Marine Resource Economics, Volume 16, pp. 219–233
0738-1360/00 $3.00 + .00

Rent Seeking and the Regulation of a Natural Resource

HARALD BERGLAND
Harstad College

DEREK J. CLARK
University of Tromsø

PÅL ANDREAS PEDERSEN
Bodø Graduate School of Business

Abstract *This article analyses rent-seeking behaviour among agents who compete for high future shares of a common natural resource. Rent-seeking behaviour occurs when the agents, based on earlier experience, expect that the distribution of the common natural resource in the future will be dependent on the agents' activities in the past. We show that allocation rules that make rent seeking individually rational, normally lead to scale inefficiency, input mix inefficiency, and fewer participants in the industry than lump-sum allocation rules.*

Key words Natural resource, regulation, rent seeking.

Introduction

It is well known that a group of agents who share a common-pool resource will not take account of the full social cost of their actions. This leads to the sub-optimal management of the resource and a scenario popularly known as the tragedy of the commons (Hardin 1968). A usual response to this problem is for a public body to attempt to regulate extraction of the resource in some way in order to enforce optimal management. Indirect regulation can be implemented through a system of taxes, whilst direct regulation involves a quantity constraint on production (Bohm and Russell 1985; Munro and Scott 1985). In this paper, we examine how rational actors' expectations of a direct regulatory regime can affect its effectiveness. This type of resource regulation implies a reduction in access for some or all of the actors in the industry, or effective limits on production for the participants, according to some pre-specified criterion. A fishery can, for example, be regulated by the use of quotas which specify a total allowable catch (TAC) for a vessel (or crew). The size of the quota is often based upon observable and verifiable variables, such as the length of

---

Harald Bergland is an associate professor, Harstad College, N-9400 Harstad, Norway, email: Harald.Bergland@hih.no. Derek J. Clark is a professor in the Department of Economics and Management, NFH, University of Tromsø, N-9037 Tromsø, Norway; and Norwegian School of Management, BI-Tromsø, P.O. Box 973, N-9260 Tromsø, Norway, email: Derek.Clark@nfh.uit.no. Pål Andreas Pedersen is an associate professor at Bodø Graduate School of Business, N-8049 Bodø, Norway; and visiting professor at the University of Kent at Canterbury, Keynes College, Department of Economics, Canterbury, Kent, CT2 7NP, UK, email: Paal.Pedersen@hibo.no.
We would like to thank the *MRE*'s reviewers and *MRE*'s editor for helpful comments on an earlier draft. The usual disclaimer applies.

the vessel and historic catch. These magnitudes can be freely chosen by the actors in an unregulated (free) fishery.

When participants know (or suspect) that an industry will be directly regulated, they, as a group, may have an incentive to seek to influence the design of the actual regulation though lobbying campaigns. In addition to spending resources on collective and coordinated lobbying, the participants will have an incentive to adjust their individual behaviour in anticipation of public interventions, even before regulation is implemented. Such collective and individual behaviour, as a response from private agents to public authorities' regulating ambitions, has been termed "rent seeking" in economic theory, since the seminal work of Krueger (1974). Let us pursue the example of a fishery given above, and imagine that direct quota regulation will be introduced. Then, different groups of fishermen might collectively fight for criteria that will give them high shares of future catch quotas. Furthermore, if we assume that quotas will be awarded to a certain extent on the basis of historic catch (defined over a certain period), fishermen can then individually secure a larger quota *ex post* by increasing the size of their catch in the periods leading up to the implementation of regulation. The individual incentive to overfish in periods before implementation of regulation is an example of rent-seeking behaviour which can counteract the efficiency of the regulatory regime. It is precisely this mechanism that is the focus of this paper.

We concentrate our analysis on three effects that individual rent seeking can cause. The first is that firms in the industry choose an inefficient scale for their operation in order to secure future resource rights (scale inefficiency). The second is that rent seeking leads to a sub-optimal combination of inputs in the production process (input-mix inefficiency). The third effect involves a reduction in the number of firms in the industry compared to the number that would have participated if one used a neutral quota sharing rule. Due to scale and input-mix inefficiency, firms' short-term profit is reduced when they act upon their anticipation of regulation. Those achieving a profit below that which represents the best alternative use of the factors of production will disappear from the industry.

The model which we use to model the phenomenon of rent seeking in anticipation of regulation has a variety of applications; *e.g.*, the extraction of a natural resource, the use of grazing land, or the emission of pollution. However, in order to motivate the type of regulation that we consider in our model, we present evidence from fisheries in the following section. Then, the model itself is presented and analysed. Finally, conclusions are offered.

Direct Regulation of Fisheries

Fisheries provide a good example of direct quantity regulation. Our main thesis is that the actors themselves can influence variables that govern the allocation of quotas. In this section, we provide evidence of this from various fisheries. Grafton (1996) examines the theory and international practice of individual transferable quotas (ITQs). "In all ITQ programmes to date, fishers have received an allocation gratis based upon an existing and/or historical participation in the fishery and/or vessel characteristics." New Zealand introduced a management system in 1983 for a limited number of deepwater fish stocks, which was subsequently extended in 1986 to almost all remaining significant fish stocks. Again, past harvest weighed heavily in the allocation of quotas. "Most ITQ's were allocated to firms in proportion to past harvest, although some quotas were sold to industry by tender" (Lindner, Cambell, and Bevin 1992). An ITQ program for the wreckfish (*Polyprion americanus*) fishery in the South Atlantic was introduced in 1992. "Shares were allocated to historical participants weighted partially on catch history." … "The initial allocation formula divided 50 of the 100 available percentage shares in direct proportion to the applicant's documented catch over the 1987-1990 period. The remaining 50 shares were divided equally among eligible applicants" (Gauvin, Ward, and Burgess 1994).

