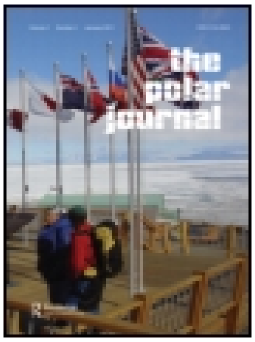

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The future of the marine Arctic: environmental and resource economic development issues

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ABSTRACT

We approach questions of Arctic marine resource economic development from the framework of environmental and resource economics. Shipping, fishing, oil and gas exploration and tourism are discussed as evolving industries for the Arctic. These industries are associated with a number of potential market failures which sustainable Arctic economic development must address. The varying scales of economic activity in the region range from subsistence hunting and fishing to actions by wealthy multinational firms. The ways in which interactions of such varied scales proceed will determine the economic futures of Arctic communities and the natural resources and ecosystems upon which they are based.

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Shipping; fishing; oil and gas extraction; tourism; environmental economics; resource economics

1. Introduction

Global interest in economic development in the Arctic has been growing rapidly. This has been driven by both supply and demand shifts for the resources and amenities produced in the Arctic. On the cost side, there is a perception that climate-change driven impacts in the Arctic will reduce ice cover (both sea-ice and land-fast ice) in the area and therefore also access costs and the broader costs of doing business in five particular industries: shipping, oil and gas exploitation, mineral resource extraction, fisheries and tourism. Simultaneously, global demand for these resources and amenities is increasing as both population and wealth increase. New international organisations exploring the Arctic business environment have come in to existence in the past few years, including the Arctic Council supported Arctic Economic Council (2014), and many business conferences have focused on one or more of the industries expected to benefit from change in the region, including an annual "Arctic Summit" put on by The Economist and the annual Arctic Shipping Forum. Regional investments are being made in cooperation for economic development by groups that include the Arctic Corridor (Finland), the Arctic Caucus (US–Canada), the Chamber of Commerce and Industry of the Russian Federation, and the Barents Euro–Arctic Council, among others.

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Notwithstanding the promise of change, several natural, technical and economic barriers remain that challenge this optimistic view of potential Arctic economic productivity. Stakeholder viewpoints differ as functions of experience and expected net benefits of development.[1] Risk assessments highlight uncertainties as well as opportunities. Northern-based news items proliferate with concerns and discussion regarding how to create "viable Arctic communities." The solutions attempted to these barriers will determine the sustainability and future paths of the Arctic for both local and global values. Fortunately for the Arctic, development opportunities come at a time when we know more than ever about the economic roots, and the potential for remedies, of challenges to cooperative behaviour, dynamic resource use, imperfect competition and externalities to production and consumption. Less fortunately, the political economy of the Arctic is a challenging arena with multiple spatial and temporal complexities that require actions that integrate ecological and economic realities.

The promotion of the Arctic as an open economic frontier, simply awaiting new technologies for exploitation, may be as misleading and detrimental to sustainable development, equity, and global well-being as, for example, the promotion of the American Great Plains as an open economic frontier was 150 years ago.[2] If subjected to similar inappropriate incentives and policies as those that transformed the Great Plains and other "frontier" areas, we must expect disruptive ecological and economic outcomes parallel to the Dust Bowl of the 1930s[3] and the boom-bust outcomes experienced in the early development of oil[4] and other resource industries.[5] These outcomes can be expected to increase inequality as well.[6]

There currently exists a narrow window for using our increased understanding of economic transitions to smooth the disruption and minimise the direct and indirect costs of Arctic economic development. In this paper, we describe the four main Arctic marine industries[7] according to the characteristics which drive some aspects of the challenges to development, and explain those general challenges, along with examples of tools for managing them in inclusive and sustainable ways.

2. Categorisation of new industrial opportunities in the Arctic

The first and second welfare theorems of economics propose equivalence between competitive economic market equilibria and maximised social welfare. These theorems are subject to four important assumptions, violation of which means that intervention into unfettered economic activity and development is likely to be necessary to achieve socially efficient outcomes for both the short and long runs. These four assumptions are described collectively as market failures: (1) the absence of externalities; (2) the absence of public good characteristics of non-excludability and/or non-rivalry; (3) perfect information; and

[1]Avango, Hacquebord, and Wråkberg, "Industrial Extraction of Arctic Natural Resources since the Sixteenth Century."
[2]Ibid., 15–30; Eckholm, "Losing Ground," 223; and Egan, *The Worst Hard Time: The Untold Story of Those Who Survived the Great American Dust Bowl*, 353.
[3]Hansen and Libecap, "Small Farms, Externalities, and the Dust Bowl of the 1930s," 665–94.
[4]Black, *The Landscape of America's First Oil Boom*, 256; and Yergin, *The Prize: The Epic Quest for Oil, Money & Power*, 912.
[5]Barbier, *Scarcity and Frontiers: How Economies Have Developed through Natural Resource Exploitation*, 768; and Sinnott, Nash, and De la Torre, *Natural Resources in Latin America and the Caribbean: Beyond Booms and Busts?* 82.
[6]Barbier, "Scarcity, Frontiers and Development," 110–22.
[7]As mining is, to date, primarily a land-based Arctic activity, we leave direct discussion of mining to other work. As a nonrenewable resource, however, many of the points raised regarding oil and gas exploitation pertain directly to mining.

(4) absence of market power that allows price to exceed marginal costs of production.[8] Further, in the case of intertemporal scarcities common in natural resources, allocations across generations must balance current consumption against future opportunities in ways that maximise dynamic returns.

