Market Power, Sharing Rule and Fishery Co-management

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1 Introduction

What happens if n independent harvesters (in fishery, forestry, etc.) got together and decided to share their output, that is, individual harvest from each member is pooled and redistributed equally while costs are bored individually? Economic theory would suggest that, *ceteris paribus*, each member-harvester would find it optimal to free-ride on others effort (shirk), and since all members make the same decision, there would be too little effort in total and suboptimal outcome would prevail – or such institutional arrangement simply would not sustain. Contrary to such theoretical suggestion, one can find many examples of such arrangement, which we will call "sharing rule" hereon, being implemented as part of resource co-management regime. Furthermore, in some cases the results of co-management are surprisingly successful – harvesting effort is coordinated, profitability enhanced and stock level increased.[1]

Sharing rule as an instrument for common pool resource management was considered in Schott [2003] and Gaspart and Seki [2003]. Both papers argue that with homogeneous fishermen there exists a sharing ratio such that Pareto efficient resource extraction is realized *through non-cooperative behavior*, a feature which Schott [2003] calls "coalition-proof."[2] However, there is one critical unaddressed question: *who is deciding to implement the sharing rule and the sharing ratio*? One might say it is the government (or some centralized authority) who makes the decisions, but *why would*

[1]Examples include small pink shrimp (*sakuraebi*) fishery in Japan [Uchida, 2004a] and false abalone (*loco*) fishery in Chile [Cancino, 2004]. According to MAFF [2001], there were 293 out of 1,734 fishery co-management organizations in Japan that have implemented the sharing rule.

[2]Such "optimal" sharing ratio can be expressed as

$$s^* = 1 - \eta,$$

where $\eta = \frac{dH(E)}{dE}\frac{E}{H}$ is the elasticity of total harvest (H) with respect to total effort (E).

(or should) fishermen accept them? Furthermore, how could the authority monitor and enforce them? If it was a tax the authority can do this through the collection of taxes, but such direct interactions between the authority and fishermen does not exist in the sharing rule.

Seki [2000] gives a different view of the role of sharing rule. Based on her observation of a small white shrimp (*shiroebi*) fishery cooperatives in Japan, she noted that sharing rule is functioning as a supporting mechanism for fine-tuned fishing effort coordination among the member fishermen. For example, in this fishery each vessel is designated to a particular fishing ground on any given day (say area A), and they rotate the fishing grounds by day (so the next day this vessel is assigned to area B, then to area C, and so on). This is in aim to avoid congestion in "hot spots" – fishing grounds with high density of shrimps. Since the location of the hot spots is stochastic, this method by itself will inevitably causes unfairness. Seki [2000] argues that sharing rule solves this problem; even if one is assigned to the location where shrimps were near-empty, as long as his colleagues have a good harvest he will receive his share based on his participation, not catch, at the end of the day. Note the subtle difference in the argument: Schott [2003]'s view was that sharing rule is an instrument to achieve cooperative outcome without actual cooperation among the fishermen, while Seki [2000]'s view is that sharing rule supports already-existing cooperation. Thus, a critical unaddressed question in Seki [2000] is: why did fishermen decide to coordinate their fishing effort in the first place? What is their rationale to maintaining the coordination?

The condition for sustainable cooperation with trigger strategy is often depicted as

$$\frac{1}{1-\delta}\pi^C \leq \pi^{CH} + \frac{\delta}{1-\delta}\pi^{NC},$$

where π^C is the cooperative return, π^{CH} is the private single-period return from cheating, π^{NC} is the non-cooperative return and δ is the discount factor. The use of output sharing to promote joint production – one form of collective action – has being considered in the labor-managed firms literature, dating back at least to Sen [1966]. The discussions that followed, however, concentrated around how to penalizing the cheater and how to prevent the cheater from leaving the team before the punishment is conducted, see for example MacLeod [1988, 1993], Lin [1990], Putterman and Skillman [1992]. These arguments are aimed to reduce π^{CH}.

