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THE INFLUENCE OF THE SUPPLY AND DEMAND CHARACTERISTICS OF FISHERIES ON THE BENEFITS FROM ECONOMIC IMPROVEMENT PROGRAMS

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Most capture fisheries are common property resources. Economic theory indicates, that in the absence of regulations, excessive quantities of labour and capital will be used to harvest these resources, relative to those required to maximise economic welfare (Gordon 1954). The social cost of resource misallocation provides an economic rationale for government intervention in the fishery, through the introduction of economic improvement programs, to reduce and maintain fishing effort below the level that would prevail in an unregulated fishery. This process has been termed rationalisation of the fishery (Crutchfield 1979).

Researchers analysing the economic benefits accruing from fisheries rationalisation programs have typically developed empirical models based on a production function specific to the fishery under study (for example, O'Rourke 1971; Bell 1972; Copes 1978; Henderson and Tugwell 1979; Carrington and Chandra 1986). While their results have indicated that the benefits may be large, the fishery specific nature of the models used has resulted in little information being provided on the general economic characteristics affecting the potential social benefits from economic improvement programs. Such information would quantify the extent to which social benefits from the programs varied between fisheries, and would enhance understanding of the factors determining the variation. Moreover, given that the implementation of economic improvement programs in fisheries is costly, it may assist fisheries management authorities to allocate resources for the development of such programs to maximise social benefits.

In this paper, a partial equilibrium model of a fishery is reviewed. An empirical model, suitable for estimating the annual gross economic benefits attainable from economic improvement programs that successfully rationalise fisheries, is developed and applied to the Southern Zone Rock Lobster Fishery in South Australia. The effect of the supply and demand characteristics of the fishery on annual gross economic benefits is examined.

The Social Benefits from Rationalisation of Fisheries

A partial equilibrium model of the fishery, employing conventional supply and demand relationships, provides a framework for quantifying the social benefits from economic improvement programs (Figure 1). Following Copes (1970), the long-run supply curve for the fishery (AC in Figure 1) can be derived from the respective yield curves and cost func-

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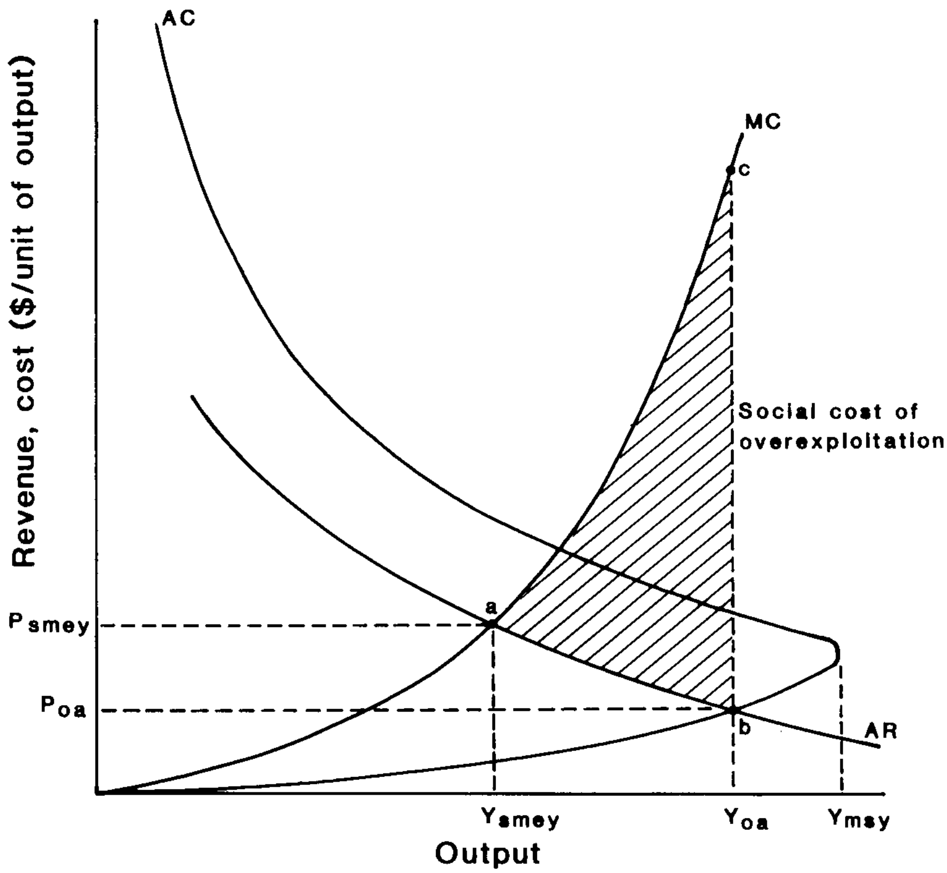

