated widespread economic spin-offs and are central to local and regional economies.

In frontier regions like Alaska, the Canadian Territories, Nunavut, and potentially Greenland, "economic decoupling" is more characteristic: the economic benefits of mining are largely exported, and the control of resources is dictated from afar (Duhaime 2004). Value-added industries, like the refining and industrial application of minerals, remain largely undeveloped. Most NWT diamonds, for example, are exported out of Canada as rough, or uncut. Exploration in Greenland has jumped in recent years, and new mines have opened, but are under pressure from falling prices (McDonald 2006; Sørensen 2008). Mining in frontier regions, where costs are high, is particularly sensitive to price fluctuations (Duhaime 2004). Developments in "benefit sharing agreements" and "corporate social responsibility" are securing regional benefits and mitigating negative impacts to a certain degree, though the threat of resource dependency remains, sewing vulnerability into a fledgling frontier economy.

Mining does not exist in Iceland or the Faeroe Islands (except sand and gravel), though large smelting operations, supplied by Scandinavian ore, contribute significantly to Iceland's economy.

Mine production is classified as mineral fuels (mostly coal), iron, ferro-alloy and non-ferrous minerals (with myriad industrial applications), precious metal ores (mostly gold and silver), or industrial minerals including diamonds. Oil and gas, sand, gravel and quarry stone are also classified as mining, though they are not considered here.

The Arctic contributes a small share of global production of minerals like titanium (.3 percent) and bauxite (1.9 percent), but contributes as much as 40 percent to the global production of palladium (used by the auto and electronics industries, among others), 26 percent of diamond gem stones, and 23 percent of industrial diamonds (Lindholdt 2006).

Arctic Russia with abundant reserves and large-scale production accounts for the largest share of Arctic mining (Linholdt 2006), but other regions are increasingly important, including one of the world's largest zinc mines in remote Alaska, and the world's second largest underground mine in Kiruna, Sweden. Greenland's rapid movement towards

exploration and production marks a new era in Arctic mining, and therefore a new era in Arctic economics and society. It is unclear how recent volatility and price fluctuations will shape current developments, however, and what the implications are for countries and communities dependant on resources with notoriously volatile prices. Data for mining in the Arctic has been irregular and inconsistent - either because of its proprietary nature, different reporting standards, or their inclusion into greater numbers for the country at large. Mining's contribution to Arctic economies therefore remains unclear.

In this paper we discuss the development of indicators for monitoring social effects of mining activities, and drivers of change in mining activities in the Arctic. The analysis provides insight into how prices and production in frontier regions relate and the changing relationship between production and employment. The goal is to contextualize mining's contribution to social and economic development by comparing data across regions and across time. We describe trends in mining across the circumpolar north and highlight systemic shortcomings in information that make comparisons and evaluation difficult. Other drivers of Arctic mining discussed include political developments in newly self-governed regions, and climate change. Climate change as a driver has very small effect at the margin, relative to the major drivers of price, infrastructure and technology, and policy as it affects access, the costs of development, and the business climate for long-term investments.

What would we really like to know and monitor?

The Arctic Social Indicators Project aims to measure outcomes in the six dimensions of human development identified in the Arctic Human Development Report:

- Material well-being
- Health
- Education
- Fate control
- Ties to nature
- Cultural continuity

Compiling social outcomes data is the primary task of other researchers in the AON-SIP project. (See Kruse et al., 2011; Berman, 2011; and Hamilton, 2011) Here we are concerned with the linkages between resource development activities and social outcomes. The AON-SIP conceptual model explicitly identifies two pathways of interactions between development activities and social outcomes: economic effects and ecosystem services, with institutions as a mediating layer. Several strands of current research suggest, however, that there are intangible pathways and effects that are also important, particularly with respect to fate control, ties to nature and cultural continuity. Haley and Magdanz (2008) speculate that increasing integration in the market economy may have mixed effects, decreasing strong social ties and well-being while increasing material standards of living. Similarly, Wernham et al (2009) discuss the potential effects of sudden increases in discretionary income, increases in social inequality, and rotating mine shifts may affect social and psychological health. Haley, et al. (2009) discuss the potential effects of migration, time with children, community conflict, and changing

patterns of social ties on cultural continuity, and discuss incorporation of local knowledge in resource decision making as a factor in fate control. Several authors in *Earth Matters: Indigenous People, the Extractive Industries and Corporate Social Responsibility* (O'Faircheallaigh and Ali, 2008) discuss how corporate social responsibility and contextual factors may affect fate control by indigenous people in the course of resource development.

In this project we did not collect indicator data on ecosystem services or the less tangible processes that affect fate control and cultural continuity. Our emphasis on currently available, time series data has led us to an almost exclusive focus on economic and production data. The economic effects of mining activity are easier to measure with existing data. The economic benefits derived from mining can fuel improvements in material well-being, health, education and institutions for local governance. (Haley et al. 2009) The indirect effects of economic activity on ties to nature, cultural activities and sense of fate control are more ambiguous and very context-specific.

Mining lifecycle stages

We begin the discussion by defining the lifecycle stages of mining activity, understanding that social effects will differ at different stages. We distinguish seven lifecycle stages of mining activities: exploration, pre-development permitting, development, operations, expansion, temporary slow down or shutdown, and decommissioning and reclamation.

Exploration is the precursor to all other activity. Exploration activities, which typically involve a handful of geologists spending time in the field, are relatively small scale, with correspondingly small costs and social impacts.

The predevelopment stage is characterized by assessment of the volume and grade of the ore and metallurgic assessment; scoping development options and assessing costs; financial planning; and assessing political risks for mine development. These activities are typically conducted by in-house specialists and contracted consultants working in corporate offices and, while more extensive and higher cost than exploration activities, they are still small compared to mine development, and have few direct impacts on the region. The permit process may involve public review, and that process may have political implications for local communities.

If the predevelopment stage gives the project a green light, development activities begin, including securing permits, final design, constructing facilities, and commencing operations. Actual development and operation of the mine generates new information about the geology, the technological challenges, the costs and the environmental risks, which may trigger reassessment and revised plans. The development stage has significant social effects through employment and potential effects on ecosystem services. Employment is typically higher in the construction phase than in operations, and there may be social impacts associated with temporary workers. Operations also mark the start of different revenue streams that may enter the local economy, such as royalties, taxes, rents, local purchases, contributions, profits and dividends. There also may be changes in population or in the character of community life.

Activities associated with mine construction and startup can create abrupt changes in the local ecosystem. If there are any social impacts associated with these changes, they are likely to be felt more acutely in the short term; in the longer term, people adapt and the changed environment becomes familiar. On the other hand, there may be more subtle or cumulative effects, such as contamination and the effects on microorganisms or human health, that manifest over time. Such long term effects may have more profound social consequences. Another type of effect is the risk of an extraordinary event with severe consequences. The existence of risk may have social impacts on governance, investment, or sense of security and fate control.

Expansion activities can expand the scale of the mine and associated impacts, or can extend the operating life of the mine and defer the impacts associated with closure. Expansion activities require the same cycle of planning and permitting as the pre-development and development stages, and has similar drivers. Because it is building on the existing infrastructure and activities, the character of the effects is continuous rather than discontinuous.

A temporary or partial shutdown has primarily short-term effects on employment and income, and the secondary effects of this on local communities. A temporary or partial shutdown might be triggered by environmental compliance issues, or low prices.

Permanent shutdown involves decommissioning the facilities and reclaiming the land. While there is a permanent loss of employment in mining, mill and transportation, there is a short-term gain in employment associated with deconstruction and salvage, earthmoving and re-vegetation. In most cases there are a few permanent jobs associated with ongoing needs for site security and environmental monitoring. Decommissioning a mine also terminates various revenue streams that may enter the local economy, such as royalties, taxes, rents, local purchases, contributions, profits and dividends. Ideally, reclaiming the land restores a range of ecosystem services, although risks from the containment of tailings and contaminants remains long term.

Ecosystem services and potential indicators

Although poorly understood, ecosystem services directly affect human well-being (Butler and Ouloch–Kosura 2005). The Millenium Ecosystem Assessment (MA)–an appraisal initiated by the United Nations of global ecosystem conditions–isolates four categories of "ecosystem services," or the benefits to humans derived from healthy, operational ecosystems. "Provisioning" services, for example, include commodities like timber, minerals, food and water. "Regulating" services include the natural control of climate through carbon sequestration or cloud formation, or flood control from healthy wetlands. "Cultural" services include the recreational, spiritual, or aesthetic values benefiting humans. Finally, "supporting" services include nutrient cycling that enhances or maintains the other services.

Key measures for ecosystem integrity include patch abundance, size, and spatial distribution. High resolution imagery from remote sensing can help observe broad-scale changes in landscape patterns and provide timely evaluation of ecosystem conditions (Bourgeron et al. 1999).

Diversity is a key resource of system resilience and adaptation. Biodiversity is a common indicator from which to begin assessing an ecosystem's health, and therefore its ability to provide ecosystem services. The UN Convention on Biological Diversity (CBD) defines biodiversity as, "the variability of all organisms from all sources…and the ecological complexes of which they are a part…including diversity within species, between species and of ecosystems." In "Breaking New Ground: The Report of the Mining, Minerals, and Sustainable Development Project," biodiversity is highlighted as a critical variable when considering the effects of mining on the environment:

> Biodiversity's critical value lies in the choice or options that it supports, for both present and future benefits – whether this relates to the alternative food sources it provides, to the range of bio-chemicals and processes that underpin modern and traditional medicinal products, or the way it increases the resilience of the biosphere's myriad natural processes, from pollination to watershed protection. Humans are somehow dependent on biodiversity, so its loss is likely to affect everyone. But those most likely to suffer the consequences of biodiversity loss are indigenous peoples or rural dwellers, many of whom continue to remain directly dependent on wild habitats and natural ecosystem services for their entire livelihood needs, whether by choice or through lack of alternatives. (2002: 258)

These are concepts that are appropriate when considering mining in Arctic regions because of subsistence livelihoods and rural economies. The same report adds that,

> The mineral sector has a key role to play in biodiversity maintenance, given that some mining ventures can eliminate entire ecosystems and all their endemic species and that its activities are increasingly prolific in relatively undisturbed high-biodiversity-value areas. (2002: 258)

Conservation International's *Guide to Responsible Large-Scale Mining* identifies several vectors through which mining impacts biodiversity, and thus ecological service flows. These include, road building, the introduction of alien pests and diseases, vegetation clearing, water use and altering its flow, and acid drainage (2000).

Mining impacts on biodiversity can be examined through the use of bioindicators, or key species that are sensitive to the cumulative effects of environmental disturbances such as air- and water-born pollutants, invasive species, or habitat loss (Andersen et al. 2004; Read et al. 2005; Majer et al. 2007). For example, Majer et al. (2007) investigate recolonization of ants in forests of Western Australia that were restored after bauxite mining occurred. Due to the strong positive association between species richness and the abundance of other taxonomic groups in the ecosystem, ants serve as drivers of ecosystem functions and processes and therefore track changes in the biological integrity of an ecosystem (Andersen et al. 2004). Hence, bioindicators are often superior to pollution parameters in assessing the geographic extent and severity of environmental impacts because they respond to cumulative effects of environmental disturbances (Read et al. 2005). In an application of bioindicators related to mining in the Arctic, Moiseenko et al. (2006) analyzed fish disease to evaluate ecosystem health in lakes of Russia's Kola North region. The authors point out that low biodiversity and short trophic chains found in ecosystems of the North result in a highly vulnerable ecosystem where pollutants migrate rapidly increasing the severity of damage to the environment.

Voilov et al (2004) and other reports recognize that proxies for biodiversity measurement, and similarly the quantitative valuation of ecological service flows, are difficult and pose a formidable challenge to researchers. In their effort to cross reference ecological, economic, and social variables on Russia's Kola Peninsula, they pursued data under different criteria, including:

1. Hydrologic cycles of the Lake Imandra basin (on the Kola Peninsula);
2. Population consumption patterns, including land use, mineral extraction, water use, food production and consumption (by different sectors of the society), and some description of indigenous knowledge of populations living in the region before large-scale development began (demographics, ethnology, sociology);
3. Contaminant transport and water quality information;
4. Biogeochemical cycles (including environmental waste absorption and buffering capacity) for various contaminants and nutrients, such as heavy metals, phosphates, SOx, NOx, etc.;
5. Non-renewable resource stocks (e.g., apatite and other ores), depletion rates, accessibility and market trends;
6. Renewable resource stocks (e.g., timber, fish, berries, mushrooms), depletion rates, growth rates and market trends (including ecotourism potential);
7. Environmental change in the region and expected impacts;
8. Economic assessment of ecosystem services and costs of pollution control;
9. Ecosystem health indicators (fish stocks, water quality, biodiversity, biological productivity, human health, etc.); and
10. Future alternative development scenarios developed by regional stakeholders.

Economic effects and potential indicators

Economic effects are easier to measure. We evaluated four types of measures for monitoring economic effects: local mine related spending, mine related employment, mining production measured in physical quantities and mining production measured by market value. To identify pan-Arctic patterns and monitor trends over time, a good indicator must meet four criteria: first, it should be a meaningful measure of local social impacts. Second, it should be available for each mine in each Arctic region. Third, it should be comparable between different regions and minerals. And fourth, it should be comparable over time. Each of the potential measures we identified failed to meet at least one of these criteria.

Local mine related spending could, if available, be the ideal measure of social impacts because it could identify all money flowing through a region including payments to local employees, governments, land owners and businesses. Unfortunately, mining companies consider this information proprietary and it is not generally available.

Mine related employment is the next best indicator of mining's social impact because employment is a direct social impact of mining. Employment is also an indicator of the

size of the mining operation. Unfortunately, employment data is collected and reported in different manners in different Arctic regions--e.g. reporting total employees vs. full-time equivalent employment, reporting employees by place of work vs. place of residence, which support services are included, and whether small scale operations and the self-employed are included. In addition, some countries only report employment by industry data at the national level, lumping Arctic and non-Arctic employment together.

Mining production has potential to be used as an indicator of mining's social impact because the inputs to mining production drive social impacts. The inputs to mining production—employment, payments to local governments, payments to land owners, and environmental impacts—have direct social impacts on a region. An increase in a region's mine production increases local spending and therefore mining's social impact on the region.

Measuring mining production in physical units allows us to compare the year-to-year change in the level of mining activity and its associated social impacts one mineral at a time. Using mining production measured in physical units as an indicator of the level of social impact does not allow one to compare the social impacts of mining different products. For example, an increase in gold production within a region has a corresponding social impact. But if gold production increases at the same time that iron production is decreasing, it is difficult to develop some understanding of the net social impact of the mining industry in the region.