In the industries under development in the marine Arctic, each is subject to one or more of these failures. By identifying these categorical properties for these industries, a base for developing viable solutions is developed that may include policy, market instruments, institutions, and other governance choices to overcome the failures. Implementation of these solutions will certainly depend on the details of the ecosystems and stakeholders directly involved in individual cases, and further complications arise in particular from the continuing non-market activities of indigenous populations and ecosystems alike that ultimately affect resource productivity, and vice versa.

2.1. Shipping

The promise of shipping in the Arctic stems from reduction in ice-cover opening the Northern Sea Route, and perhaps the Northwest Passage or even directly across the Arctic Ocean, for transport of goods between Asia and Europe or Asia and North America across Arctic routes that save time and therefore money.[9] These benefits are not certain, and are likely limited in scope to destination ships connected to natural resource development in the Arctic rather than substituting for the Panama Canal or Suez Canal by uncertainties over reliability and ocean conditions in particular.[10] Shipping is an intermediate good that derives its economic value primarily from the value of the goods that it can deliver from location to location within a period of time that does not compromise the market viability of the goods. As such, demand for shipping is a derived demand that will vary for the Arctic as a function of a wide range of political and economic variables, ranging from international trade volumes to requirements for vessels using national waters. This further increases uncertainty; for example, the Russian Federation is currently considering new legislation requiring ships used to export oil and gas to be built and registered in the country.[11]

Imperfect information about the costs of any given voyage, due to such difficulties as adverse, uncertain and rapidly changing weather conditions as well as poor existing navigation technology for Arctic conditions are the sort of challenge that insurance markets exist to remedy; in the case of the Arctic, current work in this area includes developing a class of skilled labour to serve as competent ice navigators. The success of such efforts will affect not only the viability of increased Arctic shipping but also Arctic marine tourism in both temporal and locational issues.

Shipping also functions as a network that requires infrastructure of ports, safety equipment, and related support to make it function. These fixed costs and the investment required to accommodate increased shipping in the Arctic must be taken before significant increased

[8]It is beyond the paper to discuss in detail solution design issues. One market failure can be corrected by one instrument, while several failures need policy coordination and often in practice so-called second-best solutions are developed and implemented, see eg Kronbak, Squires, and Vestergaard (2014).
[9]Smith and Stephenson, "New Trans-Arctic Shipping Routes Navigable by Midcentury," 10943–8.
[10]Humpert and Raspotnik, "The Future of Arctic Shipping," 281–307; and Emmerson and Lahn, *Arctic Opening: Opportunity and Risk in the High North*, 1–59.
[11]Staalesen, "A New Law Might Force Shipping Companies to Sail in the Arctic only under Russian Flag," June 19, 2015, http://barentsobserver.com/en/energy/2015/06/russian-arctic-russian-ships-19-06.

shipping can occur, and thus risk becoming stranded costs if trade patterns shift, regulatory barriers change, or other conditions keep the marginal costs of using the Arctic shipping routes from falling as anticipated with reduction in the ice-barrier. Thus far, three out of ten expected search and rescue stations along the Russian coast of the Northern Sea Route are in place, which represents more than any other Arctic coast where transit may occur. Lloyds and Chatham House (2012) indicate, for example, that lower ice cover could mean more mobile ice that intensifies risk for navigation. Much first year ice that was a formidable barrier has been reduced while multi-year ice remains unpredictable.[12]

The addition of marine transport support infrastructure may be appealing in relation to enhancing opportunities for local communities in terms of both employment opportunities and in terms of increased access to markets through trade. There remain many uncertainties, however, that highlight the complex non-linear relationships between climate change in the region and transport capabilities. Realities include connectivity concerns related to the loss or increased cost of use of existing roads in the ice and permafrost from warming temperatures,[13] reduction in air landing capacity when airstrips rely on ice such as at Diomede, Alaska, and concerns about increased storm damage to shore infrastructure without ice to serve as a buffer.[14] These concerns not only challenge the viability of increased trans-Arctic shipping but also threaten the viability of existing Arctic communities.[15]

Both direct movement of ships and the accompanying infrastructure are accompanied by significant potential negative externalities. In the Arctic, these shipping externalities include local and global costs from air emissions in the forms of black carbon[16] to invasive species introductions through multiple vectors including ballast water, hull fouling, and new port infrastructure.[17]

These transboundary externalities have historically been inefficiently managed,[18] but international environmental agreements have been on the rise since the 1950s, with over 1100 multilateral, 1500 bilateral, and 200 "other" environmental agreements, protocols, or amendments to international treaties existing today.[19] In the case of the Arctic, treaties governing marine resources date back at least as far as 1876 (Treaty concerning the Jan Mayen Seal Fishery, 1876), but the total count of agreements is low, and few focus on shipping externalities (see Table 1 and Appendix 1, discussed below). Recent international policy, the Agreement on Cooperation on Marine Oil Pollution, Preparedness and Response in the Arctic (2013) through the Arctic Council, and the Polar Code (2015) through the International Maritime Organization, are steps to address oil and gas and shipping concerns in the Arctic. The mandatory provisions of the Polar Code adhere to the ratified conventions of SOLAS and MARPOL rather than expand them. Polar Ship Certificate documentation follows safety measures and risk-based procedures of SOLAS and Amendments to MARPOL delineate requirements for preventing oil, sewage and solid waste pollution discharges within

[12]Bouffard, "Shipping, Natural Resources Discussion, Eighth Polar Law Symposium."
[13]Prowse et al., "Effects of Changes in Arctic Lake and River Ice," 63–74.
[14]Vermaire et al., "Arctic Climate Warming and Sea Ice Declines Lead to Increased Storm Surge Activity," 1386–90.
[15]Ford, Smit, and Wandel, "Vulnerability to Climate Change in the Arctic: A Case Study from Arctic Bay, Canada," 145–60.
[16]Corbett et al., "Arctic Shipping Emissions Inventories and Future Scenarios," 9689–704.
[17]Fernandez, "Marine Shipping Trade and Invasive Species Management Strategies," 153–68.
[18]Ibid; Fernandez, "Maritime Trade and Migratory Species Management to Protect Biodiversity," 165–88; and Fernandez, "NAFTA and Member Country Strategies for Maritime Trade and Marine Invasive Species," 308–21.
[19]Mitchell, "Data from Ronald B. Mitchell, 2002–2015. International Environmental Agreements Database Project," http://iea.uoregon.edu/ (accessed June 25, 2015).