FIGURE 1—A Partial Equilibrium Model of a Fishery.

tions. The curve describes the relationship between the long-run equilibrium quantity of a homogeneous grade of fish produced and the cost of producing that output. Fixed factor proportions and fixed technology are assumed. Figure 1 indicates that as price increases, output increases at a decreasing rate, until reaching maximum sustainable yield (Y_{msy}). At higher prices, output declines, reflecting biological overfishing of the stock (represented by the backward sloping portion of the supply curve).

A marginal cost curve (MC in Figure 1) can be derived from the supply curve. Under competitive conditions it denotes the marginal social cost of production. It is upward sloping due to the long-run diminishing productivity of fishing effort. At any point beyond the maximum sustainable yield, marginal cost becomes negative and irrelevant.

The demand (or average revenue) curve for fish (AR in Figure 1) has been superimposed on the supply curve. Assuming perfectly competitive markets, open-access equilibrium will be reached at the point where long-run average cost is equal to long-run average revenue (Y_{oa} in Figure 1).

At this point, marginal vessels will just meet factor costs, and potential rent from the fish stock will be dissipated[1].

Abstracting from any divergence between private and social costs, the socially optimal level of output (the static maximum economic yield) will occur at the point where marginal cost is equal to price (Y_{smey} in Figure 1). Any increase in production beyond this point will be economically suboptimal, as marginal costs will be greater than the additional revenue obtained on sale of the product.

The cost to society of producing at the open-access equilibrium will be equal to the area between the marginal cost and average revenue curves, to the right of the static maximum economic yield and to the left of the open-access output level (area abc in Figure 1). Implementation of an economic improvement policy that reduced fishing effort to the optimal level (static maximum economic yield) will produce an annual gross social benefit equivalent to this amount. In the following section, an empirical model is developed to estimate the size of this benefit for fisheries with varying supply and demand characteristics.

The Empirical Model

The empirical model developed applies to a fishery managed as a common property resource in which fishing effort is applied to the point where average return is equated to average cost, that is, an open-access equilibrium. It is also assumed that the fishery is not biologically overexploited, implying that it is operating on the upward sloping portion of the long-run supply curve in Figure 1. The assumption is appropriate for many fisheries. For example, non-selfregulating fish species such as rock lobster and prawns do not exhibit a stock recruitment relationship within a defined range of fishing effort. Thus, provided the fishery is exploited within this range, the long-run supply curve will asymptotically approach the maximum sustainable yield rather than bending backwards. Even if increased fishing effort did reduce recruitment in these fisheries, or, indeed, the fishery were based on a self-regulating species, implementation of biological controls such as a minimum legal size of capture and seasonal and/or area closures should be sufficient to prevent the fishery from operating on the backward sloping portion of the supply curve in Figure 1.

The initial data requirements for the empirical model are estimates of the price elasticity of supply, the price elasticity of demand and the price and quantity of fish marketed at the open-access equilibrium. Derivation of the model begins with the specification of a constant elasticity marginal cost curve as,

$$MC = aY^{b} \tag{1}$$

where MC denotes marginal cost, Y denotes the quantity of fish produced, b denotes the inverse of the price elasticity of supply and a denotes a constant. Total cost (TC) can be obtained by integrating equation (1) with respect to Y,

[1] Rents will still be earned by inframarginal vessels, if the marginal cost of fishing effort is increasing.

(2)
$$TC = \int aY^b dY$$
$$= a(b+1)^{-1}\ Y^{b+1} + c$$

where c is the constant of integration. It is assumed that total cost is zero when output is zero, implying that c would also be zero. The supply curve or average cost curve (AC) is given by,

(3)
$$AC = a(b+1)^{-1}\ Y^b.$$

A mathematical function of the type described by equation (3) can be interpreted as a local approximation to the true functional form of the supply curve, between the maximum economic yield and the open-access equilibrium, in the price–output plan where the fishery is currently operating. Its positive slope is consistent with the assumption that the fishery is not biologically overexploited.