Measuring mining production by market value allows us to aggregate and compare production across different minerals. The mineral value of a mine's production can be broken down as the cost of mining—wages, capital and the cost of intermediate inputs—plus "economic rent," defined as profits, royalties, land rents and taxes. The cost of mining is a direct measure of the level of activity and spending associated with mining. Mining activity and spending within a region creates employment and business for local vendors, resulting in direct social impacts. By contrast, the economic rents from mining do not measure activity and are drivers of social impacts only to the extent that the rents remain within the region—most often in the form of local taxes or payments to land owners.

Using the market value of production as a social indicator has two inherent problems. First, the market value of a mineral is determined by the global market price for that mineral. A short-term increase or decrease in market price will change the market value of production but have little effect on the volume of production or the social impact of mining. Second, it is an imprecise measure because the relationship between mining value and social impact differs between mines: each mining operation has different production costs, local value-added and labor characteristics. Furthermore, the reported value of production may or may not include costs associated with exploration, mining, transportation or refining.

Mining production index

To solve the problem of short term price fluctuations which affect value but do not affect mining activity or social impacts, we created an index of mining production based on long term average price. The mining production index is constructed as the physical

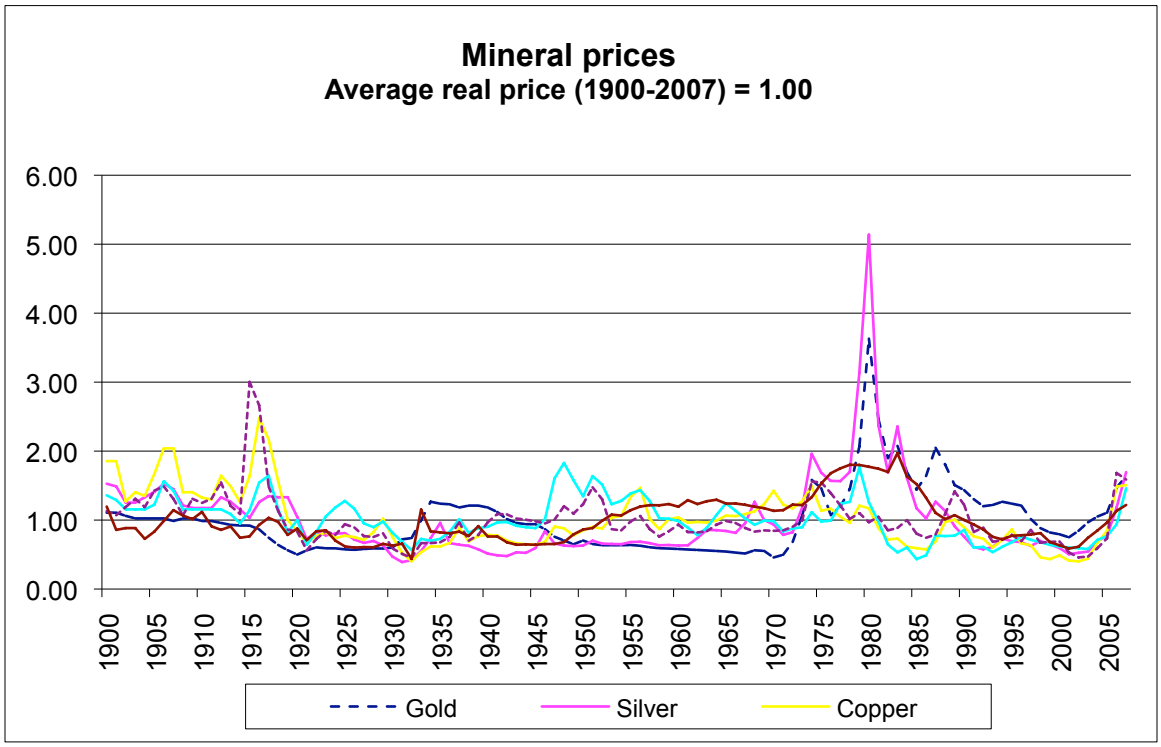
production of a mineral multiplied by its long term (1980-2007) average market price. One can interpret the mining production index as the mining value that would have existed if the mine sold its product at a long run average price instead of the prevailing market price. The prices used are from the U.S. Geological Survey mineral commodity statistics (Kelly and Matos, 2005), except coal prices which are from IMF commodity data for Australian thermal coal (EIA 2009). For diamonds we used a 10-year average price (1997-2007) to avoid the price discontinuity due to the break-up of the De Beers diamond cartel. The index includes metallic minerals, diamonds from Canada and coal from Svalbard, Norway. Most other industrial minerals are excluded from the index due to a lack of developed and consistent global market prices. Industrial minerals are important in some regions and are briefly discussed in that context.

The mining production index is a better indicator of social impacts than mining's market value because the Index normalizes mineral price fluctuations. A mining company's decision whether, and on what scale, to develop and operate a mine determines the level of mining activity and spending in a region. Mining companies use long term expected prices, not current, short term prices when making these decisions. As discussed further below, the level of mining activity and spending and associated social impacts are based on long term prices expectations and do not fluctuate with market prices.

As Figure 2 shows, mineral prices are volatile, but real (inflation adjusted) prices tend to hover around their long term average with occasional temporary price spikes. Figure 3 shows the normalized global market price of the minerals used in this analysis and indicates the level of price volatility that exists[2]. Prices are normalized with their 28 year (1980-2007) annual average price equal to 1.00.

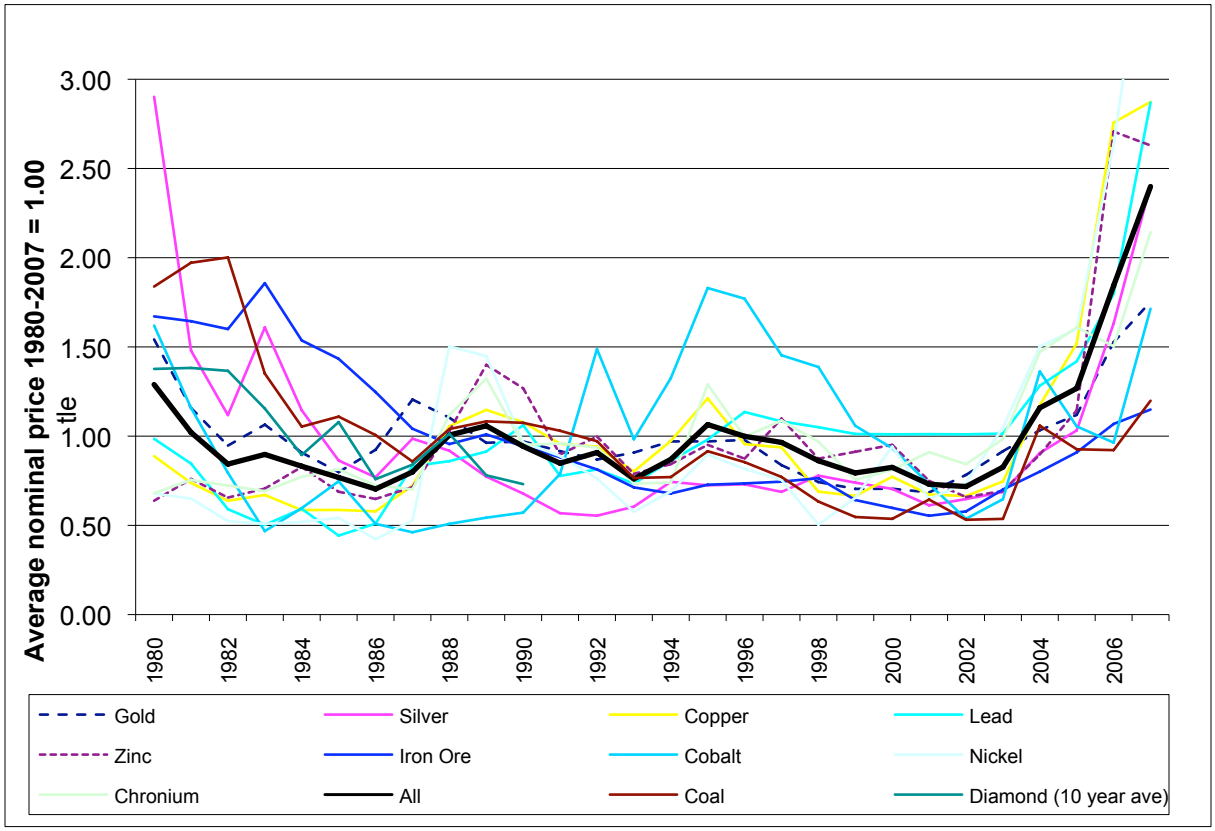
[2] Canadian diamond price, as deduced from Canadian mining data is only reported for the last ten years. Prior to this time diamond prices were determined in a monopolistic market and were not representative of production costs and social impacts.

Figure 2. Normalized real mineral prices, 1900-2007



Source: U.S. Geological Survey, mineral commodity statistics, *in* Kelly, T.D., and Matos, G.R., comps., Historical statistics for mineral and material commodities in the United States: U.S. Geological Survey Data Series 140, available online at http://pubs.usgs.gov/ds/2005/140/. (Accessed 2009.)

Figure 3. Monthly mineral price index, 1980 - 2007

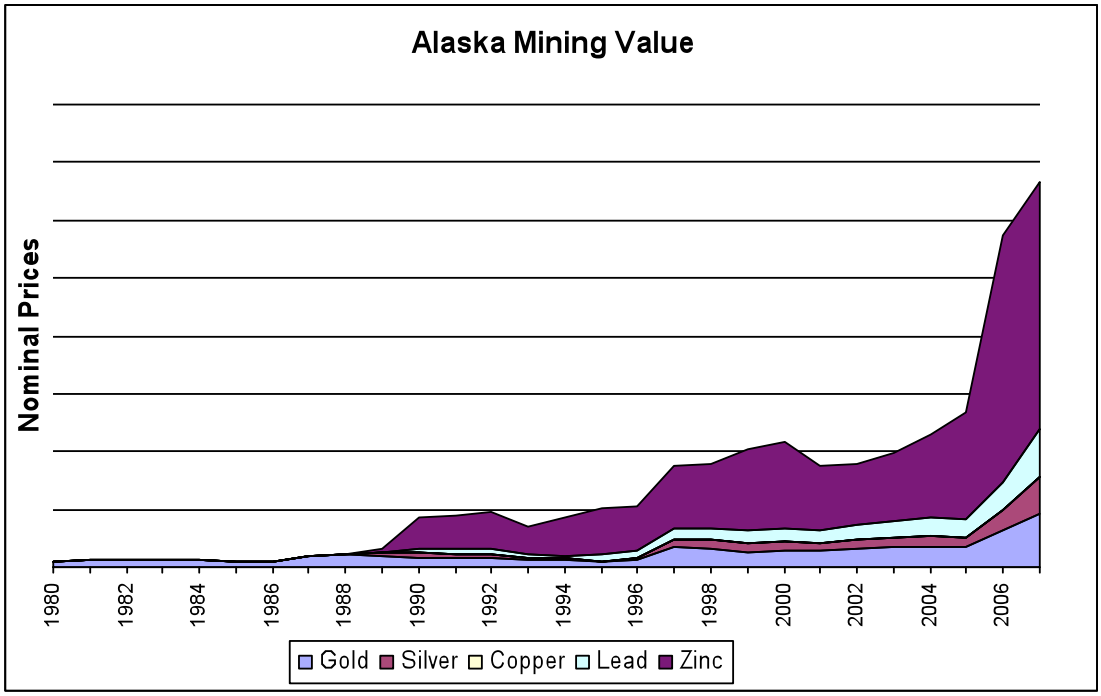


Calculated from : U.S. Geological Survey mineral commodity statistics, *in* Kelly, T.D., and Matos, G.R., comps., Historical statistics for mineral and material commodities in the United States: U.S. Geological Survey Data Series 140, available online at http://pubs.usgs.gov/ds/2005/140/. (Accessed 2009)

Mining production index case study: Alaska

The effect of the mining production index is demonstrated in the following figures using data for Alaska's mining industry. Figure 4 shows the market value, by mineral, of Alaska's mining industry from 1980 through 2007. The data show a sharp increase in mining market value in 2006 and 2007 with the bulk of the value derived from zinc mining.

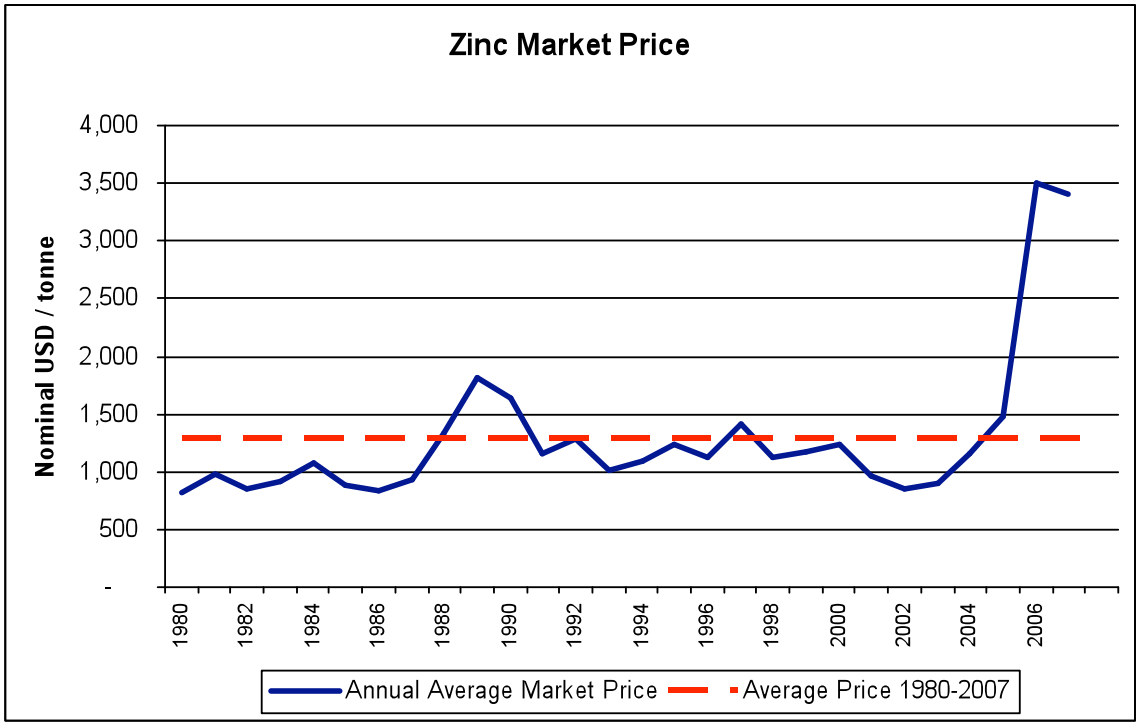
Figure 4. Alaska Mining Value



Source: Alaska Department of Natural Resources, Division of Geological and Geophysical Surveys, Special Reports nos. 62, 61, 60, 58, and 38.