Table 1. Summary of international environmental agreements addressing Arctic marine issues.

Topic	Number of agreements	Earliest agreement date	Most recent agreement date
Marine mammals (whales)	12	1970	1998
Marine mammals (polar bears)	4	1973	2000
Marine mammals (other)	20	1891	1988
Marine safety and general cooperation	4	1920	1998
Marine pollution	4	1989	2013
Other (primarily fisheries)	7+	1700s	2006
Total	49+	1700s	2013

Source: Compiled from Mitchell (2015).

3 nautical miles from any ice shelf or land fast ice. These requirements are in addition to a schedule for ending all discharges from cargo ships by time the Polar Code enters into force, upon ratification. Recommendations – rather than mandatory requirements – include guidelines to minimise ice accretion through Polar Ship Certificate ice capabilities of vessels transiting polar waters, contingency plans, and references to the Ballast Water Convention and the Antifouling System Convention. A table of Antifouling Systems included in the Polar Code suggests the use of abrasion resistant coatings. Recommendations are *voluntarily* followed if and when incentives warrant them. Avoiding introductions of invasive species to the Arctic marine environment and its ecosystem services depends on such alignment of incentives. Black carbon and heavy fuel oil threats are not even mentioned in Polar Code recommendations. The costs of ignoring these threats are expected to be extensive and multidimensional, including direct and indirect ecosystem and economic impacts.[20]

A further externality with increased vessel traffic in the Arctic is increased vessel–marine mammal interactions that result in potential losses to both the vessel owners/users and the marine mammals. These include sound damages, discussed further below, and vessel strikes of marine mammals.[21] While some traffic paths have some management of vessel–marine mammal interactions, particularly in the Northwest Atlantic, much remains to be done.[22] The multiple sources of value for marine mammals, ranging from extractive uses such as cultural harvest with food security goals to non-consumptive global biodiversity values, further complicate solutions to this challenge. While local resource co-management has begun to evolve to solve the differing use paths for marine mammals,[23] adding transnational shippers to the parties involved requires additional governance at an international level. Since the marine mammal–vessel interactions raise costs for shippers, paths forward should focus on solutions that incentivise shippers successfully to avoid such interactions. A typically proposed economic solution of fees, liability and insurance for vessel strikes

[20]Fernandez, "Bioeconomic Incentives for Addressing Marine Invasive Species in the Arctic."
[21]Reeves et al., "Implications of Arctic Industrial Growth and Strategies to Mitigate Future Vessel and Fishing Gear Impacts on Bowhead Whales," 454–62.
[22]Elvin and Taggart, "Right Whales and Vessels in Canadian Waters," 379–86; and Hartsig et al., "Arctic Bottleneck: Protecting the Bering Strait Region from Increased Vessel Traffic," 75–6.
[23]Meek, "Comparing Marine Mammal Co-management Regimes in Alaska: Three Aspects of Institutional Performance," 248; Castro and Nielsen, "Indigenous People and Co-management: Implications for Conflict Management," 229–39; and Sandström, Crona, and Bodin, "Legitimacy in Co–management: The Impact of Preexisting Structures, Social Networks and Governance Strategies," 60–76.

is incomplete in this case, not only because the marine mammals have such high global non-consumptive biodiversity, but also because the extractive use is not tied only to market production and consumption of the whales but also to the cultural practices of the hunt itself. On the other hand, spatial and/or temporal segregation of marine mammals and vessels may also be an incomplete solution due to the strong seasonal constraints on access and high overlap between navigable waters and migration routes. New, integrated ecosystem management solutions are likely to bring the greatest success.

2.2. Fishing

Fisheries are generally subject to commons problems requiring cooperative limitations of today's use of the resource in order to provide for tomorrow's resource productivity. Short run profit incentives promote fishing as much as possible and as quickly as possible, which prevents achieving long run profitability as well as sustainability of the resource.[24] While most of the world's oceans are at the least organised into regional advisory councils for fishery resources, and several of these have international management powers (see Figure 1), the Arctic lacks such agreements.

As Figure 1 illustrates, the Arctic is currently underinvested in formal cooperative solutions to overfishing threats. The ice barrier has to date prevented these threats, but the expectation of continued melting and improved technological access requires more consideration for how to supplement and replace this natural defence. Investments in joint governance involve restrictions in today's harvests and are costly both in current income and enforcement expenditures. Reductions in the efficacy of the ice barrier have prompted some unilateral action to limit and regulate future Arctic Ocean fishing, most prominently a 2009 US moratorium on industrial fishing in US waters north of the Bering Strait. This initiated similar moves by Denmark (Greenland) and Canada (2014). Norwegian law prevents Norwegian-flagged vessels from fishing in international waters without existing regional management agreements. These unilateral actions are being scaled up to the international level. An agreement amongst the five coastal Arctic states to use interim measures, such as to only authorise commercial fishing vessels based on an international fishing agreement, is now in place by the June 16 Declaration (Oslo 2015). For full impact, non-Arctic states will also need to use these interim measures for international waters.