In the examples given above, it has been historic catch that has determined the quota allocation. In the following cases, vessel characteristics also play a significant role. In 1990, individual vessel quotas (IVQs) were introduced in the British Columbia sablefish fishery. "The IVQs were assigned gratis to fishers on the basis of past catches and vessel length, denominated as a proportion of the total allowable catch,…" (Grafton 1995). According to Arnason (1993), the individual quota system in the Icelandic fisheries was introduced to the herring fisheries in 1976, the capelin fishery in 1980, and the demersal fisheries in 1984. Since 1990, all Icelandic fisheries have been subject to a uniform system of ITQs. The quota allocation has depended mainly on past harvest, but also on vessel capacity. "The initial allocation of TAC-shares to individual vessels varies somewhat over fisheries. In demersal, lobster and deep-sea shrimp fisheries the TAC-shares are normally based on the vessels' historical catch record during certain base years." …. "In the herring and inshore shrimp fisheries the initial TAC-shares were equal. The same holds for the capelin fishery except that 1/3 of the TAC-shares were initially allocated on the basis of vessel hold capacity" (Arnason 1993).

One can also find several examples in Norwegian fisheries. The northeast Arctic cod fishery (for vessels with traditional gear) was regulated in 1990 by a vessel quota system mainly involving the allocation of quotas according to vessel size on the 1st of January 1990, and catch in the period 1987–89 (Norwegian Directorate of Fisheries 1990). The quota system has been applied to trawlers in this fishery since 1976; allocations here have also depended to some extent upon vessel size, with large trawlers receiving a larger quota than smaller ones.

In 1999, access to the saithe fishery for those vessels using seine gear was restricted according to previous participation and those who had fished sufficient quantity. The participants have to satisfy three requirements. First, the owner and the vessel have to be recorded in a public register. Second, the owner must have his own seine gear and the vessel must have the necessary equipment to fish for saithe. Third, the vessel has to have fished and not delivered less than 10 tons of saithe in at least one of the years 1996, 1997, or 1998 (Norwegian Directorate of Fisheries 1999).[1]

Another example from Norway is the Greenland halibut fishery, which, after a period of overfishing in the 1980s, was almost closed in 1991. In the years following, trawlers were allowed a limited bycatch, and the coastal fleet has been permitted to fish Greenland halibut for a very short, regulated time period. In spite of the tight regulation, there has been a substantial total catch volume over the last years. Marine researchers have, therefore, considered suggesting the implementation of a quota system into this fishery.[2] The Norwegian Fishing Vessel Owners' Association argues that the distribution of these fishing rights should be based upon the historic catch volume for a period before the original regulation was introduced in 1991 (Norwegian Fishing Vessel Owners' Association 1999).

We use these examples in order to motivate the variables upon which the quota allocation can be based, and which actors themselves can influence. In the model

---

[1] Evidence that this led to rent-seeking behaviour in this fishery is indicated by an article in the Norwegian newspaper, *Nordlys* (9/6/99): "Many had expected the regulation of access. More actors participated in the saithe fishery using seine gear in order to secure access after the new rules were implemented" (our translation).

[2] Marine Researcher Olav R. Godø from the Norwegian Marine Research Institute to the newspaper *Fiskeribladet* (10/9/99).

described in the next section, we allow this allocation to depend (non-negatively) upon past production and the size of a firm's capital stock. The transition from a historically open-access fishery to individual quota regulation has often taken place in several stages. In order to regulate a fishery, open access may initially be prevented by introducing licences (often given to the fishermen already participating in the fisheries), or influenced by implementing maximal season lengths, gear restrictions, and area closures.[3] After this, the authorities may choose to implement individual harvest quotas.[4] In order to simplify our analysis, we consider an immediate transition from open access to individual, non-tradable quotas. Such a transition took place in the northeast Arctic cod fishery for vessels with traditional gear. In this fishery, there was no regulation of access before the system of vessel quotas was introduced, and the fishermen were not allowed to buy or sell quotas. No matter how the transition from open access to individual quotas is achieved, fishermen will have an incentive to rent-seek as long as they suspect that their individual harvest quotas will be based on factors that they can influence, such as historical performance (measured by catch levels and/or input use).

The Model

We consider two periods. In the first, firms are unregulated, whilst direct regulation is introduced at the beginning of the second period. To be specific, in period 1 firms are free to choose whether they want to participate in exploiting the natural resource or not. If they participate, they decide freely the level of economic activity in the first period, but face a quantity constraint in the second via the introduction of a quota scheme that limits the total amount of resource extraction. This total quota is known to all firms at the beginning of the first period. Firms' individual shares are decided by the size of their capital stock (representing a commitment to produce) and their production in period one.[5] We assume that these allocations are non-tradable.[6]

Let us denote the number of operating participants in the industry by N. Furthermore, the production function of firm $i = 1,.., N$ is assumed to be time invariant and to depend upon labor, L, and capital, K:[7]

$$y_t^i = F^i(L_t^i, K_t^i), \quad t = 1, 2, \quad i = 1, .., N \tag{1}$$

where $t = 1,2$ is a time subscript, and y is the amount produced (or extracted). In order to simplify the analysis, capital is assumed to be a fully flexible input, meaning that there is no lag between a decision to expand capital and the presence of an additional capital unit causing adjustment costs. Moreover, we normalise the product price to 1, and can thus write firm i's period 1 profit, π_1^i, as:

