Marine Resource Economics, Volume 22, pp. 363–371
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0738-1360/00 $3.00 + .00

Taxes, ITQs, Investments, and Revenue Sharing

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Abstract *There is a presumption that individual transferable quotas (ITQs) will provide incentives to invest optimally in fishing boats. This paper shows that this is not true when the crew is paid a share of the catch value instead of a parametric wage. This system of remuneration distorts investment incentives in an ITQ system of fisheries management and leads to overinvestment, but on a much smaller scale than open access. This can be corrected with a tax on fish landings, but not with a tax on quota holdings.*

Key words Fisheries economics, fishing capacity, crew share.

JEL Classification Codes Q22, Q28, H23.

Introduction

The lay system of remuneration is used extensively in fisheries. Under this system, fishermen are paid a share of the catch value, perhaps after subtracting some costs, rather than a fixed wage. There may, however, also be a fixed wage element, so that fishermen get a share of the catch value in addition to the fixed wage, or a fixed wage as a minimum in case the fishing trip turns out to be unrewarding. Recently, McConnell and Price (2006) examined the rationale and the implications of this system compared to a fixed wage. They argue that the lay system is primarily an optimal incentive contract. Matthiasson (1999) also discussed the lay system in a similar spirit, but in a less general setting, while earlier explanations saw the lay system primarily as a risk sharing device (Sutinen 1979).

Whatever the rationale for the lay system, it can be shown to have consequences for investment incentives in ITQ fisheries. This paper expands the analysis of an earlier paper, where it was shown that revenue sharing would distort investment decisions in an ITQ fishery with uncertain catch quotas, resulting in excessive investments in fishing boats (Hannesson 2000). It was noted that a crew share in excess of what would correspond to equilibrium in the labor market would correct for this, but the discussion of corrective measures was otherwise left open.

Over the last few years, there has been a revival of the discussion of taxes as corrective measures in fisheries management. This was initiated by Weitzman (2002) and followed up by Jensen and Vestergaard (2003) and Hannesson and Kennedy (2005). The focal point has been whether and when taxes could be used instead of catch quotas as instruments to control fish stocks. None of these papers explicitly considered investments in fishing boats. This could be an important omission, because investment decisions in fisheries where stocks vary for reasons other

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than fishing are distinctly different from decisions about fishing effort to be applied or the catch volume to be taken within any given period of time (Hannesson 1987). This paper examines whether a tax on fish landings or quota holdings would correct for the tendency to overinvest in fishing boats in ITQ fisheries with revenue sharing. It is found that a tax on landings would do so, while a tax on quota holdings would not.

The Model

For stocks controlled by total allowable catches (TACs), the TACs are determined with reference to the status of the stocks at the time the TAC is set (usually once a year). Fish stock abundance is determined not just by past catches but also by environmental fluctuations affecting stock growth, both growth of individual fish in the stock and recruitment of young fish to the stock. The TACs, therefore, fluctuate considerably, due to fluctuations in environmental conditions. The focus here is on the implications of these fluctuations; so for simplicity, it is assumed that the total permitted catch (Q) is a purely random variable with the probability density function $f(Q)$. This ignores the fact that the said fluctuations are typically serially correlated, but omitting this and concentrating on the random element is not misleading in this context, as the time profile of investment is not an issue.

For a fleet consisting of identical boats representing the cost-minimizing technology at given factor prices, the expected annual rent (V) from the fishery will be (Hannesson 1987, 2000):

$$EV = (p - c)\left\{\int_{Q_{\min}}^{kN} Qf(Q)dQ + kN\left[1 - F(kN)\right]\right\} - (\delta + r)KN - WN, \qquad (1)$$

where p is the price of fish, c is the operating cost per unit of fish, k is the catch per boat if used at full capacity, N is the number of boats, δ is the rate of boat depreciation, r is the rate of return on foregone investment, K is the boat cost, and W is the opportunity cost of labor used on each boat. For simplicity, the so-called stock effect is ignored so that c and k are independent of the size of the exploited fish stock. With k constant, the upper limit to what the fleet can catch is kN, so the total catch will be $\min(Q, kN)$. $F(.)$ is the cumulative density function, so $1 - F(kN)$ is the probability of $Q \geq kN$.

