Climate change and the benefits of cooperation in harvesting North-East Arctic cod

Nils-Arne Ekerhovd
SNF, Norwegian School of Economics, Bergen
nilsarne.ekerhovd@snf.no

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We examine the temporal conditions required for the sharing of the NEA cod fishery between Norway and Russia in the Barents Sea when warmer ocean temperatures positively affect the productivity of the stock through increased recruitment to the fishery. Our focus is on the determination and comparison of the noncooperative and cooperative solutions. In doing so, we compare the cooperative (sole owner) alternative outcome with noncooperation over time with an assumed increase in temperature and a corresponding increase in the numbers of recruits entering the fishery given the spawning stock biomass.
Simulate how an increase in the productivity of the NEA cod stock would affect Russian–Norwegian cooperation on the management of the fish stock

Linking a productivity increase to sea environmental conditions and to climate change through a temperature-dependent, stock-recruitment relationship

Modeling the migration pattern and harvesting strategies

To assess the benefits of cooperation, we compute the noncooperative payoffs and the cooperative outcome and compare the benefits

We contrast the results from optimal harvesting with (i) a game of two players that control their own annual harvesting, but are unable to make binding agreements.

In addition, we simulate (ii) a game where one of the players can control its own harvesting by choosing a separate effort level to the spawning stock during the spawning season, while the other player only can control its overall annual harvest
Temperature development

Figure: 1 Temperature projection. $\tau_0 = 4$, $\tau_{\text{max}} = 6$, and $\mu = 0.01$ (solid) and $\mu = 0.02$ (dashed), respectively.
Stock recruitment

Figure: 2 Observed NEA cod stock recruitment 1946–2007 (△) and the Ricker (♦) recruitment function fitted to data on spawning stock biomass, recruitment at age three years, and temperature (the Kola Section); 1946–2007 for temperatures 4°C (solid) and 5°C (dotted), respectively.
The year is split into two parts: the first four months of the year, and the remainder.

- The mature part of the stock is available to Norway only in the first period because of its spawning migration.
- We assume the immature part of the stock is equally available for Norway and Russia during the first period.
- In the second period, we assume the spawning stock has migrated back into the Norwegian and Barents Seas, and is thus equally available for both countries.
Harvesting strategies

The two parties, Russia and Norway, maximize the net present values (NPV) of their respective cod fisheries. This strategy involves setting the appropriate level of fishing effort for the fisheries; in which neither Norway nor Russia appears to have a distinct advantage over the other. Norway controls the spawning stock and is thus in a position to control the renewal of the stock. Both countries fish the immature part of the stock, and the mature part outside the spawning season, so with a time lag, any Norwegian overfishing of the spawning stock would harm Norway along with Russia. Russia fishes the immature stock and the mature stock outside the spawning season, but doing so too heavily would produce a too small spawning stock, which would affect Russia as well as Norway, through the impact on stock renewal.
Harvesting strategies

Thus, we assume that Norway has two strategic variables

- $f^{N_a}$ is the fishing effort for the mature stock in the first part of the year, which is only available in the Norwegian economic zone because of the spawning migrations.
- $f^{N_b}$ is the fishing effort for the rest of the stock that is available in its zone the first part of the year and for the whole stock available in the Norwegian zone in the second part of the year.

Russia, on the other hand, has only one strategic variable

- $f^R$, which is the fishing effort generating the fishing mortality of the stock available in the Russian zone in both parts of the year, which excludes the spawning part of the stock in the first part of the year.
(i) A single annual strategic variable for both players
(ii) Norway have two annual strategic variables, Russia one...
Table: 1 A single annual strategic variable for all parties. Present values (2007 million NOK) in different scenarios and strategic settings.

<table>
<thead>
<tr>
<th></th>
<th>( \mu = 0 )</th>
<th>( \mu = 0.01 )</th>
<th>( \mu = 0.02 )</th>
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</thead>
<tbody>
<tr>
<td><strong>Noncooperation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Russia</td>
<td>674</td>
<td>993</td>
<td>1512</td>
</tr>
<tr>
<td>Norway</td>
<td>44480</td>
<td>45156</td>
<td>45348</td>
</tr>
<tr>
<td>Total</td>
<td>45154</td>
<td>46149</td>
<td>46860</td>
</tr>
<tr>
<td><strong>Cooperation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sole owner</td>
<td>63880</td>
<td>66395</td>
<td>68296</td>
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</table>
Table: 2 Norway and the sole owner have two annual strategic variables, Russia one. Present values (2007 million NOK) in different scenarios and strategic settings.

<table>
<thead>
<tr>
<th></th>
<th>( \mu = 0 )</th>
<th>( \mu = 0.01 )</th>
<th>( \mu = 0.02 )</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Noncooperation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Russia</td>
<td>728</td>
<td>1073</td>
<td>1639</td>
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<tr>
<td>Norway</td>
<td>47893</td>
<td>48313</td>
<td>48196</td>
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<tr>
<td>Total</td>
<td>48621</td>
<td>48385</td>
<td>49835</td>
</tr>
<tr>
<td><strong>Cooperation</strong></td>
<td></td>
<td></td>
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<tr>
<td>Sole owner</td>
<td>51937</td>
<td>54340</td>
<td>56171</td>
</tr>
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</table>
Discussion

- Temperature/productivity increases appear to be favorable to the incentives for cooperation and thereby the stability of agreement on the joint management of the NEA cod fishery.
- There is the question of the relevance of assumption (ii) regarding the strategic variables. For various reasons, strategy scenario (i) of fishing the entire stock throughout the year is considered the most realistic alternative.
- However, strategy scenario (ii) may be relevant considering Norway’s advantage of being able to target the mature part of the stock separately.
- If we compare Norway’s NPVs under noncooperation in Table 1 with Table 2, we can see that Norway’s NPV by applying strategy scenario (ii) are higher than the corresponding NPVs in strategy scenario (i).
- Therefore, it is possible that Norway would expect a greater share of the cooperative NPV than Russia is willing to accept.
- This could lead to tensions between the two countries in trying to reach an agreement.