An alternative method to meet above condition is to enhance π^C relative to the RHS. This is related to the discussion on how to generate positive economic rent from common-pool resource extraction. Literature on this regard thus far concentrated on reducing the input costs through the reduction of fishing effort and capital – indeed, most models treat the output price as fixed, single and exogenous. The recognition that well-conducted output marketing could increase economic return – and perhaps quicker – has arisen in recent years. For example, in fishery, harvesters can sell their catch to higher-priced fresh market than frozen market; but this requires extra handling care of the caught fish and landing volume control since fresh fish cannot be stored for long time [Homans and Wilen, forthcoming]. This is an example of quality control. Alternatively, fishermen can market their catch so as to exercise the market power they possess in local markets. Many fisheries potentially have certain degree of local market power, since the product is very perishable and often costly to transport and thus raw product markets are likely to be local or regional in scope.[3] However, this is possible only if fishermen collude, that is, coordinate their fishing effort.

This paper is an attempt to shed yet another light to the role of sharing rule by invoking the possible market power that fishermen can exert in local ex-vessel markets if their efforts are coordinated, and its implication to fishery co-management.[4] The reason to bringing the market power into the analysis is related to answering the question: why fishermen would be interested in implementing and maintaining the sharing rule? One possible answer is that sharing rule induces fishermen to non-cooperatively achieve collusive outcome, thereby making them realize the benefit of collusion (and lowers transaction cost of moving from free competition to cooperation), and encourage coordinated resource extraction to maintain the collusive benefit. Fishermen can now further fine-tune their effort coordination in aim to increase the benefit, by intensifying market power exertion, but in return increasing the efficiency of resource management, such as voluntary minimum size restriction and selective harvesting to minimize the impact on fish biology.[5] Note that this argument has the flavor of both Schott [2003] and Seki [2000].[6]

[3] This is certainly true for many Japanese coastal fisheries, where freshness is the dominantly important attribute of the product due to high raw-consumption demand.

[4] There are several prerequisite conditions that need to be met for effective sharing rule, and fishery co-management in general. The two most important conditions are establishment of territorial use rights for fishing (TURF) and fixed, well-defined membership to which the TURF is assigned. See Uchida [2004b] for more discussions.

[5] A policy instrument that encourages fishermen to practice market power may raise some eyebrows. This paper does not intend to give normative solutions, but the following is worth noting. In light of massive consolidations in the U.S. food processing industry, particularly in beef packing, there is a debate in the literature whether the dead weight loss due to the market power is outweighed by the efficiency gain in the production due to the economy of scale [Sexton, 2000]. Similar argument can be made in our context; the efficiency gain in resource management and economic performance improvement in fishery industry may outweigh the dead weight loss due to the market power.

[6] One might argue that exertion of market power is not necessary for improving the economic performance of fishermen. As in the model analyzed by Gordon [1954], the downward sloping average and marginal value-product of fish can arise from its biological feature – depletion of biomass and/or stock size. Then, with Pareto efficient effort

2 Model

Let $p(H)$ denote ex-vessel price that a fisherman i receives. The price is a function of total landing H, which is defined as $H = \sum_{i=1}^{n} h_i$ and h_i is the harvest volume of fisherman i. Let s denote the sharing ratio defined in the interval $s \in [0,1]$; $s = 0$ implies no sharing rule (status quo) and $s = 1$ implies all individual revenue are pooled and shared. Therefore, for any fisherman i the total revenue $p(H)h_i$ is divided into the portion that is deducted and pooled ($sp(H)h_i$) and the portion that remains in his hand ($(1-s)p(H)h_i$). The total amount that is pooled is the sum of all fishermen, $\sum_{i=1}^{n} sp(H)h_i = sp(H)H$. We will assume that the pooled revenue is shared equally among the fishermen, i.e. uniformly distributed. Thus, the profit of fisherman i can be written as

$$\pi_i = (1-s)p(H)h_i + \frac{sp(H)H}{n} - ch_i, \tag{1}$$

where c is the constant unit cost of harvest and n denotes the total number of fishermen, which is assumed to be fixed.