Maximizing the expected rent implies:

$$(p - c)k\left[1 - F(kN^o)\right] = (\delta + r)K + W, \qquad (2)$$

where N^o is the optimal (*i.e.*, rent-maximizing) number of boats.

When fishermen are paid a share $1 - s$ of the (gross) catch value, instead of a given wage, the expected annual revenue (R) accruing to each boat owner will be:

$$ER = (ps - c)\left\{\int_{Q_{\min}}^{kN} \frac{Q}{N} f(Q)dQ + k\left[1 - F(kN)\right]\right\} - (\delta + r)K. \qquad (3)$$

Equilibrium investment can be found by considering a boat owner whose boat needs replacement. The boat owner will compare the annual revenue he would obtain from renewing his boat and the annual revenue he would get by renting out or selling his quota to those who remain in the fishery. The willingness of the latter to pay for quotas they rent or buy is limited by the increased revenue they would be able to obtain by the additional quota. A boat owner will earn additional revenue from additional quota only when the quota he has from before does not allow him the full use of his boat. In fisheries with TACs that vary from year to year, quotas are usually determined as shares of the TAC.[1] Hence, the smaller the TAC share that a boat owner has, the more likely it is that he will be able to use an additional share. Those with the smallest shares will, therefore, be willing to pay the highest price for an additional share. In a fishery where all hold the same quotas, the value of the quota sold or rented out by a boat owner who chooses not to renew his boat will be maximized if it is sold or rented out in equal amounts to all remaining boat owners. Assuming a quota market that accomplishes this greatly simplifies the analysis, but it is not far fetched to imagine a market that could operate like that, renting out or selling portions of the quota no longer used by a boat owner to the highest bidder.

With this assumption about the quota market, we find the willingness to pay for the quota of a boat that will not be renewed as follows. If one boat leaves the fishery and its quota is distributed in equal amounts to those that remain, the expected revenue of each remaining boat will increase by (the negative of) the derivative of equation (3) with respect to N, treating the number of boats as a continuous variable for simplicity. Multiplying by N gives the total willingness to pay:

$$-N\frac{\partial ER}{\partial N} = (ps - c)\int_{Q_{\min}}^{kN}\frac{Q}{N}f(Q)dQ. \tag{4}$$

This total willingness to pay would, in effective quota markets, be equal to what a boat owner could get for renting out his quota (or the annualized revenue from selling it once and for all). In equilibrium this would be equal to the net revenue the boat owner could get from renewing his boat, which is given by equation (3). Hence, setting expression (4) equal to (3) gives an equation for the equilibrium number of boats in an ITQ fishery:

$$(ps - c)k\left[1 - F(kN)\right] = (\delta + r)K. \tag{5}$$

This determines N, the number of boats in the fishery, for given values of the remaining arguments in equation (5), which are determined by technology, nature, or market forces.

If the ITQs under a lay system are to result in an optimum number of boats, equation (5) must have the same solution as equation (2). This would imply:

$$p(1 - s)k\left[1 - F(kN)\right] = W. \tag{6}$$

This is not compatible with equilibrium in the labor market. The left-hand side is the

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[1] Determining individual quotas in this way has the advantage of automatically adjusting the individual quotas to the TAC. It is, of course, possible to do things differently. In the first years after implementing ITQs in the orange roughy fishery, New Zealand used fixed tonnages with the intention of buying back quotas when the TAC was small and selling additional quotas when the TAC was large. It turned out that the prospects for the orange roughy stocks had been forecast much too optimistically, and this method was soon abandoned and replaced by share quotas.

