The economics of optimal fisheries license fees

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Views are my own not that of FFA

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Motivation

A common problem in fisheries policy globally is how many licenses to issue and how much to charge for these licenses. In the approach developed here We are able to address this question by modelling the relationship between a group of coastal states and a distant water fleet that share a single stock that straddles a number of distinct exclusive economic zones and the high seas. fishing on the high seas is not subject to any countries jurisdiction and each country has the autonomy to issue licenses and set fees within it's own jurisdiction.

Literature

The problem was first addressed by Gordon-Munro in 1981/1982

Munro, G. R. (1982). Cooperative fisheries arrangements between Pacific coastal states and distant water nations. In: *Renewable resources in the Pacific: proceedings of the 12th Pacific Trade and Development Conference*, held in Vancouver, Canada, 7-11 Sept. 1981. IDRC, Ottawa, ON, CA.

It still hasn't been effectively solved!

Literature

Some work since from various perspectives

- Munro, G. R. (1985). Coastal states, distant-water fleets and EFJ: Some long-run considerations. *Marine policy*, 9(1), 2-15.
- Beddington, J. R., and Clark, C. W. (1984). Allocation problems between national and foreign fisheries with a fluctuating fish resource. *Marine Resource Economics* 1(2), 137-154.
- Clarke, F. H., and Munro, G. R. (1987). Coastal states, distant water fishing nations and extended jurisdiction: a principal-agent analysis. *Natural Resource Modeling*, 2(1), 81-107.
- Nichols, R., Yamazaki, S., Jennings, S., and Watson, R. A. (2015). Fishing access agreements and harvesting decisions of host and distant water fishing nations. *Marine Policy*, 54, 77-85.
- Chesnokova, T., & McWhinnie, S. (2019). International fisheries access agreements and trade. *Environmental and Resource Economics*, 74(3), 1207-1238.

There is some other related work on regulated and limited access fisheries

The model

- We have n exclusive economic zones plus the high seas.
- We have a domestic fishing fleet in each zone that only fishes within the zone (This is a simplification but also true of many small island developing states)
- We have a single distant water fishing fleet (a simplification but generally there is no price discrimination in license fees, access fees are different and sometimes negotiated bilaterally
- There is a single shared stock (This makes the problem game theoretic in nature)
- Fleets seek to maximize rents net of license fees
- Governments seek to maximize domestic rents plus license fee revenues (Sometimes there is interest in also adding on-shore benefits to national objectives, but I do not model that here)

Formalizing the problem

Single stock that is exploited by n domestic fleets but by a single distant water fleet spread across the n EEZ's and the high seas.

$$\frac{dX}{dt} = F(X) - \sum_{i=1}^{n} h_{i,D} - \sum_{i=1}^{n+1} h_{i,F}$$

with $h = qXE$ and $F(X) = rX(1 - \frac{X}{K})$.
Model is basically an extension of the static Gordon-Schaefer fisheries model.

The Agents' decision problems

Domestic fleets maximize the following static optimization problem

$$\Pi_{i,D} = pqX(E)e_{i,D} - c_D e_{i,D} - f_{i,D} e_{i,D}, i = 1, \ldots, n$$

where $E = \sum_{i=1}^{n} e_{i,D} + \sum_{i=1}^{n+1} e_{i,F}$

Foreign fleets maximize

$$\begin{aligned} \max_{\{e_{i,F}\}_{i=1}^{n+1}} \Pi_F &= \sum_{i=1}^{n+1} pqXe_{i,F} - c_F e_{i,F} - f_{i,F} e_{i,F} \\ &= \sum_{i=1}^{n+1} pqK(1 - \frac{q}{r}(E))e_{i,F} \\ &\quad - c_F e_{i,F} - f_{i,F} e_{i,F} \end{aligned}$$

where $f_{n+1,F} = 0$.