---

[3] If such regulations are practised, Homans and Wilen (1997) use the term regulated open access to describe the institutional conditions under which the industry operates.
[4] For instance, an analysis of the transition from limited entry to individual quotas is found in Weninger and Just (1997).
[5] In the fisheries example, capital can be thought of as vessel length.
[6] The model and its qualitative results regarding rent seeking would not be affected if allocations are tradable; in this case, the marginal profit from a small increase in the individual quota would be equal for all firms (see equation 12). Hence, even though one might discuss how efficient a system of tradable quotas actually is (see Boyce [1992] and Grafton [1996]), tradability will always be preferable to a regime where it is illegal to buy and sell quotas.
[7] In order to simplify the model, we have ignored that the size of the natural resource stock in the period might influence the production technology described by the production function.

$$\pi_1^i = F^i(L_1^i, K_1^i) - wL_1^i - cK_1^i \tag{2}$$

where w is the wage rate, and c the price of capital. For simplicity, we also assume that all prices are constant across time periods.

In period 2, the public authorities are supposed to introduce quota regulation based on a maximum TAC in the regulated period, Y, which can be thought of as the catch volume that maximizes the economic yield from exploiting the natural resource. Moreover, individual quotas, $\bar{y}_2^i$, are supposed to be decided upon by the size of firms' capital stock and production in period 1:

$$\bar{y}_2^i = g^i(y_1^i, K_1^i, y_1^{-i}, K_1^{-i})Y, \;\; \forall i = 1,.., N; \sum_{i=1}^{N} g^i = 1 \tag{3}$$

where:

$$\frac{\partial g^i}{\partial y_1^i} \geq 0, \frac{\partial g^i}{\partial K_1^i} \geq 0, \frac{\partial g^i}{\partial y_1^{-i}} \leq 0, \frac{\partial g^i}{\partial K_1^{-i}} \leq 0\,.$$

Here, g^i is firm i's share of the total quota, and y_1^{-i} and K_1^{-i} are the first period production and capital of all firms other than i. The share of firm i is increasing in its own production and capital stock, and decreasing in those of other firms. Note the dual role played by capital in the allocation rule in equation (3): an increase in capital affects the quota indirectly through increasing production, and also directly.

The problem facing firm i in period 2 is to maximize its profit:

$$\pi_2^i = F^i(L_2^i, K_2^i) - wL_2^i - cK_2^i \tag{4}$$

by choice of L_2^i, and K_2^i given the share constraint:

$$F^i(L_2^i, K_2^i) \leq \bar{y}_2^i \quad \forall i = 1, ..., N\,. \tag{5}$$

The Lagrangean for this problem is then:

$$H^i = F^i(L_2^i, K_2^i) - wL_2^i - cK_2^i - \lambda^i\left[F^i(L_2^i, K_2^i) - \bar{y}_2^i\right]. \tag{6}$$

The first-order conditions for a maximum are:

$$(1-\lambda^i)\frac{\partial F^i}{\partial L_2^i} = w, (1-\lambda^i)\frac{\partial F^i}{\partial K_2^i} = c \tag{7}$$

where λ^i is the increase in firm i's profit from a small increase in its individual quota. In cases where direct regulation represents a true constraint on the activity of firm i, it will be the case that $\lambda^i > 0$. We assume this to be the case so that equation (5) holds as an equality.

The second period problem for the firm is to minimize the cost of producing its allowed amount of the good in question. Equations (5) and (7) give $3N$ equations in $3N$ unknowns, which can be solved to yield:

$$L_2^i = L_2^i(\bar{y}_2^i; w, c) \quad K_2^i = K_2^i(\bar{y}_2^i; w, c) \quad \lambda_2^i = \lambda_2^i(\bar{y}_2^i; w, c). \tag{8}$$

Hence, the second period profit of firm *i* can be expressed as:

$$\pi_2^i = \pi_2^i(\bar{y}_2^i; w, c). \tag{9}$$

Having determined optimal actions in period two, we now consider the beginning of the first period. The expected present value of firm *i*'s total profit over the two periods is:

$$V^i = \pi_1^i + \delta\pi_2^i = F^i(L_1^i, K_1^i) - wL_1^i - cK_1^i + \delta\pi_2^i\left[g^i(y_1^i, K_1^i, y_1^{-i}, K_1^{-i})Y; w, c\right] \tag{10}$$

where $\delta \geq 0$ is a common discount factor.[8] Recall that firms are not regulated in the first period so that they can freely choose labor and capital to maximize equation (10), given the factor choices of all other firms, the total quota for period 2, *Y*, and the sharing rule in equation (3). First-order conditions for a maximum are given by:

$$\frac{\partial V^i}{\partial L_1^i} = \frac{\partial F^i}{\partial L_1^i} - w + \delta \frac{\partial \pi_2^i}{\partial \bar{y}_2^i} Y \frac{\partial g^i}{\partial y_1^i} \frac{\partial F^i}{\partial L_1^i} = 0, \tag{11}$$

$$\frac{\partial V^i}{\partial K_1^i} = \frac{\partial F^i}{\partial K_1^i} - c + \delta \frac{\partial \pi_2^i}{\partial \bar{y}_2^i} Y\left(\frac{\partial g^i}{\partial K_1^i} + \frac{\partial g^i}{\partial y_1^i}\frac{\partial F^i}{\partial K_1^i}\right) = 0 \cdot$$