As the ice barrier degrades, the potential for increased fishing stems not only from the increased access, but possibly also from increased fish biomass as commercial species move northward. The probability of this latter occurrence remains uncertain. Scientific evidence about the future bio-productivity of the Arctic Ocean, particularly areas outside of national jurisdictions, is mixed.[25] While net primary production is expected to increase overall, complications, eg from nitrate supply limitations driven by sea ice loss and increased stratification may not translate into increased commercial productivity.[26]

[24]Hardin, *The Tragedy of the Commons*, 1243–8.
[25]Slagstad, Ellingsen, and Wassmann, "Evaluating Primary and Secondary Production in an Arctic Ocean Void of Summer Sea Ice: An Experimental Simulation Approach," 117–31.
[26]Vancoppenolle et al., "Future Arctic Ocean Primary Productivity from CMIP5 Simulations: Uncertain Outcome, but Consistent Mechanisms," 605–19.

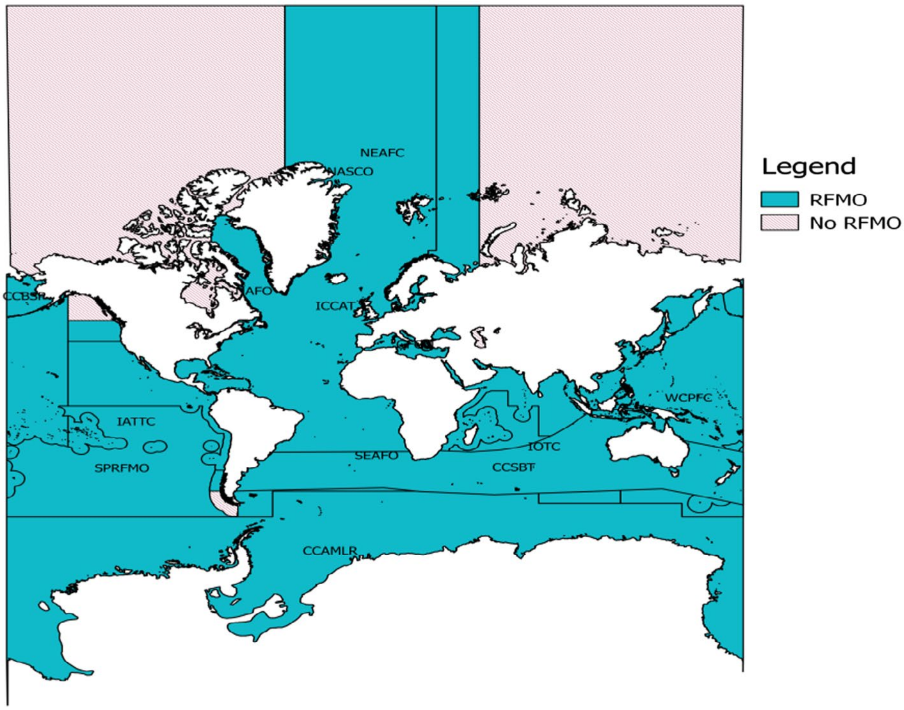

Figure 1. Existing regional fisheries management organisations (RFMOs).

In addition, fisheries are also associated with ecosystem impacts that include augmenting regime shifts[27] and externalities from vessel traffic and fishing gear,[28] which in turn can result in significant shifts in community structure and viability.[29] Any opening of commercial fisheries should be expected to directly, through increased harvests, and indirectly, through additional ecosystem changes, influence both food security and cultural values of marine-oriented Arctic indigenous communities. These communities need to be included directly in negotiations for increased biological marine resource use. As stated above, templates for co-management are growing,[30] but incentives for commercial and indigenous stakeholders may be difficult to align. Commercial interests represent growing global demand for consumptive fish biomass combined with non-consumptive marine mammal preservation, goals which are often at odds with native uses of marine resources. Additionally, these conflicts have created extensive harm to native communities trying to increase market activity and economic development through use of marine resources, such

[27]eg Moellmann et al., "Reorganization of a Large Marine Ecosystem due to Atmospheric and Anthropogenic Pressure: A Discontinuous Regime Shift in the Central Baltic Sea," 1377–93; and Springer et al., "Sequential Megafaunal Collapse in the North Pacific Ocean: An Ongoing Legacy of Industrial Whaling?" 12223–8.

[28]Reeves et al., "Implications of Arctic Industrial Growth and Strategies to Mitigate Future Vessel and Fishing Gear Impacts on Bowhead Whales," 454–62.

[29]eg Ibid.; and Anderson and Piatt, "Community Reorganization in the Gulf of Alaska Following Ocean Climate Regime Shift," 117–23.

[30]Meek, *Comparing Marine Mammal Co-management Regimes in Alaska: Three Aspects of Institutional Performance*, 245; Castro and Nielsen, "Indigenous People and Co-management: Implications for Conflict Management," 229–39; and Sandström, Crona, and Bodin, "Legitimacy in Co–management: The Impact of Preexisting Structures, Social Networks and Governance Strategies," 60–76.

as the collapse of world seal product markets due to the EU ban on seal products.[31] Local governance structures that have co-evolved with resource values and their changes over time are facing costly transitions with the expansion of interests and increasing multidimensionality of the resource values across evolving stakeholders.[32] Flexibility to address these multiple dimensions will stem from policy developments that accept tradeoffs amongst uses and users, in order to generate welfare-improving opportunities for all.

