Factors Affecting Welfare Gains from Fishing Gear Restrictions

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While the use of gear restrictions to regulate fishing activity seldom has the objective of improving economic efficiency, it is capable of achieving that result under some conditions. It can also reduce economic efficiency. This paper explores the way several factors affect the sign and magnitude of welfare gains from fishing gear restrictions. These factors include, among others: the fixity or variability of the price of fish and the presence or absence of diminishing short-run average product of effort. Some generalizations are offered regarding the characteristics of fisheries in which gear restrictions are most likely to produce welfare gains.

Introduction

Fishing gear restrictions, i.e., regulations forbidding the use of the most efficient equipment, constitute a commonly used tool of fishery managers. An example is the prohibition of dredges on most publicly owned oyster grounds in Virginia, where only hand tongs are permitted. Gear restrictions may be employed for the purpose of limiting fishing mortality in stocks in danger of extreme overfishing, or they may be viewed as a means of preserving the "way of life" of fishermen who would not be able to successfully compete if other fishermen were allowed to introduce improved technology.

Gear restrictions can be effective in limiting fishing mortality and may afford at least temporary protection to threatened groups of fishermen. Until recently, however, the literature in the economics of fishery regulation generally held that gear restrictions enacted for these purposes do nothing to improve the economic efficiency of the fishery. It was believed that these regulations produce no long-run change in producer surplus, or rents to fishermen; that all gains made possible by the reduction in excessive effort are dissipated by the higher costs of fishing with inefficient gear (see, for example, McConnell and Norton, and Crutchfield, 1982). In most of this literature, the assumption of a constant price of fish was implicitly or explicitly maintained, so little has been said about possible effects on the sum of consumer surplus and rents when price is variable (a minor exception is found in Crutchfield, 1961).

Recently, it has been realized that the conventional wisdom is incorrect. While gear restrictions are certainly not the optimal regulatory instrument for enhancing economic efficiency in a fishery, under some conditions, they may produce net economic benefits. Net losses may also result. It was shown by Anderson (1985) that long-run rents to fishermen under gear restrictions can be greater than, less than, or the same as rents with no gear restrictions.

Anderson (1985) noted additionally that the effect on the present value of the rents stream depends not only on the change in long-run rents, but also on the short-run transition to the new long-run equilibrium after the regulations are enacted. That is, changes in the entire time path of the rents accrual rate must be tracked.

The two purposes of this paper are: (1) to identify and discuss some of the factors that determine the effect of gear restrictions on both long-run and short-run rents; and (2) to extend the analysis to the case of a variable price of fish, explicitly including consumer surplus in the measurement of welfare gains or losses from gear restrictions. The discussion is organized by examining several combinations of conditions, each of which is associated with one of four general cases. The base case (Case 1) has perfectly elastic demand and constant short-run average product of effort. The other three cases introduce first diminishing short-run product of effort, then less than perfectly elastic demand, and then both.

The law of diminishing marginal product prob-

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ably compels marginal product of effort to decline in most, if not all, fisheries as effort increases, holding biomass constant. Consequently, the short-run average product of effort will usually be diminishing in the relevant range, and discussion of constant product cases might seem irrelevant. However, starting with the constant average product cases permits a more orderly exposition of the concepts, especially since the fishery economics literature has a fairly long history of using models with constant marginal and average product of effort.

Throughout, effort is assumed to adjust quickly to changes in cost and revenue. Perfect competition is also assumed. Finally, fishing effort is assumed to be subject to increasing costs, so that fishermen with specialized ability or limited alternative opportunities can earn rents. This characteristic is often explained by differences in fishing talent, or by limited alternative employment opportunities for some fishermen due to geographical isolation or cultural factors.

The analysis in this paper does not involve dynamic or static optimization in any way. No attempt is made to discuss the welfare gain foregone by regulating with gear restrictions instead of with a fully optimal regulatory instrument, such as taxes or transferable quotas. The question asked is simply, "Given that gear restrictions are enacted, what is their effect on consumer and producer surpluses?"

Case 1: Perfect Elasticity, Constant Short-Run Average Product of Effort

With perfect elasticity, of course, there is no consumer surplus and hence, no change in consumer surplus. However, the assumption of increasing marginal cost implies non-identical firms, and therefore, the existence of long-run rents to specialized resources.

If rents would be earned in the absence of gear restrictions, an increase or decrease in rents could occur after gear restrictions are enacted. This is illustrated in Figure 1, which is based on the familiar Schaefer-Gordon bioeconomic model (Schaefer, 1954, 1957, and Gordon). This model is not capable of characterizing the first-best full dynamic optimum in a fishery, but it is well suited for tracing the changes in rents caused by gear restrictions. It should be noted that surplus-production biological models such as Schaefer's constitute only one of several types of population dynamics model used in the fishery literature, and that some of the conclusions drawn below may not apply to fisheries where surplus-production models are inappropriate.