remuneration of the crew when the total quota is sufficiently large for all boats to be fully used, but the crew will also obtain income when the quotas are smaller than that. The expected remuneration (*EM*) of the crew is:

$$EM = p(1 - s)\left\{\int_{Q_{\min}}^{kN} \frac{Q}{N} f(Q)dQ + k\left[1 - F(kN)\right]\right\}. \tag{7}$$

If the labor market is sufficiently competitive, the expected remuneration of fishermen will be equal to the opportunity wage, so equation (6) cannot hold. Instead, the left-hand side will be smaller than the right-hand side, implying that *N* is greater than the optimal value.

The reason for the excessive investment in fishing boats is that the revenue accruing to a boat owner who invests in a new boat and who has already factored in the cost of his crew, would not be fully recovered by other boat owners who rent the quota, as they have to share some of it with the fishermen they hire. In the globally optimal solution, it does not matter whether a boat is added to the fishery or its quota distributed among the existing boats; the revenue from investing in a new boat is the same as the revenue realized by distributing the quota of that boat efficiently (*i.e.*, equally) among all remaining boats. This solution would be realized if the fishermen were paid a given wage independent of how much they catch (Hannesson 2000). In that case, the boat owner would keep all the additional revenue resulting from additional quota. Under the lay system we get an overinvestment in boats. Increasing the number of boats beyond the optimal level lowers the revenue of each boat owner and raises the revenue from distributing the quota of a marginal boat to the remaining boats, with an equilibrium being reached where the revenue kept by the remaining boat owners is equal to the revenue of the marginal boat owner.

For optimal investment to be obtained under the lay system, $EM > W$; *i.e.*, fishermen's expected income would have to be greater than the opportunity cost of labor. In other words, fishermen would have to possess some market power giving them a greater income than the opportunity cost of their labor. This is conceivable. In countries with highly organized labor markets, the share parameter is an outcome of negotiations between fishermen's unions and boat owners' organizations. Even if labor market conditions are likely to influence the outcomes of such negotiations, they could do so imperfectly and with a considerable time lag. In such centralized labor markets the share parameter is likely to be the same for all, except for different qualifications and roles of different crew members. Under decentralized conditions the lay system can still evolve, as indeed it did in earlier times. As pointed out by McConnell and Price (2006), if the share parameter differs among boats, it could be an additional source of inefficiency under an ITQ system.

It may be noted that if the boat owners could set the share parameter unilaterally, they would presumably set it as low as possible. With mobility in the labor market, they would not set it lower than what would make the expected remuneration of labor equal to its opportunity wage, as otherwise they would get no crew. This is precisely what is incompatible with optimal investment. For that we need equation (6), which is incompatible with $EM = W$ (cf. [7]). This presumes that the share parameter is fixed irrespective of the TAC. If the boat owners could change it at will, it could be varied with the TAC, in which case the crew would always get just the competitive wage and no distortion of investment incentives would occur.

Figure 1 compares optimal investment in fishing boats, according to equation (2), with the equilibrium investment in an ITQ fishery with a share system where $EM = W$ (equation [5]). This represents equilibrium in a competitive labor market;

fishermen's expected income would be equal to the opportunity cost of their labor. The example on which the figure is based is explained in the Appendix. The figure shows how the number of boats increases with the price of fish, but in an ITQ fishery with a revenue sharing system, it is always greater than optimal. As the price increases towards infinity, the number of boats increases to the number needed to take the maximum catch quota (100).

Taxes

Figure 1 suggests that a tax on landings would reduce investment in boats and bring about an optimal level of investment, as the size of the fleet in the ITQ fishery falls with the price of fish. Note that if the price in figure 1 is interpreted as price after tax, the fishermen are implicitly assumed to be paid a share of the catch value after tax, as the curve in figure 1 takes into account equilibrium in the labor market.