2.3. Oil and gas extraction

Oil and natural gas condensates are nonrenewable resources associated with a large array of negative externalities. There are also significant dynamic concerns due to the limited availability of the resources that must be shared across time. The long lag times – measurable in decades – expected between initiating exploration in the Arctic and bringing new product to market mean that capital intensive decisions must be forward looking in a way that correctly anticipates complex forces of demand and supply. This is no mean feat in today's volatile oil and gas industries – Royal Dutch Shell, for example, took a $2.6 billion charge against 3rd quarter 2015 profits for losses ascribed to its decision to walk away from further offshore development at the Burger J wells in the Chukchi Sea.[33] While an as-yet-unspecified amount of oil was found, it is not economically recoverable under current or expected conditions in the foreseeable future.[34] Shell has not yet relinquished costly leases in the Alaskan Arctic, however, so leaving the door for further exploration ajar.[35]

The industry's structure is also potentially subject to market power, which has significantly affected historical development of the industry.[36] As common pool resources, they are also potentially subject to tragedy of the commons if open access continues to exist. Shell's recent decision to exit Chukchi Sea exploration is not only a function of lower oil prices and growing adverse public opinion. There are also competitive and strategic elements; withdrawal of other major oil corporations from the region can be expected to make it easier for Shell to also leave. Other departures from the Arctic include Exxon Mobil's exit from Russian water exploration due to political sanctions, and Chevron, Exxon and BP's exits from Canadian Arctic waters due to low oil prices and uncertainty about sufficient time to explore under current lease arrangements.[37] Krautkraemer[38] provides an overview and analysis of economic understanding of the optimal use of these resources and the processes governing discovery and exploration, which must be understood to generate accurate expectations about the benefits and costs of oil and gas exploration in the Arctic.

[31]Sellheim, "The Goals of the EU Seal Products Trade Regulation: From Effectiveness to Consequence," 274–89.
[32]Kaiser and Roumasset, "Transitional Forces in a Resource Economy: Phases of Economic and Institutional Development in Hawaii," 1–55.
[33]Schaps and Bousso, "Shell's Profits Hit by Big Arctic, Canadian Write-Offs," Reuters, October 29, 2015, http://www.reuters.com/article/us-shell-results-idUSKCN0SN0KN20151029.
[34]Shell, *Shell Updates on Alaska Exploration*, News and Media Releases September 28, 2015, http://www.shell.com/global/aboutshell/media/news-and-media-releases/2015/shell-updates-on-alaska-exploration.html.
[35]Dloughy, "Shell Leaves Door Open for Future Exploration in Alaska's Arctic," *Houston Chronicle*, November 2, 2015. Accessed via Alaska Dispatch News, http://www.adn.com/article/20151102/shell-leaves-door-open-future-exploration-alaskas-arctic.
[36]Yergin, *The Prize: The Epic Quest for Oil, Money & Power*, 912.
[37]Kent, "Shell to Cease Oil Exploration in Alaska after Disappointing Drilling Season," *Wall Street Journal*, September 28, 2015, http://www.wsj.com/articles/shell-to-cease-oil-exploration-offshore-alaska-1443419673.
[38]Krautkraemer, "Nonrenewable Resource Scarcity," 2065-2107.

The large economic value of the resources, the location of most resources within national jurisdictions, and the large multinational corporations involved have generated interest and investment in robust solutions to challenges facing Arctic hydrocarbon exploration. For offshore endeavours, these mainly include nation-level spatial licensing for exploration and wells in addition to options for field unitisation and joint ventures.[39] There are more gas reserves than oil in the Arctic for all Arctic states.[40] Thus, due to lower prices for natural gas than for oil, direct extraction revenues may be lower. Furthermore, challenges in transporting the resource to market are physically greater and involve both more direct and more external costs from infrastructure development, particularly pipelines or LNG facilities. Differences in the regulatory environment amongst nations currently provide different incentives on timing of oil and gas operations. Whereas Canada, Greenland, Norway and Russia have exploration-based leases, the US has development-based leases.[41] The duration of a lease is longer in Greenland (16 years) and Norway (32 years) vs. Russia, Canada and the US (up to 10 years).[42] Current efforts by industry to negotiate a longer duration of drilling beyond the actual open water season persist amidst ongoing questions of risk.[43] These differences create strategic interactions between multinational corporations and the national jurisdictions in which they operate, and may pit nations against each other at the expense of environmental and risk regulations rather than support cooperative action to minimise damages from risks while maximising the resource returns not only for nations and corporations but for global concerns. Again, integrated ecosystem management that incorporates the strategic incentives of the stakeholders should be the focus of policy development.

As an intermediate good (like shipping), demand for hydrocarbon resources is a derived demand. Price fluctuations that stem from global changes in such variables as wealth, income, trade fluctuations, technology and investment in alternative forms of energy may be large, as recent events demonstrate.[44] These fluctuations, along with the evolving physical and regulatory environments, create significant uncertainty about the value of the substantial capital investments that offshore Arctic oil and gas involve. These uncertainties amplify the risks involved in initiating the offshore investments in terms of local community investments in infrastructure and expectations about financial returns to property rights holders and potential labor.