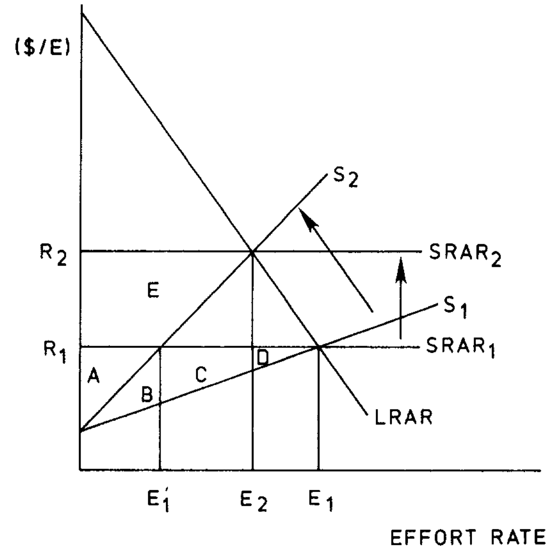

Figure 1. Perfectly Elastic Demand, Constant Short Run AP_E (Case 1)

The analysis treats fishing effort, measured in units of standardized fish catching ability, as the output being produced by fishing firms. The curve labeled S_1 is the industry supply of effort before gear restrictions, and is also the marginal cost of effort. The long-run average revenue product of effort curve (LRAR) slopes downward because, in the long run, increasing fishing effort reduces the biomass and drives average product (catch per unit of effort) down. Each point on the LRAR curve is associated with a different biomass level, and represents a biological equilibrium, or steady state.

In an open access fishery, effort increases until marginal cost equals average revenue, giving a without-regulation long-run equilibrium effort rate of E_1. When gear restrictions are imposed, the supply of effort shifts up to S_2 because the cost of producing effort has increased. In the short run, before the biomass level starts to grow in response to reduced effort, average revenue per unit of effort remains constant at R_1. Consequently, effort first falls to E_1', then gradually increases as biomass grows. Long-run with-regulation equilibrium effort is E_2, which is lower than the without-regulation rate. It is associated with a new steady-state biomass level that is higher than the previous one, and therefore, with a new average revenue level of R_2.

Before regulation, the long-run rate of rents accrual to fishermen is represented by Area A + B + C + D. After regulation, the rents rate drops temporarily to A, then grows to the new long-run rate A + E. Anderson (1985) observed that the with-regulation long-run rents rate (A + E) may be greater than, equal to, or less than the without-regulation rate (A + B + C + D). However, in the short run, the rents rate clearly falls. Therefore, the present value of the rents stream will also fall unless the new long-run rate exceeds the old rate by enough to offset not only the short-run decline, but also the effect of discounting.

Anderson's 1985 article contains an error in the graphical measurement of the short-run rents rate. As a result of this mistake, Anderson erroneously concludes that "net gains the first year . . . (are) clearly greater than the annual [long-run] gains after adjustment." Then, compounding the error by failing to note that the short-run change identified may be either positive or negative, he goes on to explain that it is the extent to which the long run dissipates these short-run gains that determines whether gear restrictions enhance economic efficiency.

However, as shown above, the short-run effect must be a net loss in rents. Therefore, the extent to which sufficiently offsetting net gains are created in the long run determines whether gear restrictions enhance economic efficiency.

Whether this occurs depends on the discount rate and on the relative changes in the short-run and long-run rates of rents accrual. The change in long-run rents, in turn, depends on the elasticity of long-run average revenue response to changes in effort in the relevant range, and on the nature and magnitude of the shift in the supply of effort curve.

The importance of the nature of the shift in the supply curve can easily be grasped by observing that if S made a parallel shift, rather than the slope-increasing shift shown in Figure 1, the long-run rents rate could only decline. An exception occurs when the long-run average revenue product curve is vertical, in which case the long-run rents rate does not change. However, regardless of whether LRAR is vertical or has a finite negative slope, the present value of the rents stream unambiguously declines when gear restrictions cause a parallel shift in S.

Thus, Anderson's (1985) suggestion that programs affecting high-cost vessels more than low-cost vessels are good candidates to produce favorable results can be restated: in order for gear restrictions to produce an increase in the long-run rents rate, it is necessary (but not sufficient) that they cause the slope of the effort supply curve to increase. Rents can increase if the intercept of the supply curve also increases, but it is less likely.

Gear restrictions that apply to all vessels equally, as is most often the case, may cause a parallel shift in the effort supply curve. Alternatively, infra-marginal (efficient) vessels may experience greater cost shifts than marginal vessels, which may already be using inefficient gear. This translates into a *decrease* in slope of the effort supply curve, which strengthens the guarantee of negative net benefits.

On the other hand, vessels already using inefficient gear may not be marginal. Their opportunity costs may be low because of limited alternatives for earning income or because of cultural factors, while vessels using modern gear may be marginal because of high opportunity costs. If so, imposition of gear restrictions may increase the slope of the effort supply curve.

In order to allow the possibility that rents increase, the remainder of this paper assumes that gear restrictions cause the slope of the effort supply curve to increase, leaving the supply curve intercept unchanged.

For a given shift in S (provided that the slope of S increases during the shift), the greater the elasticity of long-run average revenue with respect to changes in effort, the better the chances of an increase in long-run rents. In fact, if gear restrictions cause an increase in the slope of the effort supply curve but do not change the intercept, then an increase in long-run rents is assured whenever the effort elasticity of long-run average revenue is greater than one.

