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Subsidies, buybacks, and sustainable fisheries

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Abstract

Most fisheries subsidies, which on a worldwide scale are immense, are probably detrimental to resource conservation. However, payments used to buy out excess fishing capacity are often represented as useful subsidies, on the grounds that overcapacity encourages overfishing and causes economic waste. Some commentators, on the other hand, assert that most buyback subsidies are ineffective because additional capacity tends to seep back into the fishery over time. In this paper we take the latter argument further, and demonstrate that buyback subsidies, if they come to be anticipated by fishermen, will generally have a negative effect on economic performance and resource conservation. Consequently, buyback subsidies are perhaps over-rated as a management tool.

Keywords: Fisheries; Subsidies; Overcapacity; Buyback programs; Non-malleable capital; Human capital

1. Introduction

Two important issues in fisheries management are the use of subsidies, and excess fleet capacity. These issues are combined in the question of buyback, or decommissioning subsidies, used to

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reduce fishing capacity. Such buyback subsidies have been widely employed. For example, Munro and Sumaila [25] estimated that approximately one-third of the total fisheries subsidies of US $2.5 billion per annum paid by governments for North Atlantic fisheries were accounted for by buyback subsidies. More recently the European Union has proposed an additional €272 million be spent on vessel decommissioning [23]. In another area, in 2004 the US government spent US $100 million to buy out the licenses of 28 of the approximately 260 vessels in the Alaskan snow crab fishery.

World fisheries subsidies are immense, and many of these are seriously detrimental to resource conservation and management (e.g., [11,25–28,30]). Also, overcapacity in fisheries is widespread, and is thought to contribute to management difficulties [14]. In its 1999 International Plan of Action for the Management of Fishing Capacity, the United Nations Food and Agriculture Organization (FAO) states that "…excessive fishing capacity … contributes substantially to overfishing…and [causes] significant economic waste" [10]. Vessel owners, having no viable alternative uses for their vessels, often resist attempts to rebuild depleted fish stocks through the reduction of catch rates. Buyback subsidies, it is suggested, can lower this barrier to conservation [24].

In spite of their current popularity, buyback subsidies have several severe disadvantages. First, an expensive buyback program may at best remove only a marginal portion of the fishing fleet, as less efficient vessels depart while "high-liners" remain in the fishery. Consequently, actual fishing capacity may not decline to a notable degree. Second, upon completion of the buybacks, additional capacity may gradually seep back into the fishery through upgrading of the remaining fleet [15], necessitating a further round of buybacks [31]. For example, Canada's Pacific salmon fisheries recently experienced their third buyback program.

A third disadvantage centers on the possibility that buybacks may come to be anticipated by fishermen. This is an instance of the well-known inconsistency of optimal plans [20]. Specifically, once it becomes known that a government is in the habit of buying up excess capacity, fishermen will be motivated to acquire vessels, even if the prospects of making a normal return on their investments are low. Thus the anticipation of future buybacks can, and doubtlessly does, lead to greater overcapacity than would otherwise occur.

To analyze the problem of anticipated buybacks, we will consider a model of an open-access fishery that initially develops without any form of management, but ultimately becomes subject to a management program designed to rebuild the fish stock to a sustained optimal level.

2. Buybacks and subsidies

We consider a fishery that has not previously been exploited, for example, one involving a newly discovered stock of fish. At time $t = 0$ fleet capacity is built up and fishing commences. Initially there is no attempt to manage the fishery.[1]

[1] See Clark and Munro [5] and Munro and Sumaila [26] for models of buyback subsidies under regulated open access [16].

The model equations are:

$$\frac{dx}{dt} = F(x) - qEx, \tag{1}$$

$$0 \leqslant E(t) \leqslant K, \tag{2}$$

$$\frac{dK}{dt} = I - \gamma K, \tag{3}$$

$$\pi = (pqx - c)E - c_f(I), \tag{4}$$

where x denotes the biomass, $F(x)$ the natural rate of growth of the biomass, E the rate of fishing effort, q the catchability coefficient, and K the stock of fleet capital measured in terms of "standardized" vessels. The variable I denotes the rate of investment in fleet capital and γ the rate of depreciation of such capital. The price of harvested fish is denoted by p, while c denotes unit operating costs, both of which are assumed to be constant.