A constant elasticity demand function is specified as,

(4)
$$Y = (P/u)^{(1/n)},$$

where P denotes the price of fish, n denotes the price flexibility of demand and u denotes a constant. Rearranging in price form provides,

(5)
$$P = uY^n.$$

Open-access equilibrium occurs at the point of intersection between the average cost and demand functions (Y_{oa} in Figure 1). Assuming equilibrium, and using an estimate of the price elasticity of supply, a value for the parameter a can be obtained by rearranging equation (3),

(6)
$$a = (b+1)P/Y^b.$$

Similarly equation (5) can be rearranged to provide an estimate of the parameter u,

(7)
$$u = P/Y^n.$$

The quantity of fish produced at maximum economic yield (Y_{smey} in Figure 1) is calculated by equating marginal cost with price and solving for Y,

(8)
$$Y = (u/a)^{1/(b-n)}.$$

We now have estimates of parameters describing the average cost, marginal cost and demand for fish functions, as well as the equilibrium quantity of fish produced at the open-access equilibrium and at the point of static maximum economic yield. The annual social cost of economic overexploitation (SCE), defined by the area abc in Figure 1, can be calculated by subtracting the integral of the demand function between Y_{smey} and Y_{oa} with respect to quantity, from the equivalent integral of the marginal cost function[2].

[2] The expression for SCE becomes undefined when the price of elasticity of demand is equal to 1.

$$(9)\quad SCE = \int_{Y_{smey}}^{Y_{oa}} aY^b - \int_{Y_{smey}}^{Y_{oa}} uY^n$$

$$= a/(b+1)\ [Y_{oa}{}^{b+1} - Y_{smey}{}^{b+1}] - u/(n+1)\ [Y_{oa}{}^{n+1} - Y_{smey}{}^{n+1}].$$

This cost is equivalent to the annual gross social benefit of an economic improvement program that successfully caused the fishery to operate at the static maximum economic yield.

An Application of the Model

The model is now applied to the Southern Zone Rock Lobster Fishery in South Australia. However, it should be noted that this fishery has been managed as a limited entry fishery since 1968. Thus, the assumption implicit in the empirical model described above, that the fishery is operating at the open-access equilibrium, is violated. Nevertheless, Anderson (1985) has shown that even in a limited entry fishery fishermen will expand fishing effort until the average return (rather than the marginal return) is equated to marginal cost. This occurs because a limited entry regime, while prohibiting non-licensed fishermen from accessing the resource, does not guarantee any individual licence holder an exclusive right to fish. Thus, in Figure 1, equilibrium will occur when the average cost curve, which incorporates the effect of the limited entry management regime, is equated to average revenue. Therefore, the long-run equilibrium conditions in a limited entry and unregulated fishery are identical, although quantity produced at equilibrium may vary, depending on the influence of the limited entry regime on the supply of fish curve. For this reason, the empirical model developed is an appropriate representation of the Southern Zone Rock Lobster Fishery. However, the long-run equilibrium should be interpreted as a natural regulated rather than an open-access equilibrium.

It is assumed that the long-run equilibrium yield is 1650 t of fish and the equilibrium price is \$12/kg. Estimates of the gross annual social cost of economic overexploitation of the fishery, for selected supply and demand elasticities, are provided in Table 1. In Table 2, these absolute costs are expressed as a percentage of the value of the fishery at the natural equilibrium.

TABLE 1

Social Cost of Economic Overexploitation of the Fishery (\$'000) (Price \$12/kg; Quantity 1650 t)

	Supply elasticity			
Demand elasticity	0.05	0.5	1.5	30
−0.1	14166	1940	334	1
−0.9	15964	5805	1754	9
−5	16153	7223	3082	44
−50	16190	7579	3611	167
−200	16194	6711	3663	216

TABLE 2

Social Cost of Economic Overexploitation Expressed as a Percentage of Natural Equilibrium Value of the Fishery

	Supply elasticity			
Demand elasticity	0.05	0.5	1.5	30
−0.1	71.54	9.80	1.68	0.01
−0.9	80.62	29.32	8.86	0.05
−5	81.58	36.48	15.56	0.22
−50	81.77	38.28	18.24	0.84
−200	81.78	38.44	18.50	1.09