Nash equilibrium

$$e^*_{i,D} = \frac{pqK(1 - \frac{q}{r}E^*) - c_D - f_{i,D}}{p\frac{Kq^2}{r}}, \forall i$$

$$e^*_{i,F} = \frac{r(pqK[1 - \frac{q}{r}E^*] - c_F - f_{i,F})}{pq^2K}, i = 1, \ldots, n$$

As the optimal in-zone effort. This can be interpreted as the demand for fishing licenses.

and

$$e^*_{n+1,F} = \frac{r(pqK[1 - \frac{q}{r}E^*] - c_F)}{pq^2K}$$

is the high seas effort of distant water fishing nations.

With

$$E^* = \frac{r((2n+1)pqK - nc_D - (n+1)c_F - \sum(f_{i,D} + f_{i,F}))}{2(n+1)pq^2K}$$

Solution method

The game is an aggregative game, so one could try to solve it via the replacement function method, in practice using share functions is sometimes simpler. I use share functions and solve for the aggregate level of fishing effort and then solve for distant water fleets optimal effort level. See Cornes, R., & Hartley, R. (2007). Aggregative public good games. *Journal of Public Economic Theory*, 9(2), 201-219 and related literature on aggregative games. Also my paper on oligopoly Beard, R. (2015). N-Firm Oligopoly with General Iso-Elastic Demand. *Bulletin of Economic Research*, 67(4), 336-345 uses a similar approach.

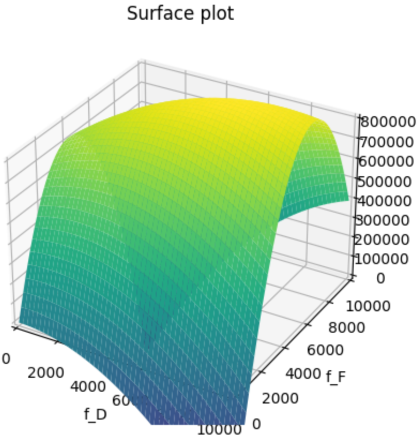
Optimal license fees

The total welfare of a coastal state is given by the sum of the rent from the domestic fishery plus license fee revenues.

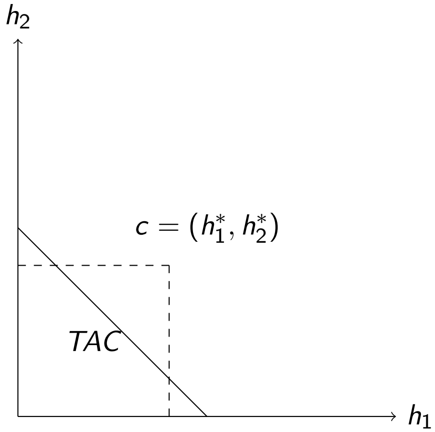
$$\max_{f_{i,D},f_{i,F}} W_i = pqX^* e^*_{i,D} - c_D e^*_{i,D}. + f_{i,D} e^*_{i,D} + f_{i.F} e^*_{i,F}$$

Because $X^* = K(1 - \frac{q}{r}E^*)$ is linear in E^* and E^* is linear in $f_{i,D}$ and $f_{i,F}$ and $e^*_{i,D}$ and $e^*_{i,F}$ are also linear then W_i is a quadratic optimization problem in the license fees.

Example: Optimal license for the bilateral case with domestic fleet and distant water fleet



Claims rules



Fisheries claims problems

A fisheries claims problem is a pair $(h, TAC) \in \mathcal{R}_+^N \times \mathcal{R}_+$ where $h = qX^*E^*$ and TAC is the total allowable catch, with $\sum_i h_i \geq TAC$. the latter is the situation where the sum of the demands for fish catch in equilibrium at the optimal license fees exceed the TAC.

Fisheries claims problems: Literature

Gallastegui, M. C., Inarra, E., & Prellezo, R. (2002). Bankruptcy of fishing resources: the northern European anglerfish fishery. *Marine Resource Economics*, 17(4), 291-307.