Fisherman i will behave so as to maximize his profit, given in (1). The first order condition by taking the derivative with respect to h_i is

$$(1-s)\left(p(H) + \frac{dp}{dH}\frac{dH}{dh_i}h_i\right) + \frac{s}{n}\left(\frac{dp}{dH}\frac{dH}{dh_i}H + p(H)\frac{dH}{dh_i}\right) - c = 0.$$

Multiplying appropriate terms to convert each derivatives into elaticity form yields

$$(1-s)p(H)\left(1+\frac{\theta}{\epsilon}\right) + sp(H)\theta\left(1+\frac{1}{\epsilon}\right), \tag{2}$$

after imposing symmetry (i.e. identical fishermen, so that $H/h_i = n$). $\epsilon = \frac{dH}{dp}\frac{p}{H}$ is the price elasticity of demand (in ex-vessel market) and $\theta = \frac{dH}{dh_i}\frac{h_i}{H} \in [0,1]$ is the "conjectural elasticity", which measures departures from perfect competition in the ex-vessel markets.[7] $\theta = 0$ denotes perfect competition, $\theta = 1$ denotes monopoly or perfect collusion and intermediate values of $\theta \in (0,1)$ representing various degrees of oligopoly power. Based on (2), we can examine the equilibrium FOCs under different combinations of sharing ratio s and conjectural elasticity θ. The results are

level induced by the sharing ratio s^*, as shown by Schott [2003] and Gaspart and Seki [2003], will generate positive economic rent.

[7] For details, see Wann and Sexton [1992] and Huang and Sexton [1996].

summarized in Table 1.

Case 1: Fishermen are perfectly competitive ($\theta = 0$)

If there is no revenue sharing rule (i.e. $s = 0$) then (2) reduces to $p(H) = c$, the usual profit maximizing condition for perfectly competitive firms. Note that, because fishermen are behaving perfectly competitive the ex-vessel price $p(H)$ is exogenous from their point of view. If there is some sharing ($0 < s < 1$) then (2) becomes $(1 - s)p(H) = c$. This implies that each fisherman will behave in order to maximize his "private portion"; the portion that is not shared. The shared portion becomes irrelevant in his maximization problem. This result is intuitive, and also suggests that full sharing ($s = 1$) under perfect competition does not have a unique solution; which indeed so from (2).

Case 2: Fishermen are perfectly colluding ($\theta = 1$)

In this case, (2) can be written as

$$p(H)\left(1 + \frac{1}{\epsilon}\right) = c. \tag{3}$$

Thus, when fishermen are perfectly colluding sharing rule has no impact on profit maximizing solution. Note that (3) is exactly the monopolist's FOC, which is is intuitive given fishermen are behaving as a single monopolist. This coincides with the private optimum in the sense that it is the ultimate maximum of the fishermen's profit.[8]

Case 3 Fishermen are colluding to some degree ($0 < \theta < 1$)

If there is no sharing ($s = 0$) then (2) is simply

$$p(H)\left(1 + \frac{\theta}{\epsilon}\right) = c, \tag{4}$$

and if revenue is fully shared ($s = 1$) then (2) becomes

$$p(H)\theta\left(1 + \frac{1}{\epsilon}\right) = c. \tag{5}$$

Both (4) and (5) are similar to (3), namely the monopolist's condition, except they are altered by

[8] But not necessarily the social welfare due to the presence of dead weight loss; hence "private" optimum.

the degree of collusion, which is indexed by θ. When there is some, but not full, sharing ($0 < s < 1$) then FOC is identical to (2), or in other words, the average of (4) and (5) weighted by the sharing ratio s.

		$\boldsymbol{\theta}$		
		0	(0, 1)	1
	0	$p(H) = c$	$p(H)\left(1+\frac{\theta}{\epsilon}\right) = c$	$p(H)\left(1+\frac{1}{\epsilon}\right) = c$
$\boldsymbol{s}$	(0, 1)	$(1-s)p(H) = c$	$(1-s)p(H)\left(1+\frac{\theta}{\epsilon}\right) + sp(H)\theta\left(1+\frac{1}{\epsilon}\right) = c$	$p(H)\left(1+\frac{1}{\epsilon}\right) = c$
	1	na	$p(H)\theta\left(1+\frac{1}{\epsilon}\right) = c$	$p(H)\left(1+\frac{1}{\epsilon}\right) = c$

