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Sole ownership in fisheries – a tentative reappraisal

Abstract (161 words)

The goal of this paper is to promote two ideas neglected by economists: sole ownership in fisheries and quantity regulation of a monopoly. By reviewing contemporary literature, the paper constructs an argument that sole ownership would not only solve many problems inherent to Individual Transferable Quotas like by-catch, high-grading, or quota-busting but can also achieve economies of scale and other technological gains. It is argued that sole ownership would lower regulation costs and that its introduction may be politically possible. The paper also develops a general two part quantity regulation model which is then applied to fishing industry. The main findings of the model are that the sole owner of a fishery tends to deliver the socially optimal output level even without regulation as long as demand is high and that, even with optimally designed annual catch limit, a sole owner can still exercise market power in some situations. The conditions preventing sole ownership from exercising its market power are identified.

Keywords: fishery, sole ownership, quantity regulated monopoly, optimal control, time discrimination

1. Introduction

Open-access fishing originates in the pre-industrial era, when pressure on fish stocks was low enough to perceive the wealth of the oceans as inexhaustible, as famously stated by Thomas Huxley in 1884 (Botsford et al., 1997). Technological progress and growing population soon refuted this notion and no longer negligible externalities made open access not only economically inefficient but also environmentally dangerous. Bottom-up initiatives to improve fishery performance usually involved cooperation of fishermen and were illegal in light of anti-trust law (Adler, 2002). Unorganized free competition prevailed, which was natural for an industry with very low barriers to entry. By the mid-20th century, top-down regulation of fisheries seemed to be the only solution and since its onset, it has been steadily evolving over time towards ever stronger limits on market entry as well as free competition in general.

Free competition attracts excessive fishing effort. The problem of overfishing started to emerge once fishermen and authorities realized that despite more effort, in some fisheries catch declined substantially and profitability of these fisheries decreased. To address this problem, researchers toyed for some time with taxation of landings (Turvey, 1964) but as it seemed politically impossible (Christy, 1973), the solution turned out to be in input controls, in the form of licenses or gear restrictions. The unintended result of these measures is commonly known as input stuffing (see e.g. Homans and Wilen, 2005) and manifests itself in competing fishermen substituting unregulated inputs for regulated inputs.

As input controls failed to address the stock depletion, attention turned to output control mostly in the form of total allowable catch (TAC). TAC is an upper limit on the amount of fish being caught in a particular fishery within a season and is based on scientific analysis of the fish population. TAC was often implemented in such a way that the regulator announced each year a season length based on the expectations about the behavior of the fleet. The regulator could adjust the season length after observing the pace of fishing within the season. This implementation of TAC is a form of input control if we treat time as input.

The TAC regulation resulted in race to fish where each fisherman was trying to catch as much as possible before the time was out. This is analogous to the input stuffing problem where time is the regulated input. The season lengths shortened, in some cases resulting in grotesque situations like the famous 2-day season in the Alaskan halibut fishery (Herrmann, 2006). It turned out that TAC alone was not only economically wasteful but also, because of rush during the season, it had negative environmental impacts like excessive by-catch (that is catching non-target species) and was dangerous to vessel crews.

Once it became clear that neither input control nor TAC can solve the problems of the fisheries, regulators turned to individual output quotas. The idea launched in early 1970s (Christy, 1973). Individual transferable quotas (ITQs) received mostly favorable publicity in the scientific community as they were perceived to be a property rights based solution to the tragedy of the commons problem. Presently, they are still praised in many publications but there are also more and more cracks appearing in their image, for example the claim that ITQs can still facilitate waste when the fish stock is heterogeneous (Costello and Deacon, 2007). The remedy often offered is to tweak the ITQ regulation so as to prevent existing shortcomings.

The change in regulation of fisheries exhibits a spiral pattern of fixes and new problems arising after these fixes. The latest invention, the ITQs, is not an exception. Even ITQs cannot fully solve the problems of the fisheries. Their proponents argue that as a property rights based approach they should be able to address the externality problem. However, a property rights based approach seems to be a misnomer here since there exist no underlying tangible property an ITQ could refer to. ITQ is a right to produce output, not a right to the underlying resource. Actions of a fisherman at the sea today affect future profit of all fishermen tomorrow, even in presence of ITQs. Hence, the “transferable output quotas” seems to better describe them than the notion of property rights.

A fully functional assignment of property rights to a fishery would mean spatial disaggregation of the fishery into territories belonging to individual fishermen in such a way that would prevent not only fish from swimming from one territory to another but also flow of water carrying both nutrients and pollutants. This is not possible, so the division of a fishery by assignment of property rights to fishermen in a way that would entirely eliminate externality is not possible either.

A natural way of internalizing the externality embedded in a fishery is to introduce regulated sole ownership. Nevertheless, the notion of regulated sole ownership does not appear in the literature of fishery regulation at all. Sole ownership is usually considered only as a benchmark case when analyzing other market structures but there is very little attempt to analyze it as a viable option. It is startling that there was no attempt to summarize the potential virtues and vices of the sole ownership and to suggest a way how could it be regulated to avoid failures associated with a local monopoly. Such an attempt is the goal of this paper. By doing that, I hope to prove that sole ownership deserves more attention in the literature.

Because of the emphasis on output constraints, the regulation of a sole owner in fisheries naturally falls into a category of a quantity regulated local monopoly. The regulatory setting where output rather than price is a primary variable of interest virtually does not exist in practice. This may be the reason why there exists no literature trying to model quantity regulated monopoly let alone empirical analysis thereof. Models presented in this paper are created from scratch and they address basic aspects of such regulation. Thus, the paper fills two gaps in the literature. It not only presents an analysis of a sole ownership as a viable option for fisheries in the light of contemporary research. It also describes a fairly general model of quantity regulated monopoly which can be applied to any industry if a necessity arises.

To fully understand the notion of regulated sole ownership in the context of a fishery it is necessary to investigate why it has received so little attention since the onset of the literature on economics of fisheries in the early 1950s. This is the goal of the second chapter of this paper. The third chapter contains arguments in favor and against the introduction of sole ownership, mostly based on theoretical and empirical findings from the contemporary literature. Finally, the argument in favor of and against sole ownership is not complete without an appraisal of the accompanying regulation. A two part regulatory model is proposed in chapters four and five. In chapter four a static, long run equilibrium is analyzed. Chapter five contains a short run, dynamic part of the model. These chapters delineate circumstances under which it is easy or hard to regulate a monopoly on inter-seasonal and intra-seasonal basis. The last chapter summarizes the paper and suggests some further research topics.

2. Sole ownership in the fisheries literature

The solution that seems to solve fisheries' problems is to introduce a regulated sole ownership. There is however surprisingly little literature investigating sole ownership as a viable option. In the contemporary literature, sole ownership is usually used as a benchmark when analyzing other market structures. The notions of a regulated sole ownership or a regulated monopoly do not appear in the fisheries literature at all. This contrasts with an overwhelming number of papers discussing open access, TAC, and ITQs.

Why then notion of a regulated sole ownership is so rare in the fisheries literature? Answer to this question is actually quite interesting. In the first half of the twentieth century, several rulings of US courts made it clear that any proprietorship in fisheries is not possible, even if backed by state law

(Johnson and Libecap, 1982). Moreover, bottom-up efforts undertaken by fishermen to create cooperatives that would help preserve stocks (and also boost prices) were ruled illegal (Adler, 2002). Therefore, when the fishery economics literature launched in the mid-1950s it was already assumed that sole ownership is not a possible option.

Although the seminal paper by Gordon (1954) does not focus on sole ownership, it was then perceived as a "study of advantages of sole ownership" as Scott (1955) states in his famous follow-up paper. This preliminary analysis not only abstained from any regulatory issues but also was done before the discovery of the backward bending supply curve of a fishery by Copes (1970) and other features considered presently as important elements in fishery analysis. Few papers continued the topic and the reasoning there was mostly qualitative, not formalized in a Samuelsonian way, and naïve in light of contemporary knowledge. Only in the early seventies did Copes (1972) introduce consumer surplus into analysis of sole ownership in fisheries, again abstaining from the topic of regulating it.