For reference, Figure 5 shows the annual zinc price for the same time period as Figure 4. The drastic increases in the market value of Alaska's mining production in 2006 and 2007 were driven by an increase the market price of zinc during the same period. The average price is used to constructing the mining production index and is shown as a dotted line.

Figure 5. Zinc Market Price, 1980-2007



Source: USGS, Historical Statistics for Mineral and Material Commodities in the United States, 2008, 2009

The mining production index uses the average price for each mineral to calculate the normalized value of Alaska mining for each year. Figure 6 shows the Alaska mining index for the same period as Figure 4. The spike in 2006 and 2007 has almost disappeared while the relative value of each mineral has been preserved.

Figure 6. Alaska Mining Production Index, 1980-2007

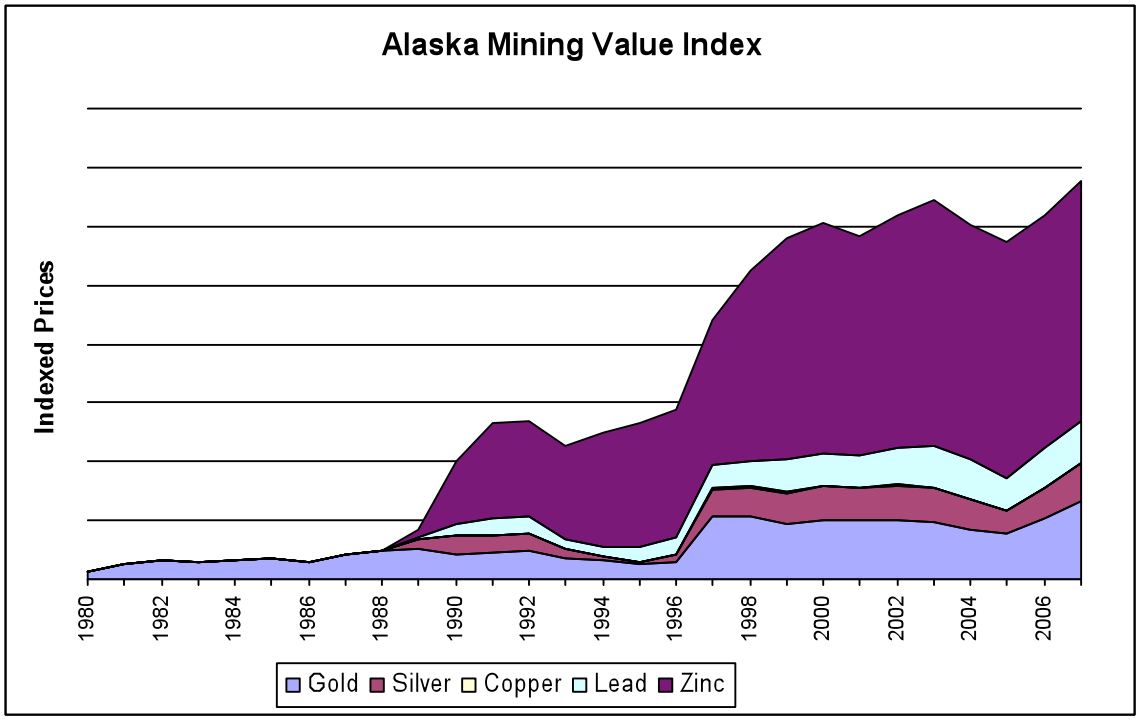
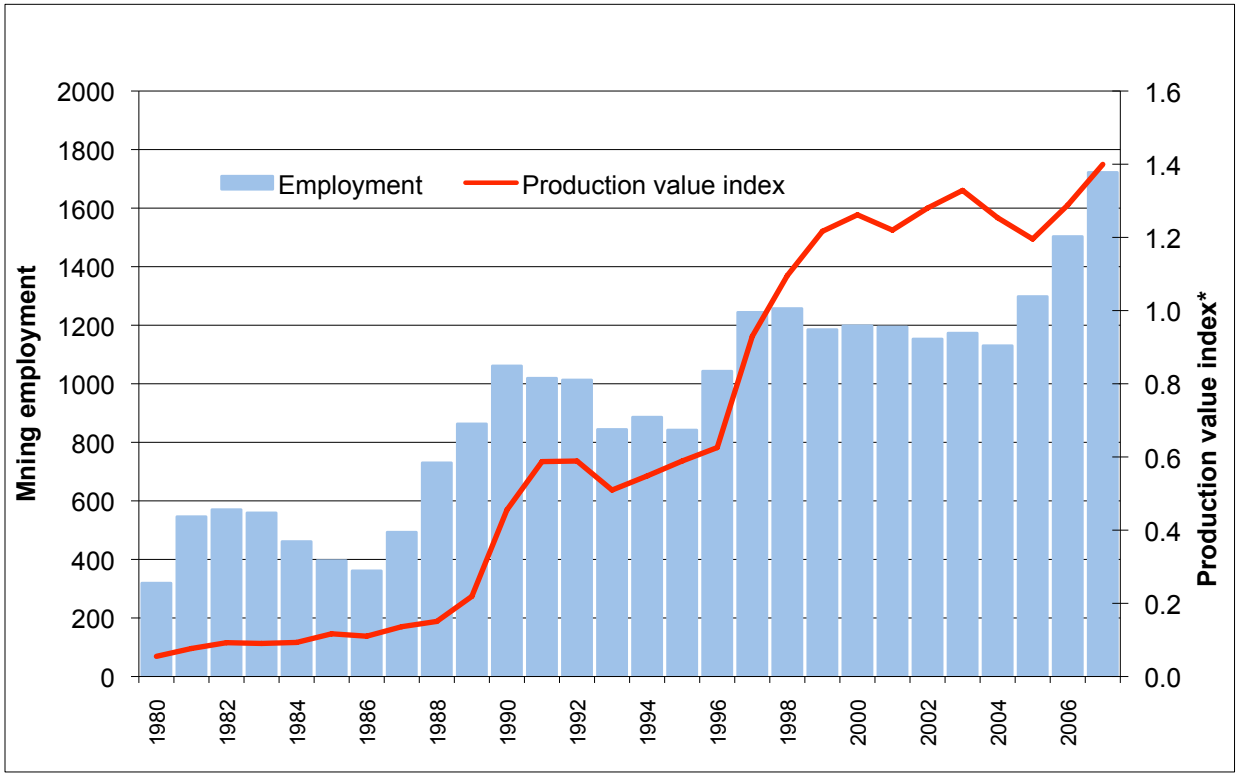


Figure 6 shows four distinct changes in the level of mining activity in Alaska during this period and are reflected in the Alaska mining production index. First, the Red Dog zinc and lead mine beginning operation in 1989. Second, Red Dog mine expanded in 1997. Third, the Fort Knox gold mine began operation in 1997. Fourth, the Greens Creek gold mine began operation in 2006 (Szumigala et al. 2008). While these changes are visible in the chart of unindexed mining value, the effect of price increases dominates, muting and distorting the impact of the changes in the Alaska mining industry.

These four increases in Alaska mining activity presumably resulted in increased social impact and should have a corresponding increase in mining employment. Employment is a direct indicator of social impact of mining and a positive relationship between the index and employment would indicate that the index is a reasonable measure. The relationship between Alaska mining employment and the Alaska mining production index can be observed by graphically superimposing one over the other (Figure 7). This rudimentary analysis indicates that the Alaska mining production index and Alaska mining employment appear to have a positive relationship. The relative increase in Alaska's mining production index to Alaska's mining employment that occurs after 1997 is likely because labor intensity (labor per unit of product) was lower at Red Dog Mine after it expanded, and the Fort Knox mine was less labor-intensive than pre-expansion Red Dog

Mine as well. This would result in the production index increasing faster than employment. It is important to note that both the index and employment experienced increases.

Figure 7. Alaska mining employment and production index, 1980-2007



* Production valued at long term average U.S. price (1980-2007), by mineral, in billions of dollars.

The mining production index is inferior to employment as an indicator of mining's economic impact: employment is a direct measure of impact, while the index is an indirect measure with more confounding factors. But as we discussed above, employment cannot currently be used as a pan-Arctic comparative measure because it is inconsistently defined and measured across countries, and in some countries cannot be broken out for the Arctic counties.

Mining production index limitations

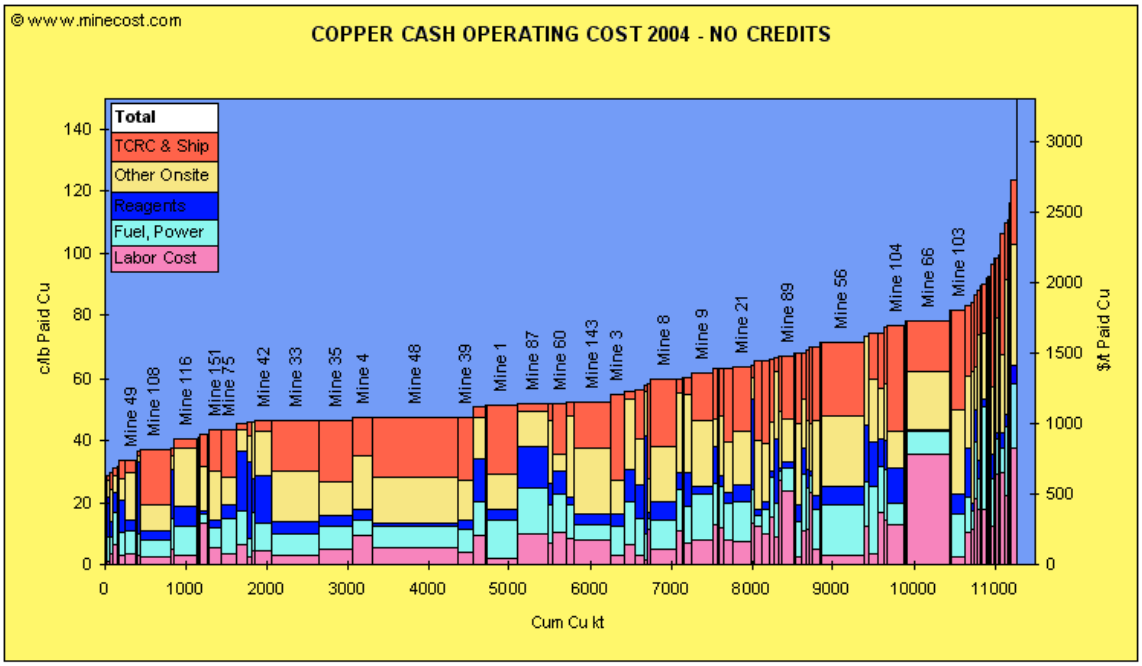
There are four inherent sources of error in the mining production index as a measure of economic impact. First, it does not account for the variability of economic rent between mines and how much of that rent remains within the region. Second, the production costs and the composition of production costs required to produce one unit of mineral production vary between different mines. Third, the amount of local value-added varies between mines. Fourth, the labor characteristics and labor's regional impact varies between mines.

The mining production index does not account for the different economic rent (or profit margins) that exist for different mines. The level of economic rent varies between mines depending on the relative quality of the resource, the cost of production and the cost of transportation, among other things. A mine with larger economic rents will have a relatively smaller social impact on the region than the index would indicate.

The production costs and the composition of production costs required to produce one unit of mineral production vary between different mines. For example, Figure 8 shows the operating costs for the world's copper mines, measured in cents per pound of copper. It also shows the composition of those costs, broken into five categories: treatment, refining and shipping (TCRC & Ship), other onsite, regents, fuel and power and labor.

Capital costs and economic rent constitute the difference between the operating and the market value of each mine. The mines on the left are either capital intensive, highly profitable, or both, while the mines on the right are high cost and economically marginal. These are the mines most at risk for shutdown if long term price falls below their costs of operation. In addition, the variation of the composition of operating costs, especially labor costs, indicates more potential error because each type of cost will have a different pattern of economic impact.

Figure 8. Mine Costs



Source: World Mine Cost Data Exchange. Accessed 3/18/2009. http://minecost.com/

Different mining operations also have different degrees of local value-added. Mines with more local value-added have a greater social impact on the region than the Index would indicate. For example, a mine that ships minerals out of the region still in ore or concentrate form will have significantly less associated social impact than a mine that does all possessing at the mine site. The index attributes the full final market value of the

mineral to the region even if a substantial portion of the value is added outside the region through refining and transportation.

Labor is an important aspect of mining's social impact on a region. For enclave mines in remote areas, as is common in frontier regions, employees often reside outside the local region and commute to the mine for work. In this scenario, almost the entire social impact of this employment, especially wages, leaves the region. The index does not account for this and will over-estimate the social impact of a mine if a significant portion of its employees live outside the region.

The exact relationship between mining value and social impacts cannot be fully understood without itemized cost data of individual mines and detailed analysis of the impact of those costs. The mining production index is the best available indicator of the social impact of mining because, unlike other potential indicators, it is able to measure and compare the level of mining activity over time, for different minerals and for different locations.

Trends in Arctic mining

The Arctic Human Development Report (2004) divided Arctic countries along the lines of their economic development, characterizing each half as either a "mature," or "resource frontier" region. The differences between the two types are represented by trends in mining. Mature regions have integrated mining operations into a broader, more diverse economy, and are well-connected to a national transportation and power grid. Frontier regions, on the other hand, are just beginning to develop new mining operations, operate in remote, challenging locations, and usually draw labor, supplies, and contractors from distant hubs. The mature regions in the Arctic are principally the Scandinavian countries – Norway, Sweden, and Finland – while Alaska, Greenland and Arctic Canada are characteristically frontier regions. Northwestern Russia, which we do not cover in this analysis, is a mature mining region, while central and eastern Siberia are frontier. Iceland and the Faeroe islands have no mining (other than sand and gravel which we do not consider here).

Methodology

The focus of this paper is specific to the role of mining in Arctic regions, with a goal of better contextualizing mining's contribution to social and economic development by comparing data across regions and across time. It therefore necessitated, first and foremost, an extensive gathering of mining and mining–related data. This information was pursued for each Arctic country, with the goal of isolating data for the Arctic share of mining, and even further, for the individual sub-regions of the Arctic as defined by the Arctic Human Development Report (AHDR). In Norway, for example, data were isolated for the counties of Nordland, Troms, Finnmark, and Svalbard, while in Canada data were sought for the Yukon Territories, Northwest Territories, and Nunavut.