From the envelope theorem, we have that:

$$\frac{\partial H^i}{\partial \bar{y}_2^i} = \frac{\partial \pi_2^i}{\partial \bar{y}_2^i} = \lambda^i \tag{12}$$

where H^i is the Lagrange function defined in equation (6). Using equation (12), we can rewrite equation (11) as:

$$\frac{\partial F^i}{\partial L_1^i}\left(1 + \delta\lambda^i Y \frac{\partial g^i}{\partial y_1^i}\right) = w; \quad \frac{\partial F^i}{\partial K_1^i}\left(1 + \delta\lambda^i Y \frac{\partial g^i}{\partial y_1^i}\right) = c - \delta\lambda^i Y \frac{\partial g^i}{\partial K_1^i} \tag{13}$$

from which it follows that:

$$\frac{\frac{\partial F^i}{\partial L_1^i}}{\frac{\partial F^i}{\partial K_1^i}} = \frac{w}{c - \delta\lambda^i Y \frac{\partial g^i}{\partial K_1^i}} \geq \frac{w}{c}. \tag{14}$$

---

[8] The value of the discount factor is dependent on the annual discount rate and the length of the regulation period (or number of years the fishermen expect to be operating in the regulated industry). The less the annual discount rate becomes and the longer the fishermen plan to participate in the regulated industry (or the longer that firms operate), the higher the discount factor δ.

Economically efficient production in period 1 would require that the rate of technical substitution between capital and labor be equal to the ratio of the factor prices. From equation (14) we see that firms' rent-seeking behaviour can prevent this; we have input-mix inefficiency. When the quota in the second period depends positively on the capital stock from the first, too much capital is employed in relation to labor.[9] Efficient production for firm *i* is ensured in the first period if the quantity constraint for period 2 does not bind ($\lambda^i = 0$), if actors do not value the future ($\delta = 0$), or if the capital stock does not affect the period 2 quota directly $[(\partial g^i / \partial K_1^i) = 0]$.

The allocation rule we considered in equation (3) depends directly on only one of the factors of production. However, input mix inefficiency would also result (apart from under very special circumstances) if the future quota depends upon both factors. To see this, consider an extended quota allocation rule:

$$\bar{y}_2^i = g^i(y_1^i, K_1^i, L_1^i, y_1^{-i}, K_1^{-i}, L_1^{-i})Y, \ \forall \ i = 1, .., N \qquad (3')$$

where, in addition to the properties of equation (3), $(\partial g^i / \partial L_1^i) \geq 0, (\partial g^i / \partial L_1^{-i}) \leq 0 \cdot$ Then, equation (14) would be amended to:

$$\frac{\dfrac{\partial F^i}{\partial L_1^i}}{\dfrac{\partial F^i}{\partial K_1^i}} = \frac{w - \delta\lambda^i Y \dfrac{\partial g^i}{\partial L_1^i}}{c - \delta\lambda^i Y \dfrac{\partial g^i}{\partial K_1^i}}. \qquad (14')$$

The right-hand side of this equation is only equal to the ratio of the factor prices (w/c), ensuring an efficient input mix, when:

$$\frac{\dfrac{\partial g^i}{\partial L_1^i}}{\dfrac{\partial g^i}{\partial K_1^i}} = \frac{w}{c}$$

measured at the firm's optimal choice. In other cases, the input mix is inefficient.

A second effect of this rent-seeking behaviour is that the scale of production in period 1 is too large to be efficient. This can be seen by rewriting equation (13) as:

$$1 + \delta\lambda^i Y \frac{\partial g^i}{\partial y_1^i} = \frac{w}{\dfrac{\partial F^i}{\partial L_1^i}} = \frac{c - \delta\lambda^i Y \dfrac{\partial g^i}{\partial K_1^i}}{\dfrac{\partial F^i}{\partial K_1^i}} \qquad (15)$$

[9] An input mix inefficiency result is also found in the general theory of public regulation (see the seminal work of Averch and Johnson 1962). However, the excessive capital-labor ratio chosen by a regulated monopoly in the Averch-Johnson model is caused by a public rate-of-return constraint, while the input mix inefficiency in our model can be explained as a result of the competition between the firms in searching for high shares of future quotas.

where the expression on the left-hand side is the marginal profit from production in period 1. The first term in this expression represents the gain in period 1 from producing an extra unit, whilst the second is the present value of this extra production in period 2, which originates from an increase in firm *i*'s quota. The term in the centre and to the right in equation (15) is the marginal cost of increasing period 1 production by one unit by employing more labor and capital, respectively. If capital is a normal (non-inferior) factor, it is immediately apparent from equation (15) that the firm employs more capital than it would without the impending implementation of direct regulation, because both the scale and substitution effects are positive. Whether the firm employs more or less labor (if labor also is a normal factor) in the rent seeking case than in the free competition case, however, depends on whether the positive scale effect dominates the negative substitution effect on labor. Finally, it should be remarked that there is no scale effect if the quota in period 2 is independent of $y_1^i (\partial g^i / \partial y_1^i = 0)$. The findings so far are summarized in result 1:

> **Result 1:** Rent seeking as a response to impending regulation can have two effects on firms participating in the exploitation of the natural resource. An inefficient scale is chosen if future production quotas depend positively on current production. Additionally, the input mix will be inefficient if future quotas depend directly upon the employment of factors of production.