Net revenue flow $\pi(t)$ consists of net operating revenue $(pqx - c)E(t)$ minus investment costs $c_f(I)$. It is assumed that:

$$c_f(I) = \begin{cases} c_1 I & \text{if} \quad I > 0, \\ c_s I & \text{if} \quad I < 0, \end{cases} \tag{5}$$

(and $c_f(0) = 0$). Here c_1 is the unit purchase price of capital, i.e., the cost of one vessel, and c_s is the scrap or resale value of one vessel.

In Clark et al. [3], fleet capital is deemed to be perfectly malleable if: $c_1 = c_s$; perfectly non-malleable if: $c_s = 0$ and $\gamma = 0$; and quasi-malleable if $\gamma > 0$, or $0 < c_s < c_1$. For the discussion to follow, we shall assume, for ease of exposition, that fleet capital is perfectly non-malleable. Hence

$$0 \leqslant I(t) \leqslant +\infty. \tag{6}$$

The case $I(t) = +\infty$ allows for a possible instantaneous jump in K.

Clark et al. assume implicitly that all other inputs (e.g., labor) are perfectly malleable. We shall adopt this assumption, until the final section of the paper, where we speculate on the consequences of human capital being non-malleable, in the context of developing country fisheries.

The characterization and measurement of fishing capacity involve various complexities [19], which we ignore in the present discussion. According to Eq. (2), fishing capacity (or fleet capital) is here represented as the maximum effort level that the fleet is capable of exerting. This simple characterization captures the main features of optimal capacity and excess capacity.

The flow of net operating profits is

$$\pi_{\text{op}}(t) = (p - c_{\text{var}}(x))qx(t)E(t), \tag{7}$$

where $c_{\text{var}}(x)$ denotes unit variable costs of harvesting:

$$c_{\text{var}} = \frac{c}{qx}. \tag{8}$$

If $\pi_{\text{op}}(t) > 0$, we can assume that in the unregulated fishery the existing fleet will be used to full capacity, i.e., $E(t) = K(t)$. There will, however, be a biomass level at which $\pi_{\text{op}}(t) = 0$, which we shall denote $x(t) = x_a^0$. The biomass x_a^0 is given by

$$p - c_{\text{var}}(x_a^0) = 0 \tag{9}$$

specifically, $x_a^0 = c/pq$; see Eq. (8). We can be certain that the resource would not fall below that level, since fleet operating profits would be negative at all biomass levels below x_a^0. We therefore have:

$$E(t) = \begin{cases} K(t) & \text{if} \quad x(t) > x_a^0, \\ 0 & \text{if} \quad x(t) < x_a^0. \end{cases} \tag{10}$$

The pure open-access equilibrium biomass level under the assumption of perfectly malleable capital (i.e., $c_s = c_1$), denoted as x_b^0, is given by

$$p - c_{\text{total}}(x_b^0) = 0, \tag{11}$$

where $c_{\text{total}}(x)$ is the unit total cost of harvesting:

$$c_{\text{total}}(x) = \frac{c_{\text{total}}}{qx}, \tag{12}$$

where $c_{\text{total}} = c + \delta c_1$, and δ is the discount rate. The biomass level x_b^0 (specifically, $x_b^0 = c_{\text{total}}/pq = (c + \delta c_1)/pq$) is simply the bionomic equilibrium, familiar from standard fisheries economics literature [13].[2]

McKelvey [21] has demonstrated that vessel owners will have an incentive to invest in vessel capital so long as $x > x_b^0$, but will have no incentive to do so once $x < x_b^0$. We assume that at time $t = 0$, i.e., at the time that the new fishery commences, investment in vessel capital occurs instantaneously.