Data were sought on mineral production including industrial minerals (specifically diamonds and olivine), metal ores, and energy minerals (coal). Gravel and stone operations, which generally contribute more to local construction supplies than to exports, were omitted in this study. Oil and gas data were compiled separately. Published information on mining value, employment, exploration expenditures, and claims data

were also collected. These categories are defined and reported differently by different agencies across the Arctic, necessitating further research to understand discrepancies and make appropriate corrections when comparing between countries. Our transformation of the data to facilitate comparison of the mining sector in different countries and identify trends is discussed further below.

We attempted to construct a time series of mining data from 1980 to the present day. The availability of historical data varies, and missing data are noted. In some instances, data available online were supplemented by research in situ at agency vaults or libraries (in Greenland, Alaska, Norway and Russia), as well as personal contact with statistical, geological, or mining personnel (in Alaska, Canada, Sweden, and Norway).

Mature Regions

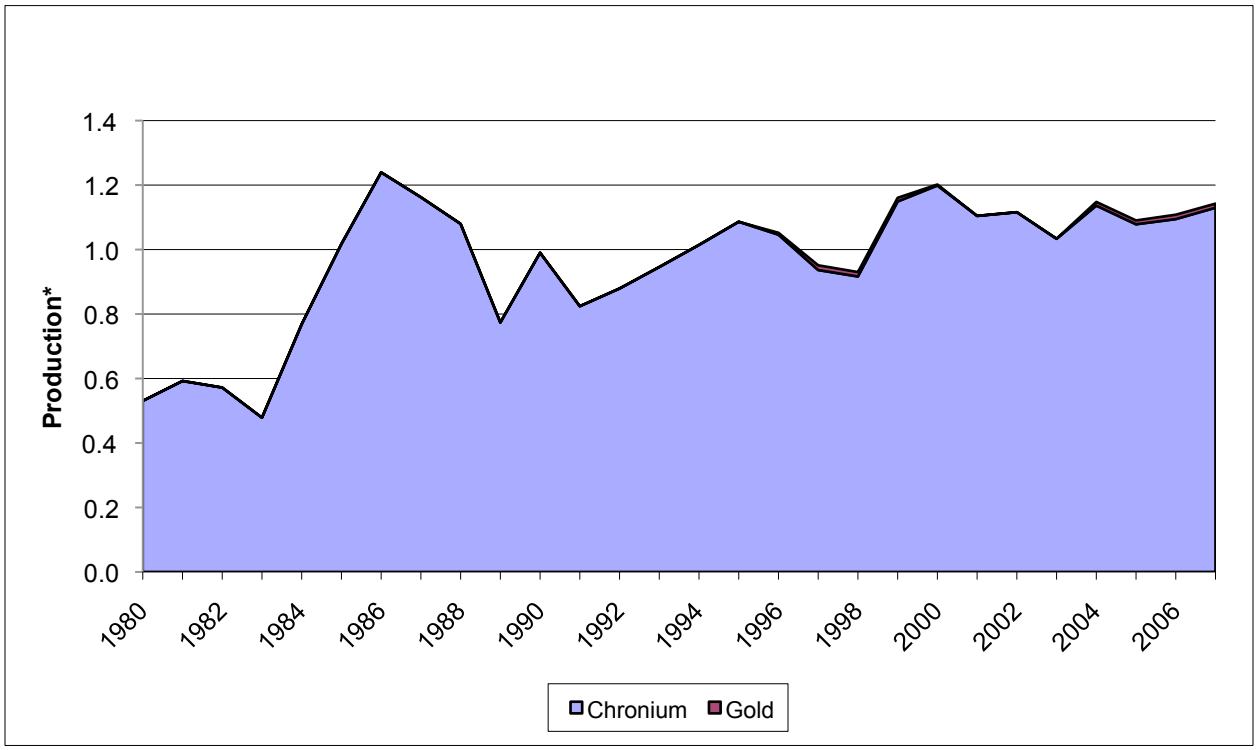
The Scandinavian countries continue to host several large, productive mines, but new developments, exploration and growth (through 2008) have been minimal. High prices encouraged some investment, but largely at pre-existing mines. The overall value of mining in mature regions of the Arctic has increased modestly over time. The following country narratives discuss developments in each country since 1980, or the years for which data were available.

Finland (Arctic provinces: Lapland and Oulu, including Kainuu and North Ostrobothnia)

Mining records in Finland date back to 1530, and Oulu in the Arctic region hosts the third largest stainless steel plant in the world (Outokumpu Chrome), supplied by a Lapland chromite mine. Domestic iron ore deposits once fed the Raahe carbon steel processing plant, but the last mine shut down in 1988 and the plant now relies on imports from Sweden and Russia – a telling indicator of Finnish mining itself.

Besides a historic mining legacy, Finland's northern economy is well-integrated into the larger national economy, and not wholly dependant on resource extraction. Much of the minerals extracted there are processed locally. Manufacturing in other industries, including telecommunications, outstrip mining's contribution to the economy of Arctic Finland. Even the household incomes in Arctic Finland are only marginally lower than those of southern counterparts (McDonald et al. 2006, p. 52), distinguishing it from other Arctic regions in this respect. Arctic Finland is therefore not dependent on mining, even if it remains an important component of the overall economy. Mining faces an uncertain future in places like Finland, where old mines yield fewer new discoveries, but where easy transportation exists, and new investment continues. Figure 9 shows the value-weighted index of mining production in Finland. It demonstrates the relatively constant level of production in Arctic Finland, with some normal fluctuations.

Figure 9. Arctic Finland mining production, 1980 - 2007

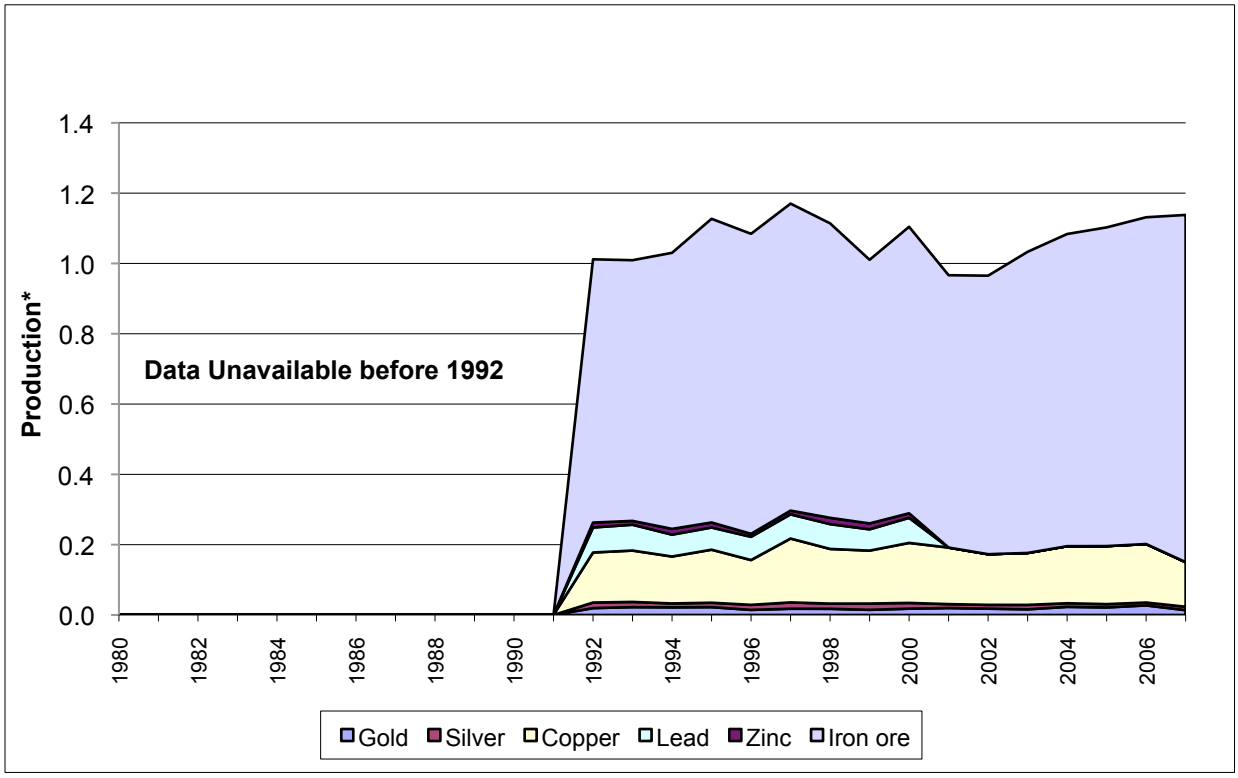


* Production valued at long term average U.S. price (1980-2007), by mineral, in billions of dollars.

Sweden (Arctic Counties: Västerbotten and Norbotten)

Swedish mining is composed of a handful of long-producing mines located in Norbotten County. Like in Finland, Swedish mining regions are well-integrated into the greater transportation and overall economic network. Within the Swedish Arctic, mining contributes a mere 2.5 percent to the economy (compared to 45 percent from services, 2002). Historic data for Sweden is absent prior to 1992, but Figure 10 nonetheless illustrates relatively steady mining production values over recent years in Arctic Sweden. Employment, however, has steadily declined over the decades – raising new questions about the contribution of mining to the economy as a whole.

Figure 10. Arctic Sweden mining production



* Production valued at long term average U.S. price (1980-2007), by mineral, in billions of dollars.

Norway (Arctic Counties: Finnmark, Troms, Nordland, and the territory of Svalbard)

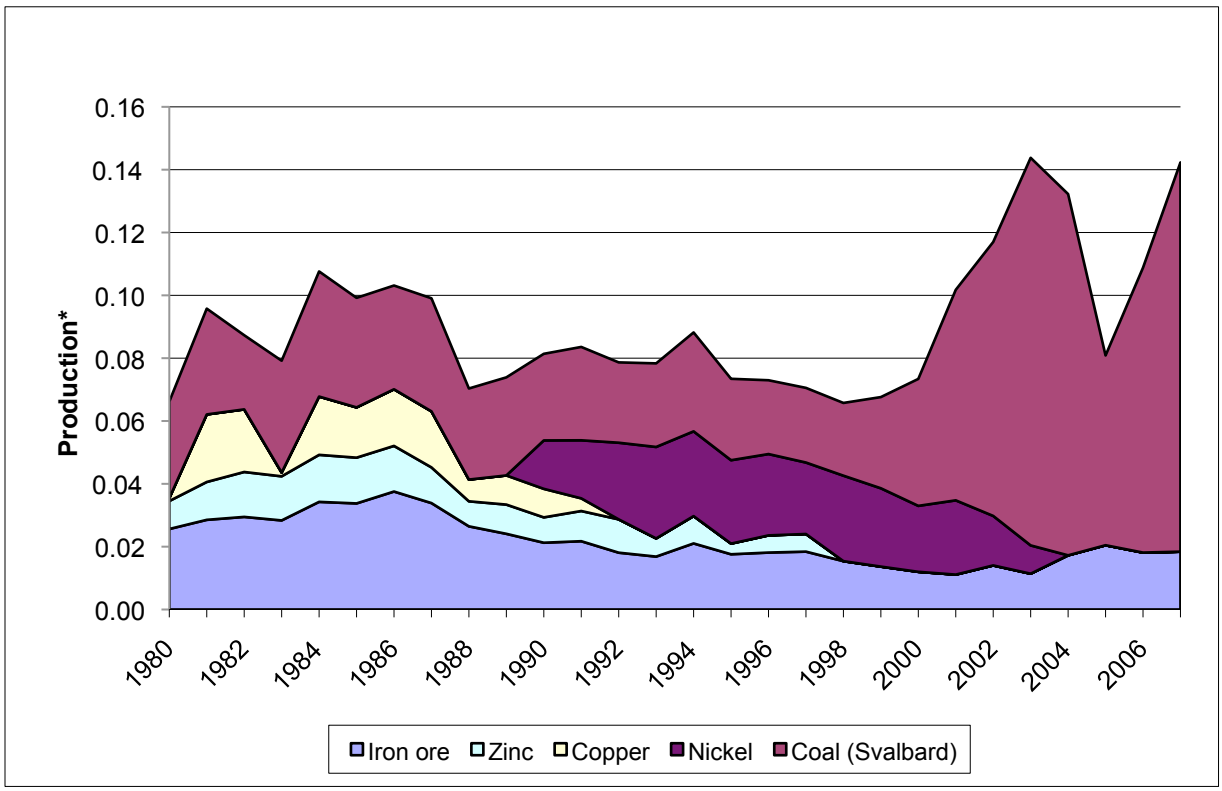
Mainland Arctic Norway is well-served by road, air, and sea, including deep-water ports and sleek, new airports. In spite of important hubs, including Bodø, Tromsø, Alta, Hammerfest, and Kirkenes, and important Sámi centers like Kautokeino and Karasjok, the north is rural, somewhat remote, and largely dependant on natural resources, such as reindeer herding and especially fish. Mining's contribution to the regional economy, and to that of Norway as a whole, is small. Mining comprised a mere .4 percent of Arctic employment, and only .8 percent of regional GDP in 2002. The Arctic share of total mine output for metal ores and industrial minerals, however, is relatively large, approximately 40 percent of Norway's total.

Mining in mainland Norway is currently not very dynamic. Figure 11 shows the steadily declining iron ore production of the only remaining metal mine in the Arctic region; three other metal mines closed between 1991 and 2003. Locals have pinned their hopes on oil and gas development instead, anxiously awaiting trouble-free production from Snøhvit – the much-watched, expensive, and contentious Liquefied Natural Gas facility in Hammerfest. Other communities are hoping for their share in Barents Sea oil and gas development, including impending developments in Russia. The Norwegian government's High North Strategy (2006) dedicates a brief passage to mining, acknowledging a desire for increased development under a regulated framework. This is

merely a token compared to the attention devoted to marine resources and petroleum activities in the same document.

On Svalbard, however, coal mining is both an important employer and the only source of coal in Norway. Its production has wavered, but has increased dramatically since 2000.

Figure 11. Arctic Norway mining production, 1980 - 2007



* Production valued at long term average U.S. price (1980-2007), by mineral, in billions of dollars.

Frontier Regions

Frontier regions, including Alaska, Canada and Greenland, differ dramatically in comparison to mature regions. Mining values have increased steeply, in line with new developments, dramatic increases in exploration development and recent high commodity prices. Unlike the mature regions, new mines have come online since 1980, and undeveloped resources are plentiful. On the other hand, environmental obstacles and lack of infrastructure continue to make development challenging. These areas also continue to struggle to retain added value from mining operations and generate more sustainable local economic development and employment.