In addition to the two effects in result 1, it is conceivable that participating firms' reaction to impending regulation can reduce the actual number of participants in the industry compared to the numbers of firms which would have chosen to participate if no rent seeking was undertaken. The thought here is that rent-seeking behaviour leads to scale and input-mix inefficiency which reduce firms' net present values. If this net present value is sufficiently reduced, then the firm will exit the market. To examine this effect, we will now simplify the analysis further by assuming that all firms are identical. In relation to the model, this means that they have a common production function $F(L_t^i, K_t^i)$, $i = 1, \ldots, N$, $t = 1,2$. We focus on the symmetric equilibrium in which all firms take the same actions. Using the quota allocation rule in equation (3), one can determine the profit of one of the firms in the second period of a symmetric equilibrium as $\pi_2\{\bar{y}_2[F(L_1, K_1), K_1, N, Y], w, c\}$. The present value of a firm's two-period profit can thus be written as:

$$V = F(L_1, K_1) - wL_1 - cK_1 + \delta\pi_2\left\{\bar{y}_2\left[F(L_1, K_1), K_1, N, Y\right], w, c\right\}. \qquad (16)$$

Maximizing V with respect to L_1 and K_1 means that the first-order conditions in equation (11) can be written:

$$V_L = F_L - w + \delta\lambda \frac{\partial \bar{y}_2}{\partial y_1} F_L = 0, \quad V_K = F_K - c + \delta\lambda \frac{\partial \bar{y}_2}{\partial y_1} F_K + \delta\lambda \frac{\partial \bar{y}_2}{\partial K_1} = 0 \qquad (17)$$

where λ is the Lagrange multiplier on the firms' second period production constraint.[10]

In order to determine the number of agents endogenously, we introduce a minimum net present value condition:

$$V \geq Q \qquad (18)$$

[10] The second-order condition is given in the Appendix.

$Q \geq 0$ is supposed to be an exogenously determined minimum level of the net present value. We may think of Q as the net present value the firms would earn by the best alternative use of their initial resources. The maximum number of participating firms in the rent-seeking equilibrium when assuming open access to the industry is then endogenously determined by equation (18), interpreted as an equality at the same time as the conditions in equation (17) are satisfied.

As a benchmark, let us assume that public authority consider direct regulation which does not give rise to any rent-seeking behaviour (denote this case *NRS*). In order to achieve this, we may think of a situation where the public authorities distribute future quotas to all firms that choose to participate in period 1, but where past individual behavior does not count; *i.e.*, $[\partial g/\partial y_1 = \partial g/\partial K_1 = 0]$. For instance, such a neutral allocation rule (or lump-sum distribution of quotas) might be implemented by dividing the total quota equally among the N participating actors in period 1, no matter what their catches or capital investments were in that period. In this case, the optimal choice of inputs in period 1 is characterised by the condition that marginal profits in this period be equal to zero ($\partial \pi_1/\partial L_1 = \partial \pi_1/\partial K_1 = 0$). Denoting these optimal factor levels as L_1^{NRS} and K_1^{NRS}, the net present value of a firm's profit will be:

$$V^{NRS} = F(L_1^{NRS}, K_1^{NRS}) - wL_1^{NRS} - cK_1^{NRS} + \delta\left[\frac{Y}{N} - wL_2 - cK_2\right] \tag{19}$$

where L_2 and K_2 represent the least cost levels of producing the quota in period 2. The maximum number of participants in this case is found when $V^{NRS} = Q$. Denote this by N^{NRS}.

Now consider what happens in the case of rent seeking (*RS*), but assume that there are N^{NRS} participants. It can be seen from equation (17) that marginal profits in period 1 will be negative ($\partial \pi_1/\partial L_1 < 0$, $\partial \pi_1/\partial K_1 < 0$). However, since the equilibrium on which we focus is symmetric, the quota in period 2 will be Y/N^{NRS}; *i.e.*, the same quota as in case *NRS*. Comparing these cases, more resources are used to secure an identical quota when there is rent seeking; hence, the net present value of profit must fall below Q when N^{NRS} actors rent seek. In order to achieve the profit constraint in equation (18), the number of participants must be reduced below N^{NRS} when rent seeking is possible. Hence, an industry in which rent seeking occurs would be expected to have fewer participants than one where rent seeking is individually irrational. This result is stated below:

> **Result 2:** The number of participating firms is lower when the quota allocation rule leads to a rent-seeking mechanism (*RS*) compared to a situation where a neutral allocation is practised and, therefore, no rent seeking takes place.

This result is illustrated in figure 1, where the relationship is depicted between the present value of two-period profit (V) and the number of participating firms in the *RS* and *NRS* cases, *ceteris paribus*. The maximum number of firms in the two cases is determined where the falling V-curves cross the profit constraint, implying that each firm earns exactly Q in equilibrium. Earning above this level would give an incentive to other firms to enter the industry at the beginning of the first period. If expected earnings are below Q, then firms would exit the industry. Given that the V-curve in the *NRS* case lies above the V-curve in the *RS* case, it is seen that the number of participants is higher in *NRS* than in the *RS* case.