Given our assumption that $\gamma = 0$, the only costs relevant to the vessel owners (once the vessels have been acquired) are operating costs. Exploitation of the resource by the fleet will cause the biomass to decline to $x(t) = x_a^0$, unless investment in fleet capacity is insufficient to reduce the biomass to this level.

Consider now Fig. 1, adapted from McKelvey [21,22]. We denote the initial biomass $x(0)$ as x_0, and assume that $x_0 > x_b^0$ in the figure, which is an $x - K$ state-space diagram. The figure can be viewed as a type of feedback prediction of both the level of investment in fleet capital, and the amount of fishing effort under pure open access. The curve σ_1 is a switching curve. There are three sub-regions: Region R_1, which is the area below the switching curve σ_1 and greater than x_b^0; region R_2, which is above σ_1 and at biomass levels equal to x_a^0 or greater; and region R_3, which is at a biomass level less than x_a^0. The line $S-U$ denotes the minimum amounts of fleet capital, K, required to harvest the resource on a sustainable basis at all biomass levels between x_a^0 and x_{opt}.

Fig. 1 also indicates the values of the variables E and I that occur in each region R_i. For example, in the region R_1 investment is maximal ($I = +\infty$), resulting in a pulse increase in fishing capacity K, up to the level specified by the curve σ_1. (If the initial point $(x(0), K(0))$ lies above σ_1 then no further investment takes place.)

[2]Clark et al. [3] demonstrate that an implicit assumption underlying the Gordon model (and its dynamic version [4]) is that vessel capital is perfectly malleable.

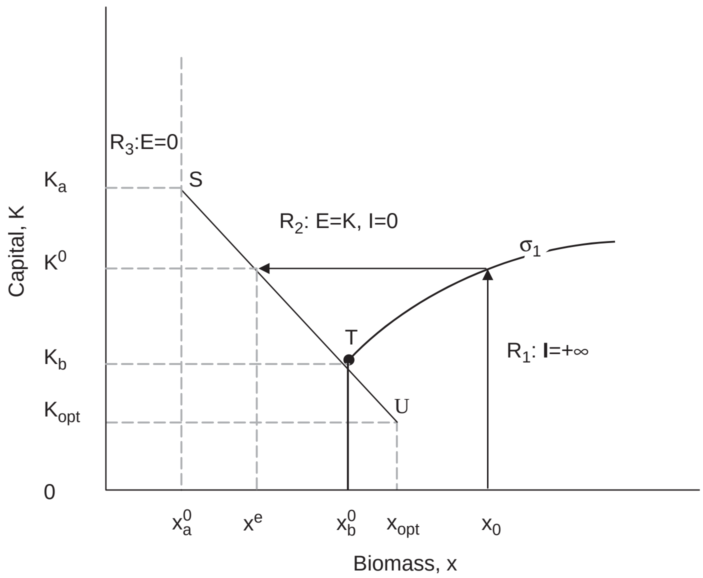

Fig. 1.

Once initial investment is made in fleet capital, K^0, at $t = 0$, effort E is set equal to K^0, as long as $x > x_a^0$. If x falls below x_a^0, E will be set equal to 0, until x has again increased to x_a^0. Hence, once the investment in fleet capital has been made at $t = 0$, $x(t)$ will decline, but will not fall below x_a^0, except momentarily. Let K_a be the stock of fleet capital required to harvest x_a^0 on a sustainable basis, viz., $K_a = F(x_a^0)/qx_a^0$. Given x_0, p, c and c_1, we could well find that $K^0 < K_a$, and that an open access equilibrium biomass level x^e lying between x_a^0 and x_b^0 will be achieved. This is the situation depicted in the figure.[3]

Now let us turn to the switching curve, σ_1. Since vessel capital is assumed to be perfectly non-malleable, would-be investors would have no choice but to attempt to forecast future profits from the fishery. Berck and Perloff [2] were the first to introduce the concept of rational expectations into fisheries economics. We shall adopt their definition of rational expectations, or perfect foresight, and their definition of the polar opposite, myopic decisions, which depend only upon past and current events. We assume that investors' expectations about fish population dynamics, and about the total number of vessels entering the fishery, are rational in the Berck and Perloff sense.