Table 1: FOCs for various cases

Figure 1 shows how these FOC results compare to each other. An interesting observation is that when collusion is incomplete ($0 < \theta < 1$) the total output declines as sharing ratio (s) increases (as expected), but as s approaches 1 the total output surpasses and ends up less than private optimum (this corresponds to reading the second column of Table 1 vertically). This also means that, by reading Table 1 horizontally, private optimum is approached from above as collusion index (θ) increases if there is no sharing ($s = 0$), but when the revenue is fully shared ($s = 1$) it is approached from below. Thus, equation (2), which is the FOC for intermediate collusion and sharing ratio ($0 < \theta < 1$ and $0 < s < 1$), lies within the shaded area in Figure 1. This implies that even with the absence of increasing collusion, profit maximization can be achieved by adjusting the sharing ratio.

2.1 Parameter conditions

There are certain parameter conditions that need to be met for FOCs in Table 1 for them to be feasible. Specifically, the value of ϵ is restricted due to the fact that marginal cost (c) is assumed to be strictly positive and thus the LHS of each FOC also needs to be strictly positive.

1. **When** $s = 0$ **and** $0 < \theta < 1$), or at point B in Figure 1:

   The FOC is

$$p(H)\left(1+\frac{\theta}{\epsilon}\right) = c.$$

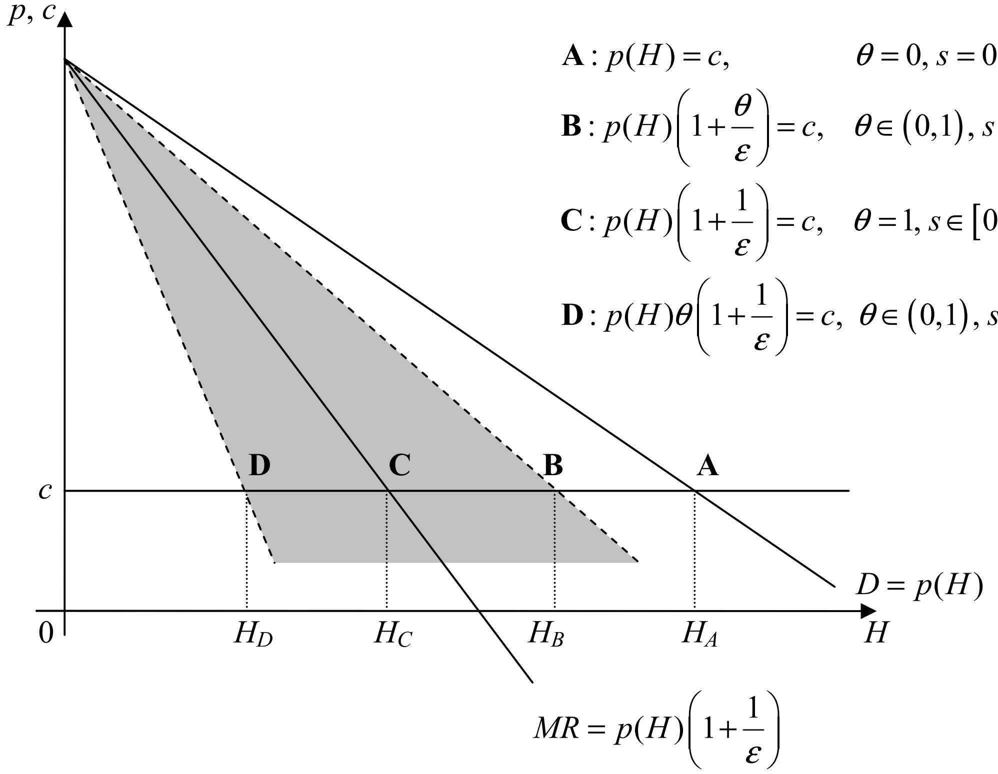

Figure 1: Equilibria based on various FOCs

Thus, the condition which assures the LHS to be strictly positive is

$$\epsilon < -\theta. \tag{6}$$

This condition implies that if fishermen are not "perfectly collusive" they could be operate on the *inelastic* region of demand. This is consistent with what Figure 1 depicts as total harvest level H_B, which corresponds to point **B**, could be at where marginal revenue is negative.