Note that in the neighborhood of a given point, the steeper the LRAR curve, the *higher* the elasticity of average revenue. This relationship between slope and elasticity is opposite to the one pertaining to linear demand curves.

Assuming a "dome" shaped growth rate curve, one important determinant of the elasticity of average revenue is the magnitude of the equilibrium effort rate relative to the effort rate that produces maximum sustainable yield (E_{MSY}). If the stock is heavily exploited ($E > E_{MSY}$, and the supply curves intersect LRAR near its lower end), then reduction in effort results in an increase in long-run total catch rate. Thus, assuming a constant price of fish, the elasticity of average revenue must be greater than one in this range. This is one way of explaining why a heavily exploited stock makes its fishery a good candidate for efficiency improvement through gear restrictions, as Anderson (1985) suggested.

The assumption of perfect price elasticity of demand need not imply that the price of fish is constant as effort changes. If the price is a function of the average size of the fish landed, and if average size is related to biomass and hence, to steady-state effort (Gates), then the price will change as a result of gear restrictions. Assuming that increasing biomass is associated with larger average size and that larger fish command a higher price per pound, then long-run average revenue product of effort will rise more sharply as effort is reduced (LRAR will be steeper) than in the absence of what Gates called a "size effect" on price.

The presence of a size effect, therefore, makes a net gain in the long-run rents rate more likely.

Case 2: Perfect Elasticity, Diminishing Short-Run Average Product of Effort

The term "diminishing product" is used in this paper to refer to the behavior of short-run average product of effort. "Short run" refers to the time after imposition of gear restrictions and before the biomass level changes in response to a change in effort caused by imposition of gear restrictions. That is, the biomass level is assumed to remain constant in the short run.

The fact that long-run catch per unit of effort diminishes with increasing effort in the Schaefer-Gordon model (along with the fact that an unrestrained fleet will expand effort until marginal cost equals average revenue) characterizes a fishery with the well known stock externality problem. If, in addition, short-run (holding biomass constant) average product also diminishes (as it must if the law of diminishing marginal product is truly universal), then the fishery exhibits a second type of externality, as well.

Brown called this externality the "congestion externality," but it might be more usefully labeled the "current expansion externality." Many factors, including actual physical crowding on the fishing grounds, could explain diminishing average product of effort as effort expands when biomass is held constant. In fishery models where time is treated as both a continuous and a discrete variable, a similar distinction between two types of externality is usually made by identifying them as interperiod (stock) and intraperiod (current expansion) externalities (e.g., Henderson and Tugwell).

The general relationship between long-run rents before gear restrictions and long-run rents after gear restrictions is unchanged by this new assumption. As in Case 1, the long-run rents rate may rise, fall, or remain constant.

However, a short-run decrease in the rents rate is no longer inevitable. In Figure 2, the without-regulation long-run equilibrium is where S_1 intersects the long-run average revenue product curve (LRAR), as before. In this case, however, when imposition of gear restrictions shifts the supply of effort to S_2, the ensuing reduction in effort causes average revenue product to rise in the short run, even though biomass level does not change. This is shown in Figure 2 by a negatively sloped short-

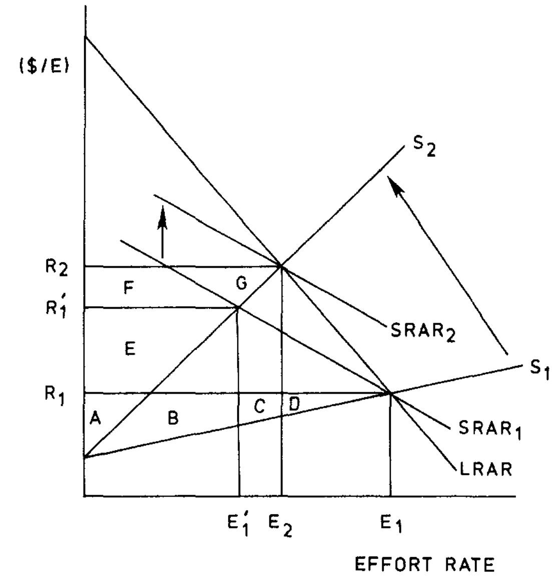

Figure 2. Perfectly Elast. Demand, Diminishing Short Run AP_E (Case 2)
Less Than Perf. Elast. Demand, Constant Short Run AP_E (Case 3)
Less Than Perf. Elast. Demand, Diminishing Short Run AP_E (Case 4)

run average revenue product curve ($SRAR_1$). The short-run equilibrium effort rate (E_1') is greater than when short-run average product is constant, and the short-run average revenue level rises to R_1', rather than remaining constant at R_1.

The without-regulation long-run rents rate is again area A + B + C + D, but this time the short-run with-regulation rents rate is A + E, not just A. Depending on the nature and magnitude of the shift in S and on the effort elasticity of short-run average revenue, A + E may be greater than, less than, or equal to A + B + C + D.

As the short run lengthens into the long run, the biomass grows and the short-run average revenue product curve gradually shifts to $SRAR_2$. The new (with-regulation) long-run equilibrium effort rate is E_2 and the with-regulation long-run rents rate is A + E + F + G. Since A + E + F + G is always greater than A + E, if gear restrictions cause a short-run increase in the rents rate, the present value of net economic benefits will always rise.