The next question is, how are investors' expectations regarding resource managers' future policy formed? It might seem contradictory to suppose these expectations could be entirely myopic. It may be, however, that the resource managers are so successful in concealing their intentions about future policy that the vessel owners have nothing to go on, other than past and current policy.

[3]Region R_2 in Fig. 1 (with $E = K$, $I = 0$) includes the entire area between x_a^0 and x_b^0, both above and below the equilibrium line SU. Points (x, K) in this region below SU would never be reached under the scenario considered here, but the feedback control rule $E = K$, $I = 0$ still applies to such points.

We will therefore first assume that vessel owners' expectations with respect to future management policy are indeed myopic. Now, once the vessels K^0 have been purchased, operating profits alone become relevant. Since there has been no intervention by resource managers in the past, the total present value of these operating profits will be perceived by vessel owners as being equal to:

$$\mathrm{PV}(x_0, K^0) = \int_0^\infty e^{-\delta t}\{pqx(t) - c\}E(t)\,dt, \tag{13}$$

where $x(t)$ and $E(t)$ are as specified earlier in the paper, for all $t > 0$.

We further assume that all vessels have identical capacity and the same fishing costs. An owner of a single vessel will anticipate receiving an average share of the present value, Eq. (13), i.e., the total present value of operating profits divided by the number of vessels, K^0. Thus, we can argue that investment in fleet capital will proceed up to the point where

$$c_1 K^0 = \mathrm{PV}(x_0, K^0). \tag{14}$$

The switching curve σ_1 is thus determined by Eq. (14).

We now suppose that some time after x^e is achieved the fisheries authorities intervene with a vigorous management program. Since the vessel owners' expectations regarding the resource managers' policy have been myopic, the vessel owners are completely taken by surprise. The managers deem the present situation to be undesirable, and set a new target stock level $x_{opt} > x^e$, and a corresponding optimal fleet capital stock size K_{opt} that would allow harvesting at x_{opt} to be undertaken on a sustained basis. Harvesting has to be reduced temporarily, and the amount of vessel capital employed has to be reduced permanently. Vessel owners, who (at the margin) are just breaking even under current conditions, and who have no alternative fishing opportunities, put up intense and politically effective resistance. The managers then respond by introducing a buyback program to remove $K^0 - K_{opt}$ from the fleet, an action that is also unanticipated by the vessel owners. Subsequently, with $E = K_{opt}$ the resource rebuilds gradually to x_{opt}. Finally, the fisheries authorities are able to ensure that there is no seepage of fleet capital back into the fishery [7], so that the stock of fleet capital remains at $K = K_{opt}$ forever. Under these conditions, the buyback subsidies are indeed conservationist in nature, helping to remove a critical barrier to resource stock recovery. Also in this case, the resource managers' policy is consistent with the long term best interests of society.

Now, let us change the scenario and suppose that the expectations of vessel owners regarding the policies of resource managers are rational rather than myopic. The vessel owners anticipate fully the future intervention of the authorities, and the accompanying buyback program. We also assume that the vessel owners anticipate that the resource managers will, at the time of the inception of the program, declare that only those vessel owners who entered the fishery no later than $t = 0$ are to be deemed bona fide participants in the fishery.

Finally, we assume for simplicity that the buyback program is introduced at $t = \theta > 0$, which is far enough into the future to ensure that the buyback occurs after the original open access equilibrium has been reached. We consider the effect that such anticipation will have on the initial fleet capacity K^0. The present value of the post buyback fleet operating profits discounted back to $t=\theta$ can be expressed as follows:

$$\mathrm{PV}_1(K_{\mathrm{opt}}) = \int_\theta^\infty \mathrm{e}^{-\delta(t-\theta)}(pqx(t)-c)E(t)\,\mathrm{d}t \tag{15}$$

where $E(t)=K_{\mathrm{opt}}$.

