Challenges of marine decision making in the Arctic: Insights from the Moscow Summer Academy 2015 on how to model interplays between ecology and economic behaviour

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The current article has been inspired by the interdisciplinary set of lectures that were offered in terms of the Summer Academy on Economic Growth and Governance of Natural Resources in Lomonosov Moscow State University (MSA 2015, 20/07 - 01/08/2015), as well as by the recent developments in Arctic marine governance.

Scholars with intimate knowledge of issues related to economic growth, resource governance and management of natural resources have, in terms of MSA 2015, addressed a series of issues that play a discernible role in current environmental challenges, including Arctic ecosystems, in a wider context of non-linear social-ecological systems undergoing rapid changes. This endeavour largely succeeded in providing MSA participants with a comprehensive view of methodologies and applications through the use of robust modeling tools. Foremost experts in game theoretic settings, optimal control theory and analysis of dynamic systems have paved the way for MSA participants, through their lectures, for developing a better understanding of how environmental managers deal with uncertainty, risk and complex decision making processes with respect to existing constraints.

Fig. 1 MSA 2015 Participants

The tools and methodologies presented, have managed to stimulate discussions among the participants and broaden understanding of socio-economic transitions mediated by ecological changes. Having been myself involved in research related to Arctic marine governance and stewardship of Arctic marine resources, these topics piqued my interest and I strongly believe that the use of such tools can

provide a host of extensions that can help penetrate to the core of the economic and social vulnerabilities related to the dramatic environmental transformation Arctic ecosystems are lately experiencing.

The analysis that follows touches upon the recently signed "Declaration Concerning the Prevention of Unregulated High Seas Fishing in the Central Arctic Ocean" (16/07/2015) in Oslo, by representatives from the five Arctic Ocean coastal states (A5) - Canada, Denmark, Norway, Russia and the United States. In the Declaration text it is clearly being stated that "commercial fishing in the high seas portion of the central Arctic Ocean is unlikely to occur in the near future", an approach which clearly increases the stature of the "Precautionary Principle". The reasoning behind this perception is that, according to what scientific information indicates for now, the extensive ice coverage is not expected to allow the expansion of fishing activities up north. Waters around the North Pole and the Arctic Ocean surrounding it are considered international and are often referred to as "high seas". The A5 have sovereignty rights within the Exclusive Economic Zone (EEZ) which is 200 nautical miles from their coasts. With the adoption of the United Nations Convention on the Law of the Sea (UNCLOS, 1982), a legal framework has been created for the governance of the underlying marine resources, thus allowing countries to claim, upon ratification of the convention and within a 10 year period, an extended continental shelf. These claims, on the condition of validation (through a very long process which includes scrutiny of scientific argumentation), can provide exclusive rights to resources on or below the seabed of that extended shelf area. Furthermore, it is a subject worthy of discussion that currently in surrounding marine ecosystems (e.g., sub-Arctic such as the Barents Sea) there are different management regimes among national EEZs, but the above mentioned Declaration is the first official attempt to regulate international waters of the Central Arctic Basin. Fisheries management in the wider area includes complex decision making challenges, while it is also complicated by multiple confounders, including transboundary fish stocks (often ranging in EEZs of more than one country) and straddling stocks arising from the unsettled maritime boundary lines, thus often calling for the establishment of an effective bilateral or multilateral regime.

The contentious and divisive issue of how to handle Arctic living marine resources has mostly been discussed so far in literature from a biodiversity standpoint rather than an economic one. The latter could potentially set the grounds for optimal use of resources and thus contribute to preventing irrational behaviours that may lead to the collapse or disruption of the ecosystem. Optimization theory provides critical insights for interested individual actors/units in pursue of payoffs and by the same token it can also prove useful for decision-making processes whereby all interested parties cooperate in the management of Central Arctic fish stocks. Game theory on the other hand, can potentially contribute in a more complex setting, with two or more actors/players (or states in our case) involved in the management of fishing resources and with each actor being able to choose from amongst a set of available options having his/their payoff dependent on other players' or states' choices.