2. **When** $0 \le s \le 1$ **and** $\theta = 1$, or at point C in Figure 1:

   The FOC is

   $$p(H)\left(1 + \frac{1}{\epsilon}\right) = c.$$

   The feasibility condition is $\epsilon < -1$; the usual condition that monopolist will operate only in an elastic region of demand.

3. **When** $0 < s < 1$ **and** $0 < \theta < 1$, or at points between B and D in Figure 1:

The FOC, with slight rearrangement, can be written as

$$p(H)\left[(1-s)\left(1+\frac{\theta}{\epsilon}\right)+s\theta\left(1+\frac{1}{\epsilon}\right)\right]=c.$$

Since $p(H)>0$ the focus is on the terms inside the brackets, which yields

$$1-s+\theta\left(s+\frac{1}{\epsilon}\right)>0. \quad (7)$$

It turns out that this condition becomes useful in comparative static (next section). Further rearranging (7) yields

$$s<\frac{\epsilon+\theta}{\epsilon(1-\theta)}.$$

Since $\epsilon(1-\theta)$ is non-positive and s is positive by construction in this case, the condition is the same as (6), i.e., $\epsilon<-\theta$.

4. **When** $s=1$ **and** $0<\theta<1$, or at point D in Figure 1:

   The FOC is

$$p(H)\theta\left(1+\frac{1}{\epsilon}\right)=c.$$

   Since $p(H)>0$ and $\theta>0$ by construction in this case, the condition is the same as the monopolist's case, i.e., $\epsilon<-1$. This is consistent with Figure 1, as point **D** is to the left of monopolist optimum point **C**, where marginal revenue is definitely positive implying that the demand is elastic.

2.2 Comparative Statics

We are interested in the signs of $\partial p/\partial s$ and $\partial H/\partial s$. From Table 1 and Figure 1, our conjecture is $\partial p/\partial s>0$ and $\partial H/\partial s<0$: holding the value of θ constant the total harvest decreases as sharing ratio increases (Table 1), which in turn increases the ex-vessel price (Figure 1). We will verify these conjectures analytically.

First, from the inverse demand function $p=p(H)$ we have

$$\frac{\partial p}{\partial s}=\frac{dp}{dH}\frac{\partial H}{\partial s}.$$

Also by differentiating the FOC with respect to s we have

$$p(H)\left(\theta - 1 - \frac{\partial \epsilon}{\partial s}\frac{\theta}{\epsilon^2}\right) + \frac{dp}{dH}\frac{\partial H}{\partial s}\left[1 - s + \theta\left(s + \frac{1}{\epsilon}\right)\right] = 0.$$

Stacking above two equations into a matrix form,

$$\begin{bmatrix} 1 & -\frac{dp}{dH} \\ 0 & \frac{dp}{dH}\left[1 - s + \theta\left(s + \frac{1}{\epsilon}\right)\right] \end{bmatrix} \begin{bmatrix} \frac{\partial p}{\partial s} \\ \frac{\partial H}{\partial s} \end{bmatrix} = \begin{bmatrix} 0 \\ -p(H)\left(\theta - 1 - \frac{d\epsilon}{ds}\frac{\theta}{\epsilon^2}\right) \end{bmatrix}.$$

The determinant of coefficient matrix $\mathbf{M}$ is

$$|\mathbf{M}| = \frac{dp}{dH}\left[1 - s + \theta\left(s + \frac{1}{\epsilon}\right)\right] < 0.$$

The inequality sign follows from $\frac{dp}{dH} < 0$, from normal goods assumption, and (7). Thus,

$$\frac{\partial p}{\partial s} = -\frac{\frac{dp}{dH}p(H)\left(\theta - 1 - \frac{\partial \epsilon}{\partial s}\frac{\theta}{\epsilon^2}\right)}{|\mathbf{M}|} > 0$$
$$\frac{\partial H}{\partial s} = \frac{-p(H)\left(\theta - 1 - \frac{\partial \epsilon}{\partial s}\frac{\theta}{\epsilon^2}\right)}{|\mathbf{M}|} < 0$$