No vessel owner will sell out if he/she can do better by remaining in the fleet. At a minimum, the resource managers will have to offer, at $t=\theta$, a buyback price of $\mathrm{PV}_1(K_{\mathrm{opt}})/K_{\mathrm{opt}}$, per vessel. Let it be supposed that this minimum is sufficient to achieve the resource managers' aim, so that the buyback price c_2 of vessel capital at $t=\theta$ is indeed

$$c_2 = \left[\int_\theta^\infty e^{-\delta(t-\theta)}(pqx(t)-c)E(t)\,dt\right]\Big/K_{\mathrm{opt}} \tag{16}$$

Note that under this assumption owners who stay and those who leave the fishery get the same reward at $t=\theta$. The buyback price discounted back to $t=0$ is $e^{-\delta\theta}c_2$.

For the new scenario, we denote investment in K at $t=0$ as K_1^0. Then K_1^0 will be determined by

$$c_1K_1^0 = \int_0^\theta e^{-\delta t}(pqx(t)-c)E(t)\,dt + e^{-\delta\theta}c_2K_1^0, \tag{17}$$

(where $E=K_1^0$ for $0\leqslant t\leqslant\theta$) provided this equation has a solution K_1^0.[4] Observe that Eq. (17) can be rewritten as:

$$c_3 = \frac{\int_0^\theta e^{-\delta t}(pqx(t)-c)E(t)\,dt}{K_1^0}, \tag{18}$$

where

$$c_3 = c_1 - e^{-\delta\theta}c_2. \tag{19}$$

Thus, under perfect foresight pertaining to the resource managers' policy, the anticipated buybacks constitute a subsidy to vessel owners at $t=0$. Observe that there is no guarantee that c_3 will be positive.

Let us first consider the case in which $c_3>0$, and in which there is thus a solution to Eq. (17). Then the consequences of the subsidy are as illustrated in Fig. 2.

There is now a new switching curve, σ_2, which is given by Eq. (17), and which obviously lies above the old switching curve, σ_1. Correspondingly, there is a new open access equilibrium, x_1^{e}. We can refer to $K_1^0-K^0$ as the anticipated buyback-induced extra investment in fleet capacity, and $x^{\mathrm{e}}-x_1^{\mathrm{e}}$ as the anticipated buyback-induced extra overexploitation of the resource. Thus, the buyback scheme when anticipated serves to intensify economic waste through increased investment in fleet capacity, and also serves to intensify the negative conservation consequences of open access.[5]

[4]It may appear that with $E(t)=K_1^0$, the symbol K_1^0 cancels out and disappears from Eq. (17). This is not the case, however, because itself depends on K_1^0. In fact, $x(t)$ is a decreasing function of K_1^0, which implies that Eq. (17) either has a unique solution for K_1^0, or no solution.

[5]It is not the case that an anticipated buyback program will always lead to an intensification of resource overexploitation. Return to the case of unanticipated buybacks and suppose K_0 was such that x was reduced to x_{a}^0. If buybacks become anticipated and the perceived cost of fleet capital is thereby reduced, the resource would not be

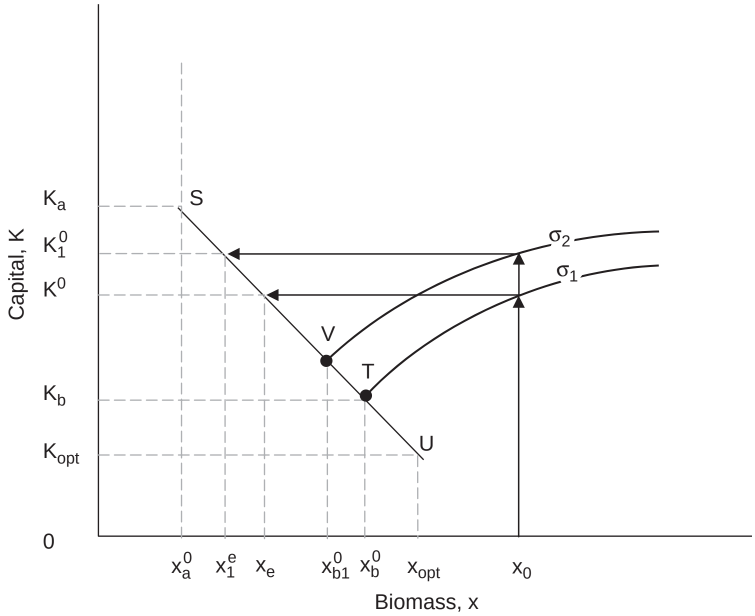

Fig. 2.