Within the first two decades after the fishery economics literature had launched, the overall interest in fisheries regulation was stifled by the assumption that competition is the only lawful solution to the problem. In 1976, the enactment of Magnuson-Stevens Fishery Conservation and Management Act changed the legal climate at least in the United States. It became clear that fisheries preservation is an important national goal and it can be achieved only by regulation. As an effect, first regulatory regimes were focused mostly on preserving stocks rather than economic efficiency and they involved input controls or limited entry.

In 1980, Clark published a paper commonly recognized as a foundation for formal analysis in fishery economics. This paper in a single framework deals with open access fishery, taxes, vessel quotas, input controls, total catch quotas, and licenses but makes no attempt to analyze sole ownership let alone regulated sole ownership.

In 1983, a single paper praising sole ownership in fisheries emerged out the blue (Keen, 1983). The author recognizes scarcity of literature and proposes a government agency as an entity in charge of fisheries. Then, he contrasts its potentially superior efficiency with efficiency attained by a limited entry regulation which was popular at that time (although the literature on ITQs started in 1973 with Christy's tentative proposal, this approach was still gaining momentum at that time). This paper spawned little interest with one notable response in which the interlocutor argued that a well-designed limited entry regulation can attain similar efficiency as a sole ownership (Dow, 1984).

Over time, rights based regulatory designs started to gain more interest as input control proved to be inefficient. Fisheries economists were focused on this new clever solution to the fisheries' problems. They probably didn't see many advantages of sole ownership over ITQs especially because effects of ITQs were not well known yet and, as pointed out by Keen (1983), in the US and many other countries, there is a strong cultural bias in favor of competition. Recently, ITQs started to get more and more criticism, but it seems that they are still on a roll and policymakers focus on trying to improve their regulatory designs rather than on seeking for alternative solutions.

Sole ownership doesn't seem to be so distant an option nowadays, when many local monopolies mandated by law operate under auspices of the state and with blessing from economists. The growing importance of the environmental issues might be able contest the bias in favor of competition prevalent in the nations. And finally, as will be pointed out in the next chapter, introduction of a sole owner shouldn't be hard at least in some fisheries, where market forces seem to favor sole ownership and only regulatory constraint prevents it from happening.

3. Regulated sole ownership: pros and cons

Comparing something that does not exist to something that does exist is a methodologically challenging task. This is true especially in the case of fisheries where various aspects of fishing elude being captured in a single model. The attempt to compare regulated sole ownership to existing regulatory regimes made in this chapter is a presentation of loosely related facts and conjectures rather than formal, let alone exhaustive, analysis. As such, I make no claim about the generality of conclusions drawn from this argument. The only conclusion is that *sometimes* regulated sole ownership *may be* superior to current designs. Fisheries differ in sizes, species, fishermen's social structures and market interdependencies as well as currently employed regulation, thus optimal solutions may be different for different fisheries.

It seems necessary to define precisely the non-existing object that is going to be compared to the existing ones, so as to avoid any confusion along the argument. The regulated sole ownership I propose here entails a single firm having a full property right to the fishery defined territorially. This firm can grant access to the fishery for leisure fishermen if commanded by regulator, but controls entire commercial fishing for every non-migratory species, including invertebrates. This entity has a single objective, namely to maximize profits. The regulator acts as a counterweight to the sole owner's market power and sets output targets based on the maximum economic yield for all species managed by the sole owner. The sole owner has to meet the targets with some level of tolerance, otherwise a penalty is imposed. Sole owner has freedom to choose the technology, subject to regulation if necessary. The regulator's objective is to maximize social welfare that is the difference between social benefit brought by the fish caught and the social cost of catching it. Social welfare is also the main criterion used in this chapter to evaluate this regime vis a vis existing regimes.

Note that in a simple static model with perfect information about the demand, the quantity regulation of a monopoly is equivalent to price regulation. A monopoly must anticipate and charge a market clearing price. If the price is too high, then quantity sold is lower than expected and a penalty is imposed. If the price is too low, the demand is not fully satisfied and profits are not maximized. Therefore under these perfect assumptions, as long as regulator is able to set socially optimal target quantity, a regulated monopoly has incentives to conform and as a result maximize social welfare. In reality, these perfect assumptions are not necessarily valid, which is investigated in more detail in chapter five.

A feature inherent to ITQs and other popular regulatory regimes is their misalignment of incentives. Fishermen have incentives to fish beyond the limit in the same way as cartel participants want to cheat on their partners. A fisherman making a decision about exceeding his quota faces an instant gain for his own enterprise on one hand and future losses diluted across whole fishery on the other hand which in turn creates a problem of quota busting (Copes, 1986). This results in a pressure to exceed maximum sustainable yield. Growing literature on illegal landings confirms that this is a real issue (see Jensen and Vestergaard 2002 or Ainsworth and Pitcher, 2005).

As long as discount rates are not unusually high, a sole owner has incentives to preserve the stock (Clark, 1973). The fishing rate is not above maximum sustainable yield therefore incentives of a sole owner are compatible with sustainability; meanwhile incentives of fishermen under other regulatory regimes are not. Quota busting under sole ownership is reversed and sole ownership may want to deliver less output than is desired. However, this problem seems to be easier and less costly to regulate. Buyers of fish may not be willing to report that they bought illegal and thus cheaper fish because it reduces their costs. The same buyers may be also unwilling to report that they bought something even though they didn’t, because reduction of output increases prices and thus increases their costs. As a result buyers are more willing to cooperate with regulator under sole ownership regime than under ITQs. Moreover, as shown in next chapter, incentives of a sole owner are not only compatible with the goal of sustainability but under some circumstances they are also compatible with the goal of maximizing social welfare.

The fishery externality manifests itself not only through the quantity pressure but also in all other decisions made by fishermen at the sea. One of the phenomena resulting from externality, broadly recognized as a problem hard to solve in ITQ regimes is excessive high-grading. It occurs when a fisherman decides to discard caught fish after observing its quality and perceiving that the price would be too low and his quota could be used for a better product (see e.g. Gillis et al., 1995). Such a behavior damages the future stock as the discarded fish is usually young (and thus small). Like with quota busting, marginal gains from high-grading are faced by individual fisherman but marginal costs are distributed across entire fishery. This problem is eliminated in the regulated sole ownership setting. A sole owner chooses the level of high-grading that maximizes industry profit, and since it cannot choose output level or price freely, the resulting level of high-grading is a level that minimizes social cost.

Another phenomenon often mentioned next to high-grading is the problem of by-catch. Here fishermen discard their fish not because it is of too low quality but because this is not the species they have quota for (for more detailed analysis of by-catch see Hall et al., 2000). It seems that introduction of multi-species ITQs can abate this problem. Nevertheless, even with multispecies ITQs the situations when a fisherman accidentally exceeds his quota may arise. And again, incentives to reduce by-catch problem are lower for individual fisherman than for a sole owner, analogically to quota busting and high-grading. As a result, a sole owner chooses technology which is a socially optimal solution to the by-catch problem, at least with respect to species that are in its jurisdiction.

Sole ownership not only can solve broadly discussed problems in the ITQs but can also introduce far-reaching improvements into profitability of the fishery. It is reasonable to assume that technology employed in the ITQ fishery can be also used by a sole owner with little overhead. On the other hand, sole owner can choose a technology which is not possible under ITQs (for example remunerate fisherman with wage rather than performance based payment). Therefore, a sole owner has much more freedom in terms of choosing incentives for the labor, coordinating the labor, and making capital investment. Sole ownership can also introduce aquaculture or fish tagging into its fishery which are impossible under competition based regimes due to misalignment of incentives (unless mandated and funded by the regulator). There is a lot of evidence suggesting that technology employed by a sole ownership would be far superior to technology currently used in competition based fisheries. An example is a study by Costello and Deacon (2007) who show that stock heterogeneity can cause inefficiency in an ITQ fishery. The heterogeneity issue would be solved by sole ownership through effort coordination.

