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THE COMMONS AS A NATURAL BARRIER TO ENTRY:
WHY THERE ARE SO FEW FISH FARMS

by

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1. Introduction

A competitive industry which overuses a common access resource may create a barrier to entry similar to Spence's (1977) example of a cartel that uses excess capacity to prevent entry. In most industries when a new firm enters, existing firms find that their demand curves have fallen, so they reduce their output to "accommodate" the new entrant. In Spence's (1977) model, the cartel disintegrates upon entry so that the output of existing firms increases which may make entry unprofitable. In an open-access fishery, the supply curve bends backwards. Thus, a fall in demand created by the entry of a fish farm increases rather than decreases supply. An important implication of this theory is that fish farms are more likely to be unprofitable the more heavily overharvested is a species in a common-property, competitive market. This natural barrier to entry may explain why although 93 species of fish are cultured in at least 28 countries (Brown, 1977), true mariculture is "barely in its infancy" (Bardach, Ryther, and McLarney, 1972).

2. The basic model

To illustrate this possibility, we examine the simple dynamic Schaefer model of an open-access fishery described by Smith (1969). A single variable, X , adequately describes the stock of a fish population which grows at a rate

$$f(X) = (a - bX)X,$$

without harvesting. When K boats each harvest at a rate h , X evolves at the rate

$$\dot{X} = (a - bX)X - hK. \quad (1)$$

Let

$$c(X, h) = \frac{gh^2}{X} + I$$

be the cost of harvesting at rate h when the fish stock is X , where g is a parameter and I is the fixed cost (or opportunity value of the boat in another fishery). Each boat then chooses its harvest rate to maximize profits. That is, it sets h so that price equals marginal cost, which implies that

$$h = \frac{pX}{2g}. \quad (2)$$

The demand curve facing the open-access fishery is the market demand less the supply from the fish farm. We assume, for simplicity, that this demand curve is linear:

$$p = d - ehK, \quad (3)$$

where p is the market price and hK is the harvest in the open-access fishery.

Solving equation (2) and equation (3) for the harvest per boat as a function of X and K yields

$$h = \frac{dx}{2g + eKX}. \quad (4)$$

Substituting for h from equation (4) into equation (1) gives

$$\dot{X} = (a - bX)X - \frac{dXK}{2g + eKX}, \quad (5)$$

which describes the evolution of the fish stock as a function of X and K alone.

In Berck and Perloff (1981), we argued that the rate of entry of boats into the commons should be based on rational expectations about the present value of profits. It is standard in these open-access models, however, to assume that the rate of entry is proportional to instantaneous profits (e.g., see Smith, 1969). For simplicity, we follow that practice here. Profits per boat are

$$(d - eKh)h - \frac{gh^2}{X - I} \quad (6)$$

so if the constant of proportionality is m , then evolution of the stock of boats is

$$\dot{K} = m \left[\frac{d^2X}{2g + eKX} - \frac{(eK + g/X)d^2X^2}{(2g + eKX)^2} - I \right], \quad (7)$$

where we have substituted for h from equation (4). Equations (5) and (7) characterize the open-access fishery.

The equilibria of the open-access fishery are determined by the intersections of the curves $\dot{X} = 0$ and $\dot{K} = 0$, as shown (by the heavy lines) in (X, K) phase space in Figure 1. Let $K = G(X, d, e)$ solve $\dot{X} = 0$. Setting $\dot{X} = 0$ from (5) gives

$$G(X, d, e) = \frac{2g(a - bX)}{beX^2 - aeX + d}. \quad (8)$$

The K intercept of (8) is found by evaluating $G(0,d,e)$ which is $2ga/d$, and the X intercept is found by solving $G(X,d,e) = 0$ for X, which is a/b . Taking the derivative of G with respect to X shows there is at most one critical point in the strictly positive orthant.

Similarly, we can solve $\dot{K} = 0$, equation (7), for K:

$$H(X,d,e) = \frac{d\sqrt{gIX} - 2gI}{eIX} \quad (9)$$

Setting $K = H(X,d,e) = 0$ gives the X intercept, $4Ig/d^2$. Setting the differential with respect to X equal to zero reveals a single relevant critical point. Taking the limit of H as X approaches infinity shows that the curve becomes asymptotic to the X-axis. Thus $\dot{X} = 0$ and $\dot{K} = 0$ in Figure 1 are as drawn, and there are at most three equilibria. (See Smith for the single equilibrium case.)

The entrance of a fish farmer shifts the derived demand curve, equation (3), inwards. For instance, suppose the supply curve for fish farming is $y = np$. If market demand is

$$p = u - vQ, \quad (10)$$

where Q, total quantity, is $y + hK$, then

$$p = \frac{u}{1 + vn} - \frac{v}{1 + vn} hK \sigma d - ehK \quad (11)$$

is the derived demand facing the commons. Initially, in the absence of a fish farm, n is zero, and the derived demand facing the commons, equation (11), is identical to the market demand curve, equation (10). After a fish farm enters, it produces $n > 0$, and the derived demand curve shifts inwards.