Before we proceed with our analysis, result 2 deserves some comment. Even though a lump-sum distribution of future rights to the natural resource means higher participation than allocation rules that make it advantageous for firms to rent seek, it

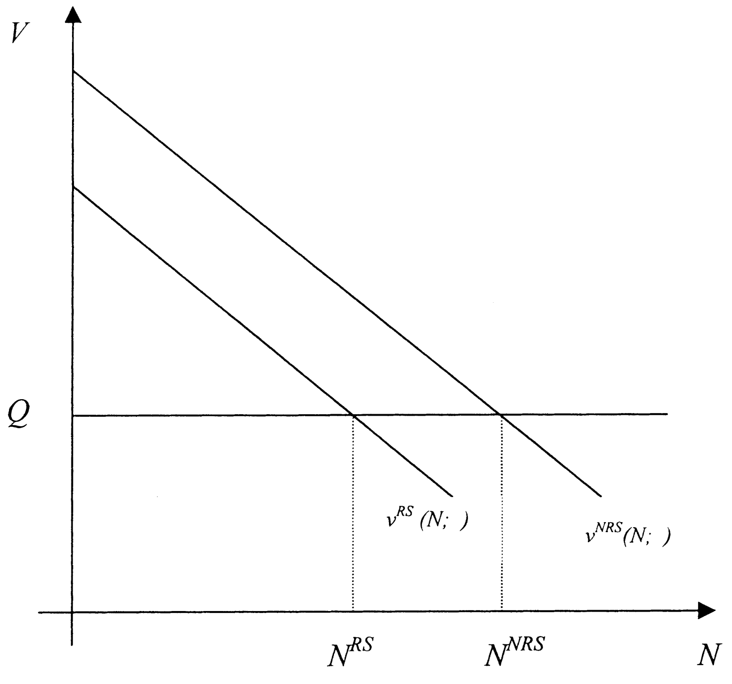

Figure 1. Optimal Number of Participants in the RS and NRS Cases

is not clear whether a continued, unregulated industry would give a lower or higher number of participating firms than cases where regulation is implemented. Future quota regulation can cause more or fewer participants in the industry than a continued, unregulated fully open-access fishery.[11] In order to see why, let us now take into account the possible effects following from changes in the stock of the natural resource from one period to the other. Suppose that the periods leading up to quota regulations are characterised by overfishing and a substantial decline in the stock of the natural resource. This implies relatively low marginal productivity for the inputs used, and therefore, relatively low resource rent in the industry. Hence, if no regulation is expected to be introduced, the number of firms finding it advantageous to operate might be relatively low. However, if the actors believe that quota regulation is going to be implemented in the near future, bringing the future total production down and the stock size upwards, the marginal productivity of inputs will increase. Comparing these two scenarios, there will be at least two relevant effects influencing the number of operating firms. First, there will be a negative direct effect on the number of firms due to the reduction in total harvest compared to the scenario where no regulation is introduced. Second, there will be a positive indirect effect on the number of participants stemming from higher marginal productivity of the input caused by the increase in stock size. Empirically, it is often found that implementing individual quotas based on historical production leads to an increase in industry participation, implying that the indirect positive effect dominates the direct negative effect. For instance, this seems to be the evidence from the Canadian and US Pacific halibut fisheries (Munro and Scott 1985; Stollery 1986; Homans and Wilen 1997) and in the Norwegian saithe fishery (see footnote 1).

[11] We are grateful to the journal's reviewers for making us aware of this point.

Returning to our model, it is also interesting to know how changes in the total allowed quota, discount factor, factor prices, and minimum present value of profit will influence the number of participating firms in our rent-seeking model. Based on an analysis of partial changes in these variables (given in the appendix), we state our third result:

> **Result 3:** The number of participants who compete for quota shares in the future of a common natural resource is increasing in the total allowed quota (Y) and the discount factor (δ), and is decreasing in factor prices (w and c) and the minimum present value of profit (Q).

The intuition behind these conclusions is quite simple. If firms accept lower earnings from their activity (Q falls), the number of participants who are able to reach this minimum will increase. If the total allowed quota increases (Y increases), the future advantage of obtaining a higher individual quota increases, which gives an incentive for new firms to enter the industry. As the discount factor rises (δ increases), future incomes count more, strengthening the incentives for new firms to enter the industry. However, when factor prices increase (w and/or c rise), there will be fewer active firms because the individual profits in both periods fall.

An increase in the total allowable quota, Y, or an increase in the discount factor, δ, is illustrated in figure 2, which is constructed in the same way as figure 1. If Y or δ increase, the V-curve shifts up from v^0 to v^1, and the number of participants increases. Correspondingly, higher factor prices shift the V-curve down, leading to fewer participants; a higher minimum present value of profit would shift up the Q-curve, which also reduces the number of active firms.

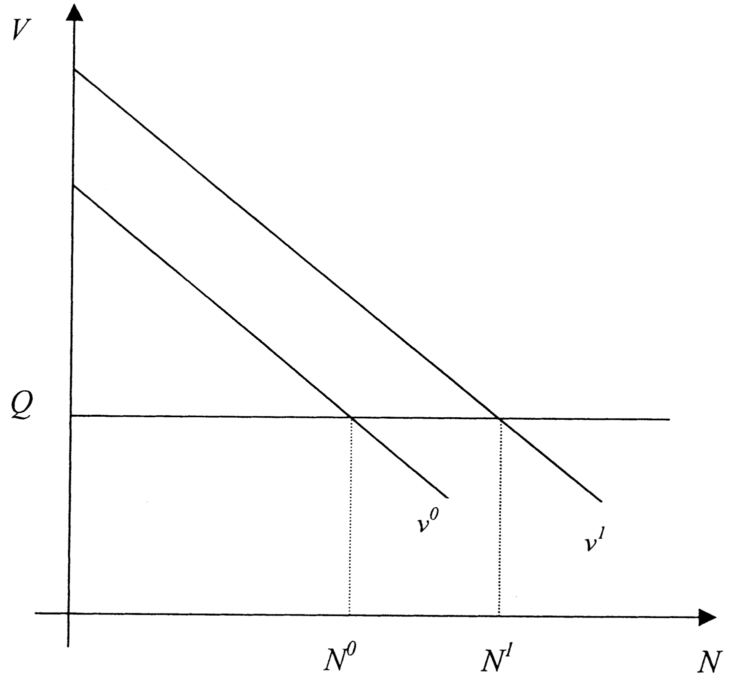

Figure 2. Impact on the Number of Participants from a Marginal Increase in TAC, Increase in the Discount Factor, or Decreases in Factor Prices