Alaska

Alaska is a prototypical frontier economy. In mining, much of the product, along with its value, is exported out of state. Remote, roadless regions and frozen shipping lanes make construction, transportation and exploration both demanding and expensive. But this has not deterred an explosion in exploration and development in recent years: record high

prices generated a total mineral industry value of over $4 billion in 2007. This was a 100 percent increase in value compared to 2005, a then record-setting year itself. Exploration expenditure increased three-fold between 2005 and 2007, marking the fourth consecutive year of dramatically increased exploration expenditures (Figure 12). New gold mines throughout the state spurred increases in development spending as well. Unlike the trends in mature regions, Alaska's production index trends steadily upwards (Figure 8). As Figure 9 shows, Alaska's share of total U.S. mineral production by value has increased dramatically, from less than one percent in 1980 to nearly 13 percent by 2006. Only very recently have prices for zinc, lead and other minerals retreated, if not collapsed, and it remains unclear how mining operations will respond. Gold prices have remained relatively stable, however, and mines from Southeastern Alaska, Nome, and the interior are moving forward with development and production.

Figure 12. Alaska mining expenditures, 1980-2006

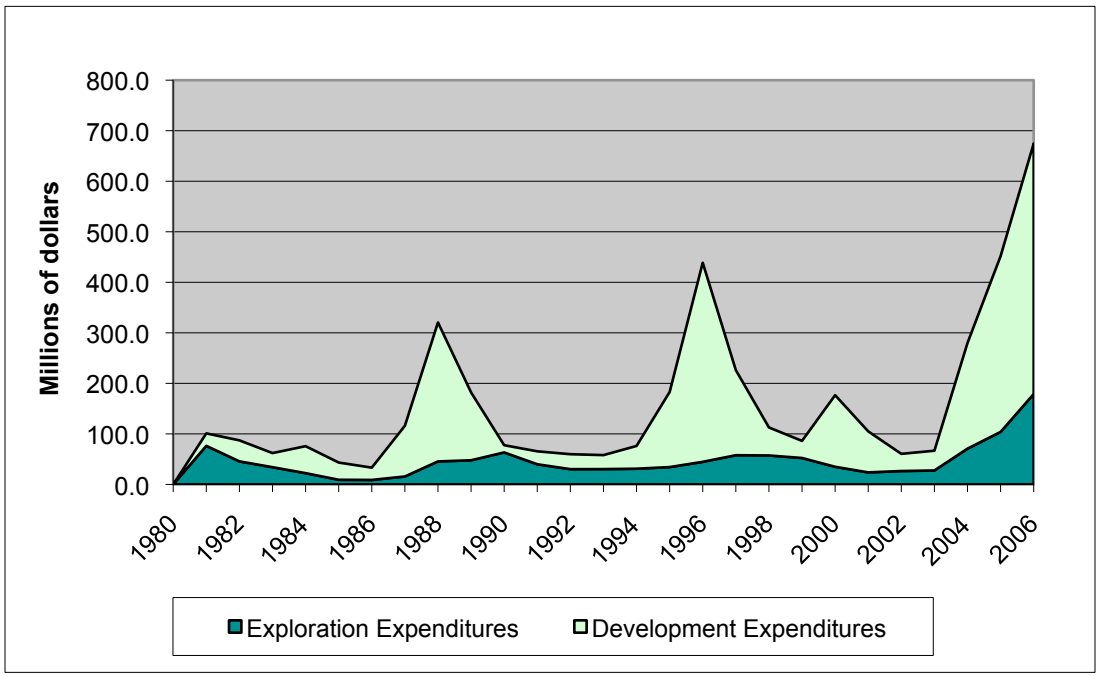
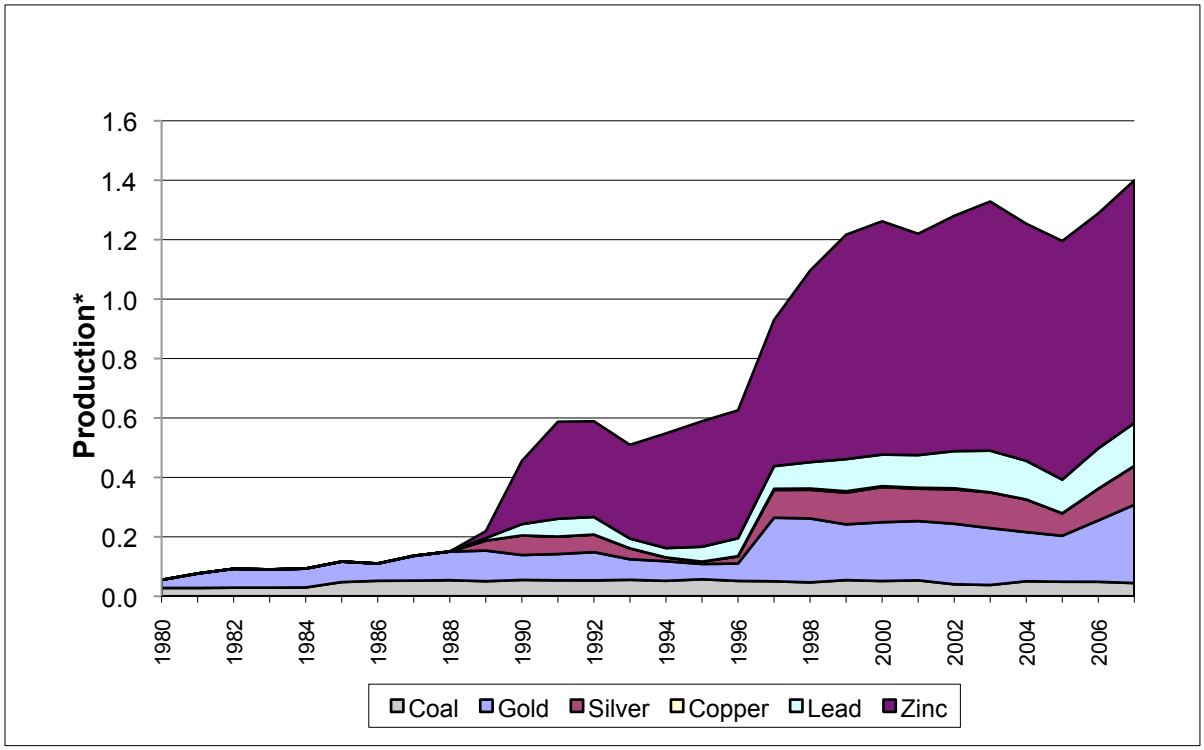
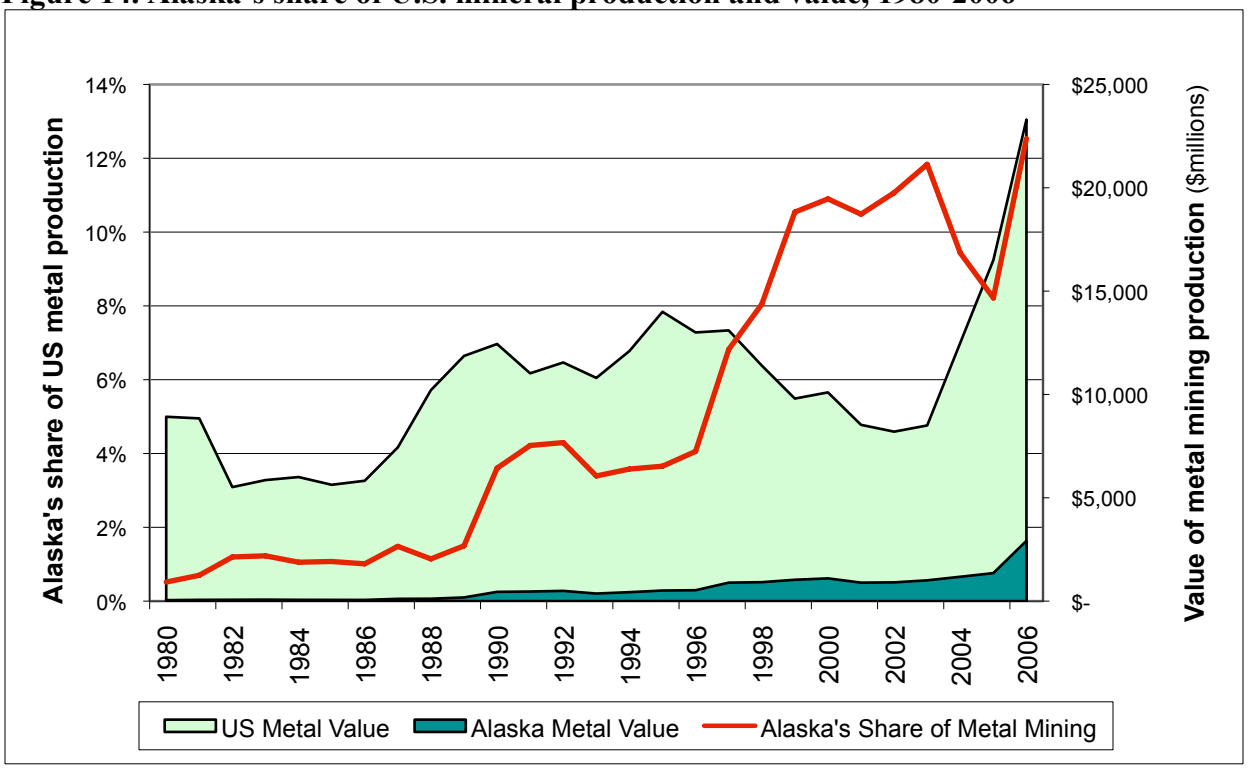


Figure 13. Alaska mineral production, 1980-2007



* Production valued at long term average U.S. price (1980-2007), by mineral, in billions of dollars.

Figure 14. Alaska's share of U.S. mineral production and value, 1980-2006



Teck Cominco's Red Dog mine is of particular importance. Located near Kotzebue in northwestern Alaska, it is responsible for over 72 percent of the value of production in Alaska in 2006, and two-thirds of U.S. zinc reserves are located at Red Dog. Its ore grade is considered of extremely high quality, yielding as much as 480 pounds of valuable lead and zinc (combined) for every ton milled - a combined concentration of 24 percent. This compares to .023 ounces of gold per ton at the Fort Knox gold mine. One negative effect of Red Dog's extremely high ore content is that its waste tailings still contain relatively high concentrations of metals, and will require active containment and monitoring in perpetuity.

The joint venture operating agreement between the NANA Regional Corporation – a Native-owned regional corporation organized under the Alaska Native Claims Settlement Act (ANCSA) which owns the land and mineral rights – is a model for increasing local benefits and regional development in the Arctic.

Environmental concerns persist in Alaska, however, and challenge development. The proposed Pebble Creek copper, gold and molybdenum mine in Southwest Alaska has fostered a contentious public debate about the safety of waste ponds. And currently, the fate of potential Kensington mine tailings (in Southeast Alaska) is being decided by the U.S. Supreme Court.

Canada (Arctic Territories: Northwest Territories, Yukon Territory and Nunavut)

Canada exemplifies the changes in Arctic economic systems. It is an advanced country with a highly developed southern tier, but resource development dominates the rural

economy of the north–a prototypical resource frontier region. Oil, gas, and other types of mining–particularly diamonds–have spurred industrial development by Canadian and foreign multinational firms in remote areas with difficult climates. Revenues have benefited the central government, and to some degree local communities, but much of the profit has flowed to the southern tier and distant financial capitals. Effective indigenous self-organization, and increased autonomy in Nunavut, has begun to reverse the outward flow of profits and stimulate local development.

For the territories and Nunavut combined, mining and oil and gas accounted for 36.4 percent of total economic activity in the region in 2004 (Glomsrød and Aslaksen 2006). High quality diamonds have established Canada as a major global supplier of the precious mineral. Some small companies process diamonds in the Northwest Territories, though the majority is exported for processing elsewhere. Nonetheless, the value of diamond mining–mostly from NWT mines, and recent additions from Nunavut–rose from $791 million in 2002 to $2.1 billion in 2004, then backtracked to $1.4 billion in 2007. Diamond mining has spurred economic development by stimulating exploration in the north, and through capital expenditures resulting from the expense of building and maintaining the mines (Statistics Canada 2008).

Though mining remains largely undeveloped throughout the Canadian Arctic, with only small contributions to the production of minerals other than diamonds and trace amounts of gold, its overall share of mining expenditure has grown dramatically (Figure 15). In 1990, For example, the Arctic share of mining expenditure in Canada was a respectable 7 percent. It rose dramatically in the early 1990s and now hovers around 25 percent. Figure 11 shows a corresponding increase in Arctic mine production.