An interesting question at this juncture is how much does the intensification of economic waste and resource overexploitation really matter? After all, one could argue that the resource will eventually be restored, and once x_{opt} has been achieved the fishery will be prosperous through time. It therefore seems reasonable that in spite of the negative consequences of the buyback being anticipated, it could still serve the long term interests of society. Our results indicate that the intensification does indeed matter. If the assumption of perfect foresight is valid, then the outcome of an active resource management/buyback program will, in economic terms, be worse than what would occur if resource managers simply let the pure open access fishery run its course.

In our example, the Net Present Value (NPV) of revenue flows from the fishery, $t = 0$ to $t = \infty$, is the PV of operating profits minus the cost of vessel capital incurred at $t = 0$. From Eq. (14), it can be seen that the NPV of the revenue flows from a pure open access fishery, in the absence of intervention by the resource managers, will be zero, as expected. If the resource managers intervene in a hitherto pure open access fishery, with a resource management/buyback program that is fully anticipated by the industry, the NPV will be negative.

Denote the PV of operating profits from the interventionist fishery as PV′. From Eqs. (15)–(17), it can be seen that we can express PV′ as follows:

$$\mathrm{PV}' = \int_0^{\theta} e^{-\delta t}(pqx(t) - c)E(t)\,dt + e^{-\delta\theta}c_2 K_{\text{opt}}, \tag{20}$$

where $E = K_1^0$ for $0 \leqslant t \leqslant \theta$.

(*footnote continued*)
reduced below x_{a}^0. What one can say is that buyback schemes, when they are anticipated, create the distinct possibility that resource overexploitation will be intensified.

Investment in K_1^0, at $t = 0$, is given by Eq. (17). A comparison of Eq. (17) and (20) makes it transparently clear that $c_1 K_1^0 > \mathrm{PV}'$.[6] Hence, the NPV of economic benefits derived from the fishery is negative. The problem of course is that the rational investors in vessel capital at $t = 0$ are taking into account, not just the pre and post buyback profits from the fishery, but also the buyback subsidies themselves. In any event, a policy of non-intervention in the fishery, bad as it is, is superior to the interventionist policy when vessel owners have perfect foresight.

In the event that $c_3 < 0$, we see that the incentive for expanded capacity becomes unlimited. A new vessel obtained at cost c_1 later earns a discounted buyback payment $e^{-\delta\theta} c_2 > c_1$, with the consequence that there is no upper bound on the number of vessels that may enter the fishery, and hence no upper bound on the economic loses that may be caused by the buyback program.[7]

Of course, the assumptions of perfectly non-malleable capital[8] and perfect foresight are extreme. The point remains, nonetheless, that buybacks, if anticipated, can readily aggravate problems of both conservation and economic waste.[9] If the assumption of perfect foresight with respect to the resource managers' policy seems difficult to accept, the alternative assumption of vessel owner myopic expectations strains one's credulity to the breaking point.

3. Human capital in fisheries and subsidies: some conjectures

We turn now to the promised speculation on the applicability of our analysis to capacity in fisheries in the form of human capital. It has been implicitly assumed, up to this point, that unlike fleet capital, human capital is perfectly malleable with respect to the fishery. Human capital can flow easily into the fishery, and can exit with equal ease. We know, of course, that there are numerous cases in which human capital in fisheries is far from being perfectly malleable. The question of non-malleable human capital in fisheries is of particular interest to developing country inshore fisheries, where capacity in the form of human capital is likely to be much more important than capital in the form of fleets, and where barriers to labor mobility are commonplace. The equivalent to buybacks with respect to human capital in the fishery might take the form of retraining schemes, or simply payments not to fish.