The signs for each comparative static follows **if** $\partial\epsilon/\partial s < 0$; I have not yet proved this, however. Nonetheless, this assumption and the signs of comparative statics all fall in nicely (Figure 2). The signs are consistent with our conjectures, and if so, as sharing ratio increases the equilibrium point moves along the demand curve upward – demand is more and more elastic, implying that ϵ is *decreasing* (its absolute value is increasing).

3 Sharing rule and collusion

We will analyze the condition at which sharing rule can mimic collusive outcome. Recall that with the absence of collusion FOC can generally be written as

$$(1 - s)p(H) = c,$$

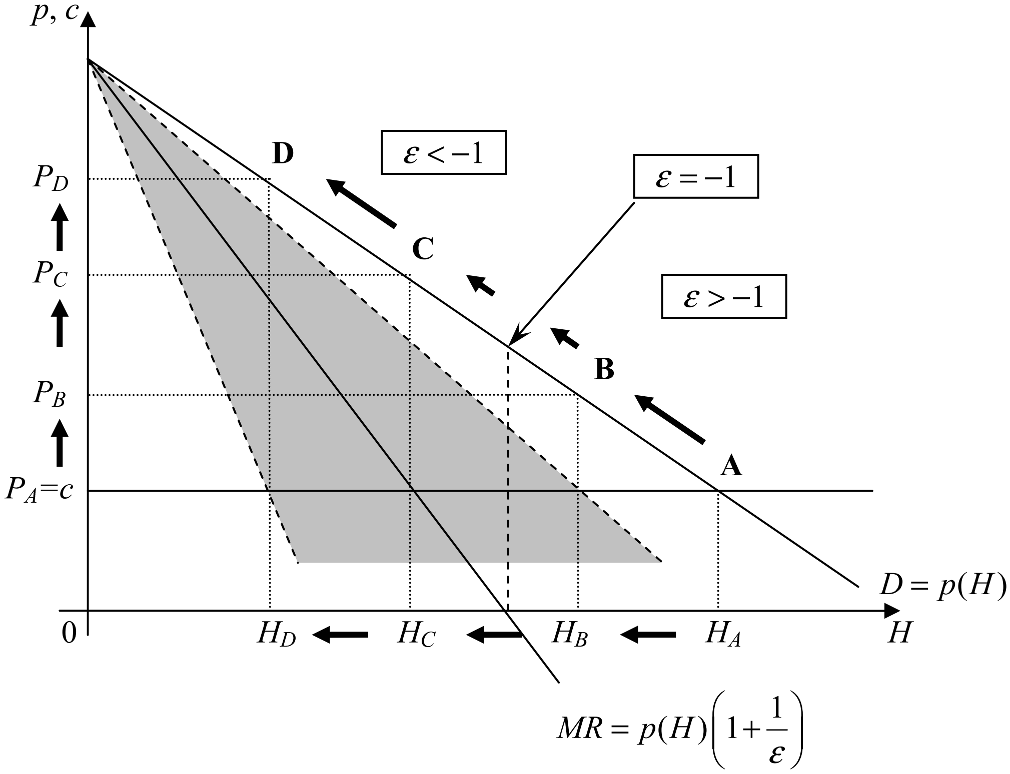

Figure 2: Comparative static as sharing ratio increases

and the same for some collusion was

$$(1-s)p(H)\left(1+\frac{\theta}{\epsilon}\right)+sp(H)\theta\left(1+\frac{1}{\epsilon}\right)=c.$$

By equating the two, we can derive a value of sharing ratio, t, that would mimic the result of given collusion level, θ. The result is

$$s^* = \frac{\theta}{\theta-\epsilon-1} \tag{8}$$

For example, to mimic perfect collusion, $\theta = 1$, above equation shows that $s^* = -\frac{1}{\epsilon}$. Substitute this into the FOC corresponding to no collusion and some sharing ratio (first column second row of Table 1) yields $p(H)\left(1+\frac{1}{\epsilon}\right) = c$, which is the FOC for perfect collusion.