Conclusion

We have documented that several fishing industries around the world have been regulated by public authorities by determining TACs for different fish stocks. Furthermore, the total quota is often distributed to active firms based on actual choices of individual catches and inputs in the past. Based on a simple model in which the agents know this allocation mechanism, we have seen that it is individually advantageous for agents to attempt to influence the allocation through rent-seeking behaviour. The effects of the behaviour can be inefficient scale and inefficient input mix choices (result 1). Furthermore, we have seen that an allocation rule that induces rent seeking leads to fewer active firms than a neutral allocation rule where the authorities share the common natural resource without taking into account actual, past individual behaviour (result 2). We have also shown that the number of participants in the industry is increasing in total quota size and the discount factor, and decreasing in factor prices and the minimum present value required by the firms (result 3).

As mentioned above, our conclusions are based on a model where we have made several simplifying assumptions. The two most critical assumptions deserve comment. We have assumed that the firms have perfect information about the future total quota (Y), the actual quota allocation rule chosen by the public authority, and the exact point of time when regulation is implemented. As mentioned in the introduction, different groups of firms in the industry will have an incentive to spend resources in lobbying campaigns to secure their positions when future rights to the natural resource are going to be distributed. This leads to uncertainty as to what kind of distribution rule will finally be implemented, bringing uncertainty also to the future gains from rent seeking. This would very possibly lead to less rent seeking compared to a situation where relevant information concerning the future public regulation was known. For instance, suppose that the firms believe that the final solution is that the authorities share the total allowable quota in the future on individual average production and individual average levels of inputs, estimated on the basis of statistics for some unknown years in the past. Then, the firms' current ability to influence future individual quotas is weakened, and the possible advantage of rent seeking for a single year is reduced. Secondly, in our modelling we have ignored the dynamics of the renewable natural resource. This means that we have ignored that high total harvest in one period might reduce future growth in the natural stock or, in extreme cases, the stock of the natural resource as well. For instance, if rent seeking leads to a high total extraction in the first period, this may induce the public authorities to choose a low total allowable quota in the regulated period. If the firms are aware of this, they may behave less aggressively than in a situation where no such feedback mechanism exists. The reason is obvious. There will be a lower total quota to be shared by the participants, and, therefore, the possible gains from rent seeking will be reduced. Again, this is a mechanism which may weaken rent-seeking incentives.

Even though our analysis is based on several simplifying assumptions, and on others than explicitly commented on above, we believe that this paper points to an important issue that occurs in the practical regulation of common natural resources. The theoretical findings point out the problems of overutilization and overcapacity often found within industries based on common natural resources, and also when a public authority wants to implement quantitative regulations. However, further theoretical research concerning the type and size of possible rent-seeking mechanisms is necessary, as are empirical studies from different common natural resources.

References

Arnason, R. 1993. The Icelandic Individual Transferable Quota System: A Descriptive Account. *Marine Resource Economics* 8(3):201–18.

Averch, H., and L.L. Johnson. 1962. Behavior of the Firm Under Regulatory Constraint. *American Economic Review* 52:1052–69.

Bohm, P., and C.S. Russell. 1985. Comparative Analysis of Alternative Policy Instruments. *Handbook of Natural Resource and Energy Economics*, vol. I, A.V. Kneese and J.L. Sweeney, eds., Chap. 10. Amsterdam: North-Holland.

Boyce, J.R. 1992. Individual Transferable Quotas and Production Externalities in a Fishery. *Natural Resource Modeling* 6:385–408.

Fiskerbladet. 1999. Newspaper article. September 10 (in Norwegian). Harstad.

Gauvin, J.R., J.M. Ward, and E.E. Burgess. 1994. Description and Evaluation of the Wreckfish (*Polyprion americanus*) Fishery under Individual Transferable Quotas. *Marine Resource Economics* 9(2):99–118.

Godø, O.R. 1999. Newspaper article in *Fiskeribladet*, September 10 (in Norwegian). Harstad.

Grafton, R.Q. 1995. Rent Capture in a Right-Based Fishery. *Journal of Environmental Economics and Management* 28:48–67.

___. 1996. Individual Transferable Quotas: Theory and Practice. *Reviews in Fish Biology and Fisheries* 6:5–20.

Hardin, G. 1968. The Tragedy of the Commons. *Science* 162:16–30.

Homans, F.R., and J.E. Wilen. 1997. A Model of Regulated Open Access Resource Use. *Journal of Environmental Economics and Management* 32:1–27.

Krueger, A.O. 1974. The Political Economy of the Rent-Seeking Society. *American Economic Review* 64:291–303.

Lindner, R.K., H.F. Cambell, and G.F. Bevin. 1992. Rent Generation During the Transition to a Managed Fishery: The Case of the New Zealand ITQ System. *Marine Resource Economics* 7:229–48.

Munro, G.R., and A.D. Scott. 1985. The Economics of Fisheries Management. *Handbook of Natural Resource and Energy Economics*, vol. II, A.V. Kneese and J.L. Sweeney, eds., Chap. 14. Amsterdam: North-Holland.

Nordlys. 1999. Newspaper article, 9th June. (In Norwegian). Tromsø.

Norwegian Directorate of Fisheries. 1990. Guidelines for the Regulation of Cod Fishing with Conventional Gear North of 62’N. (In Norwegian). J-11-90. Bergen.

