THE BACKWARD-BENDING SUPPLY CURVE OF THE FISHING INDUSTRY[1]

PARZIVAL COPES

Proceeding from an article by Gordon, published in 1954, the substance of an economic theory of the fisheries has emerged from the writings of a number of economists.[2] The theory has emphasized the common-property nature of the fishery resource, generally leading to an 'over-exploitation' that results in dissipation of the rent that the resource could yield.

The literature stresses, on the supply side, the relationship of output to the amount of fishing effort—the latter, in turn, providing a link with cost. But the consequences of these and other relationships in terms of conventional supply and demand analysis—as may be traced in simple price/output graphs—do not appear to have been treated exhaustively. It is in this area that the present article attempts to make a modest contribution. The analysis that follows purports to demonstrate that the long-run supply curve of a fishery, as a matter of course, may be expected to exhibit a negative slope for higher price ranges. A few of the consequences of this phenomenon are explored.

The initial model presented here considers, in isolation, a fishery based on the exploitation of a circumscribed stock of fish of one species with an unchanging matrix of natural conditions and bioligical relationships. Factor proportions and the state of fishing technology are regarded as fixed and it is assumed that there is unrestricted entry to the fishery. Supply is considered statically in terms of a long-run equilibrium in the weight of catch (per given time span). The time allowed for equilibration must be adequate for the adjustment of fishing effort to (long-run) conditions of market demand and, simultaneously, for biological adjustment of the fish stock to changes in the level of fishing effort. In other words, the supply in any instance, is one that is characterized by the sustained application of a particular level of fishing effort.

[1] I am indebted to A. D. Scott and R. A. Holmes for their helpful critique. Several of their suggestions are reflected in the final version of this paper. They bear no responsibility for the remaining faults.

[2] H. Scott Gordon, 'The Economic Theory of a Common-Property Resource : The Fishery,' *Journal of Political Economy*, Vol. 62, April 1954, pp. 124-42. Another notable contribution is Anthony D. Scott, 'The Fishery' : The Objectives of Sole Ownership,' *Journal of Political Economy*, Vol. 63, April 1955, pp. 116-24.

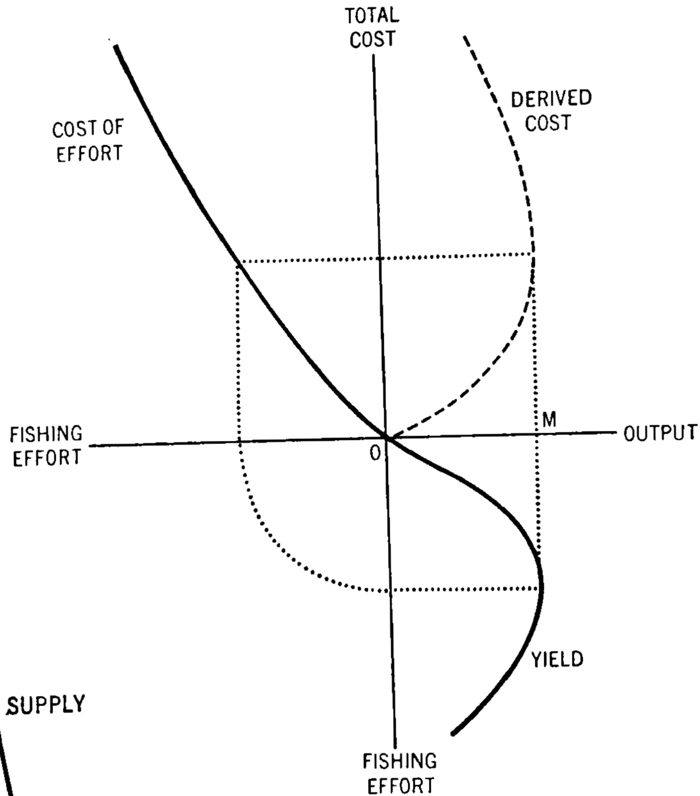
TOTAL
COST
DERIVED
COST
COST OF
EFFORT
FISHING
EFFORT
0
M
OUTPUT
YIELD
FISHING
EFFORT