The long-term horizon that is required for the feasible exploitation of the Central Arctic, as is clearly stated in the Declaration, needs to be considered when conducting economic analysis. The timescale should also be factored when expanding the limited regional studies in order to determine those policies that will maximize effective social welfare. For example, using a game theoretic setting, states with fishing interests in the Central Arctic (not only the A5) can be regarded as competing agents operating in a dynamic deterministic framework over a long time period that might have to be addressed by an infinite horizon dynamic game. The long-term "fishing perspective" in the Central Arctic, with the retreat of ice being a rather gradual process, also adds some different dimensions that need to be accounted for. Arguably, the period of transition will include a significant degree of uncertainty with environmental data analysis being fraught with uncontrollable variables. Economic tools such as the aforementioned ones, that MSA 2015 has been focusing on, can illuminate ambiguous points and prevent situations where states become eager to defect by intensifying their fishing efforts and proliferating their catches, which is very likely to lead to other states following a similar behaviour, thus resulting in an extended period of competition that will definitely put the marine ecosystem in peril.

My personal perception of approaching the existing risks and uncertainties over Arctic marine resources, would be to use as a baseline scenario a differential game setting. A differential game in this case seems suitable since there is an underlying assumption that the "Arctic players" involved make decisions at all time points and not necessarily in specific time intervals. Furthermore a repeated static game, such as the Prisoner's Dilemma, would probably lack a robust baseline here, since the pay-off functions of our players would not be time-dependent. Considering first a cooperative solution where all involved Arctic states agree to cooperate on the management of marine resources in the Central Arctic, would need to be solved as a standard optimal control problem, through the use of maximum principle or dynamic programming. In other words the outcome of optimizing a joint welfare function should be examined regarding its efficiency, which practically brings together the different "Arctic players" in a joint effort to maximize their weighted average of their individual welfare. Besides the cooperative solution described above, Nash equilibrium related concepts which are extensively being used in non-cooperative game theory, can provide useful insights with regard to incentives and motivations, especially in cases, like the one described here, where it is rather daunting to predict how different players will behave in a game. An open-loop solution that gives Nash equilibrium would result in all players having absolutely no incentive to deviate from their specific strategic path, given the path of other players or in other words having the players at a Nash Equilibrium would make them unwilling to act differently, since they would be worse off if they did.

An Open Loop Nash Equilibrium can be examined where there is exclusive dependence on the time variable; if a player deviates from the equilibrium control, even if briefly, and decides to return to its former behaviour, the Equilibrium is broken. Conversely, in a Feedback (or closed-loop) Nash Equilibrium which is strongly time consistent, the dependence lies on the current state of the system. Differential games can generally help towards answering whether a potential cooperative solution can be achieved through a Nash equilibrium of a non-cooperative game.

Inferring methodologies and responses from studies on similar cases of joint management cooperation on fish stocks, the examination of a framework like the one described above would require us to assume that all countries would prefer cooperating instead of competing for fishing in the Central Arctic, only if the Net Present Value is larger than the non-cooperative case, thus covering the opportunity costs arising from the cooperative case. If this condition is not satisfied we will have to accept that there will be a noncooperative behavior up to the point that cooperation turns lucrative for all players.

Game theoretic approaches with regard to stock management have so far provided useful insights and directed new lines of inquiry but the dynamically changing Arctic raises issues that permeate those discussions and rather call for coordinated responses among affected parties through the use of more robust tools such as evolutionary game theoretic approaches. With a view to all those northward moving species that are expected to expand to yet unexploited parts of Arctic waters, one of the most prevalent concerns are the consequences of coastal states' harvesting activities on society's wellbeing and the ways in which it will be made possible to leave a positive legacy for future generations. Thus it behooves scientists to commit a significant research effort to devising ways to answer those questions by utilizing the interplay of ecology and economic behavior. Meticulous research on strategies of defection, cooperation and enforcement can be a cornerstone for establishing and managing effective ways to protect the Arctic marine environment, taking into account the current dearth of research in existing and future biodiversity. I dare to envision that through delineating research steps that are necessary for acquiring a deeper understanding of this interplay between ecology and economic behavior in Arctic Oceans, that often polarizes the research community, I will be able to effectively address one of the most vexing problems of Arctic fisheries management. The magnitude of predicted environmental changes expected in the Arctic Oceans, on biodiversity and ecosystem functioning, that carry along a series of threats such as bioinvasions (that may originate either from northward moving species, ballast water, hull fouling etc) personally behoves me to commit an extensive research effort to devising some way of

addressing those challenges, especially knowing that often enough there are interests at odds due to the potential of the new lucrative fisheries arising up north.