There are numerous studies of fishermen who voluntarily form cooperatives for the sake of improving efficiency in their fisheries. These cooperatives are not themselves full solutions to the misalignment of incentives problems, as they encompass multiple agents with multiple objective functions. But their very existence proves that coordinating effort across fishermen is profitable. Two notable examples are worth mentioning (for details see Costello and Deacon, 2007).

“Shiroebi” shrimp fishery in Toyama Bay, Japan is the first of them. Two groups of fishermen fish there on alternate days using the same harbor facilities. One of the groups share information and coordinate effort and the other group do not. As a result, the members of the former are much better off compared to the members of the latter.

Second example comes from Chignik Salmon Cooperative. In 2002 a group of 77 fishermen elected to be in a cooperative which was granted a total quota from the regulator. They decided that 22 of them would actually fish and the remaining 55 would have share in revenues without any fishing effort. Moreover, fishermen in the cooperative coordinated their effort and in result reported lower costs and higher catch quality than competitors. Sadly, this cooperative had been soon ruled illegal by a court.

The former example mimics a natural experiment design and is a clear evidence that cooperation increases efficiency. The latter example shows that fisherman may have incentives to give up their sovereignty and voluntarily switch to joint-profit maximization. What is important here is that the cooperative in this case was not ruled illegal because of anti-trust laws but because it violated regulatory design. In fact, US Department of Justice often doesn’t oppose cooperation among fishermen in ITQ regimes because output there has already been limited. Anyway, both information sharing and effort coordination seem to be important efficiency improvers. In the popular regulatory designs which favor competition, full cooperation may be hard to achieve because of mistrust, free riding and costs needed to maintain coalitions. In contrast, the very nature of sole ownership facilitates full cooperation.

Another efficiency inferiority of regulatory designs favoring competition can be derived from economies of scale related to physical capital. According to analysis of New Zealand ITQ fisheries undertaken by Connor (2001), bigger fishing companies tend to choose fewer larger vessels rather than more smaller vessels. In general, trends in quota aggregation in some ITQ fisheries support existence of economies of scale. As pointed out by Yandle and Dewees (2008): "Consolidation and loss of small fisheries can be seen as a natural (and desirable) consequence of increased efficiency, effort reduction, and industry rationalization."

Having analyzed issues of externalities unresolved by other regulatory regimes and indirect evidence for superior cost efficiency, it seems natural to turn to costs of regulation as next aspect favoring sole ownership. In the regulated sole ownership there exists only one entity to be regulated as opposed to many entities in ITQ fisheries and other popular designs. As mentioned above, the buyers of the fish under sole ownership will be more willing to cooperate with regulator than under competition favoring designs, thus decreasing monitoring expenses incurred by the regulator.

A sole owner has much higher incentives to ensure that nobody else exploits its stocks than individual independent fishermen. As a result it may be expected that sole owner sets up their own operation aimed at monitoring and preventing illegal fishing, in turn releasing much of the burden shouldered currently by public in the form of coastal guard etc. Moreover, sole owner has a stake in ensuring that its fish stock is correctly assessed and thus may be willing to participate in research aimed at determining maximum sustainable/economic yield. It is not hard to imagine that the sole owner itself actually conducts research and few regulatory officials only monitor the research for potential fraud. This is what happens in Australian NPF Industry Pty Ltd (a company operating Australian North Prawn Fishery, for details see Dichmont et al., 2010). Keep in mind that failures of many ITQ fisheries are attributed to poor information on stocks (Rosenberg et al., 2006).

It is worth pointing out that under sole ownership it is somewhat easier to solve the problem of wealth distribution than under ITQs. Regulator can impose a tax on sole ownership's profits to extract the excessive rents and return the tax to the local community or whatever other desirable destination. It should be much easier to tax a single corporation than many individual fishermen, both politically and technically.

This completes the list of potential advantages of regulated sole ownership. This regulatory design has also numerous potential disadvantages. Probably the most important one is a concentration of market power. A sole ownership is a viable option only if a regulatory policy can be designed in such a way so that it is possible to prevent abuse of monopoly power. This topic is further pursued in the next two chapters.

Sole ownership doesn't solve the problems related to highly migratory species. The only solution to those problems would be to create an entity which would cover the whole region of migration. This includes vast areas of oceans, often far beyond 200-mile exclusive economic zones (EEZs) or would have to cover EEZs belonging to many countries. This topic is not going to be pursued here since international fisheries are beyond the scope of this paper.

Another problem with sole ownership arises from agency issues. This is an intrinsic characteristic of a big organization that its efficiency is impaired because incentives of employees are not necessarily compatible with incentives of the owners and because of bureaucratic overhead. Ensuring that fishermen employed by a sole owner do what they are supposed to do shouldn't be very hard because modern technology allows for cheap and comprehensive monitoring. However, the creativity they had when they were entrepreneurs themselves would be in general stifled. Chignik Salmon Cooperative example shows that efficiency losses due to giving up independence may be lower than efficiency gains due to cooperation but it is impossible to assume a priori that this would hold in general.

A straightforward consequence of rationalizing the industry is unemployment. Again, as shown clearly by Chignik Salmon Cooperative example and in compliance with the popularly acknowledged presence of overcapacity in fisheries, sole owner would likely reduce number of the fishermen at the sea. Possibility of unemployment would certainly create political pressure against sole ownership but unemployment itself cannot be treated as something economically undesirable even though it is socially undesirable. It is a natural consequence of releasing some of initially inefficiently utilized resources and making them available for other, more efficient purposes. This in turn is one of the sources of economic growth. Besides, in order to counter strength of this argument, the rents generated by sole owner may be initially distributed to fired fishermen as unemployment benefits.

Aside from unemployment, some other undesirable and unintended consequences may arise. It is not wise to ignore business environment in which a fishery operates, especially interactions between the fishermen and the processors. These relations are usually complicated and involve not only buying fish but also other aspects. For example, in ITQ fisheries processors tend to be quota owners who subsequently lease their quotas to fishermen. Obviously, processors have stakes in fishing industry and they are likely to become owners of the sole owner if they are permitted. There is a risk that such vertical integration may result in less competitive processing sector and thus pose a threat to social welfare if not properly regulated. A lot of other unexplored risks lurk in the pressure sole ownership would inflict on its market surroundings.

Next argument against sole ownership can be derived from the popular argument in favor of ITQs. Namely, ITQ as a proxy for property right ensures that a fisherman at the sea has incentives to preserve the stock. The employees of the sole owner would not have the same incentives because they will not own the stock directly, the argument goes. Issue of stewardship under ITQs has been already discussed in this chapter but nevertheless it deserves here some additional elaboration. In some ITQ fisheries fraction of the fishermen who sell their quotas (mostly to processors) and subsequently lease them on an annual basis is more than 40% (see Newell et al., 2005). If the argument is valid, it is valid only in a fraction proportional to amount of fish caught by quota owners in a given fishery rather than quota leasees.

Finally, it may be hard to implement sole ownership because of political pressure and possible unemployment is not the only source thereof. Implementation of sole ownership would effectively destroy many enterprises of individual fisherman and replace them with a huge single enterprise. Such a solution is aimed against the heart of mainstream economic culture which promotes individualism and competition. Local politicians are likely to undertake actions to protect communities of small businesses against interests of large companies not the other way round. And in many countries the current law (for instance in the form of Magnuson-Stevens Act in the US) favors much more implementation of ITQs rather than regulated sole ownership.