Diminishing short-run average product of effort along with perfectly elastic demand appears to make an improvement in efficiency with gear restrictions more likely than when the short-run average product of effort is constant.

Any size effect on price would work the same way in this case as in Case 1, i.e., it increases the effort elasticity of long-run average revenue product of effort, and thereby increases the gain in long-run rents. The size effect is not present in the short run, since biomass is constant. Consequently, the elasticity of short-run average product of effort is unchanged.

Case 3: Less than Perfect Elasticity, Constant Short-Run Average Product of Effort

When the price of fish depends on the catch, the shape of the long-run average revenue product curve is dictated not only by diminishing long-run average product, but also by the fact that, holding average size of the fish constant, increasing effort first increases steady-state catch, driving prices down, then decreases catch, driving prices up. Gates calls this a "quantity effect" on price to distinguish it from a size effect.

Therefore, when effort is low, the LRAR curve is steeper than it would be with a constant price, and it is less steep when effort exceeds E_{MSY}. For example, if the LRAR curve is a straight line when demand is perfectly elastic, as in Figures 1 and 2, it must be convex when elasticity of demand is less than perfect. The curve could conceivably turn up and have a positive slope at very large effort rates.

In addition, although short-run average revenue product (SRAR) is constant with perfectly elastic demand, it slopes downward with less than perfect elasticity, even though no current expansion externality is present. This is because decreasing effort reduces catch in the short run and drives price up. The steeper the demand curve, the greater the effort elasticity of SRAR (the steeper the SRAR curve).

Using Figure 2, but assuming that the short-run average revenue curves (SRAR) are downward sloping because of a quantity effect on price, rather than diminishing short-run average product, implies the same general conclusions about the effect of gear restrictions on rents to fishermen. That is, rents may either increase or decrease in both the short run and the long run. The with-regulation long-run rents rate (A + E + F + G) is always larger than the short-run rate (A + E), so a short-run net gain (A + E > A + B + C + D) implies the present value of the net benefit stream with regulation will be greater than without.

Similarities notwithstanding, Cases 1 and 2 differ from Case 3 in one important respect. In Case 3, the effort elasticity of LRAR may not exceed one whenever the stock is heavily exploited (when $E > E_{MSY}$). Thus, while a less than perfect elasticity of demand makes short-run rents after gear restrictions larger than they would otherwise be with constant short-run average product of effort, it weakens the likelihood that long-run rents will rise for a heavily exploited stock. (It has the opposite effect for lightly exploited stock.) The effect on the present value of rents is indeterminate.

Of course, a size effect on price increases the effort elasticity of LRAR, other things equal, just as in the perfect elasticity of demand cases (Cases 1 and 2).

It is possible to show how both consumer surplus and producer surplus are affected by gear restrictions by introducing value of marginal product and marginal revenue product curves to the graph in Figure 2 (Anderson, 1980). However, attempting to show both long-run and short-run changes in such a graph causes extreme visual clutter. Moreover, by depicting supply of and demand for fish as functions of the catch rate, it is possible to show these effects and also to show explicitly how catch and price of fish are affected. Figure 3 represents the fishery for a stock with a dome shaped biomass growth function. The short-run (constant biomass level) supply curve without regulation is S_1. It is associated with the steady-state biomass level of the without-regulation bioeconomic equilibrium. The long-run supply curve (which takes account

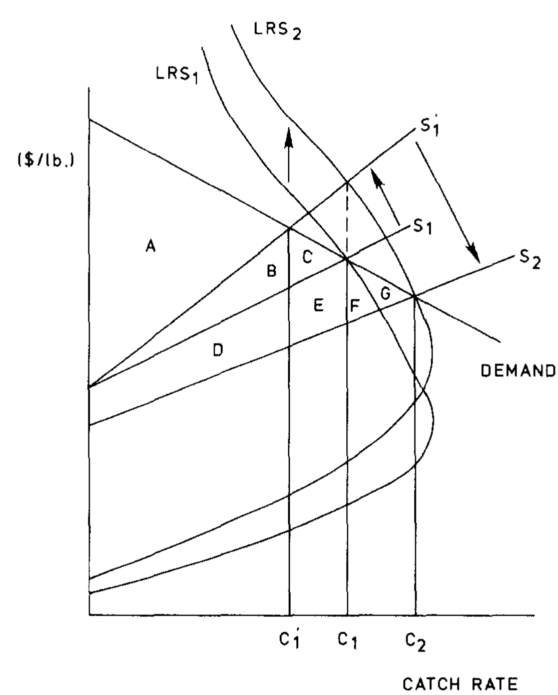

Figure 3. Less Than Perfect Elasticity of Demand, Constant Short Run Average Product of Effort, No Size Effect (Case 3)

of changes in steady-state biomass level induced by hypothetical price changes) without regulation is LRS_1. Steady-state equilibrium catch without regulation is C_1, where S_1 and LRS_1 intersect the demand curve. The short-run supply curve associated with any biomass level is a marginal cost curve, under the assumption of no current expansion externality.