Note, however, that s^* needs to be non-negative. The relational condition between θ and ϵ to assure that s^* is feasible is

$$\theta - \epsilon > 1. \tag{9}$$

It is immediately clear that if $\epsilon < -1$ then (9) is satisfied. This means that s^* can mimic any level of collusion as long as the outcome (e.g. total harvest level) corresponds to elastic region of demand.

However, if the outcome corresponds to inelastic region of demand (such as point **B** in Figure 2) there is a constraint; both in terms of the existence of feasible s^* and, when it does exist, the limit in collusion level outcome that a sharing rule can mimic. Recall that when the outcome is within the inelastic region of demand the condition as depicted in (6), or equivalently,

$$\theta < |\epsilon| \tag{10}$$

must hold. This implies that, for example, if $\epsilon = -0.8$ then $\theta < 0.8$, and if $\epsilon = -0.3$ then $\theta < 0.3$. However, it is clear that feasible s^* does not exist in the second example because $\theta - \epsilon < 1$ for all possible θ, which contradicts the feasible condition (9). In general, feasible s^* does not exist if the elasticity of demand of outcome is $\epsilon \geq -0.5$: while (6) implied that the realized outcome could be in the inelastic region of demand, there is a limit as to *how much* inelastic the demand could be.

At this point, it is clear that (10) is actually a general constraint as to the range of collusive outcome that sharing rule can mimic with non-cooperative behavior. Since $\theta \in [0, 1]$, all levels of collusion can be mimicked if the outcome is in the region of demand such that $\epsilon \leq -1$. If the outcome is in the region of demand such that $-1 < \epsilon < -0.5$ then θ is constrained as in (10), and if $\epsilon \geq -0.5$ then no feasible s^* exists.

4 Concluding remarks

This paper introduced a model that links between fishing effort coordination by fishermen in aim to exercise market power and adoption of sharing rule. It showed that when a fishery is facing a downward sloping demand curve, choosing an appropriate sharing ratio s and redistributing the pooled revenue uniformly can induce fishermen to achieve the monopolist's profit maximizing (private) optimum through *non-cooperative* actions of each fisherman. Such conclusion is similar to that of Gaspart and Seki [2003], but what this model differs from them is that fishermen are strictly better off under the private optimum than status quo (i.e., no cooperation and no sharing). This conclusion comes out straightforwardly from the symmetry assumption.

An obvious caveat of this paper is that the relation between the private optimum and efficient resource extraction is not addressed. If the status quo is such that the level of fishing effort is excessive and economic rents are dissipated, then the implementation of sharing rule would certainly has positive impact; harvest level will decrease along with the reduction of fishing effort, and economic rents will increase. However, the harvest level at the private optimum has nothing to do with biological sustainability, let alone resource extraction efficiency. This caveat is by construction since current model does not consider fish population dynamics. Nonetheless, we would argue that positive impact is better than nothing, though it may not be fully efficient.

The model presented in this paper only assumed uniform distribution of pooled and shared proceeds but in real-world fisheries we also observe weighted distribution, i.e. full sharing ($s = 1$) but distributed non-uniformly reflecting the heterogeneity of skills and/or equipment capacity. Note, however, that partial sharing ($s < 1$) is equivalent to weighted sharing rule because the proceeds not shared under the partial sharing rule should correlate with personal skills and equipment capacity. This suggests that sharing rule, when implemented appropriately, can induce collective resource extraction and management even if fishermen are heterogeneous. This challenges the widely-accepted notion that collective resource management can only be successful if extractors are homogeneous; however, formal analysis is necessary to make a definitive assertion on this regard.[9] Incorporating heterogeneity, therefore, is another possible extension of this model.

[9] Gaspart and Seki [2003] shows that sharing rule can be sustained when moderate degree of heterogeneity in fishermen's skill exists, but to make their argument, they introduce a "status-seeking" behavior of fishermen and incorporate that in their utility-maximization approach model. Our argument does not rely on such behavioral assumption.

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