When considering these obstacles it is worth to recall the example of Chignik Salmon Cooperative. Fishermen are sometimes willing to give up their independence. Moreover, in many fisheries currently regulated by ITQs, fishermen sell their quotas to bigger companies. These companies often accumulate the quotas up to the point where the regulatory constraint on the market concentration becomes binding (see Yandle and Dewees, 2008). In such fisheries, simply lifting the maximum quota share for a single company could lead to formation of a local monopoly. If such a monopoly forms as a result of market forces while the output controls ensure that there is no abuse of market power, it is reasonable to believe that this local monopoly has a cost advantage over the previous market structure. An example of such a naturally formed firm is Australian NPF Industry Pty Ltd, a company almost single handedly operating Australian North Prawn Fishery (it has 96% of the fleet), the fishery recently recognized by United Nations as a model for sustainable fisheries management (see Dichmont et al., 2010). After investigating that such a local monopoly indeed increases social welfare, it could be granted sole ownership over the fishery which in turn would facilitate further improvements in efficiency.

The situation may be not as straightforward in fisheries which currently do not have ITQs or where there are no natural trends for market concentration. In ambiguous cases I propose to endow fishermen with stock of a newly created company and let them choose its structure, management style etc. If they decide to hold on to the system focused on individual entrepreneurship a sole ownership may be just a holding company bundling their highly independent businesses and at most coordinating their efforts.

By no means should an introduction of sole ownership be mandatory. I tried to argue in this chapter that sole ownership sometimes may be more efficient that current regulatory regimes but it is hard to believe that it will always be. Probably the best approach is to create institutional framework that would facilitate creation of a single firm and then turn it into a sole ownership only if the single firm was naturally created by market forces without harming social welfare by abuses of market power. The remaining issue is how to ensure that market power is not abused and this is the topic of the two following chapters.

4. Inter-temporal regulation

Before diving into analysis of a single fishery it is necessary to make some assumptions about the inter-fishery market. Throughout the entire paper I assume that the world consists of multiple fisheries, each supplying its products to the global market. The fisheries differ in their location and species they supply which in turn creates product differentiation, interacting with consumers' tastes and locations. Each fishery faces its own aggregate demand curve. Demand levels and price elasticities can be different depending on size of the adjacent consumer population, their wealth and preferences, supply provided by adjacent fisheries, transportation costs, prices of meat, etc. Thus, it is hard to call a sole owner operating in such a market a monopolist or even a local monopolist since it faces imperfect competition in the global market – often from firms producing almost identical product. Such a sole owner is however a monopsony in the fishery labor market.

The idea of the model for quantity regulation of a monopoly is straightforward. A regulator imposes an output target which must be met by the single firm. In practice, this output will be spread over particular period of time like a year or a fishing season. It seems necessary to ensure that given total output target, a monopoly does not abuse market power by unfairly manipulating its output rates within the season. A two part model seems to be here a natural solution, where the first part is responsible for setting up the total target and second part is responsible for intra-seasonal modeling of the single firm's behavior.

The model of a fishery proposed in this chapter is a first part of the aforementioned two-part model. This part is a single-species (single-product), long-run, and static. It embeds a generalized version of the broadly acknowledged Schaefer Model (Clark, 2006, p. 38) in a fairly general partial-equilibrium setting. The part built on the Schaefer Model is used only to derive fishery long run cost structure. The framework presented here can be thus easily applied to analyze a quantity regulated monopoly in other industries if a necessity arises.

The Shaefer Model is derived using stock dynamics and allows for analyzing long run equilibria in the fisheries. Because it was used in many important publications (notably Clark, 1980) on various regulatory regimes, it seems natural to use it as a starting point for the analysis of sole ownership. Unfortunately, it has a shortcoming. A popular notion of maximum economic yield, as defined in the context of the Shaefer Model, is actually based not on the concept of maximum net present value, but it uses maximum sustained economic rents instead (Clark, 2006). The two concepts are equivalent only for zero interest rates, which is not a plausible assumption. Nevertheless, because of simplicity of this approach and because other research seem to indicate that for low interest rates the results should be similar (Clark, 1973), I decided that it is fair to use the Shaefer Model for the purpose of this paper and leave the dynamic setting for future research.

The two main components of the model are a differentiable, non-increasing inverse demand function $P(Q)$ and a twice differentiable yield-effort curve $Q(E)$ where effort and price are measured in the same units (for example dollars). Consistently with Schaefer Model, the latter is assumed to be strictly quasi-concave in general and strictly concave between zero effort and effort maximizing yield. Strict quasi-concavity and strict concavity can be relaxed to regular quasi-concavity and concavity, without loss for general conclusions, but they highly simplify the reasoning. Let's also assume that no effort results in no catch, that increasing effort results in increase in catch in the neighborhood of no effort, and that there exists a production level for which industry revenues exceed costs to ensure existence of an equilibrium. Additionally, let's assume that agents are interested in maximizing sustainable rents.

Denote Q^* as the maximum sustainable yield, that is the maximum value of $Q(E)$ and E^* as the corresponding effort. Note that for $E \in [0, E^*]$ function $Q(E)$ is invertible. Its inverse defines effort required to catch given amount of fish. In other words, this is a total cost function. Let's call it $C(Q)$. Note that from the properties of $Q(E)$ we have $C(0) = 0, C(Q) > 0, C'(Q) > 0$ for all $Q \in (0, Q^*)$. Moreover $\lim_{Q \to Q^*} C'(Q) = +\infty$, that is marginal cost tends to infinity as the production level approaches maximum sustainable yield. Note that $C''(Q) > 0$ for all $Q \in (0, Q^*)$ which is equivalent to assuming that $Q(E)$ is concave for $E \in [0, E^*]$. This seems reasonable as each additional unit of effort should increase catch by a smaller amount that previous unit of effort. See Fig. 1 for how cost function and sample demand functions could look like.

Note that we are not interested in the combinations of (E, Q) in which the effort exceeds E^* that is it is beyond the level needed to accomplish the maximum sustainable yield – they are inefficient since the same amount of fish can be caught with less effort and won't be considered as a potential solution by an agent optimizing profit or social welfare. In this model I assume that the fishery operates inside the efficient interval, that is there is no overfishing and $E \in [0, E^*]$.

It is easy to show that in this setting single firm does not always choose the socially optimal level of output. Denote Q^s as socially optimal level of output (maximum economic yield) and Q^m as a level of output chosen by a single firm.

Proposition 1. $Q^m \leq Q^s < Q^*$.

Proof. Single firm's optimization problem is $\max_Q QP(Q) - C(Q)$. The optimum is characterized by $Q^m P'(Q^m) + P(Q^m) = C'(Q^m)$, that is marginal revenue equals marginal cost. Assumptions made about the demand function make this condition necessary but not sufficient, that is multiple local maxima can exist. However, the following and all other conclusions made in this paper are valid for all local maxima, including the global maximum.

Social planer's problem is $\max_Q \int_0^Q P(q)dq - C(Q)$. The optimum is characterized by $P(Q^s) = C'(Q^s)$. Notice that welfare function is strictly concave, hence first order conditions are sufficient. Assume $Q^m > Q^s$. This implies $P(Q^m) = C'(Q^m) - Q^m P'(Q^m) \geq C'(Q^m) > C'(Q^s) = P(Q^s)$ which cannot be true because demand is non-increasing. Note also that $P(Q)$ and $C'(Q)$ have to intersect at $Q^s < Q^*$ because for $Q \geq Q^*$ function $C'(Q)$ is undefined and intersection point must exist.

■

When production level differs from the optimal one, the welfare is not optimized. Regulator must impose a target output on a fishery so as to prevent sole owner from exercising its market power. But maybe it is sometimes not necessary to do so? What are the conditions which make sole owner deliver the same amount of goods as would be prescribed by the social planner?

Proposition 2. If the single firm is a price taker, then it delivers socially optimal level of production.

Proof. Being a price taker is equivalent to $P'(Q) = 0$ for all relevant Q. In such a case both the single firm's and the socially optimal production are characterized by $P(Q) = C'(Q)$. Since left hand side is non-increasing and right hand side is strictly increasing, there exists a unique solution to this equation. In turn $Q^s = Q^m$. ■

Proposition 3. As demand grows, if the demand is elastic in the limit, single firm's production level approaches social optimum.