The short-run supply curve shifts up to S_1' just after regulation is imposed, but before biomass level begins to adjust. Short-run equilibrium catch after regulation is C_1' where S_1' intersects the demand curve. Regulation reduces the catch in the short-run. This means that the catch rate is temporarily less than the biomass growth rate, so biomass begins to grow.

As biomass grows over the long run to its new steady-state level, short-run supply gradually shifts from S_1' down to S_2. It is shown becoming less steep as it shifts. With the commonly used Cobb-Douglas catch production function, increasing biomass level has this effect on short-run supply curves in addition to shifting them down.

The long-run supply curve with regulation, LRS_2, shifts from LRS_1 because gear restrictions make the cost of catching fish higher than before for all given biomass levels. C_2, the long-run catch rate with regulation after biomass level adjusts, is determined by the intersection of S_2 and LRS_2 with the demand curve, which is downsloping to illustrate the quantity effect on price of fish. Figure 3 assumes that prices show no size effect.

Without regulation, the sum of rents to fishermen and consumer surplus is area A + B + C. After regulation is imposed, the sum makes a short-run decrease to area A as catch falls and price rises.

In this case, the sum of rents and consumer surplus can only fall in the short run. Note, however, that Figure 2 was used above to demonstrate that rents to fishermen may increase in the short run when demand is less than perfectly elastic, giving rise to the possibility of a short-run transfer of net benefits from consumers to fishermen.

Figure 3 represents a fishery on a heavily exploited stock, with biomass below the level that produces maximum sustainable yield. As the biomass grows after imposition of gear restrictions, the catch rate increases in the long run to a level above its original pre-regulation level, accompanied by a fall in price. The new long-run sum of rents and consumer surplus is area A + B + C + D + E + F + G. The new long-run total net benefits rate may be larger than, smaller than, or equal to the rate before regulation, although if gear restrictions do not cause the intercept of the short-run supply curve to increase, holding biomass level constant, then net benefits increase unambiguously.

The consumer surplus accrual rate clearly decreases in the short run with gear restrictions, but the long-run consumer surplus rate will increase if the fishery is heavily exploited. It is not clear what happens to the present value of the stream of consumer surplus.

Since long-run consumer surplus not only increases, but by enough to offset the possibility that long-run rents may decrease (shown in Figure 2), long-run total net benefits always increase (Figure 3). The certainty of increasing the long-run total net benefits rate does not, of course, guarantee an increase in the present value of the net benefits stream, because the decrease in the short run may outweigh the long-run increase.

When comparing the effect of gear restrictions on total net benefits in a heavily exploited fishery under (a) perfectly elastic demand versus (b) less than perfectly elastic demand, the following conclusions are reached:

(a) A constant price minimizes the loss in short-run total net benefits. To see this, refer to Figure 3 and rotate the demand curve counter clockwise about the point where it intersects S_1. As it becomes less steep, the short-run loss in total net benefits (B + C) becomes smaller and is minimized when demand becomes perfectly horizontal.

(b) On the other hand, a quantity effect on price makes a long-run total net benefits increase more likely than if price is constant (of course, an increase is guaranteed if regulation does not change the supply curve intercept, biomass constant). In the long run, the falling price as catch expands beyond its original long-run equilibrium level restrains effort more effectively than would a constant price. This permits the biomass to grow more and, hence, permits the supply curve to shift down further.

Moreover, up to a limit, the greater the fall in price as catch expands, the stronger the restraining effect on effort, and hence, the larger the steady-state biomass level with regulation. The larger the new long-run biomass level, the lower the new long-run supply curve, and the larger the new long-run total net benefits rate. That is, as demand is less elastic (again, up to a limit), the likelihood is greater that long-run total net benefits will increase after gear restrictions are imposed on a fleet that is exploiting its stock heavily.

However, this rule holds only so long as the slope of the demand curve does not exceed a limit.

If the demand curve is steeper than the upper branch of the long-run supply curve, then their intersection represents an unstable equilibrium. In this circumstance, the demand curve also intersects the lower branch of the long-run supply curve, where a stable equilibrium exists. But in this equilibrium the biomass level is greater than the level that produces maximum sustainable yield, and the stock is not considered to be heavily exploited.

The preceding discussion suggests that, among fisheries on heavily exploited stocks, the fishery that offers the most hope for increasing the present value of both consumer surplus and fisherman rents through gear restrictions is one with a concave demand curve. Such a demand curve can be highly elastic in the region above its intersection with the without-regulation supply curve (S_1) and highly inelastic in the region below it. This configuration reduces short-run loss from gear restrictions and increases long-run gain. Such a configuration is undoubtedly rare.

If the fleet exploits the stock lightly (i.e., if the demand curve intersects the backward bending long-run fish supply curve in its lower, positively sloped, segment), an increase in the present value of total net benefits is more difficult to achieve with gear restrictions. See Figure 4. Here it can be concluded that (a) total net benefits again fall unambiguously in the short run (from area A + B + C + D + E + F + G to area A); and (b) an increase in the long-run total net benefits rate is not inevitable, even if regulation does not change the supply curve intercept, holding biomass constant.