Figure 15. Canadian exploration expenditures and the Arctic share, 1980-2006

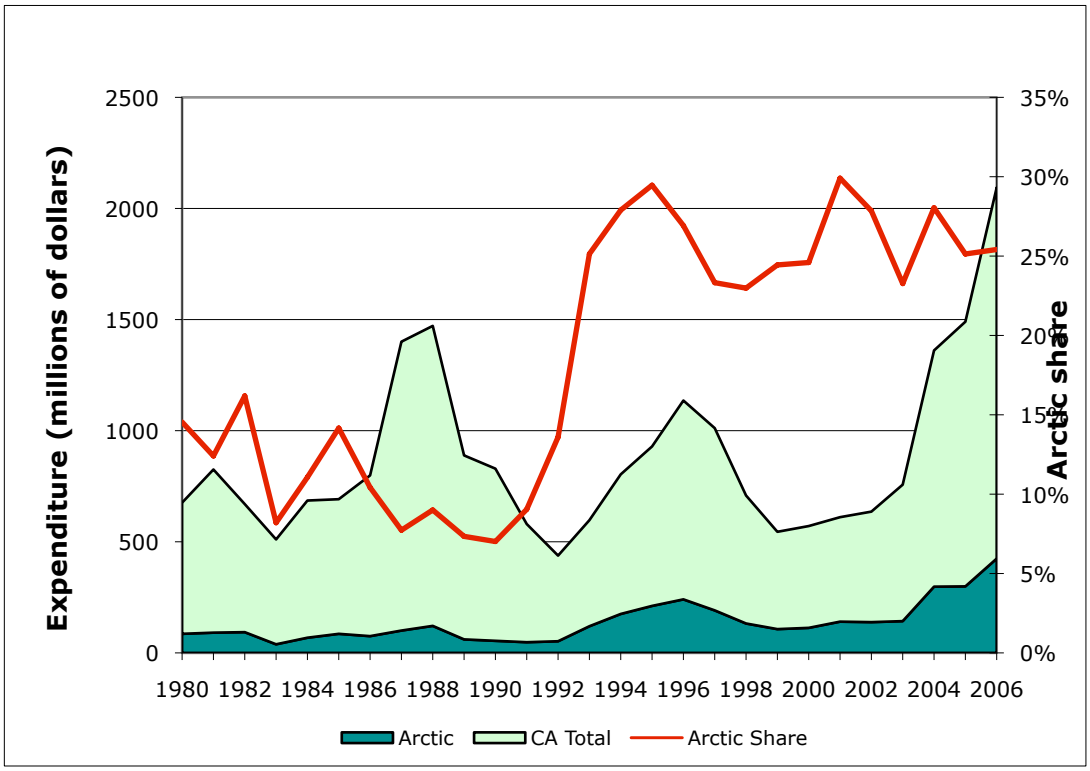
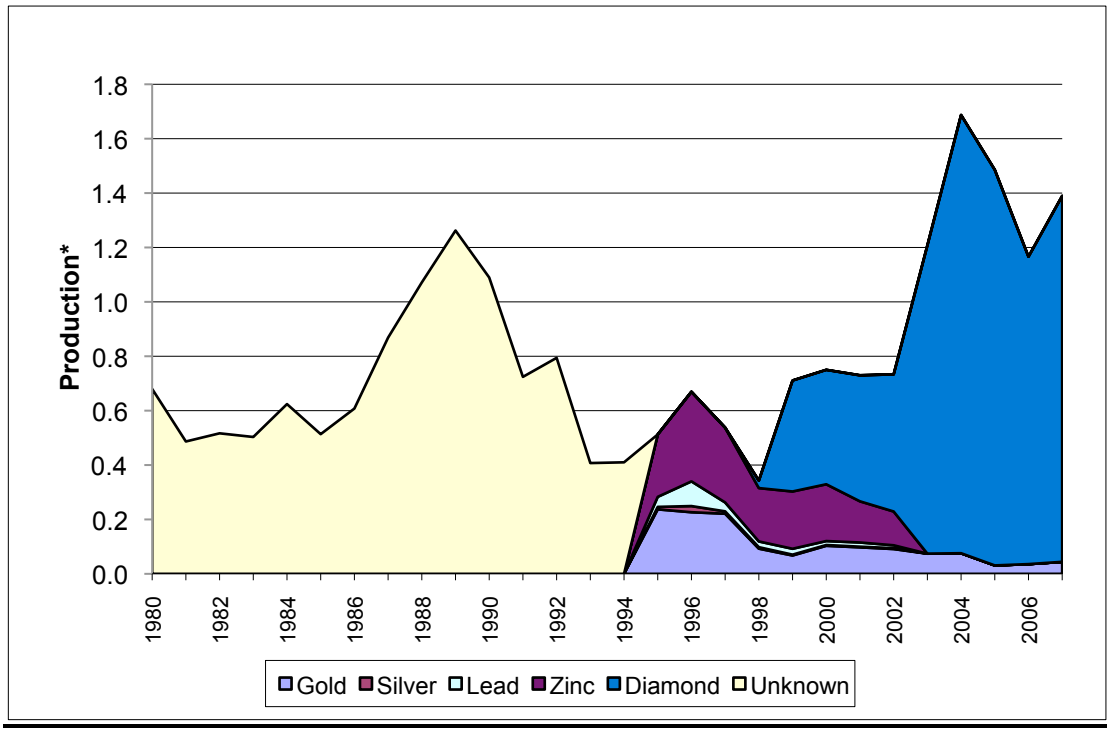


Figure 15. Arctic Canada mining production, 1980 - 2007



* Production valued at long term average U.S. price (1980-2007), by mineral, in billions of dollars.

Greenland

Greenland is a compelling example of heightened search for Arctic non-renewable resources. Like Arctic Canada, it is a frontier region with little infrastructure and obvious physical barriers to exploration. Exports are 90 percent based on fish – especially shrimp. But exploration for petroleum and minerals has recently boomed (Figures 16 and 17). The first gold mine started production in 2003 and an olivine (an industrial mineral) mine opened in 2004.

Figure 16. Mineral exploration commitments in Greenland

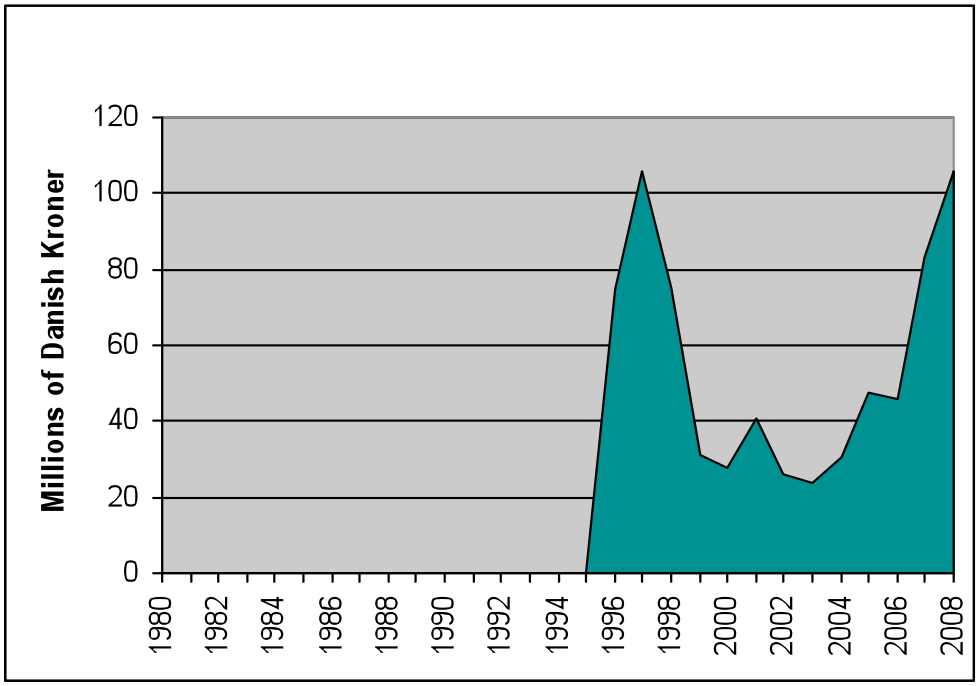
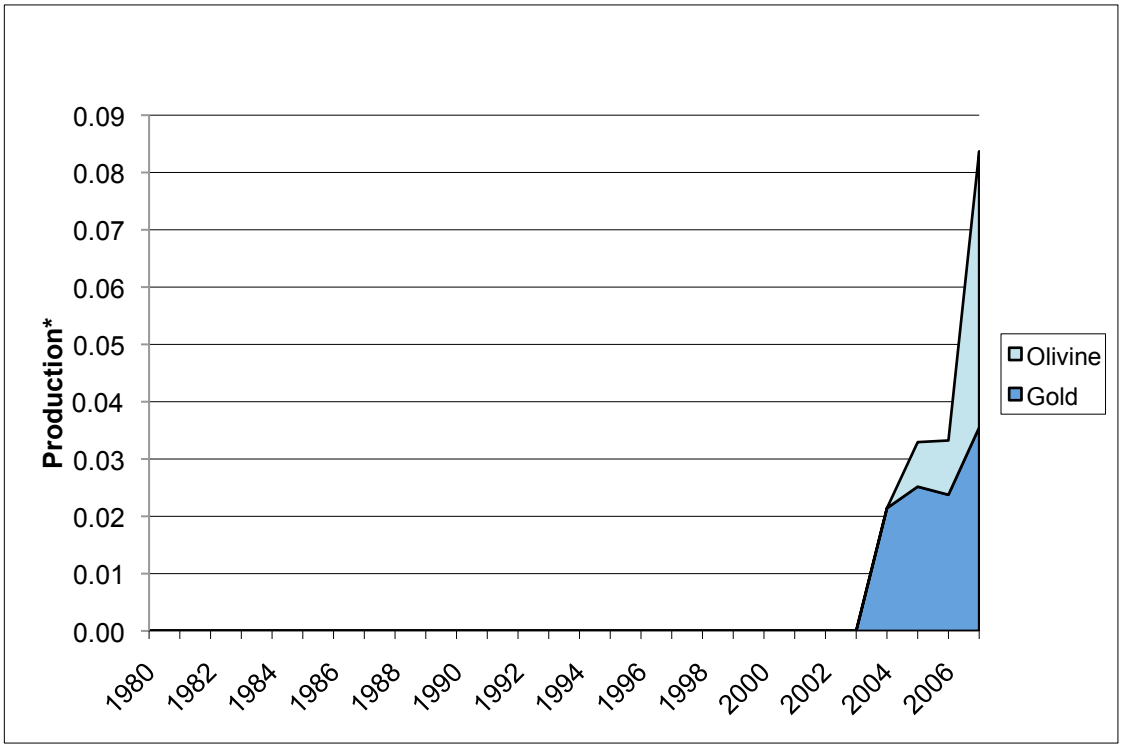


Figure 17. Greenland mining production



* Production valued at long term average U.S. price (1980-2007), by mineral, in billions of dollars.

Greenland does, however, have a historical legacy of mining, including a now-depleted cryolite mine near Ivigtut that was a major contributor to Greenland's economy before 1973 (Lycke and Taagholt 1987). 3.5 million tons of cryolite, which aids in aluminum production, was extracted before depletion. Between 1956-1962, 130,000 tons of lead and zinc were extracted from the Mesters Vig site in East Greenland. 600,000 tons of coal was mined at Qutdliqssad on the island of Disko between 1924-1972. There have also been reserves identified for Iron, Chromium, Molybdenum, Tungsten, Anorthosite and Uranium. None of these were deemed economically viable, but this could change (Lycke and Taagholt 1987).

Complicating the current and future development of resources in Greenland is the relationship between Greenland Home Rule Authorities and the Danish government. Greenlanders recently voted for increased autonomy and are counting on mineral royalties to help finance their home-rule government. Minerals, including oil and gas, are being heavily explored for their economic potential. Recent political and institutional developments are discussed in greater detail below.

Other Regions

Russia (Arctic Regions: The Republics of Karelia, Komi, the Oblasts of Archangelsk, Murmansk, and the Autonomous Okrugs of Khanty-Mansi and Yamalo-Nenets, Taymir, Evenks, Sakha, Chukotka, Magadan, Koryakia)

The Russian Arctic blends characteristics of the resource frontier with those of mature regions. Northwestern Russia has a long history of large-scale mining and well developed infrastructure that class it with the mature regions. The central and eastern Arctic also have a long history of mining, but because of the vast, remote and largely unexplored territory and limited infrastructure, these regions would be classed as frontier. The region holds substantial resources and is of increasing interest to Russian officials and companies alike.

Russian statistics are difficult to obtain, assess, and compare with other Arctic regions. Data are complicated by different reporting standards and methodologies. Mining statistics are not centralized nor available electronically. Our project personnel traveled to Anadyr, Chukotka to gather data from paper archives for that region since 1991, but we found it to be of limited value for our database. Our discussion below is based on secondary sources.

Northwestern Russia: Murmanskaya Oblast

Mining in the Murmansk Oblast is supported by a well developed transportation and energy infrastructure. From 2000 to 2006 minerals accounted for 32% to 21% of Murmanskaya Oblast's exports (London Metal Exchange 2011). It's mineral exports include iron ore, apatite, nickel, copper, and cobalt. Murmansk accounts for nearly 100% of Russia's production of apatite. It also produces 12% of Russia's iron ore and iron ore concentrates, 43% of Russia's nickel, and as a byproduct of nickel mining produces 15% of Russia's copper and 40% of its cobalt.

In the last decade Murmansk's iron mines have been integrated into Severstal, a vertically integrated, international steel producer (Olenegorsky GOK 2011). The Oblast's nickel mines are now part of Norilsk Nickel, Russia's largest nickel producer (Norilsk Nickel 2011). Despite the large role that mining plays in Murmansk, the Oblast's future seems more tied to the development of the Shtokman gas fields in the Barents Sea. Of the ten investment priorities listed in the Oblast development plan, only one, the Fedorov Tundra enrichment plant, involves mining (Ministry of Economic Development of the Murmansk Region 2011).

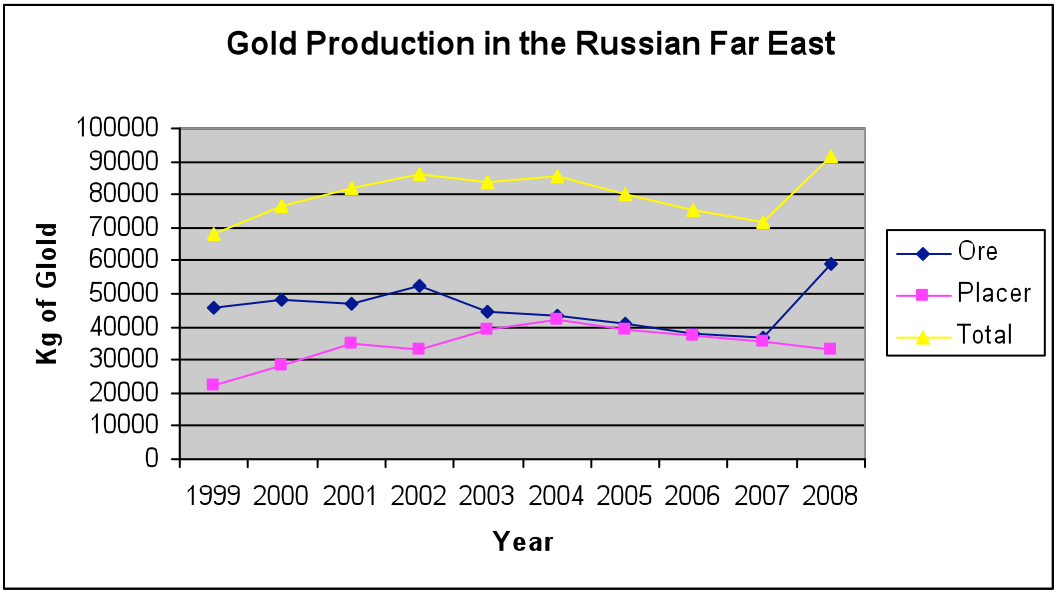
Northeastern Russia

Northeastern Russia, which includes the Republic of Sakha (Yakutia), Magadanskaya Oblast and the Chukotka Autonomous Okrug, holds a large portion of Russia's untapped mineral wealth. It has an underdeveloped transportation and power infrastructure, and very low population density. These factors all raise the cost of mining operations and have focused production on high value minerals. Russia produces about 20% of the world's diamonds and nearly 100% of Russia's production comes from four mines in the Western portion of the Republic of Sakha. In 2008 Russia accounted for approximately 7% of the world's gold production, at 163.9 metric tons (Goldsheet Mining Directory 2011), and nearly a quarter of Russia's production came from the Northeast. Similarly, in 2009 Russia produced 42.2 million tons of silver or around 6% of the world's production, (The Silver Institute 2011), and Northeast Russia accounted for more than 30% of Russia's silver production. Most of the silver produced in this area is a byproduct of gold mining (Far Eastern Okrug Natural Resources Report 2011).