In accord with the economic theory of a common property resource, the results in Tables 1 and 2 indicate that a fishery at the natural equilibrium will always impose a positive cost on society. However, the magnitude of the cost is extremely sensitive to the specified elasticities, emphasising the influence that the supply and demand characteristics of the fishery exert on the potential benefits from economic improvement programs. A fishery characterised by an inelastic supply (0.05) and elastic demand (−200) could produce a social cost of up to 81.8 per cent of the value of the fishery at the natural equilibrium. Implementation of economic improvement policies in fisheries of this type could produce potentially large gross benefits to society. In contrast, the social cost of economic overexploitation in a fishery with an elastic supply (30) and inelastic demand (−0.1) is small relative to the size of the fishery (equivalent to only 0.01 per cent of the value of the fishery at the natural equilibrium). Thus the potential benefit from the introduction of an economic improvement policy will reduce as the price elasticity of demand decreases and/or the price elasticity of supply increases.

While the annual gross social benefits from economic improvement programs depend on the supply and demand characteristics of the fishery, in many fisheries the benefits, relative to the size of the fishery, will be large. This can be attributed to the economic characteristics frequently prevailing in fisheries.

More specifically, the supply of fish is often price inelastic. Many fisheries in Australia and throughout the world are fully exploited biologically. From Figure 1, the long-run supply curve in such fisheries will asymptotically approach maximum sustainable yield. An increase in price will bring forth a proportionately smaller increase in output, implying an inelastic supply of fish. Indeed, it seems likely that the price elasticity of supply for fish from such fisheries is often less than 0.5.

The demand for fish is often price elastic. This is the case with a product that is sold on the export market, and where the exporting country holds a small share of the total market. In many of the bio-economic analyses previously undertaken to determine the optimal level of fishing effort to apply in particular fisheries, it has been assumed that the demand for fish is perfectly price elastic (for example, Copes 1978; Henderson and Tugwell 1979; Belin and Sturgess 1979; Carrington and Chandra 1986). For

Australia, Haynes, Geen and Wilks (1986), concluded that the demand for fish products exported was highly price elastic. Even the demand for fish sold on the domestic market was considered to be price elastic (although less so than the export production).

Using price and quantity data for the Southern Zone Rock Lobster Fishery, and assuming that the price elasticity of the supply of fish is less than 0.5 and that the (absolute) price elasticity of demand for fish is greater than 0.9, the annual gross social benefits from the introduction of an economic improvement program that reduces fishing effort to the static maximum economic yield, are estimated to vary between \$5.8m and \$16.2m (Table 1). While this amount represents a small proportion of the total economy, it is large relative to the size of the fishery: equivalent to at least 29 per cent, and possibly as much as 81 per cent of the natural equilibrium value of the fishery (Table 2).

However, there could be some fisheries where the potential benefits from an economic improvement program are small relative to the size of the fishery. A fishery that is biologically underexploited would be operating on the flatter portion of the long-run supply curve in Figure 1, implying that the supply of fish will be more responsive to price[3] (Figure 1). There would also be some fish species for which demand is price inelastic. For example, Gleeson (1979) reported an inelastic demand for garfish in South Australia. Anderson (1973) noted that the price elasticity of demand for several fish species in the United States was inelastic (Table 3). The results in Tables 1 and 2 indicate that under these conditions, the potential benefits from economic improvement programs are reduced.

It is also apparent from Table 2, that the sensitivity of the estimated social cost of economic overexploitation to changes in the price elasticity of demand decreases as the supply of fish becomes more inelastic. With

TABLE 3

Price Elasticities of Demand for Selected Species in the United States

Species	Estimated elasticity
Atlantic groundfish	−1.0000
Halibut	−1.0000
Northern lobsters	−0.5995
Sea scallops	−0.6337
Clams	−0.6047
Oysters	−0.6724
Shrimp	−0.3099
Crabs	−0.1487
Tuna	−0.8632
Salmon	−0.7066
Sardines	−0.9837

Source: Anderson (1973)

[3] It is assumed that the prevailing fishery management policy would not prevent an expansion of output in a fishery that was biologically underexploited.

a supply elasticity of 0.5, the social costs vary from 9.8 per cent to 38.4 per cent of the natural equilibrium value of the fishery, as the demand elasticity varies from −0.1 to −200. The corresponding figures for a fishery with a supply elasticity of 0.05 are 71.5 per cent to 81.8 per cent. Therefore, in fisheries that are fully exploited biologically, economic improvement programs will always produce large social benefits relative to the size of the fishery. These benefits will be less affected by changing demand conditions than would be the case if the supply of fish was more price elastic (or if the fishery was biologically underexploited).