FIG. 1

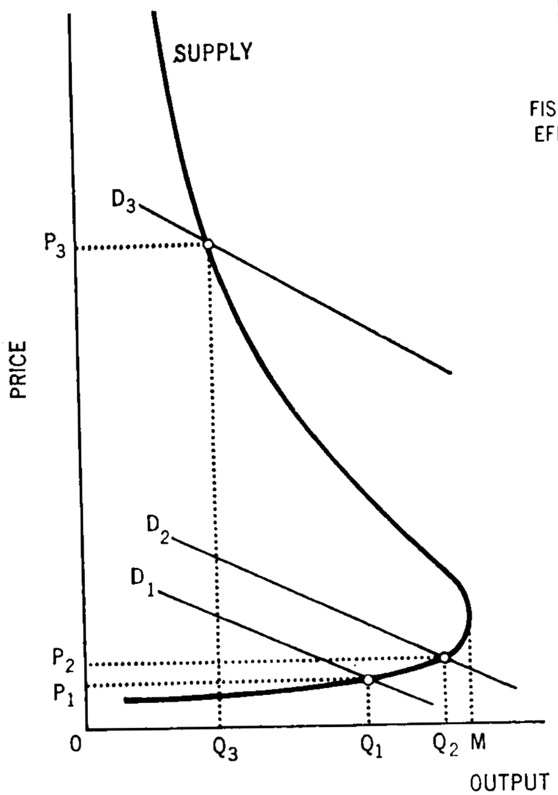
SUPPLY
PRICE
D3
P3
D2
D1
P2
P1
0
Q3
Q1
Q2
M
OUTPUT

FIG. 2

The analysis proceeds from relationships established in the existing literature,[3] which are brought out through Figure 1. In this diagram the S.W. quadrant remains vacant, its two axes recording, identically, varying amounts of fishing effort. The S.E. quadrant shows the relationship of output—measured by total weight of catch—to fishing effort, assuming a fixed pattern of gear selectivity.[4] An important characteristic of the yield curve is that it peaks at a specific level of sustained effort, measuring at that point the ' maximum sustainable yield ' (OM).

In the N.W. quadrant the total cost of output is recorded in relation to fishing effort. Assuming fixed techniques, fixed factor proportions and a multiplicity of small fishing units, the amounts of factors used will be proportional to fishing effort. Cost is calculated here for all factor units at the rate of marginal opportunity costs. It therefore includes any rents that intramarginal factor units may enjoy by virtue of their lower opportunity costs. Bearing in mind that some increase in rewards will need to be offered to divert additional factor units from alternative employment, a gradually rising cost-of-effort curve has been portrayed.

From the two relationships described, total cost may be derived for each weight of output, as is shown in the N.E. quadrant. The derived total cost curve may be readily converted to a cost curve per unit of output, portrayed in Figure 2. Owing to the stipulated condition of unrestricted entry, the fishing force (and consequent fishing effort) will adjust itself to demand conditions in such a fashion that the opportunity cost of producing a marginal unit of catch will equal its market price. No rent is enjoyed at the margin; the rent that the fishery resource itself could yield having been dissipated by the unrestricted entry.[5] The curve described in Figure 2, then, relates long-run equilibrium output to each given price and is therefore in the nature of a long-run supply curve.

Biometric studies suggest that for a typical fishery the yield curve will have the sigmoid shape indicated in Figure 1.[6] The curve for total cost in relation to output will be of exactly the same shape (allowing for

[3] See particularly Ralph Turvey, ' Optimization and Suboptimization in Fishery Regulation ', *American Economic Review*, Vol. 54, March 1964, pp. 64-76. The definitions and qualifying assumptions of this article apply here insofar as they are relevant.

[4] By changing the selectivity of fishing gear with respect to the size of the fish caught, the effect of any level of fishing effort on the equilibrium catch may be modified. Turvey's analysis (op. cit.) applies specifically to a trawl fishery in which the selectivity of gear may be manipulated by regulated variation in the permissible minimum mesh sizes. In the present article a fixed pattern of gear selectivity is assumed (not necessarily confined to trawling gear) in conformity with the postulation of a fixed technology. The yield curve in the S.E. quadrant of Figure 1 here corresponds with a yield curve for a fixed mesh size in Turvey's analysis.