Mining plays a significant role in the economy of this region. In 2006 the Republic of Sakha had more than 22 mining companies operating, while Magadanskaya Oblast had 118 and Chukotka had 9 mining enterprises. Since the collapse of the Soviet Union there have been significant foreign investments in gold mining in this area. Large Russian mining conglomerates, like Russia's largest gold mining company Poly-metal, have significant investments and production in Russia's Northeast (Bloomberg Business Week 2011).

This area began intensive gold production in the 1930s under the Soviet's first five-year plans. Production focused on the exploitation of extremely rich placer gold deposits, primarily in the Kolyma, Aldan and Lena river systems (Jensen et al. 1983). These placer deposits are being depleted, and a significant portion of the remaining reserves are now ore deposits (Far Eastern Okrug Natural Resources Report 2011). The move toward increased production from ore deposits can be seen in the jump in Figure 18.

Figure 18. Gold production in the Russian Far East



Source data: http://www.tfidvfo.ru/msb/m3.htm (Natural resources report of the Far Eastern Okrug)

A similar trend can be observed in the production statistics for the Republic of Sakha (Yakutia), Magadanskaya Oblast, and especially for the Chukotka AO where the start of production at the Kubaka mine, an ore based deposit, increased the Okrug's total gold production nine fold in one year (Far Eastern Okrug Natural Resources Report 2011). This shift to ore deposits explains not only the increase in gold and silver production, but also the influx of new capital into the area. Ore deposits require greater capital investment to exploit than placer deposits. In Chukotka, Western capital financed two large gold mining projects, Kupol and Maisekoe. The Kupol project, owned by Kinross Gold of Canada, produced its first gold in June 2008. (Shalaginov 2009). In the first half of 2009, Kupol had delivered more than 15 tons of gold to the Kolyma Refinery and made Chukotka Russia's largest gold producer (Paxton 2009). The Maiskoe deposit,

which is estimated to be larger than Kupol and be one of the five largest gold deposits in Russia, is expected to start producing gold in 2012 (Polymetall 2008). Since 2000 the Russian government has intensified geological work in Chukotka including new work on uranium deposits near Provideniya (Vasilev 2008).

While this area saw some mining of less valuable minerals like coal, tungsten and tin during the Soviet era, the only mines which have survived are those that produce coal for local consumption, or have access to developed infrastructure (Vasilev 2008). The large coal field at Neryungri Yaktutia, for example, is linked to Russian and international markets with a spur from the Baikal-Amur Railroad (Russia Channel 2011).

Iceland

Iceland has no significant mining industry, and is not included in this report. It does, however, have a growing aluminum smelting industry fueled by cheap geothermal electricity, and supplied by year–round ore shipments from Norway.

Faeroe Islands

The Faeroe Islands currently have no commercial production of mining resources, though there are coal reserves on the island of Suðuroy that were exploited in from about 1770 through World War II. The Faeroe Islands may confront difficult decisions with respect to oil and gas development, however, particularly with how new developments might mesh with the economic mainstay of fishing.

Pan-Arctic Summary

Figures 19 and 20 summarize the preceding discussion. Production is increasing rapidly in the frontier regions of Greenland, Svalbard, Arctic Canada and Alaska, while growth is modest in the mature regions of Arctic Finland and Sweden, and showing modest decline in mainland Norway. Although data is not available for Russia, reports indicate recent growth in mining in the eastern Arctic, and stable production in the Kola Peninsula in the mature west.

Figure 19. Mining Production Index for Arctic Regions

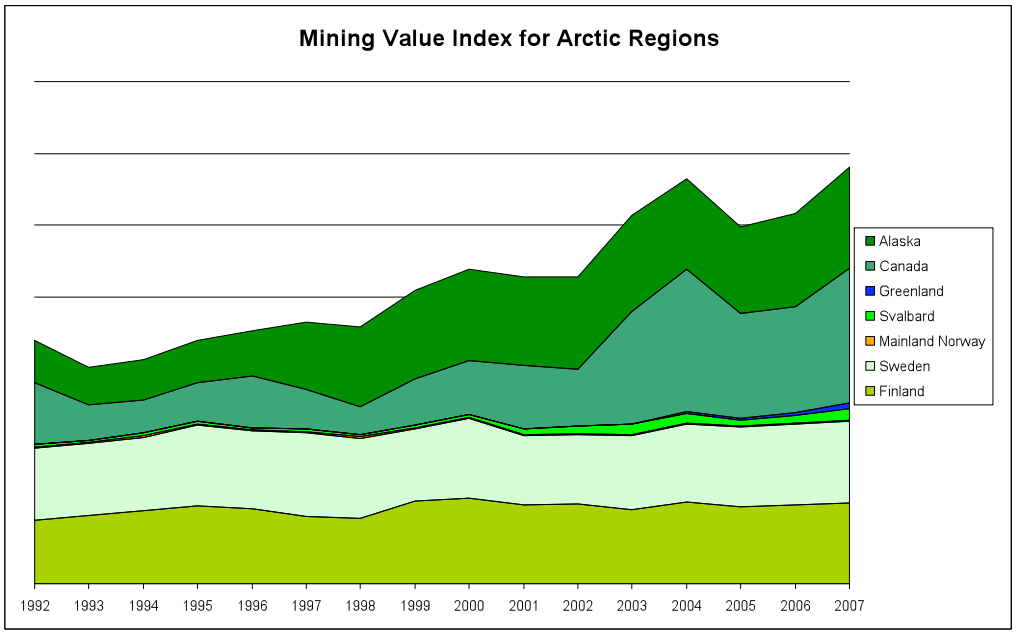
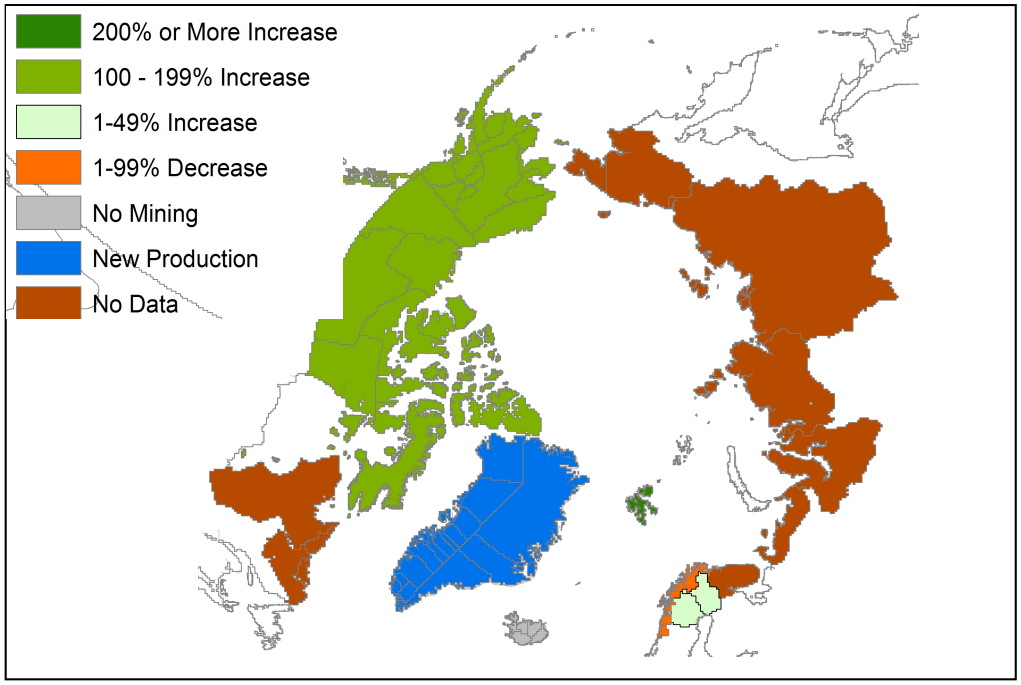


Figure 20. Changes in mining activity, 1992 - 2007



Assessing Data

As noted earlier, each country reports mining statistics differently, and data varies in its availability or level of detail. Information is usually divided, or sometimes reported using different criteria, between a national mining bureau and a national statistics bureau. Canada is particularly thorough in its reporting, with annual reports available online including production levels and values divided by mineral, and further reported by province, facilitating the isolation of Arctic regions there.

In spite of recent developments that have improved reporting standards and availability in Norway, historical data is largely unavailable online. Historical mining data is likewise unavailable in Sweden and Finland in electronic format prior to 1991 and 1997, respectively. For this project we were able to obtain some data electronically from NGU staff and compiled other data from paper reports in the NGU archives. Unfortunately, Norway reports mining data in aggregations that preclude cross-country comparisons for Arctic regions. When Norway reports data by mineral, it is aggregated nationwide and not broken out by county. When Norway reports production by county, it is aggregated in broad categories: energy minerals, metal minerals and industrial minerals. This frustrated efforts to distinguish trends, isolate the added value of specific minerals, or construct a pan-Arctic index. Detailed geographic knowledge is required to disaggregate statistics for the Arctic counties from reported national data by mineral.

Employment data is also reported disparately between countries and agencies. Historical data is regularly unavailable, and reporting standards differ between "full time equivalency" (FTE) versus the number of employees, or wage and salary employment. Some countries collect employment data by place of residence, while others collect it by place of work, or even by the location of the company headquarters. Different reporting standards result in very different numbers for the same location, distorting trends over time. It is sometimes unclear whether the underlying methodology includes the self-employed or small-scale mining operations. Again, Canada and Alaska are particularly thorough in their reporting and methodologies were recorded and noted.

In a similar manner, methods for calculating and reporting value of production may vary, and may or may not include costs associated with exploration, mining, transportation or refining. In most cases, however, it is clear that "value" reflects the value of the final, refined product at its global market price.

Russia poses the greatest logistical challenge for non-local researchers. A combination of a lack of centralized data, limited online reporting, a major regime change in the early 1990s, and language barriers make a comprehensive review of mining statistics especially challenging.

Drivers of change in the Arctic

Mining is a global industry driven by global markets and global players. Mining activities in the Arctic are driven by the same forces and factors as mining in any other region. First and foremost is geology: the presence or prospect of major ore deposits is the first determinant of industry interest. Available information concerning the geology of a

region helps a firm decide where to explore, and more information makes a region relatively more attractive because it lowers the uncertainty. A second threshold factor is access to the land, which is a function of government policies and current land use: an ore deposit under a city won't be developed or considered. Other factors that play include expected economic viability, assessment of political risks, and firm-specific strategy relative to global markets and supply. Each firm has a portfolio of exploration and development options to consider, and a given prospect must compete against others both internally and externally to make the cut. And the different lifecycle stages of mining activities discussed above each have somewhat different drivers.

The Arctic is one of the largest remaining frontier regions on the globe, and as such is regarded as a vast storehouse of potential resources (AHDR, 2004). Known deposits include Red Dog's world-class lead and zinc mine, Canadian diamond mines like Ekati and Diavik, Russia's Norilsk Nickel, and smaller, but competitive gold mines throughout Alaska, Canada, and Greenland. But the Arctic remains relatively unexplored, so the potential for major new finds is high. In this respect, the Arctic will continue to be a region of particular industry interest for the long term. The Arctic also has vast tracts of undeveloped land, so in jurisdictions with favorable government policies, access to the resource is relatively attractive. But remote regions of the Arctic, with no existing infrastructure, have the countervailing challenge of high costs of development and operations.

In the sections below, we discuss four drivers of particular interest for understanding mining trends in the Arctic: market price, technological change, policy changes, and climate change. Although we have not attempted to quantify their relative contributions, price is clearly the most important and climate change the least important.

The effects of short and long term price

The evolution of an undiscovered ore body into an operating mine has three distinct phases of capital investment: exploration, predevelopment, and development. The exploration phase searches for and identifies large amounts of minerals in a concentrated area open to mining development. The predevelopment phase improves the understanding of the geological resource and determines if the mine would be profitable if developed. The development phase is the actual construction of an operating mine and is an expensive capital undertaking, usually an order of magnitude greater than the exploration and predevelopment phases. Both junior and major mining companies participate in the exploration and predevelopment phase, with the predevelopment phase often a joint venture between a junior and a major mining company. Only major mining companies have access to the capital necessary, through debt financing, to enter the development phase of a mine.

Short and long term prices have different effects on mining activities at different stages of the mine life-cycle. As we discussed in section 2, monthly mineral prices are quite variable, with an historically small range of variation most of the time, punctuated with occasional spikes in price. While there are no futures markets to track long term price expectations, the long term prices that firms use internally for investment planning are relatively stable. The revenues of major mining companies, which own operating mines, increase in direct proportion to the price increases; the profits increase at an even greater

rate. For example, a mine with a 20% profit margin will see its profits increase by six fold if mineral prices double[3]. Major mining companies will become awash in cash when prices are high.

An environment of capital competition exists within mining companies, meaning available capital is scarce relative to the amount of potentially profitable projects. Capital competition means that potentially profitable projects are shelved only because of lack of available capital. Expenditures on exploration and predevelopment projects are constrained by the amount of cash the company has on its books. A short term price increase will increase the amount of available cash and temporarily loosen the capital constraint and allow for more exploration and predevelopment.[4] The cash flow from a short term price increase is temporary and unpredictable so the investment may not be able to be funded to completion. Exploration and predevelopment projects can be stopped and then restarted without losing any value of the initial investment. The real option value of exploration and predevelopment projects make them a good investment for cash generated by short term price increases.

High prices also make it much easier for junior mining companies to raise equity. Junior mining companies only do exploration and predevelopment; they do not develop or operate mines. Junior mining companies have no revenue stream and their activities are financed through selling equity. The junior mining industry operates under a business model that could best be described as a "high stakes gamble" model. If a junior mining company finds a profitable ore body it will couple with a major mining company to develop the mine, drastically increasing the value of its equity. If it fails to find a profitable ore body then it will go bankrupt and investors lose all their money. When mineral prices are high, potential investors either perceive that finding a profitable ore body is suddenly more likely, or the ore bodies that are already being explored now have a much higher value. The result is an increase of equity available to junior mining companies, increasing their capacity to explore.