Proof. To mathematically describe growing demand, let's construct an infinite sequence of inverse demand functions $\{P_n(Q)\}_{n=1}^{\infty}$ such that for each Q in the relevant range $\lim_{n\to+\infty} P_n(Q) = +\infty$. Each element in this sequence is a differentiable, non-increasing function. Now, denote Q_n^m and Q_n^s as optimal production levels for the single firm and the social planner respectively, given the inverse demand function P_n and the cost function $C(Q)$.

First, I am going to show that $\lim_{n\to+\infty} Q_n^s = Q^*$. Consider any $\epsilon > 0$. Note that $\lim_{n\to+\infty} P_n(Q^* - \epsilon) = +\infty$. Therefore $\exists N : \forall n \geq N \; P_n(Q^* - \epsilon) > C'(Q^* - \epsilon)$. But $P_n(Q^* - \epsilon) > C'(Q^* - \epsilon)$ implies that $Q^* - \epsilon < Q_n^s < Q^*$. To sum up, $\forall \epsilon > 0 \; \exists N : \forall n \geq N \; |Q_n^s - Q^*| < \epsilon$ which is the very definition of $\lim_{n\to+\infty} Q_n^s = Q^*$.

Second, I am going to show that $\lim_{n\to+\infty} Q_n^m = Q^*$. Let's define ε_n as price elasticity of demand given inverse demand function P_n and the production level Q_n^m. In other words $\varepsilon_n = \frac{P_n(Q_n^m)}{Q_n^m P_n'(Q_n^m)}$. The single firm's equilibrium condition is $Q_n^m P_n'(Q_n^m) + P_n(Q_n^m) = C'(Q_n^m)$. This can be rewritten as $P_n(Q_n^m)\left(1 + \frac{1}{\varepsilon_n}\right) = C'(Q_n^m)$. As long as the demand is elastic in the limit, that is $\lim_{n\to\infty} \varepsilon_n < -1$, the second factor on the left hand side is positive in the limit. $\lim_{n\to\infty}\left(1 + \frac{1}{\varepsilon_n}\right) = \alpha$ for some $\alpha > 0$. It guarantees that $\lim_{n\to+\infty} P_n(Q)\left(1 + \frac{1}{\varepsilon_n}\right) = +\infty$ for all relevant Q. Now we can proceed analogically to the previous case. Consider any $\epsilon > 0$. Note that $\lim_{n\to+\infty} P_n(Q^* - \epsilon)\left(1 + \frac{1}{\varepsilon_n}\right) = +\infty$. Therefore there exists N such that for all n greater or equal N the following holds: $P_n(Q^* - \epsilon)\left(1 + \frac{1}{\varepsilon_n}\right) > C'(Q^* - \epsilon)$. But $P_n(Q^* - \epsilon)\left(1 + \frac{1}{\varepsilon_n}\right) > C'(Q^* - \epsilon)$ implies that $Q^* - \epsilon < Q_n^m < Q^*$. To sum up, $\forall \epsilon > 0 \; \exists N : \forall n \geq N \; |Q_n^m - Q^*| < \epsilon$ which is the very definition of $\lim_{n\to+\infty} Q_n^m = Q^*$.

Finally, $\lim_{n\to+\infty} |Q_n^m - Q_n^s| = \lim_{n\to+\infty}(Q_n^s - Q_n^m) = \lim_{n\to+\infty} Q_n^s - \lim_{n\to+\infty} Q_n^m = Q^* - Q^* = 0$. ■

Proposition 2 shows something which is very intuitive – as the competition between entities increases, a single entity tends to choose socially optimal production level. Proposition 3 shows something more specific to the situation of the fishery. The demand doesn't have to be perfectly elastic. It can be just slightly elastic, but as long as demand increases, the production level approaches social optimum (and maximum sustainable yield). Fig. 1 shows how optimal output changes with demand increases for both social planner and single firm.

The assumption about demand being elastic in the limit is crucial. For example, imagine linear demand functions with horizontal intercept fixed at Q^* and vertical intercept increasing to infinity, which corresponds to a fixed number of ever richer consumers. In this setting Q_n^s tends to maximum sustainable yield and Q_n^m tends to half that value. Note however that each of these demand functions is inelastic for output levels greater than half of Q^*.

That can mean that if some weak assumptions are satisfied, the annual quantity regulation may not be necessary as long as demand is high, even if it is far from being perfectly elastic. For this statement to be valid, the welfare loss also should go to zero. It obviously does as demand tends to perfect elasticity. But does the same hold as demand increases? Unfortunately, diminishing welfare loss requires stronger conditions to be satisfied by the demand sequence than suggested in Proposition 3. The Proposition 4 investigates this issue.

Proposition 4. Welfare loss under unregulated sole ownership is bounded from above by $\left(-\frac{P_n(Q_n^m)}{\varepsilon_n}\right)(Q^* - Q_n^m)$.

Proof. Welfare loss equals $\int_{Q_n^m}^{Q_n^s}\left(P_n(q) - C'(q)\right)dq \geq 0$. Note that because demand is non-increasing, marginal cost is increasing, and $Q_n^s < Q^*$ we have $\int_{Q_n^m}^{Q_n^s}\left(P_n(q) - C'(q)\right)dq < \int_{Q_n^m}^{Q^*}\left(P_n(Q_n^m) - C'(Q_n^m)\right)dq = \left(P_n(Q_n^m) - C'(Q_n^m)\right)(Q^* - Q_n^m) = \left(-\frac{P_n(Q_n^m)}{\varepsilon_n}\right)(Q^* - Q_n^m)$. ■

Proposition 4 offers sufficient (but not necessary) condition for the welfare loss to vanish. According to this condition, welfare loss will tend to zero as long as any of the following conditions holds:

1. Price elasticity of demand grows faster than price itself.
2. Price elasticity of demand grows at the same pace as price.
3. Price elasticity of demand grows slower than price but supplied quantity converges to maximum sustainable yield fast enough to offset it.
4. Price elasticity of demand remains unchanged and price grows proportionally slower than the gap between actual output and maximum sustainable yield diminishes.

Condition (1) is consistent with the bounded elasticity assumption which was crucial in Proposition 3 and can be applied to situation when thanks to improvements in trade competition between fisheries tightens. Condition (2) implies that price elasticity of demand grows to infinity; therefore this assumption is also automatically met. Condition (2) is equivalent to a situation in which demand grows in such a way that for a given quantity price increases but slope of the inverse demand function remains the same. In conditions (3) and (4) the first factor of the expression grows, therefore the convergence of the whole term to zero relies on the second factor falling to zero.

Further research may be required to determine which of these situations can happen in practice and under what circumstances. Besides, the formula is a gross overestimation of the welfare loss. The precision of the estimate may be improved by imposing some additional assumptions (like convexity of marginal cost) and using linear approximation instead of an upper bound. Moreover, Proposition 4 offers an estimate of a welfare loss given we observe monopoly’s outcome and maximum sustainable yield. Therefore it cannot be used to predict effects of relaxing regulation ex ante.

Finally, it is worth noticing that if the cost of regulation increases with the precision the regulator wants to use to set output target, it may still pay to discard inter-seasonal regulation even if conditions in Proposition 4 are not satisfied and welfare loss does not tend to zero.

5. Intra-temporal regulation

There is very little literature on quantity regulation of a monopoly. There are also virtually no real life examples of such a design. Therefore it is hard to come up with any unintended consequences it might bring. One of the possible problems is intra-temporal price discrimination. If the regulator sets target output for entire season, the sole owner of a fishery may still be able to exercise some market power, taking advantage of changes in demand or cost within the season.