The externalities associated with oil and gas extraction extend considerably beyond the general and serious public concern of the anticipated damages of a spill or accident in the region. They begin as early as initial surveying for likely deposits, which currently produce significant noise externalities that interfere with marine mammal populations.[45] The International Council on Clean Transportation's 10 year projection of maritime activity in the US Arctic region[46] shows an anticipated increase in Polar Classes 3, 6 and open water vessels. These include cargo, tugs and tankers for offshore activity and seismic programmes

[39]Blyschak, "Offshore Oil and Gas Projects Amid Maritime Border Disputes: Applicable Law," 210–33; and Efimov et al., "Cluster Development of the Barents and Kara Seas HC Mega Basins from the Novaya Zemlya Archipelago."
[40]National Petroleum Council, *Arctic Potential: Realizing the Promise of U.S. Arctic Oil and Gas Resources*, 1–87.
[41]Ibid.
[42]Ibid.
[43]Ibid.
[44]Tokic, "The 2014 Oil Bust: Causes and Consequences," 162–9; and Baumeister and Kilian, *Understanding the Decline in the Price of Oil since June 2014*, 1–36.
[45]Richardson et al., *Marine Mammals and Noise*, 481.
[46]ICCT, 2015.

in the Beaufort and Chukchi Sea oil and gas exploration leases, and a gas condensate facility. The spatial coincidence of marine mammal populations with areas of interest for hydrocarbon exploration and the lack of attenuation of sound transmission in water are already leading to restrictions on the timing and location of surveying,[47] and growing awareness of the importance of managing cumulative impacts as well. This may lead to changes in technology (such as air guns) used by industry to carry out the seismic studies generating the noise.[48] So far, the US oil industry contends the Conflict Avoidance Agreement between it and the North Slope Whaling associations for subsistence harvesting is a means towards addressing overlap issues.[49] The Agreement is only for extractive activities. As such, it does not have a focus on marine habitat management for the purpose of sustaining marine flora and fauna for non-extractive purposes. As with transnational shipping, solutions will require multidimensional strategic and bioeconomic components.

2.4. Tourism

Tourism in the Arctic is primarily based on non-consumptive use of environmental and natural resources as experiential and visual amenities, although significant tourism based on resource extraction, eg fishing and hunting activities, affect the existing socio-ecological systems. In this context, marine mammals and other Arctic marine resources have some public goods aspects, particularly in the form of (congestible) non-rivalry, and to some extent, non-excludability. The former is due to the ability of many tourists to enjoy the amenities provided by the same marine resources, while the latter is due to the fact that, while tourists must pay for access to the environment, their access fees are not directly related to the funding of the provision of the marine resources. In this way, tourists may be "free riders" who enjoy access to the marine resource amenities without paying to help provide them.

Many cruise ship operators bringing tourists to the Arctic may follow industry developed guidelines through the Association of Arctic Expedition Cruise Operators for Svalbard, Jan Mayen, parts of Arctic Canada, Greenland and Russia. These guidelines are not directly linked to sovereign Arctic state policies.

Solutions to these challenges may include linking tourist access to conservation funding, such as used by the island of Bonaire, which charges a fee for all island visitors that is used for marine conservation.[50] Like other taxes or fees aimed at supporting environmental quality, two important considerations should be made. First, the fees change prices for the resource or amenity, and price elasticities that may lead to choosing substitute experiences (eg cruise tourism in Greenland vs. Alaska) should be included in any estimates of expected profitability and impact of such an action. Second, funds from such fees should be spent on the provision of the resource, rather than improving access to the resource, if the goal is to protect it. This is because while increasing the resilience, quality and/or quantity of the resource and its habitat will increase its supply and the ability of present and future

[47]Wright, "Marine Mammals and Ocean Sound: Sources, Impacts, Uncertainties, Controls, and Future Decision Making."
[48]Wright and Kyhn, "Practical Management of Cumulative Anthropogenic Impacts with Working Marine Examples," 333–40.
[49]National Petroleum Council, *Arctic Potential: Realizing the Promise of U.S. Arctic Oil and Gas Resources*, 1–87.
[50]Thur, "User Fees as Sustainable Financing Mechanisms for Marine Protected Areas: An Application to the Bonaire National Marine Park," 63–9.

generations to enjoy the benefits, increasing access to the resource serves to lower the costs of human species interactions and their potential negative effects.

In some cases, payments for ecosystem service (PES) systems may provide more comprehensive solutions, challenges notwithstanding.[51] Incentivising local communities to directly and indirectly maintain ecosystem functioning may simultaneously provide incentives to maintain cultural heritage and experience in ways that direct fees-for-use cannot. Appropriately designed PES policies can serve to provide income for communities that maintain integrated socioecological systems rather than simply preserve "environment" over sustainable multiple uses.

Many of the existing international agreements for the Arctic marine environment focus on an interesting combination of marine mammals and safety at sea in particular, as shown in Table 1 and elaborated upon in Appendix 1.[52] The protections for these migratory species evolved primarily due to direct use pressures on the resources and the desire to reduce tragedy of the commons problems, but contain within them the changing mores over conservation that may be positively correlated with increased wealth.[53] Wealth is in turn expected to be positively correlated with increased spending on tourism[54]; indeed, income elasticities for international tourism are routinely estimated as greater than one, signaling them as luxury goods that increase at a faster rate than income, as it increases.[55]

These agreements will fortuitously provide some support for these environments and the tourists who travel in them as tourism grows, but incentives for unique tourism experiences will require additional oversight. This is due to the fact that tourism pushes the interaction between marine mammals and humans into potentially dangerous interactions for both parties.[56]

3. Interactions amongst industries and the need for integrated, ecosystem-based management

By examining these four industries together, we can highlight the interactions that further complicate expectations about Arctic economic development. We particularly want to stress two important aspects that need constant consideration. The first stems from the compressed spatial and temporal scales involved in the Arctic. The second is the tight connection between Arctic communities and the ecosystems upon which they depend, which increases the importance of incorporating human behaviour and incentives into decision-making over resource use and economic development. Both of these considerations strengthen the need for governance of Arctic resources that incorporates bioeconomic and strategic

[51]Hayes et al., "Can Conservation Contracts Co-exist with Change? Payment for Ecosystem Services in the Context of Adaptive Decision-Making and Sustainability," 69–85; Polasky et al., "Implementing the Optimal Provision of Ecosystem Services," 6248–53; and Milder, Scherr, and Bracer, "Trends and Future Potential of Payment for Ecosystem Services to Alleviate Rural Poverty in Developing Countries," 4.