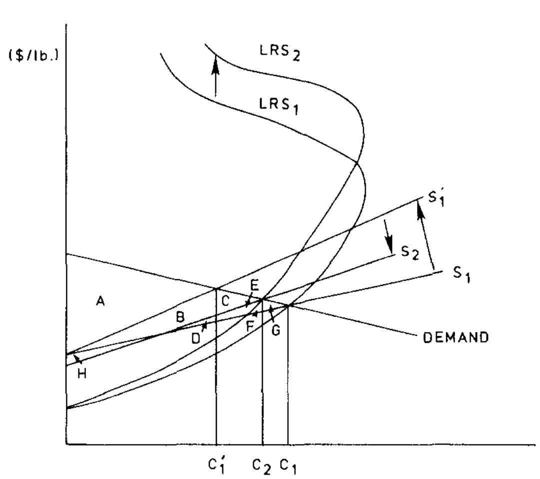

Figure 4. Less Than Perf. Elast. Demand, Constant Short Run AP_E, No Size Effect (Case 3)

Conclusion (b) follows from the fact that S_2 cannot lie entirely below S_1 when the stock is lightly fished, and contrasts with the corresponding conclusion obtained in the situation where the stock is heavily exploited. Long-run total net benefits are certain to increase if gear restrictions do not cause an intercept shift.

S_2 cannot be shifted entirely below S_1 because the steady-state (long-run) catch rate falls (from C_1 to C_2) as effort is cut back on a stock whose biomass level is on the right side of the Schaefer growth dome. The long-run total net benefits rate without regulation is area A + B + C + D + E + F + G. The total net benefits rate with regulation is area A + B + C + H, which may be larger, smaller, or the same as without regulation.

An interesting distinction between a fishery on a lightly exploited stock and one on heavily exploited stock is when the stock is lightly fished, less than perfectly elastic demand may not improve the likelihood of increasing long-run net benefits, as compared with a fixed price. With-regulation long-run equilibrium catch is less than without-regulation long-run equilibrium catch and the price is higher than its original level, so effort is restrained by less than if the price remained at its original level. The biomass level does not rise as much, and the supply curve does not shift as far down.

With a size effect on price of fish, the steady-state biomass level determines not only the location of the supply curve, but also the location of the demand curve. The size effect shifts the demand curve upward as the size of the biomass increases. This prevents the supply curve from shifting down as far as it would in the absence of a size effect, and biomass from growing as large. Figure 5 depicts a scenario in which the shift in demand does not occur until after biomass reaches an interim steady state level, with supply settling temporarily at S_2'. The shift in demand dictates transition to another new steady state, with supply settling finally at S_2.

Of course, if the demand curve begins shifting as soon as the biomass begins growing from its original steady-state level, the supply curve might shift more or less directly from S_1' (its position immediately after imposition of gear restrictions) to S_2, without going to S_2' first.

As Figure 5 shows it, the final long-run total net benefits rate after regulation exceeds the without-regulation rate. The new demand curve lies entirely above the old one, of course, and the new supply curve (S_2) lies entirely below the original supply curve (S_1). However, if the demand curve shifts up far enough, S_2 intersect S_1, the change in long-

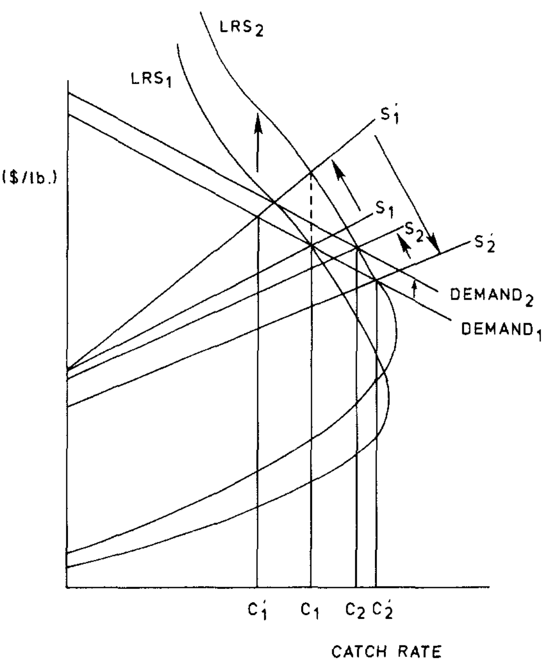

Figure 5. Less Than Perf. Elast. Demand, Constant Short Run AP_E, With Size Effect (Case 3)

run total net benefits from regulation would then be indeterminate.

Thus, introducing the size effect to the model eliminates the guarantee of an increase in long-run total net benefits that exists when there is no price effect (assuming no change in the intercept of the effort supply curve). On the other hand, it is also possible that the size effect could cause an even greater increase in the long-run total net benefits than would occur without it. These ambiguous results for total net benefits stand in contrast to the clearly positive impact of a size effect on long-run rents, which can be seen in Figures 1 and 2. There a size effect increases the effort elasticity of long-run average revenue product of effort.