One situation in which our analysis of perfect foresight does not apply to the study of human capital, is the case of a "closed" fishery, that is, a fishery with no likelihood of labor flowing into it. An example is provided by the Maldives, where there is no perceptible movement of labor into the fishery, and where the human capital participating in the fishery appears to be immobile [12]. In such a case, retraining schemes would make eminently good sense, if human capital in the

[6] Unless, of course, $K_1^0 = K_{\mathrm{opt}}$, which can never occur so long as the bionomic equilibrium level of x lies below x_{opt}.

[7] We have assumed throughout that the problem of "seepage" has been eliminated. We would speculate that the time consistency problem would be *less severe*, if seepage is not fully eliminated. Anything that serves to undermine the post buyback profits from the fishery should reduce investment in vessel capital at $t = 0$.

[8] If the fleet capital is quasi-malleable, rather than perfectly malleable (e.g., if $\gamma > 0$), the results will be much the same, albeit more complex.

[9] Empirical evidence in support of the claim that buyback/decommissioning subsidies will stimulate the expansion of fleet capacity is given by Jorgensen and Jensen [18], who conclude that the impact of buyback subsidies in the EU acts as a stimulus to investment in fleet capacity. These subsidies not only influence EU investors in fleet capacity directly, but also influence the investors' bankers, who offer more generous credit than would otherwise be the case.

fishery is deemed to be excessive, since there is no risk that anticipation of the schemes would draw additional human capital into the fishery.

A case in which the preceding analysis might apply, on the other hand, is one in which the flows of human capital to and from the fishery are asymmetric. Human capital can flow easily into the fishery, but once there it becomes trapped. This case is by no means uncommon in the developing world. A recent study commissioned by the FAO [29] shows that there are still inter-generational occupational shifts into fishing from other sectors of the rural economy in Tanzania, The Philippines, Bangladesh and India. Hence, in these countries (and most likely in many other developing countries) the flow of labor into fisheries is still a reality. In many, if not most, of these countries, once fishers enter a fishery, it is difficult for them to get out mainly due to the lack of access to alternative income sources [29].

Retraining schemes become relevant in the case described if there exists a non-rural sector in the economy, say a manufacturing and services sector, into which human capital can flow, given that it has been enhanced through training. In such a situation, the expectation of retraining in the fisheries sector, unaccompanied by retraining in the other sectors of the rural economy, could draw human capital into the fishery, in exactly the same way that anticipated buyback schemes will draw in fleet capital.

The solution in this case, however, is obvious and does not involve the abandonment of retraining schemes. Rather, it requires that there be simultaneous retraining schemes in the other sectors of the rural economy, as well.

In any event, it is our intention in this section to do no more than to offer some conjectures. The real research into the question of human capital in fisheries and the impact of the equivalent of buyback subsidies remains to be undertaken.

4. Conclusions

If vessel buyback programs can overcome the seepage problem, they can have a beneficial impact on fisheries conservation and can reduce economic waste—provided that vessel owners' expectations pertaining to resource managers' policy are myopic. If the buybacks are anticipated, however, then even though the seepage problem has been eliminated, the subsidies can have a strong negative impact, both in terms of conservation of the resource, and in terms of economic efficiency. This conclusion is not particularly radical, and is really an acknowledgement of the fact that it is folly to assume that vessel owners are myopic in their investment decision making.

We have no easy solutions to offer to the problems of capacity and conservation, other than to say that there appears to be no way out other than to adopt what the FAO refers to as an incentive adjusting (as opposed to an incentive blocking) approaches to management [9]. This would involve using taxes, or, some form of rights based system, such as individual transferable quotas, cooperatives, or community-based management.[10] How these are crafted together will certainly depend on the type of fishery being managed.

[10] See, for example, [1,6,8,17].

Acknowledgments

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