In fisheries where the demand for fish is price elastic, the social cost of economic overexploitation is relatively more sensitive to changes in the supply elasticity than to the demand elasticity (Table 2). Assuming an estimated supply elasticity of 0.05, a change in the demand elasticity from −5 to −200 would increase the social cost from 81.6 per cent to 81.8 per cent of the natural equilibrium value of the fishery. Assuming an equivalent variation in the demand elasticity, a change in the supply elasticity from 0.05 to 0.5 would result in costs varying between 36.5 per cent and 81.8 per cent of the natural equilibrium value. Therefore, in evaluating the effects of specific economic improvement programs in fisheries for which the demand for fish is price elastic, it is necessary to obtain accurate estimates of the supply elasticity. This will require information on the nature of the yield and cost functions.

The empirical method used in this study requires estimates of price and quantity at the long-run equilibrium. As fisheries are dynamic bioeconomic systems, they are seldom operating at the long-run equilibrium, implying that these data may not be known with certainty. The sensitivity of the results to these parameters is indicated in Table 4, where the same equilibrium quantity of 1650 t and a higher fish price of $15/kg is used, and in Table 5, where price is retained at $12/kg and the equilibrium quantity is increased to 2500 t. Comparison of the results contained in Tables 1, 4 and 5 indicates that the annual social cost of economic overexploitation is sensitive to the price and quantity data used. Thus, in applying the model it may be useful to conduct sensitivity analyses of the costs to these parameters.

The results presented above provide guidance to fisheries managers on the economic conditions (the supply and demand characteristics) under which economic improvement programs can produce potentially large gross

TABLE 4

Social Cost of Economic Overexploitation of the Fishery ($'000) (Price $15/kg; Quantity 1650 t)

	Supply elasticity			
Demand elasticity	0.05	0.5	1.5	30
−0.1	17707	2525	417	1
−0.9	19954	7256	2192	12
−5	20191	9028	3852	56
−50	20238	9474	4514	208
−200	20242	9513	4579	270

TABLE 5

Social Cost of Economic Overexploitation of the Fishery ($'000) (Price $12/kg; Quantity 2500 t)

	Supply elasticity			
Demand elasticity	0.05	0.5	1.5	30
−0.1	21464	2940	505	2
−0.9	24187	8796	2657	14
−5	24474	10943	4669	67
−50	24531	11484	5472	253
−200	24535	11531	5550	327

economic benefits. Provided an objective of the fisheries management authority is to increase economic efficiency, these findings suggest that economic improvement programs should be initially developed in fisheries that are fully exploited biologically and subject to an elastic demand for output.

Summary and Conclusions

A model is developed and used to provide estimates of the gross social cost of economic overexploitation of biologically safe fisheries. The results indicate that the actual costs of overexploitation are very sensitive to the supply and demand characteristics of the fishery. It is concluded that economic improvement programs, implemented to rationalise fisheries, are likely to produce large gross benefits to society relative to the size of the fishery, when the fisheries are both fully exploited biologically (implying an inelastic supply of fish) and where the demand for fish is price elastic. All of Australia's export fisheries are likely to be of this type. As the price elasticity of the supply of fish increases and/or the price elasticity of demand for fish decreases, the annual gross social benefits relative to the size of the fishery will decrease. Before proceeding with a particular economic improvement scheme, the circumstances applicable to the individual fishery need to be examined (including the costs of implementing the scheme).

There may be some fisheries, whose supply and demand characteristics are such that the potential benefits to society from rationalisation are relatively small. These fisheries typically produce a low value product, for which demand is price inelastic, and which are biologically underexploited. This may be the situation for some of Australia's fisheries supplying fresh fish to the domestic market. If the costs of implementing the policies exceed the benefits, it is preferable to allow these fisheries to operate at the natural equilibrium.

A limitation of the model is its static long-run equilibrium nature which disregards the dynamics of the fishery. Exclusion of uncertainty and time effects may cause the model to be relatively inefficient in predicting actual economic benefits of specific economic improvement policies. Nonetheless, it is useful for identifying the economic characteristics of fisheries for which programs are likely to be beneficial.

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