Case 4: Less than Perfect Elasticity, Diminishing Short-Run Average Product of Effort

The assumption of diminishing product implies a current expansion externality in addition to the stock externality. Therefore, the short-run (biomass constant) supply curves for fish are not marginal cost curves, and cannot be used to demarcate net benefits triangles. Common property ownership of the resource encourages expansion of effort until the short-run average revenue product of effort equals the marginal cost of effort. This means that catch expands beyond the point where marginal cost of fish equals price, so the marginal fish cost curve lies above the supply curve. In a fleet of identical vessels, catch expands until average cost of fish equals price, and the industry average cost curve is the supply curve. But in a fleet with increasing cost of effort, the supply curve for fish must be drawn somewhere between the marginal and average fish cost curves.

Figure 6 illustrates the variable price, diminishing short-run average product case when the stock is heavily fished. To reduce visual clutter, the long-run supply curves (LRS_1 and LRS_2) have been omitted. The arrows indicating the path of shifting have also been omitted for the same reason. Three marginal cost and supply curve pairs are shown: without regulation, the fish supply curve is S_1 and the associated marginal cost curve is MC_1; the supply and marginal cost curves immediately after regulation begins are S_1' and MC_1', respectively; and S_2 and MCl_2 are the relevant curves in the long run with regulation. Each pair of curves has a single intercept, which does not imply that gear restrictions do not change the intercept (although Figure 6 is drawn to show no change in intercept, holding biomass constant).

After gear restrictions are put in place, the catch rate goes from C_1 to C_1', and then to C_2. Note that

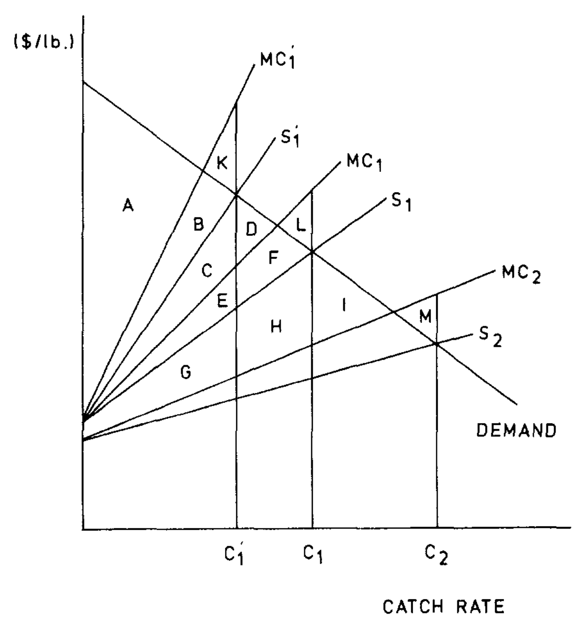

Figure 6. Less Than Perfect Elasticity of Demand, Diminishing Short Run Average Product of Effort, No Size Effect (Case 4)

because C_1 is greater than the catch rate at which MC_1 intersects demand, there is a welfare loss triangle (L) to be subtracted from total net benefits. The short-run and long-run equilibria after regulation begins also involve welfare loss triangles (K and M). If these triangles are relatively small, as when the demand curve is steep or when there is little divergence between the supply and marginal cost curves (i.e., the current expansion externality is insignificant), Case 4 is nearly identical to Case 3 (no current expansion externality) and the same general conclusions apply. But if one or more of the welfare loss triangles are large, different conclusions must be drawn.

Before regulation, the total net benefits rate is A + B + C + D − L, the area between the demand curve and MC_1 minus the welfare loss triangle L. Immediately after imposition of gear restrictions, the total net benefits rate is A − K. In Figure 6, this appears to be smaller than total net benefits before regulation because A is clearly less than A + B + C + D, and the welfare loss triangle K appears to be approximately equal to, or perhaps larger than, welfare loss triangle L. However, if the demand curve were convex, or if gear restrictions somehow narrowed the gap between the marginal cost and supply curves, K could be smaller than L and the short-run effect of gear restrictions would then be ambiguous.

Thus, the presence of a current expansion externality creates the possibility for a short-run gain in the total net benefits rate when demand is less than perfectly elastic, just as it does when price is constant and total net benefits consist entirely of rents to fishermen (see Case 2 and Figure 2). Consumer surplus must decline in the short run. But the downward sloping demand curve and the current expansion externality jointly make the short run rents rate larger than it would be in their absence (*ceteris paribus*), and they make it possible for the short run rents rate after regulation to be larger than the rents rate before regulation. In fact, the rents rate can increase by enough in the short run to compensate for the short-run loss in consumer surplus.

The long-run total net benefits rate with regulation is area A + B + C + D + E + F + G + H + I − M, which is the area between the demand curve and MC_2 minus the welfare loss triangle M. It can be greater than, less than, or equal to the without-regulation rate. As is true when there is no current expansion externality (see Case 3 and Fig. 3), the likelihood of an increase in the long-run rate when the stock is heavily exploited is improved by (a) low price elasticity of demand, (as long as the demand curve is not steeper than the long-run supply curve), and (b) minimal change in the marginal cost-of-effort intercept.

However, in contrast to the conclusion obtained in the absence of a current expansion externality, an increase in the long-run total net benefits rate is not guaranteed when gear restrictions leave the marginal cost curve intercept unchanged. The reason is that, while MC_2 will still lie entirely below MC_1, the welfare loss triangle after regulation (M) may be larger than the corresponding area without regulation (L), especially if the demand curve is convex.