___. 1999. Changes in the Guidelines for the Regulation of Saithe Fishing North of 62’N. (In Norwegian). J-79-99. Bergen.

Norwegian Fishing Vessel Owners’ Association. 1999. Regulation of the Greenland Halibut Fishery, (In Norwegian). Note submitted to the Norwegian Department of Fisheries, 16th August.

Stollery, K. 1986. A Short-Run Model of Capital Stuffing in the Pacific Halibut Fishery. *Marine Resource Economics* 3(2):137–53.

Weninger, Q., and R.E. Just. 1997. An Analysis of Transition from Limited Entry to Transferable Quota: Non-Marshallian Principles for Fisheries Management. *Natural Resource Modeling* 10:53–83.

Appendix

In this appendix, we prove result 3. The second order condition for a profit maximum of equation (17) is:

$$D = V_{LL}V_{KK} - (V_{KL})^2 > 0 \tag{A1}$$

where:

$$V_{LL} = F_{LL} + \delta \frac{\partial\lambda}{\partial\bar{y}_2}\left(\frac{\partial\bar{y}_2}{\partial y_1}\right)^2 (F_L)^2 + \delta\lambda \frac{\partial^2\bar{y}_2}{(\partial y_1)^2}(F_L)^2 + \delta\lambda\frac{\partial\bar{y}_2}{\partial y_1}F_{LL} \tag{A2}$$

$$V_{KK} = F_{KK} + \delta \frac{\partial\lambda}{\partial\bar{y}_2}\left(\frac{\partial\bar{y}_2}{\partial y_1}\right)^2 (F_K)^2 + \delta\lambda \frac{\partial^2\bar{y}_2}{(\partial y_1)^2}(F_K)^2 + \delta\lambda\frac{\partial\bar{y}_2}{\partial y_1}F_{KK}$$

$$+ 2\delta\frac{\partial\lambda}{\partial\bar{y}_2}\frac{\partial\bar{y}_2}{\partial y_1}\frac{\partial\bar{y}_2}{\partial K_1}F_K + 2\delta\lambda\frac{\partial^2\bar{y}_2}{\partial y_1\partial K_1}F_K + \delta\frac{\partial\lambda}{\partial\bar{y}_2}\left(\frac{\partial\bar{y}_2}{\partial K_1}\right)^2 + \delta\lambda\frac{\partial^2\bar{y}_2}{(\partial K_1)^2}$$

$$V_{LK} = V_{KL} = F_{LK} + \delta\frac{\partial\lambda}{\partial\bar{y}_2}\left(\frac{\partial\bar{y}_2}{\partial y_1}\right)^2 F_K F_L + \delta\lambda\frac{\partial^2\bar{y}_2}{(\partial y_1)^2}F_K F_L$$

$$+ \delta\lambda\frac{\partial\bar{y}_2}{\partial y_1}F_{LK} + \delta\frac{\partial\lambda}{\partial\bar{y}_2}\frac{\partial\bar{y}_2}{\partial y_1}\frac{\partial\bar{y}_2}{\partial K_1}F_L + \delta\lambda\frac{\partial^2\bar{y}_2}{\partial y_1\partial K_1}F_L.$$

Assuming that equation (18) in the text holds as an equality, we can totally differentiate this expression using equation (16) to obtain:

$$F_L dL_1 + F_K dK_1 - w dL_1 - c dK_1 - L_1 dw \tag{A3}$$

$$- K_1 dc + \delta\lambda\frac{\partial\bar{y}_2}{\partial y_1}F_L dL_1 + \delta\lambda\frac{\partial\bar{y}_2}{\partial y_1}F_K dK_1 + \delta\lambda\frac{\partial\bar{y}_2}{\partial K_1}dK_1$$

$$+ \delta\lambda\frac{\partial\bar{y}_2}{\partial N}dN + \delta\lambda\frac{\partial\bar{y}_2}{\partial Y}dY - \delta L_2 dw - \delta K_2 dc + \pi_2 d\delta - dQ = 0.$$

Using equation (17) we can rewrite equation (A3) as:

$$\delta\lambda\frac{\partial\bar{y}_2}{\partial N}dN + \delta\lambda\frac{\partial\bar{y}_2}{\partial Y}dY - (L_1 + \delta L_2)dw \tag{A4}$$

$$- (K_2 + \delta K_2)dc + \pi_2 d\delta - dQ = 0$$

From equation (A4) it follows that:

$$\frac{\partial N}{\partial Y} = -\frac{\dfrac{\partial \bar{y}_2}{\partial Y}}{\dfrac{\partial \bar{y}_2}{\partial N}} > 0,\ \frac{\partial N}{\partial w} = \frac{L_1 + \delta L_2}{\dfrac{\partial \bar{y}_2}{\partial N}} < 0,\ \frac{\partial N}{\partial c} = \frac{K_1 + \delta K_2}{\dfrac{\partial \bar{y}_2}{\partial N}} < 0 \tag{A5}$$

$$\frac{\partial N}{\partial \delta} = -\frac{\pi_2}{\dfrac{\partial \bar{y}_2}{\partial N}} > 0,\ \frac{\partial N}{\partial Q} = \frac{1}{\dfrac{\partial \bar{y}_2}{\partial N}} < 0$$

where we have used the fact that

$$\frac{\partial \bar{y}_2}{\partial N} = -\frac{Y}{N^2} < 0, \frac{\partial \bar{y}_2}{\partial Y} = \frac{1}{N} > 0$$

at the symmetric equilibrium.

Result 3 can now be seen directly from equation (A5).