[52]Mitchell, "Data from Ronald B. Mitchell, 2002–2015. International Environmental Agreements Database Project," http://iea.uoregon.edu/ (accessed June 25, 2015).

[53]Mills and Waite, "Economic Prosperity, Biodiversity Conservation, and the Environmental Kuznets Curve," (2009): 2087–95; and Jacobsen and Hanley (2009): 137–60.

[54]Ackerman, "Valuing the Ocean Environment," in *Managing Ocean Environments in a Changing Climate: Sustainability and Economic Perspectives*, 376.

[55]Peng et al., "A Meta-Analysis of International Tourism Demand Elasticities," 611–33.

[56]Criddle, "Managing Hotspots of Ship-Resource Encounters to Ensure Natural and Cultural Protections from Emerging Cruise Tourism in Arctic Alaska" (Presentation at ESSAS Annual Science Meeting, Seattle, WA, June 15–17, 2015).

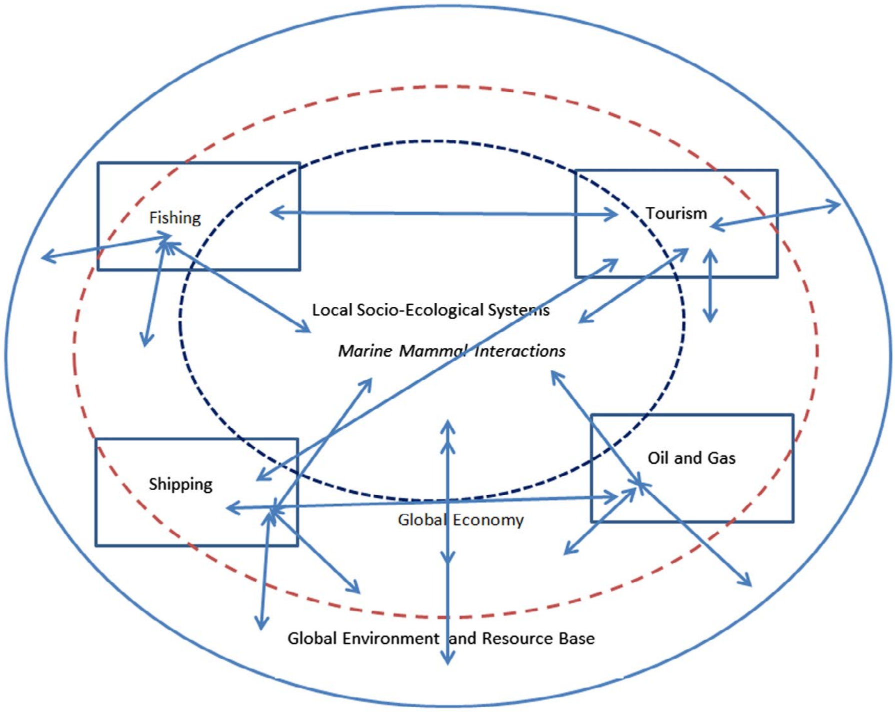

Figure 2. Arctic industry interactions with economy and environment.

considerations[57] in order to increase the possibilities for sustainable, welfare-improving development in the Arctic.

Figure 2 illustrates the interconnectedness of not only the four industries, but the Arctic socioecological systems currently in place, the global economy that surrounds these systems, and the global resource environment that encompasses all. While climate change acts to shrink the global environmental resource base, this in turn squeezes the economy and the Arctic systems. The proposed industrial developments have potential direct feedback impacts on all three layers, as well as interconnections amongst each other.

4. Summary

As one can see in Figure 2, each of the four industries has interaction with local systems, the global economy, and global ecosystems. Local systems should be considered tight socioecological systems, where the role of ecosystems and environment are not fully separable through market interventions and related regulatory tools. That is not to say, however, that insights into human economic behaviour do not help elucidate both challenges for sustainable development and their solutions. Rather, they highlight the vital need to incorporate fully the many dimensions of ecosystems and the humans who depend upon them into decision-making. This requires full consideration of the ongoing challenges to having various entities, and the variety of values they hold, represented in policy or agreements.

[57]Kaiser et al., "Spatial Issues in Arctic Marine Resource Governance Workshop Summary and Comment," 1–5.

To date, Arctic examples of development appear to be extractive industries episodic cases of rather than comprehensive, long term policies of other entities. This is supported by the growing disconnect between the global economy and environment which sustains it. They have become more separated at the same time that global access to resources and global demand for both extractive and non-extractive use of these resources have increased manifold. Local management alone cannot optimise sustainable development, but neither can internationally imposed legislation generate complete solutions to the challenges ahead. Optimal resource use that enables sustainable development requires increasingly coordinated oversight at multiple spatial and temporal scales. Economic theory can help elucidate solutions that meet these challenges if it is integrated across ecosystems and stakeholders.