Inarra, E., & Skonhoft, A. (2008). Restoring a fish stock: a dynamic bankruptcy problem. *Land Economics*, 84(2), 327-339.

Kampas, A. (2015). Combining fairness and stability concerns for global commons: The case of East Atlantic and Mediterranean tuna. *Ocean & Coastal Management*, 116, 414-422.

Kampas, A. (2015). On the Allocation of Possible EU Total Allowable Catches (TAC) for the Mediterranean Swordfish: An Envy-Free Criterion and Equitable Procedure. *Journal of Agricultural Economics*, 66(1), 170-191.

Folmer, H., & Norde, H. (2008). Fishery management games: How to admit new members and reduce harvesting levels. *International Game Theory Review*, 10(3), 1-15.

Proportional rule

The proportional rule awards a catch share in proportion to the claim. So in a fisheries claims problem the rule would be

$$C(h, TAC) = \lambda h$$

where λ is chosen to achieve balance to so that $\sum h_i = TAC$. In other words we scale each claim by a multiplier so that summing the multiples equals the TAC. so $\lambda = \frac{TAC}{\sum h_i}$ satisfies this.

Proportional rule

Using the catch equation $h_i = qX^*E^*$and the demand for foreign and domestic licenses and the demand estimate for fishing on the high seas we obtain the following claims for fishing in each zone and the high seas.

$$h^*_{i,D} = qX^* e^*_{i,D}, \forall i$$
$$h^*_{i,F} = qX^* e^*_{i,F}, i = 1, \ldots, n$$

and the high seas catch

$$h^*_{n+1,F} = qX^* e^*_{n+1,F}$$

then substituting into the rule we get the following allocation

$$C(h, TAC) = \lambda h = \lambda[h^*_{i,D}, h^*_{i,F}, h^*_{n+1,F}]$$

$$[\lambda h^*_{i,D}, \lambda h^*_{i,F}, \lambda h^*_{n+1,F}]$$

λ

where

$$\lambda = \frac{TAC}{\sum h^*_{i,D} + \sum h^*_{i,F} + h^*_{n+1,F}}$$

and

$$h^*_{i,D} = qX^* e^*_{i,D}, \forall i$$
$$h^*_{i,F} = qX^* e^*_{i,F}, i = 1, \ldots, n$$
$$h^*_{n+1,F} = qX^* e^*_{n+1,F}$$

Constrained equal awards

Another rule that is commonly proposed that has a number of desirable properties is the constrained equal awards rule.

$$C(h, TAC) = (\min(h_i, \lambda)), i \in N$$

with λ chosen to achieve balance (efficiency).
Both constrained equal awards and the proportional rule have been studied in the fisheries context by others.

Should Strong-use rights fisheries satisfy minimal rights?

In the following I consider use rights from an allocation perspective.

- Intuitively one would expect strong use rights fisheries to satisfy minimal rights, however there are some difficulties
- A **minimal right** is the remainder of the TAC that is left after all other claimants have been fully compensated.
- Can minimal rights form the basis of an allocation rule by adjusting claims downwards, No. (Thomson p. 72)
- Rules can be modified to allocate minimal rights first, however
- Not all claims rules satisfy minimal rights first: Proportional rule and Constrained equal awards rules do not.

Reference: W. Thomson, *How to divide when there isn't enough*. Cambridge University Press, 2019.

Conclusion

- Aim was to develop a framework to compute how many licenses to issue and how much to charge for licenses
- Extension: License fee design problem: design an incentive compatible and individually rational license fee schedule (exploit cost/vessel type heterogenity to achieve this).
- To estimate the model empirically one can still estimate the catch-effort relationship to identify key biological parameters
- Prices and costs need to be obtained from other sources or through estimates.
- Have used the same approach for computing and estimating license fees and the optimal number of licenses to issue with data (can't present here as it is confidential)
- Use of more realistic (more institutional features) regional mathematical programming models to solve the optimal licensing problem

Thanks for listening!

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