With a tax on the fish landings, the parameter p in the above equations (except [1] and [2]) is replaced by $p(1 - t)$, where t is the tax rate. Equation (5) becomes:

$$\left[p(1 - t)s - c\right]k\left[1 - F(kN)\right] = (\delta + r)K. \tag{5'}$$

It is now possible that ITQs will result in an optimal number of boats. If equations (2) and (5′) have the same solution, we get:

$$p\left[1 - s(1 - t)\right]k\left[1 - F(kN^o)\right] = W. \tag{6'}$$

When fishermen get a share of the revenues after tax, equation (7) becomes:

$$EM = p(1 - t)(1 - s)\left\{\int_{Q_{\min}}^{kN} \frac{Q}{N} f(Q)dQ + k\left[1 - F(kN)\right]\right\}. \tag{7'}$$

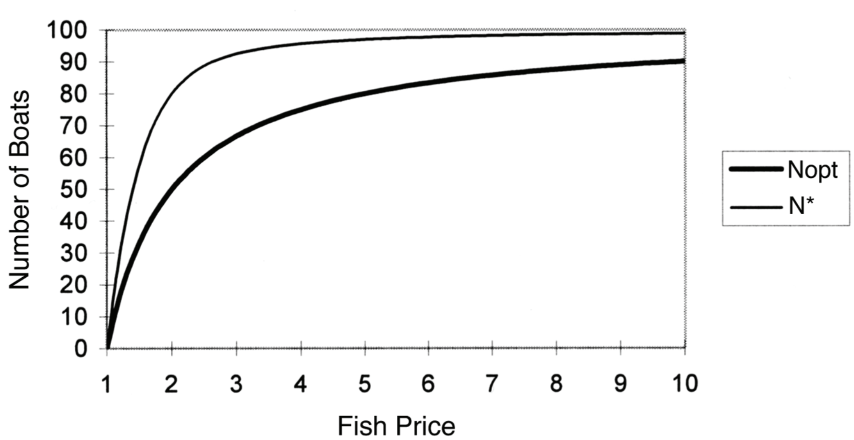

Figure 1. Number of Boats (N^*) in an ITQ-controlled Fishery where Fishermen Receive a Share of the Revenue from Fishing versus Optimal Number (Nopt) of Boats

Setting W equal to EM implies:

$$ptk\left[1 - F(kN^o)\right] = p(1 - t)(1 - s)\int_{Q_{\min}}^{kN^o} \frac{Q}{N} f(Q)dQ. \tag{8}$$

Clearly, it is possible to find a combination of a tax and a share parameter that provides incentives to invest optimally while being consistent with equilibrium in the labor market (solving equations [6′] and [8] simultaneously). Figure 2 shows the tax rate that would ensure optimal investment, as a function of gross market price. The model behind this figure is explained in the Appendix.

It does not matter whether or not the crew share is calculated on the basis of the price before or after tax, but needless to say, this has implications for which share is compatible with the labor market equilibrium. If the crew share is calculated on the basis of the pre-tax price, we get instead of equations (5′) and (6′):

$$\left[p(s - t) - c\right]k\left[1 - F(kN)\right] = (\delta + r)K, \tag{5''}$$

$$p(1 - s + t)k\left[1 - F(kN^o)\right] = W, \tag{6''}$$

while equation (7) is now valid for EM. Setting EM equal to W gives:

$$ptk\left[1 - F(kN^o)\right] = p(1 - s)\int_{Q_{\min}}^{kN^o} \frac{Q}{N} f(Q)dQ, \tag{8'}$$

and again the optimal t and s can be found from solving equations (6″) and (8′) si-