Entrance of the fish farmer also shifts the $\dot{X} = 0$ curve upwards and the $\dot{K} = 0$ curve downwards, as shown (by the light lines) in Figure 1. Substituting for d and e into $H(X,d,e)$ gives

$$H^*(X,n) = \frac{(u\sqrt{gIX} - 2vgInp - 2gI)}{vIX}. \quad (12)$$

Since $D_n H^* = -2vgIp/(vIX) < 0$, the $\dot{K} = 0$ locus shifts inwards when fish farms enter. Similarly, substituting into $G(X,d,e)$ gives

$$G^*(X,n) = \frac{2ag + 2avgnp - (2hvgnp + 2bg)X}{bvX^2 - avX + u}. \quad (13)$$

Its derivative is

$$D_n G^* = \frac{2vgp(a - bX)}{bvX^2 - avX + u}, \quad (14)$$

which is positive for fish stocks less than the natural carrying capacity, a/b , which are the only relevant fish stocks. Therefore, the $\dot{X} = 0$ locus shifts up with fish farm entry.

3. Supply and demand analysis

The previous analysis illustrates how the entry of a fish farm can lead to a reduction in overharvesting, a larger stock of fish, and a larger catch. These results can also be shown using a simple supply and demand model, as shown in Figure 2.

Rewriting the $X = 0$ equation, we know that, in a long-run, steady state, the open-access fishery supplies

$$S = hK = (a - bX)X. \quad (15)$$

In an open-access fishery, boats enter until the marginal boat earns zero profits, or price equals average cost:

$$p = \frac{gh}{X} + \frac{I}{h} = 2 \sqrt{\frac{gI}{X}}. \quad (16)$$

where the second expression is obtained by substituting for h from equation (2). We can use equation (16) to eliminate X from (15) so that we can write the supply curve as

$$S = (a - 4bI \frac{g^2}{p}) - 4I \frac{g^2}{p}. \quad (17)$$

This curve is shown in Figure 2. The open-access supply curve is backward bending, which illustrates the possibility of overharvesting. The heavy, straight line in Figure 2 is the market demand curve (in the absence of a fish farm). The light, straight line shows the residual demand curve after a fish farm enters. Equation (16) shows that higher prices are always associated with smaller fish stocks, so the ordering of the equilibria in Figure 2 corresponds to that in Figure 1.

If the initial equilibrium is at E_1 where there is overfishing, the entry of a fish farm can cause the equilibrium to shift to F_1 , where there is a larger catch, a lower price, and a larger stock of fish. There is, of course, a more dramatic possibility: the fish farm could cause a shift to F_3 .

4. A large shift

The possibility of a large shift is illustrated in the phase space diagram of Figure 3 (X, K). As the figure shows, if the original equilibrium was at E_1 , the new equilibrium could be at either F_1 or F_3 . The new equilibrium certainly will be F_3 if the entry of the fish farm leads to a single

equilibrium, such as when the light demand curve in Figure 2 swings down so far that it only intersects the supply curve once on the upward sloping section of the supply curve. Similarly, in Figure 1, the $\dot{X} = 0$ could rise and the $\dot{K} = 0$ fall by enough that there is only one equilibrium at F_3 .

When entry moves the equilibrium from E_1 to F_3 , the open-access fishery's output increases greatly and the price falls precipitously. Thus, if the fish farm has large fixed costs (heretofore ignored), this drop could easily drive it out of business.

5. A possible harm from fish farms

The previous discussion illustrates how the entry of a fish farm can increase output in a competitive industry where there is overharvesting. That is, we showed how the entry of the fish farm could lead to a shift from equilibrium E_1 to F_1 or possibly to F_3 . Perversely, it is also possible that if the initial equilibrium was at E_3 (i.e., output can only be increased by increasing fishing effort), that the entry of a fish farm could cause the equilibrium to shift to F_3 . That is, in this case, the commons would start overharvesting after the fish farm entered. For this outcome to occur, E_3 must have a higher level of K than occurs at F_2 .

6. Welfare implications

From society's viewpoint, the change from the low-stock to the high-stock equilibrium will involve a lower price for the product and an increased catch which increase the welfare of consumers; but it may also cause short-run losses for existing fishing vessels which will, of course, exit the fishery. Without knowing the interest rate, it is impossible to say if the gainers could compensate the losers. There are two situations, however, where this shift will definitely be welfare improving. If the interest rate is close to

zero, then the future matters as much as the present. As a result, the long-run consumer gains must outweigh the short-run producer losses. Similarly, if the costs of shifting a boat from this open-access market to another fishery are low, this shift in equilibrium will certainly be welfare-improving.

Where either interest rates are low or the cost of changing fisheries is low, the government could subsidize fish farms to provide competition to an overused natural fishery. Since fish farms reduce overharvesting in the open-access fishery but the owners of the farms do not capture this social benefit, there will be a tendency to undersupply fish farms. Unfortunately, fish farms cannot lead to a first best equilibrium in the open-access fishery, since the commons problem continues. Given a near zero social discount rate, consumer plus producer surplus is maximized where the social marginal cost curve (the curve marginal to the upward sloping portion of the supply curve in Figure 2) equals demand, an equilibrium which is not obtainable by a competitive industry at positive levels of output. Thus, the best the government can hope to accomplish by encouraging fish farming is to reduce the overfishing problem, not eliminate it.

If the government tried to encourage fish farming by transferring property rights, such as the sole right to fish a certain river or stream, there would be two effects. The removal of fishing grounds from the open-access fishery shifts the $X = 0$ equation downwards, as does the entry of competition from the newly created fish farm. Thus, the effects are reinforcing and the analysis is as before, using natural habitat to encourage fish farming can drive an open-access fishery from a point like E_1 to a point like F_3 .

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