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Appendix 1. Current and historical international environmental agreements affecting the Arctica marine environment

Agreement	Years of treaty and subsequent amendments and notes	Nations involved[*,ŧ]
Agreement between the government of the United States of America and the government of her Britannic Majesty for a Modus Vivendi in relation to fur seal fisheries in Bering Sea	1891, 1892, 1896, 1911	US[ŧ], UK[ŧ]
Arrangement between Great Britain and Russia concerning a system of protection of fur seals in the North Pacific Ocean	1893	UK[ŧ], RU[ŧ]
Agreement between the USA and Russia for a Modus Vivendi in relation to the fur seal fisheries in the Bering sea and the North Pacific Ocean	1894	US[ŧ], RU[ŧ]
Convention for the preservation of the fur seal and sea otter in the North Pacific Ocean and Bering Sea	1897	JP[*], RU[*], US[*]
Convention respecting measures for the preservation and protection of the fur seals in the North Pacific Ocean	1911, 1957, 1963, 1969, 1976, 1980, 1984[*]	JP, US, UK, RU
Treaty (and protocol to) concerning the Archipelago of Spitsbergen	1920	40 nations in 2015
Convention between Finland and Russia regarding fishing and sealing in the territorial waters of both countries in the Arctic Ocean	1922	FI, RU
Temporary agreement between the governments of the United Kingdom and of the Union of Soviet Socialist Republics, for the regulation of the fisheries in waters contiguous to the northern coasts of the territory of the U.S.S.R.	1930	UK[ŧ], RU[ŧ]
Exchange of notes constituting a provisional agreement between the governments of the United States of America and Canada relating to fur seals	1942, 1947	US[ŧ], CA[ŧ]
Exchange of notes constituting an agreement between the USA, CA and Japan relating to scientific investigations of the fur seals in the North Pacific Ocean	1952	CA, JP, US
Agreement on the regulation of North Pacific whaling	1970, 1971	JP, RU, US
Agreement between the government of CA, the government of the Republic of Iceland and the government of the Kingdom of Norway concerning an international observer scheme for land-based whaling stations in the North Atlantic area	1972	CA, IS, NO
Agreement between the United States of America and Japan concerning an international observer scheme for whaling operations from land stations in the North Pacific Ocean	1973, 1974, 1975, 1976, 1986	US[ŧ], JP[ŧ]
Agreement on conservation of polar bears	1973	CA, DK, NO, RU, US
Agreement between the UK, Norway, and the USSR on the regulation of the fishing of North-East Arctic (Arcto-Norwegian) cod	1974	NO, RU, UK
Agreement between Japan and the Union of Soviet Socialist Republics on the regulation of North Pacific whaling	1974, 1976	JP[ŧ], RU[ŧ]
Exchange of notes between the government of Canada and the government of Norway amending the agreement between the government of Canada and the government of Norway on sealing and the conservation of the seal stocks in the Northwest Atlantic	1975	CA[ŧ], NO[ŧ]
Agreement between Norway and the Soviet Union on a temporary practical scheme for fishing in an adjacent area in the Barents Sea (Grey Zone Agreement)	1978	NO[ŧ], RU[ŧ]

(Continued)

Appendix 1. (*Continued*)

Agreement	Years of treaty and subsequent amendments and notes	Nations involved*,[t]
Agreement between the government of the USSR and the government of the Polish People's Republic relating to fishing in the areas of the Barents Sea adjacent to the sea frontage of the USSR	1978	RU[t], PL[t]
Agreement between the government of the USSR and the government of the People's Republic of Bulgaria concerning fishing in the areas of the Barents Sea adjacent to the sea frontage of the USSR	1978	RU[t], BU[t]
Agreement between the Inuvialuit and the Inupiat on polar bear management in the Southern Beaufort Sea	1988[t], 2000	US, CA
Agreement between CA and the US on Arctic cooperation	1988	CA[t], US[t]
Agreement on cooperation in research, conservation and management of marine mammals in the North Atlantic	1988	Faroes, GL, IS, NO
Agreement between the government of the USA and the government of the USSR concerning cooperation in combatting pollution in the Bering and Chukchi Seas in emergency situations	1989	US[t], RU[t]
Agreement between CA and the Russian Federation on cooperation in the Arctic and the North	1992	CA[t], RU[t]
Agreement on cooperation in prevention of environmental pollution in the Arctic	1994	US[t], RU[t]
Protocol on intentions between the State committee of the Russian Federation on environmental protection and the Ministry of environmental protection of Norway about cooperation in the field of creation of the automated network of measurement of radiating pollution in the Northwest region of Russia and an exchange of results of measurements between the Russian Federation and Norway	1998	NO[t], RU[t]
Amendments to the international convention for the safety of life at sea (SOLAS) – Adoption of resolution and annexes on ship reporting systems for North Atlantic right whales off the north-eastern and south-eastern coasts of the US	1998	158 nations in 2015
Agreement (and protocols) between Iceland, Norway and Russia concerning certain aspects of cooperation in the area of fisheries	1999	IS, NO, RU
Agreement on the conservation and management of the Alaska -Chukotka polar bear population	2000	RU, US
Bilateral agreement between Norway, on the one hand, and Denmark with Greenland's National Board, on the other side of the delimitation of the continental shelf and fishery zones in the area between Greenland and Svalbard	2006	NO[t], DK[t]
Agreement on cooperation on marine oil pollution, preparedness, and response in the Arctic	2013	CA, FI, NO, RU, DK*, Faeroe Is*, GL*, IS*, SE*, US*

Notes: [a]We exclude the many fisheries agreements in the North Pacific and North Atlantic Oceans that begin as early as the 1700s because they distract from the issue of increased physical access and changed habitat expected in the Arctic Ocean. We do include whale- and seal- related agreements for migratory species that are likely to pass in to Arctic Ocean waters; *Signed but not ratified; [t]Unverified by IEA database.