Short term price increases, therefore, temporarily increase the amount of exploration and predevelopment activity in the mining industry, but do not increase investment in mine development. Mines are long term investments and can take up to twelve years to develop and can last for more than fifty years. Short term price fluctuations are meaningless in the analysis of projects with such long time horizons. Instead, mining companies use long term price expectations that are not affected by temporary price fluctuations. The development phase of a mine is expensive and must be debt financed. A major mining company may have multiple profitable development options but can only pursue a portion of them without taking on too much debt. A short term price increase

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[3] Consider a hypothetical mine with annual costs of $8 million and revenues of $10 million. The profit is $2 million and the profit margin 20% ($2 million/$10 million). If prices double then revenues will also double to $20 million while costs remain $8 million. Profits increase to $12 million and the profit margin to 60% ($12 million/$20 million). A mine with a smaller profit margin will see an even greater relative increase in profits.

[4] If there was no capital competition and all potentially profitable projects were already pursued then an increase in available capital would increase exploration or predevelopment expenditures. Capital competition is prerequisite for short term price increases to cause an increase in exploration and predevelopment activity.

will not loosen the capital constraint on development projects because it will not increase the ability of a company to take on debt. The cash flow from a short term price increase is temporary and unpredictable, so a cash-financed investment might not be funded to completion. A development project stopped before completion will need to be decommissioned and will lose all of the value of the initial investment, making it a more risky investment than exploration or predevelopment.

Short term price fluctuations do not affect the decision to develop a mine but might affect the pace and timing of development. A short term decrease in price reduces mining revenue and cash may be diverted from development into operations. Likewise, price increases will create extra cash that can be diverted to speed development, allowing mining operations to commence sooner and possible capture extra revenue by selling its first mined products before prices return to normal. The effects of short term price changes on the speed of expansion are the same as the effect on development, as the decision to expand a mine mirrors the decision to develop one. The decision of when to decommission a mine is generally based long term prices but a price fluctuation in the final years could speed or delay the actual decommissioning by a few years.

The number one driver for decommissioning a mine is depletion of the ore body, or decline in volume or grade to the point that it is no longer economic to produce. Short-term changes in prices or costs can affect the timing for shutdown at the margin. Long term changes in market demand, or production and transportation costs, or environmental or permit requirements can also make a mine uneconomic.

Technological Changes in Mining and Shipping

Technological developments have turned previously unfeasible, or economically marginal mining deposits into potential investments. Some of these developments are specific to the mining industry itself, including improved materials and equipment, while some affect exploration or transportation of mineral ore.

Examples of general technological improvements instituted in the Arctic include new developments in seismic exploration and mapping technology which have improved the overall understanding of potential deposits in frontier regions and result in more efficient exploration. Nunavut Tunngavik Incorporated, for example, promoted improved mapping and knowledge through the Canada-Nunavut Geoscience Office.

Other technological processes that are specific to the Arctic include methods to mine in permafrost or unstable and melting permafrost. The Diavik diamond mine in Northwest Territories is actively freezing existing permafrost to prevent surrounding lake waters from inundating the mine. An incident at Red Dog mine in Alaska where a miscalculation of permafrost led to a release of contaminated waters from its waste pond and killed fish motivated the search for new techniques for building in discontinuous permafrost.

In the realm of Arctic shipping, Norilsk Nickel has built a fleet of double-ended, ice protected vessels that can transport ore year around across the Barents Sea. Operating without ice-breaker assistance cuts shipping costs about 30 percent.

Mining policies and the effects of devolution in governance

A number of important political developments, as well as the advent of innovative policy making, has increased the autonomy of indigenous peoples in resource frontier regions, and therefore their ability to influence the nature and scope of new mining operations (Grover et al 2008).

Nunavut

Nunavut was born out of the Nunavut Act of 1993, and was made official in 1999. Its creation was in part driven by increased natural resource development, and a need to better define property rights and regulatory regimes on Aboriginal land. Like Greenland's Home Rule (see below), Nunavut's government is public and therefore serves all inhabitants, not distinguishing between Aboriginals and other Canadians. Also like in Greenland, however, the overwhelming majority of citizens are indigenous.

Important developments regarding mineral rights include provisions under the Nunavut Land Claims Agreement (NLCA) for Inuit Owned Lands (IOL) – a portion of which includes surface and sub-surface property rights (~2 percent), and a portion of which includes only surface rights (~16 percent). The remainder is Crown administered. The NLCA states that IOLs are intended to "provide Inuit with rights in land that promote economic self-sufficiency through time, in a manner consistent with Inuit social and cultural needs and aspirations" (Hardin and Donihee 1997). Ownership of **surface** rights is vested in three Regional Inuit Associations (RIA): Kitikmeot Inuit Association, Kivalliq Inuit Association, and the Quikiktani Inuit Association. Inuit-own **mineral** rights are centralized through Nunavut Tanngavik Incorporated (NTI). Importantly, no development can take place on IOL without an Inuit Impact and Benefit Agreement in place (see section below), partly negotiated by the Nunavut Impact Review Board.

Dispelling any notions that self-determination in Nunavut means a reduction in resource extraction, NTI's first Vice-President, James Eetoolook, told an audience at the Nunavut Mining Symposium in 2000 that, "NTI has clearly committed itself to *supporting and promoting* mining. We want the opportunities that mining can bring. There should be no doubt that we support mining and we want it" (speaker's emphasis). He added that, "we have a vision in which the development of our mineral resources – including oil and gas – will bring greater prosperity." Nunavut mining symposiums continue annually, and discuss developments in issues ranging from technology to governance and benefit sharing.

While strictly less *autonomous* than their counterparts in Greenland under Home Rule, people in Nunavut have "more possibilities for participating in the institutions of the Canadian federal system," and arguably more influence over resource development there (Loukacheva 2007: 151). This is accomplished between efforts to incorporate *Inuit Qaujimajatuqangit* (IQ, or Inuit societal values, knowledge, and wisdom of elders) into Nunavut governance structures, and the existence of the NTI, which Loukacheva describes as a "powerful land claims organization with 100 percent Inuit membership – creating a sort of second level of corporate governance along with Nunavut's public government. *This phenomenon does not exist in Greenland* (emphasis added)" (2007: 151).

Greenland home rule

Greenland achieved home rule in 1979. Section 8 of the Home Rule Act of 1978 provides that "the resident population of Greenland has fundamental rights in respect of Greenland's natural resources." While Greenlanders have assumed autonomy with respect to natural resource management in fisheries and agriculture, they continue to share control of mineral resources with the Danish government. As Grover et al note, "this does not give the Home Rule Government control over all natural resources" (2008: 10). For minerals preliminary study, prospecting and the exploitation of resources is regulated by an agreement between the Danish Government and the *Landsstyre.* "The Act provides for the *Landsting* to determine that the *Landsstyre* may not consent to an agreement" (10). Ultimately, though the Home Rule Government's Bureau of Minerals and Petroleum grants many of the permits, a joint committee between the Danish and Home Rule governments usurps decision-making from Greenland. Different Danish bureaucracies house important data, further limiting Greenland's control. Grover et al conclude that, "(The Greenland Home Rule Government) does not have full control over mineral resources, although the Home Rule Act recognizes the rights of the population over its natural resources" (2008,10).

Nevertheless, Greenland has taken gradual steps towards self-determination and total independence from Denmark. This provides a challenge for Greenland authorities, however, whose government and economy benefits from annual subsidies and money transfers from Denmark. Greater decision-making with respect to mineral management means that a Greenland government needs to fund its developing autonomy. Currently, minerals, including oil and gas, are being heavily explored for their economic potential. In the Annex to the *Programming for the Sustainable Development of Greenland*, it is written that, "Greenland's long-term political goal is a more independent economy based on its own resources and greater integration into the world economy" (8). Like in Nunavut, mineral resources are considered a potential gateway to greater economic development, and a means to fund increased autonomy. Unlike in Nunavut, however, and in spite of the sophisticated Home Rule Act that grants great autonomy, Greenland currently has less input into decisions affecting mineral development than their counterparts in Nunavut (Loukacheva 2007).

Public policy developments and stakeholder involvement

It is well understood that large-scale resource extraction in remote areas has caused social disruption in communities and cultures adjacent to the new developments (O'Faircheallaigh 1991; Gibson and Klink 2005; Hipwell et al. 2002; Brubacher and Associates 2002; Tatz et al. 2006; North Slave Metis Association 2002). Economic benefits–often the only allure of mining to a potential host community–have many times escaped the local region. Labor and technical expertise is sought from contract labor abroad instead of a local labor supply, royalties go to a central government, and spin-offs from the need for suppliers benefit businesses based far outside the local region.

Recent policy developments, however, are being institutionalized, and normalized into business practice, that begin to reverse the harm resulting from mining in frontier regions. Natural Resources Canada identifies different agreements between mining companies and Aboriginal communities or governments as progress in the area of improved outcomes

from mining. These include arrangements as simple as Memorandums of Understanding (MOU) between a community and company during the exploration phase, to more precise arrangements that consider a spectrum of issues affecting human well-being. Some of these include:

- Socio-Economic Agreements (SEA). The Government of the Northwest Territories (GNWT) requires SEAs that compliment already-negotiated IBAs. SEAs have been struck in the Yukon Territories as well, and exist, for example, between the Ekati Gold Mine and GNWT.
- Joint Venture Agreements (JVA). JVAs are a business arrangement between communities and mining companies that address employment and training, but also how profits are distributed.
- Impact and Benefit Agreements (IBA). (or Inuit Impact and Benefit Agreements in Nunavut as required by Arcticle 26 of the Nunavut Land Claims Agreement). IBAs have become particularly important, and almost *de rigeur* practice for companies operating in Canada. As Sosa and Keenan (2001) define them, "agreements are mechanisms for establishing formal relationships between mining companies and local communities. Their primary purposes are: i) to address the adverse effects of commercial mining activities on local communities and their environments, and ii) to ensure that First Nations receive benefits from the development of mineral resources"(2).

These include agreements regarding funding, training, employment preferences for local residents, revenue sharing and environmental concerns. IBAs were struck, for example, between Kitkimeot Inuit Association, in Nunavut, and the Jericho diamond mining project, as well as the Doris North gold project. A complete list of known IBAs in Canada can be reviewed at the IBA Research Network's website: http://www.impactandbenefit.com/IBA_Database_List.html

Where not required through a land claims agreement, or by First Nations, government might demand that an IBA be negotiated for a specific project, on an ad hoc basis. Sosa and Keenan (2001) explain further:

> Such a requirement may be part of an overall social policy to benefit Aboriginal communities or may result because the mine is predicted to have a significant social and/or environmental impact. In the case of the Ekati mine in the Northwest Territories, the mining company BHP and aboriginal organizations voluntarily entered into IBA negotiations. During the approval process for a water license, when an agreement was not yet forthcoming, the Minister of the Department of Indian Affairs and Northern Development (DIAND) made the granting of the license conditional on there being "satisfactory progress" in the negotiations during a 60 day period. The negotiation of IBAs is now considered to be a de facto, albeit unwritten, regulatory requirement in the North. (Sosa and Keenan 2001: 7-8)

IBAs have caused some discontent in communities where some regard such an agreement with either skepticism of its effectiveness and enforcement, or capitulation that ultimately permits development, in spite of ongoing opposition. Shortcomings and imperfect results are inevitable, but each of the above developments better insert the values of local inhabitants into the development calculus, and better address community concerns.

Climate change

Climate change concerns all parties involved in mining operations in the Arctic and has local effects, but it is not an important driver of increased mining overall.

In Greenland, longer operating seasons and retreating ice are cited by the Bureau of Minerals and Petroleum as cause for high expectations of mining exploration and development. But climate change also creates new hazards and costs for industry in the Arctic. As the Greenland Ice Sheet breaks up, some coastal areas are experiencing increases in large ice bergs which create serious hazards for shipping, particularly with rapid and unpredictable changes in weather and currents.

In other regions, infrastructure is threatened by soil instability due to melting permafrost, exemplified by the incident with the tailings ponds at Red Dog Mine in Alaska and the open pit diamond mines in Northwest Territories, Canada.

Ice roads are possibly the most integral infrastructure in the Arctic directly impacted by climate change. In 1970, temperatures were cold enough to allow safe tundra travel on ice roads for more than 200 days of the year, according to the Alaska Department of Natural Resources (DNR). DNR statistics now show that period has shrunk to about one hundred days (Muse 2008). In 2006, the Tibitt-Contwoyto Winter Road north of Yellowknife, which services several diamond mines, was closed weeks earlier than normal because of mild temperatures, reducing scheduled shipments to mines by 40 percent. Remaining supplies were airlifted at great expense (Katz 2007). Ice road construction costs as much as $100,000/mile, according to the North Slope Borough's Transportation Plan in Alaska (2005). Given the great expense of ice road construction, and dwindling seasons, their cost-effectiveness might ultimately be reconsidered.

Ultimately, the effects of climate change vary greatly, and local effects determine its influence on mining operations and exploration.

Summary and Recommendations

In this paper we have sought to review and assess potential indicators for monitoring social effects of mining on Arctic communities. We would like to be able to monitor social effects through ecosystem services pathways as well as economic pathways, as mediated by institutions. Monitoring social effects through less tangible pathways affecting fate control, cultural continuity and ties to nature is further off, as it will first require development of a conceptual model.

The most universal measures we found address mineral production and value. We found these to be imperfect proxies for economic or social effects. We found no generic measure of effects on ecosystem services.

We also reviewed and assessed the state of data to describe and monitor mining trends in the pan-Arctic. We found that historical data on mineral production and value is unavailable in electronic format for much of the Arctic, specifically Scandinavia and Russia. Completing the historical record back to 1980 will require work with paper archives.

Trends in mining activity include stasis or decline in mature regions of the Arctic, and strong growth in the frontier regions. Climate change has diverse and regionally-specific

effects, and does not contribute to trends overall. The biggest driver in the Arctic frontier is the availability of large, undiscovered and untapped resources with favorable access and low political risk.

The most critically needed improvement in data collection and reporting is to develop comparable measures of employment. The eight Arctic countries each use different definitions of employment, and different methodologies to collect the data. We recommend that the Arctic Council call a convention of statistical agencies across the eight countries to define and develop one measure of employment that is common to all. Furthermore, many countries do not report employment by county and industry, so the Arctic share of mining employment cannot be identified. This should be part of the Arctic Council call. (If there are confidentiality problems due to the small number of northern mines, in the Scandinavian countries for example, the Nordic Council countries could pool their data for reporting.)

More work needs to be done developing indicator measures for ecosystem service flows. The leading candidate is developing a generic measure of biodiversity that can be used to compare across regions and across time. The successful application of bioindicators in monitoring environmental impacts from production and mine-closure in Australia shows that a similar approach could be pursued in Arctic regions. Finding suitable bioindicators for Arctic ecosystems is essential and could target species that are abundant, easy to sample, and sensitive to mining impacts.

More work also needs to be done developing conceptual models of effects of mining activities on fate control, cultural continuity and ties to nature for local Arctic communities.

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