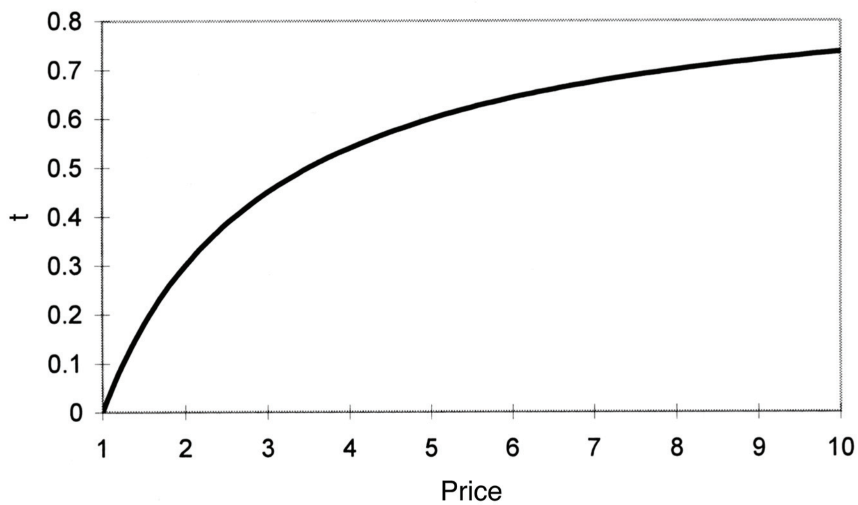

Figure 2. Landings Tax Rate that would Ensure Optimum Investment

multaneously. The optimal tax rate is the same whether or not the fishermen's remuneration is calculated on the basis of pre- or post-tax price, with the share parameter, s, absorbing the difference between the two cases. Figure 3 shows the boat owners' share of the catch value in the two cases. The fishermen's share $(1 - s)$ of the catch value is, of course, lower in case their income is calculated on the basis of the pre-tax price.

The corrective tax is the same in both cases, which can be seen as follows. If we want to achieve the same investment and labor market equilibrium in both cases, the price received by boat owners and fishermen, respectively, must be the same in both cases. Let t and s, versus t^* and s^*, denote the tax rate and the share parameter in the two cases. Identical prices to fishermen and boat owners in both cases implies:

$$p(1 - t)(1 - s) = p(1 - s^*) \tag{9a}$$

$$p(1 - t)s = ps^* - pt^*. \tag{9b}$$

Adding equations (9a) and (9b) implies $1 - t = 1 - t^*$.

In contrast to a tax on landings, a tax on quota holdings would not work as an instrument to achieve optimal investment in an ITQ fishery. With a tax on quota holdings, the expected annual revenue of a boat owner would be:

$$ER = (ps - c)\left\{\int_{Q_{\min}}^{kN} \frac{Q}{N} f(Q)dQ + k\left[1 - F(kN)\right]\right\} - (\delta + r)K - \frac{t}{N}. \tag{3'}$$

The last term in this expression is the tax on quota holdings. It is assumed that the quota system is of the share quota variety, and with all boat owners holding equal quotas, the holdings of each will be $1/N$. Equation (4) in this case becomes:

$$-N\frac{\partial ER}{\partial N} = (ps - c)\int_{Q_{\min}}^{kN} \frac{Q}{N} f(Q)dQ - \frac{t}{N}. \tag{4'}$$

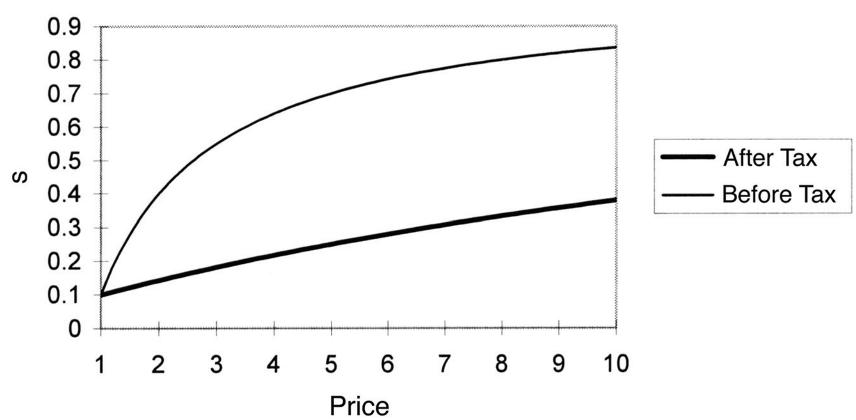

Figure 3. Boat Owner Share of Revenues (s) when Fishermen's Remuneration is Calculated from Revenue Before versus After Tax