In this chapter I develop a general dynamic intra-temporal model of quantity regulated monopoly. I interpret its findings in the context of a fishery but there are no elements of the model that are specific to this particular industry and all findings hold in general. I assume that the quota for the season has been established by the regulator. The intra-temporal demand is modeled as an instantaneous inverse demand function $p(q,t)$ which is positive as well as continuously differentiable and non-increasing in q. It doesn't have to be continuous in t. The instantaneous total cost may also vary with quantity and time and is denoted by $c(q,t)$. It is increasing and convex in q (but not necessarily continuous in t), that is $\frac{\partial c}{\partial q} > 0$ and $\frac{\partial^2 c}{\partial q^2} \geq 0$. The seasonal quota is set to Q via the first part of the model and the length of the season is T. For the clarity of exposition I will denote $\frac{\partial c}{\partial q} \equiv c'$ and $\frac{\partial p}{\partial q} \equiv p'$. I assume that the total socially optimal production level (derived from equality between seasonal demand and seasonal supply) is bigger than the seasonal quota and that demand at each instant of time is high enough for production to take place. This guarantees existence of interior solution and fairly simplifies calculation without substantially impairing generality of the conclusions. Social planner and single firm choose a production paths $q^s(t)$ and $q^m(t)$ respectively, to maximize their objective functions. There is no discounting since we are in a single period. I also assume the same fishing technology under all regulatory designs.

The social planner faces the following maximization problem:

$$\max_{0 \leq q(t)} \int_0^T \left(\int_0^{q(t)} \big(p(q,t) - c'(q,t)\big) dq \right) dt$$

Subject to $\int_0^T q(t)dt = Q$.

The first order conditions in this problem are $p(q^s(t),t) - c'(q^s(t),t) = \lambda$. The intuitive interpretation of these conditions is that the social planner chooses production path in such a way so that marginal welfare loss is the same at each instant of time. The sufficient conditions for uniqueness of the solution require instantaneous welfare function to be strictly concave which in turn can be achieved by having strictly decreasing instantaneous inverse demand or strictly increasing instantaneous marginal cost or both.

Proposition 5. ITQs result in the same production path as socially optimal.

Proof. ITQ consists of many fishermen, each having their own quota. The price-taking fishermen maximize their profits and since the total quota is binding, all fishermen use their entire allotted shares. For each instant of time we can identify a marginal fisherman that is the fisherman whose profit margin is the lowest. Since I assume the same technology under all regulatory regimes, marginal fisherman at time t earns marginal profit $p(q(t),t) - c'(q(t),t)$, where $q(t)$ is the instantaneous output at the time t. If there exists a different instant of time $\tilde{t}$, where $p(q(t),t) - c'(q(t),t) < p(q(\tilde{t}),\tilde{t}) - c'(q(\tilde{t}),\tilde{t})$, the marginal fisherman at time t will reduce his effort at time t and increase his effort at time $\tilde{t}$. This process will continue until equilibrium is attained, that is profit margin for marginal fishermen is equalized across the whole period. Profit margin for marginal fishermen equals marginal welfare loss, which concludes the reasoning. ■

Proposition 5 is illustrated in Fig. 2. The argument here is more like an economical intuition rather than formal mathematical proof, which would require setting up a multi-agent optimization problem. It shows that ITQs are efficient in intra-temporal allocation of effort. Can a sole owner exhibit the same characteristic? The next three propositions show when sole ownership achieves an efficient outcome. But first, let's consider the single firm's optimization problem:

$$\max_{0\le q(t)} \int_0^T \big(q(t)p(q(t),t) - c(q(t),t)\big)dt$$

Subject to $\int_0^T q(t)dt = Q$.

The first order conditions are $p(q^m(t),t) + q^m(t)p'(q^m(t),t) - c'(q^m(t),t) = \mu$. The interpretation of these conditions is that the single firm chooses the optimal path in such a way so that the marginal profit is constant over time. Indeed, it makes sense intuitively, as if at some instant of time the marginal profit was higher than at another, the single firm would shift effort from the latter to former and improve their overall profit. Note that most of the popular demand specifications yield strictly concave revenue functions and then the solution to single firm's optimization problem is unique. However, this is not necessarily true in practice, especially when consumers can be assigned to many fairly homogeneous groups.

First order conditions for a monopoly are not equivalent to first order conditions for the social planner; therefore the solutions to the two problems in general will not be the same. In fact, it is easy to construct an example where the solutions are different. Thus, monopoly regulated with a target output to be realized over a period of time can still exercise monopoly power using time discrimination.

Proposition 6. Single firm results in the same production path as social planner as long as it is a price taker.

Proof. Being a price taker is equivalent to $p'(q,t)=0$. The first order condition for a single firms becomes $p(q^m(t),t)-c'(q^m(t),t)=\mu$ which is exactly the same as the condition for social optimum. Note that multiple local optima can arise. In this case each social optimum has a corresponding single firm's optimum, and thus global social optima have their corresponding single firm's global optima (and vice versa). ■

Proposition 7. If demand and cost do not vary over time and single firm's solution is unique, then it is also the solution to social planner's problem.

Proof. The first order condition for a single firm becomes $p\big(q^m(t)\big)+q^m(t)p'\big(q^m(t)\big)-c'\big(q^m(t)\big)=\mu$. Assume that $q^m(t)$ is not constant over time. Then there exist two points in time, namely t_1 and t_2 such that $q^m(t_1)\neq q^m(t_2)$. Note that the production path being the same as $q^m(t)$ except for neighborhoods of t_1 and t_2, which are swapped in the new path, yields the same profit and satisfies the constraint. Therefore if the solution to single firm's problem is unique, it is constant over time, that is $q^m(t)=q^m=\frac{Q}{T}$.

Let's assume that $q(t)=\frac{Q}{T}$ is not the global solution to the social planner's problem. This output path satisfies the constraint so it must be that there exist a positive measure subset of $[0,T]$ for which $q^s(t)<\frac{Q}{T}$ and a positive measure subset of $[0,T]$ for which $q^s(t)>\frac{Q}{T}$. If we denote the instantaneous welfare function as $w(q)$, the following inequality holds $\int_0^T w\big(q^s(t)\big)dt>\int_0^T w\left(\frac{Q}{T}\right)dt=\int_0^T w\left(\frac{1}{T}\int_0^T q^s(\tau)d\tau\right)dt$ which cannot be true because w is a concave function. Thus $q^s(t)=q^m(t)=q^m=\frac{Q}{T}$ is the global solution to social planner's problem. See Fig. 3 for illustration. ■

Proposition 8. If instantaneous marginal cost is constant both in time and quantity, the efficient outcome can be imposed on the single firm by enforcing a constant price.

Proof. Denote instantaneous marginal cost as mc. If the instantaneous marginal cost is constant, both in time and quantity, the socially optimal path is characterized by $p(q^s(t),t)-mc=\lambda$. Therefore $p(q^s(t),t)=mc+\lambda$ that is the price doesn't change over time even though the demand may fluctuate. Now, assume that regulator imposes price $mc+\lambda$ on the single firm. The single firm faces the following optimization problem:

$$\max_{0\leq q(t)\leq q^s(t)}\int_0^T \lambda q(t)dt$$

Subject to $\int_0^T q(t)dt=Q$, where λ is profit margin implied by the price regulation and constraint $q(t)\leq q^s(t)$ comes from the fact that at price $mc+\lambda$ consumers are willing to buy at most $q^s(t)$. The only way to simultaneously satisfy conditions $\int_0^T q(t)dt=Q$ and $q(t)\leq q^s(t)$ is to set $q^m(t)=q^s(t)$ for all t. ■

I assume the demand is not perfectly known to the regulator, so it cannot impose an arbitrary price on the single firm to make Proposition 8 work in practice. A more realistic approach would be to let the single firm choose the price according to their expectations and incentivize her to keep the price constant over the season (by for example imposing penalties for intra-seasonal price variability). Then, assuming that monopoly can precisely anticipate market clearing price, the optimal outcome should be attained. The mechanism is presented on Fig 4.