The discussion in the preceding three paragraphs seems to suggest that when significant current expansion externalities exist in fisheries on heavily exploited stocks, the best hope for an increase in the present value of total net benefits through gear restrictions lies in a fishery with a demand curve having the following shape: convex in the region above its intersection with the without-regulation supply curve (S_1), and concave in the region below it. It is steeply sloped in both its upper and lower regions, but nearly horizontal in the middle region, where it intersects S_1. This configuration makes both the short-run and long-run welfare loss triangles with regulation (K and M, respectively) smaller than the pre-regulation welfare loss triangle (L).

However, in some situations this hope would not be realized. The short-run and long-run welfare loss triangles shown in Fig. 5 would indeed be smaller than the without-regulation loss triangle if the demand curve had the shape described above. And if the gear restrictions are designed so as to leave the marginal cost intercept unchanged, sufficient concavity of the demand curve below the original intersection point would insure that the new long-run total net benefits rate would be larger than the old one. But there are two reasons why this shape cannot guarantee an increase in present value of the total net benefits stream:

(a) The total net benefits rate may still fall in the short run, especially if convexity of the upper part of the demand curve increases the short-run loss in positive net benefits (B + C + D + E + F), as compared with linearity.

(b) Even if both the short-run and long-run total net benefits rates are higher than the without-regulation rate, there is the intermediate run to consider. Convexity of the upper part of the demand curve does not eliminate the possibility that as the supply and marginal cost curves shift down from their short-run positions (S_1' and MC_1', respectively) toward their new long-run positions (S_2 and MC_2), the total net beneifts rate could decrease temporarily to a level lower than its original without-regulation long-run level.

For a fishery on a lightly exploited stock, the effect of gear restrictions on the long run total net benefits rate is also ambiguous. Moreover, it is no longer valid, as it is in Case 3, to state that an increase in the long-run total net benefits rate is more difficult to achieve than when the stock is heavily fished (see Fig. 4 to understand why it is valid in the no-current-expansion-externality case). The reason for this reversal is that the long-run welfare loss triangle after regulation may be smaller than before regulation, making an increase in total net benefits more likely.

As in Case 3, the presence of a size effect on price shifts the demand curve upward in the long run. Consequently, the final positions of the fish supply and marginal cost curves will be also higher than those drawn in Fig. 6. It will come as no surprise to readers of Case 3 that introducing a size effect in this case does nothing to improve the predictability of outcomes after gear restrictions are imposed.

Summary and Conclusions

Regulation of fishing activity through the use of fishing gear restrictions should be considered no better than second best as a method for improving economic efficiency in a fishery. However, when fishery managers choose gear restrictions to accomplish other objectives, net economic benefits may still increase. On the other hand, efficiency could be further degraded.

A number of factors affecting welfare gains from gear restrictions have been identified and analyzed in this paper. The signs of the change in welfare that are possible in each of the four cases discussed are summarized in Table 1.

In addition to the specific conclusions drawn in each case, a few broad generalizations can be made, subject to the limitations of the Schaefer-Gordon model:

(a) The gear restrictions should be designed so as to minimize their impact on the firms with the lowest opportunity costs. This guarantees that the slope of the effort supply curve will increase, a necessary condition for increasing producer surplus.
(b) The best hope for achieving welfare gains will usually lie in fisheries on heavily exploited stocks. This is true with perfectly elastic demand because such fisheries have elastic long-run average revenue product of effort curves, which enhance the prospects for an increase in the long-run rents rate. It is true with less than perfectly elastic demand because reducing effort will increase long-run catch rate and reduce price, thereby guaranteeing an increase in the long-run consumer surplus.
(c) Consumers will always bear a loss in the short run, unless consumer surplus was zero to begin with, because reducing effort always causes a reduction in the catch rate in the short run.

Table 1. Summary of Possible Effects on Producer Surplus and Consumer Surplus Caused by Gear Restrictions

	Case			
	1	2	3	4
Price of Fish	const	const	var	var
AP of Effort	const	dimin	const	dimin
Short Run PS	−	±	±	±
Short Run CS	0	0	−	−
SR Total	−	±	−	±
Long Run PS	±	±	±	±
Long Run CS	0	0	±	±
LR Total	±	±	±	±
PV of Total	±	±	±	±

0 means no change
− means decrease
± means increase, decrease, or no change

(d) In fisheries with downward sloping demand curves, total net benefits (consumer surplus plus rents) have the potential to increase in the short run only if current expansion externalities are present. Only then can short-run average product of effort have sufficient elasticity to permit the possibility of a short-run increase in producer surplus greater than the inevitable short-run decrease in consumer surplus.

(e) A size effect on the price of fish enhances prospects for an increase in long-run rents, but does not necessarily enhance prospects for an increase in long-run total net benefits.

(f) Since net gains will usually be realized only in the long run, the lower the discount rate, the more beneficial (or the less costly) gear restrictions will appear.

The best bet for improvement in efficiency through gear restrictions is probably a fishery with perfectly elastic demand, a strong size effect on price, a strong current expansion externality, and a stock that is heavily overfished.

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