We see that putting equation (3′) equal to equation (4′) nets out the quota tax term, and we end up with equation (5), as in the absence of any tax. A corollary of this is that a tax on quota holdings would be neutral, so it would not cause inoptimal investment if the economic system is otherwise without distortions of investment incentives.

Conclusion

Open-access fisheries are known to result in wasteful competition, not least in the form of excessive investment in fishing boats. As ITQs provide incentives to maximize the value of a given catch quota and minimize the cost of taking it, the presumption is that this would result in an optimal investment in fishing boats. This paper has demonstrated that this will not occur if the fishermen are paid a share of the revenues rather than a fixed wage.

It is not suggested that the investment equilibrium under an ITQ system with share payments need be similar to the open-access equilibrium; indeed the presumption is that the major difference is between the ITQ equilibrium and the open-access equilibrium (see Hannesson 2000), and that an ITQ system will in any case be a major improvement over an open-access system. Neither is it suggested that a fine tuning of the investment decisions through a landings tax will be easy, especially in the presence of imperfect information about costs. What is suggested is that landings taxes in ITQ fisheries will not necessarily be distortive. On the contrary, they would improve the allocation of resources in a share system, up to a point. Taxes on quota holdings would not correct for this, but would not be distortive.

Finally, note that the above results depend on the fixity of the share parameter s. If it were continually revised to reflect equilibrium in the labor market, the investment incentives would not be distorted. The fishermen would then always get the opportunity cost of their labor and no more. The share system could still serve the purpose of an incentive contract to ensure that fishermen exert the necessary effort to obtain an income equal to their opportunity wage.

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Appendix

Let the catch quota be evenly distributed between a minimum $Q_{min} = 0$ and $Q_{max} = 100$, so that:

$$f(Q) = \frac{1}{100}, \quad F(Q) = \frac{Q}{100}. \tag{A1}$$

Ignoring unit operating cost, c, for simplicity, and setting $k = 1$, the condition for maximizing expected annual rent (equation [2]) becomes:

$$p\left[1 - \frac{N^o}{100}\right] = (r + \delta)K + W. \tag{A2}$$

This equation gives the optimal number of boats (N^o) in figure 1, where we have set $(r + \delta)K = 0.1$ and $W = 0.9$. These values will be used throughout.

The equilibrium number of boats (N^*) in an ITQ regime is given by equation (5), which is:

$$ps\left[1 - \frac{N^*}{100}\right] = (r + \delta)K. \tag{A3}$$

The parameter, s, must be compatible with equilibrium in the labor market, $EM = W$. From equation (7) we get:

$$s = \sqrt{\frac{1}{4}\left(\frac{2W + (\delta + r)K}{p} - 1\right)^2 + \frac{(\delta + r)K}{p}} - \frac{1}{2}\left(\frac{2W + (\delta + r)K}{p} - 1\right). \tag{A4}$$

The resulting N^* is shown in figure 1.

Equation (6') is:

$$p[1 - s(1 - t)]\left[1 - \frac{N^o}{100}\right] = W, \tag{A5}$$

and equation (8) is:

$$ptk\left[1 - \frac{N^0}{100}\right] = p(1 - t)(1 - s)\left[\frac{N^o}{200}\right]. \tag{A6}$$

Solving equations (A5) and (A6) for t and s yields the tax rate shown in figure 2. The s is shown in figure 3. The solution of equations (6′′) and (8′) is analogous, with the resulting s also shown in figure 3.