Note that any of the above three conditions: 1) perfect elasticity of demand, 2) demand and cost don't change over time within the season, and 3) marginal cost is constant both over time and in quantity can yield the socially optimal solution. However it is easy to imagine a secluded fishery where demand is inelastic and cost function fluctuates with harsh weather. In such cases sole ownership may exercise its market power and ITQs seem to guard against excessive welfare loss.

It is also worth noting that in the intra-temporal setting there is one additional factor that increases instantaneous demand elasticity and which was absent in the inter-temporal setting. Availability of frozen fish can be a good substitute for fresh fish, efficiently reducing sole owner's power to time discriminate.

6. Conclusions

There is very little analysis of sole ownership as a viable option in fisheries. Because of present legal climate and cultural bias in favor of competition, this solution to fishery problem has been neglected both by researchers and by policymakers. However, evidence is mounting that current regulatory designs have flaws that could be solved by sole ownership. Some notable examples are quota-busting, high-grading, by-catch, and stock heterogeneity. Sole ownership would also allow higher efficiency through economies of scale and changes in technology derived from increased cooperation between fishermen as well as introduction of new improvements to production process like big scale aquaculture. Moreover, the regulatory cost of the sole ownership design should be lower not only because it is a single company to deal with in place of many, but also because a sole owner would bear much of the cost incurred currently by regulators and law enforcement agencies. Furthermore, sole ownership doesn't seem technically hard to implement since in some ITQ fisheries it can emerge simply after relaxing constraint on market shares for quota holders. The Australian company, NPF Industry Pty Ltd. as an entity very close to something proposed in this papers stands as a proof that this solution can be not only possible to implement but also successful and superior to other regulatory regimes.

A general two part model of a quantity regulated monopoly was developed to analyze specific features of such a design in fisheries. The model consists of the inter-seasonal part responsible for deriving output target for each single period and the intra-seasonal part responsible for analyzing how output is distributed over time within the season. The inter-seasonal setting yields a general result that single firm can be efficient if demand is perfectly elastic. This result is enriched by a fishery specific outcome, namely that a sole owner can tend to provide optimal level of production as long as demand is high, even if the demand is far from being perfectly elastic. The intra-seasonal part of the model shows that ITQs in general yield efficient intra-temporal allocation of effort and under some circumstances a single firm can also be efficient. These conditions are: 1) perfectly elastic demand, or 2) demand and cost constant over time, or 3) cost constant in both quantity and time. In case (1) and (2) monopoly automatically reaches the socially optimal level of output and in case (3) it can be incentivized to do so by a regulator.

By putting together all these arguments the paper is hoped to convince readers that sole ownership in fisheries as well as quantity regulation of a monopoly deserve more attention than they currently attract. The results obtained in the paper are preliminary and a lot of further research is needed to construct a framework that could be used to reinforce decisions on implementing sole ownership in particular fisheries. The potential research areas that could contribute to the idea are vast.

The primary field of further development is modeling of quantity regulated monopoly. There is an astonishing void in the literature on that topic, probably because there is virtually no regulatory design all over the world that would employ such an idea. The analysis presented in this paper is rudimentary and surely does not capture many important effects such a regulation would have.

Another interesting issue are unintended side effects of the consolidation in the fishing industry. It is well known that processors tend to be quota owners in the ITQ fisheries. Increased concentration in a fishery would necessarily have an influence on the processing sector. Are processors going to be incentivized to merge? If this can reduce competition and thus cause additional inefficiency, can it be prevented by a well-designed regulation of the processing sector? If it cannot be prevented does the potential welfare loss exceed the increase in efficiency brought by a sole owner?

Aquaculture poses another interesting question. After obtaining property right to the whole fishery, a sole owner will be incentivized to introduce aquaculture that is to manage stocks in an intensive way. This may include promoting growth of some profitable fish species by for example feeding them and discouraging growth of others (e.g. unprofitable predators or parasites). The productivity of such a fishery may be expanded greatly in the same way use of fertilizers increased productivity in growing crops. There are many questions spawned by such potential behavior of a sole owner since it is very likely to require regulation. Such regulation would have to aim at not only preventing extinction of commercially non-desired species (if they compete for natural resources with commercially desired species) but also at determining the socially optimal level of aquaculture. Aquaculture may be beneficial to the society if it means expanding maximum sustainable yield, but monopoly may have no incentives to further expand output given the demand because it reduces prices. Whether this statement is true, is left to future studies.

One of the propositions presented in this paper puts an upper bound on the welfare loss induced by an unregulated sole owner. This estimate can be calculated ex post introduction of an unregulated sole ownership. The likely course of event is however opposite. It can be expected that the sole owner is initially regulated. Only if regulator perceives that the market conditions are appropriate, it can relax the regulatory constraint. It would be thus interesting to develop a method of evaluating potential welfare loss ex ante, based on the data available while the regulation still takes place.

As a reminder, the use of Shaefer Model in the first part of the model above assumes instantaneous rent maximization instead of maximization of net present value of the rents. This limitation can be lifted in the future research to undermine or reassure sole ownership as a viable option for fisheries. Another extension could introduce multi-species fishery instead of single species treated in this paper.

Finally, something ignored in this paper but also indisputably relevant to the idea is the fate of migratory species and international fisheries.

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Figures

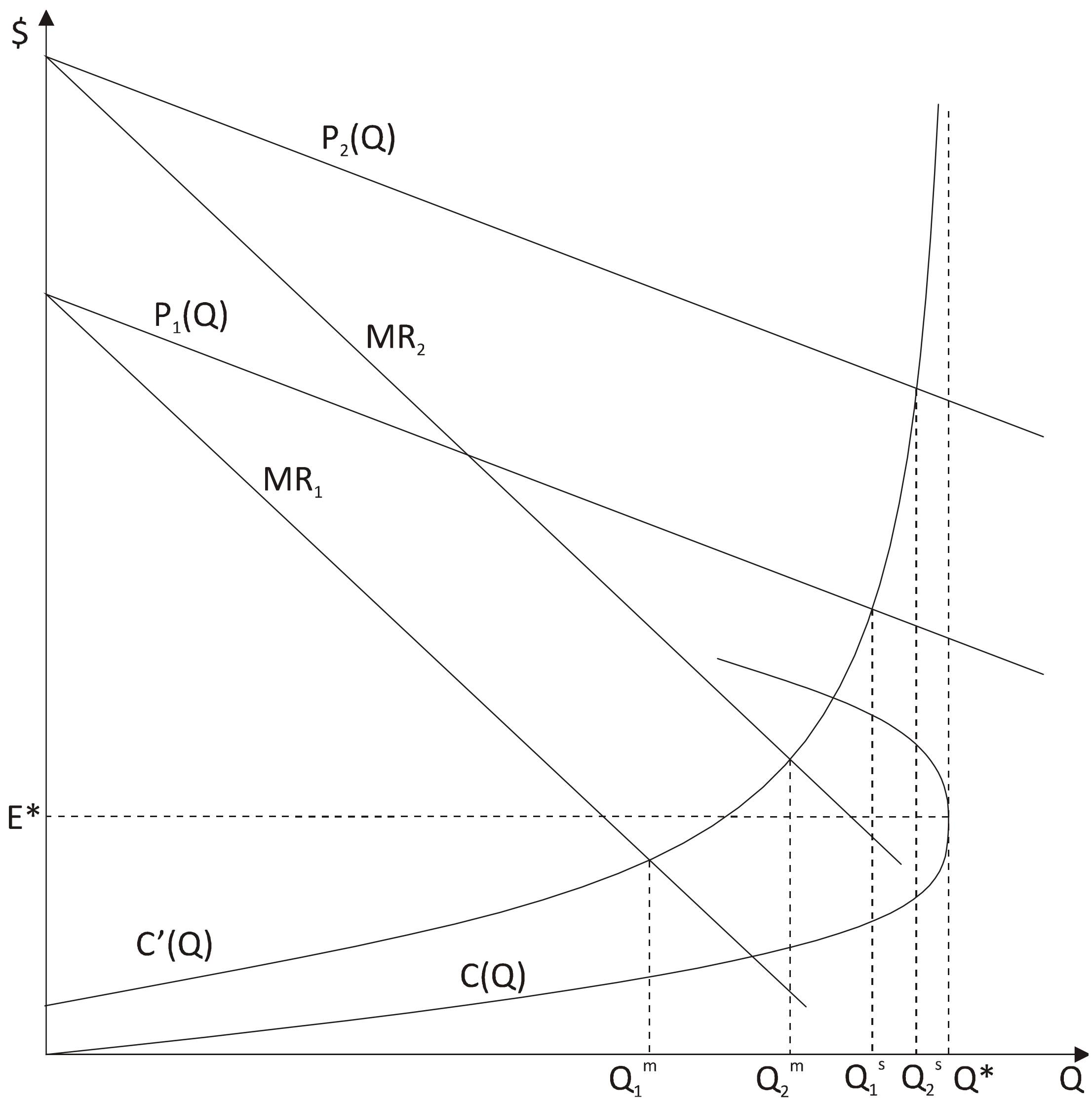

Fig 1. The industry total cost curve is depicted by C(Q) and it is backward bending as a it an inverted effort-yield curve of the Schaefer Model. Only the part below E* level is used to derive industry marginal cost curve denoted as C'(Q). For the demand level P_1, the corresponding monopoly and socially optimal output levels are respectively Q_1^m and Q_1^s. When demand increases to P_2, the corresponding monopoly and socially optimal output levels shift right to Q_2^m and Q_2^s.

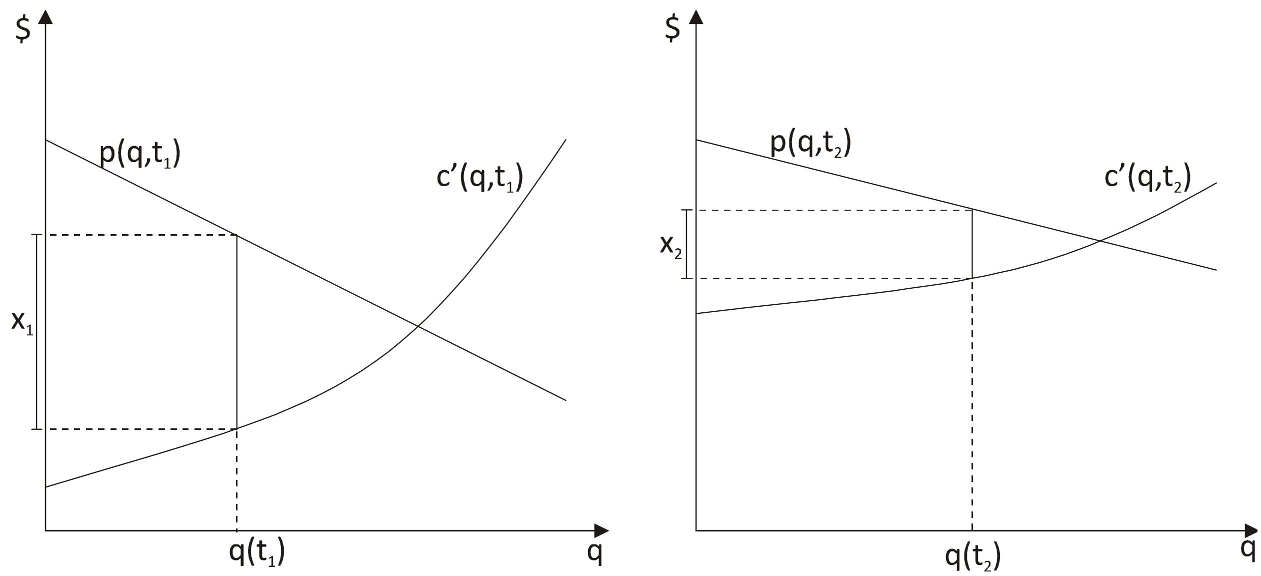

Fig 2. The fisherman who fishes at time t_2 and has a marginal profit of x_2 is willing to cut on his production in this period and shift the fishing effort to time t_1, because marginal profit he can ear then is higher: x_1. Shifting of effort will continue until $x_1 = x_2$.

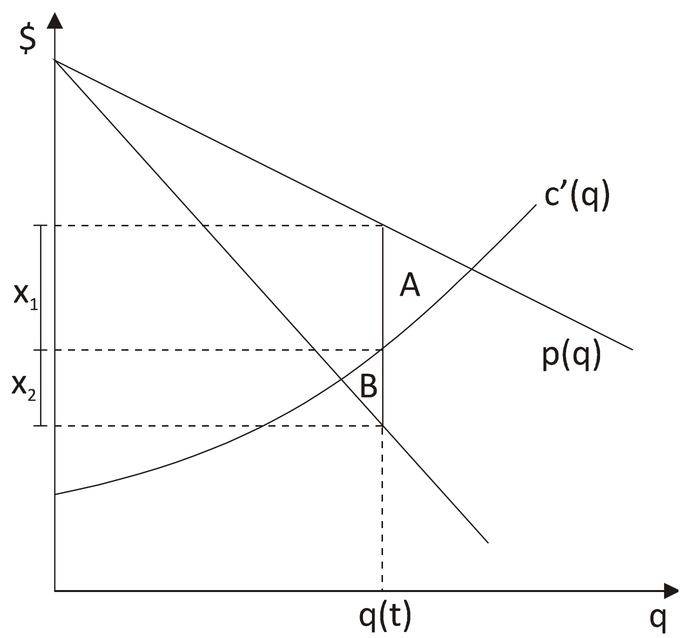

Fig 3. When the demand and cost function are constant over time, the optimal production level is also constant over time and the same for a monopoly and social planner. In this case marginal welfare loss equals x_1 and marginal profit equals x_2. Instantaneous welfare loss is equal to the area A and instantaneous profit loss is equal to area B. Nether social planner nor single firm has incentives to deviate for this path. The former wants to expand production by is constrained by the total quota and the latter wants to contract output but is also constraint by the total quota.

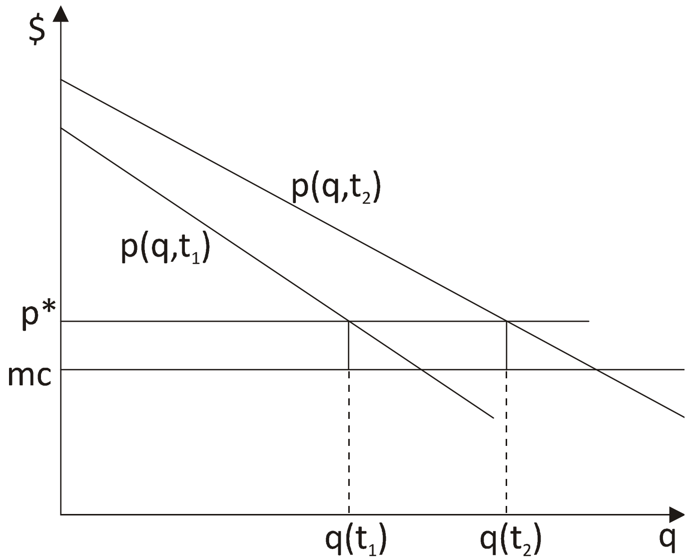

Fig 4. For two different demand curves at two distant points in time, setting a constant price results in marginal welfare loss equalized, as long as marginal cost is constant both in time and quantity. A monopoly has incentives to choose correct price p*. Wrong p* will result in not meeting the total quota. With correct p* monopoly cannot deliver more than optimal q(t) because there won't be customers willing to buy the product. Therefore it cannot also deliver lower quantity, because it will violate the total quota constraint.