[5] However, intramarginal factor units will enjoy rents attributable to themselves as measured by the difference between marginal opportunity costs and their own opportunity costs (cf. Turvey, op. cit., p. 66.)

[6] The standard work in the field is R. J. H. Berverton and S. J. Holt, *On the Dynamics of Exploited Fish Populations*, United Kingdom, Ministry of Agriculture, Fisheries, and Food, 1957.

expansion or contraction of the scales used) if cost is a linear function of fishing effort, which in much of the relevant literature is considered a justifiable simplication.[7] The assumption of moderate curvature in the latter function—suggested above—would modify the curvature of the total cost curve but would not affect its general shape. The important characteristic of this total cost function is that, while cost increases continuously, output rises until it reaches the maximum sustainable yield and then declines. This characteristic is transmitted in modified proportions to the average cost curve of Figure 2. This latter curve, then, has a backward-bending segment at prices higher than the level that will bring forth a maximum output. If the assumptions of the model are realistic in their essential features, such a curve may be considered representative for the fishing industry.

As a result of this reversing slope of the supply curve, one may expect that with a steadily increasing demand for the product of a fishery, typically the quantity produced will first increase (Q_1, Q_2) and eventually decrease (Q_2, Q_3), while the price will continue to rise (P_1, P_2, P_3). There are enough recognized instances of 'overfishing' (see below) to intimate that for specific fisheries demand levels have indeed pushed operations to a point on the backward slope of the supply curve, where increased effort is accompanied by lower output and a higher (real) price.

A point of at least theoretical interest is the possibility that a backward-bending supply curve offers for the simultaneous existence of more than one point of stable long-run equilibrium (A and B in Figure 3) with given demand (D_1) and supply schedules.[8] This possibility relates to the circumstance that a total cost curve of sigmoid shape converts to a price-output supply curve that is asymptotic in relation to the price axis and thus convex towards the origin in the upper part of its negatively sloped portion. Obviously, the equilibrium point with larger output and lower price (B) is socially preferable to the other (A). The former yields both a greater consumers' surplus and a lower cost. Assuming fluctuations in demand, however, it is likely that the less favourable equilibrium (A) will prevail. If the equilibrium is initially at B, a (temporary) increase in demand is liable to induce an expansion of fishing effort that may not be easily reversed—at least not fully so. The increased demand could call for an equilibrium (at C) that would by-pass A. A subsequent reversal of demand to its former level would find fishing effort being reduced until an equilibrium was reached at A, without any inducement to fall further.

It might be argued, conversely, that with an initial equilibrium at A, a (temporary) reduction in demand (D_3) could lead to an equilibrium on

[7] Gordon, op. cit., pp. 137-40, and Scott, op. cit., p. 118.

[8] Vernon L. Smith ('On Models of Commercial Fishing', *Journal of Political Economy*, Vol. 77, March/April 1969, pp. 181-98), focusing on the relationship between fishing effort and the fish stock, also draws attention to the case of two stable and one unstable equilibrium positions.

the lower slope of the supply curve (E). A subsequent restoration of demand might then come to rest in equilibrium at B. Against this it could be held that reductions in fishing effort (through reductions in fishing capacity) are less easily achieved than increases. It takes longer to wear out equipment than to create it. The short-run mobility of manpower, both into and out of the fishing industry, is limited. But with a given labour force, fishing capacity may be increased through technological improvements.[9] These, however, are likely to be irreversible.

To assure the relevance of the above analysis to actual relationships in the fishing industry, it is necessary to demonstrate that a backward-bending supply curve may be confronted by a relatively inelastic demand curve. The latter may occur where the product of a fishery is in the luxury class and does not face close substitutes in the market. This condition, in turn, suggests that the market must be defined with a wide extent and that the corresponding supply base encompass all fishing operations producing the given species of fish for this market. In practice, this would mean that the supply would have to be the aggregate of supplies from separate fishing grounds, each with its own production function represented by a backward-bending supply curve. An aggregation of these supply curves would give the curve confronting the market demand curve. As each of the separate fishing ground supply curves is asymptotic, the aggregate supply curve would have to

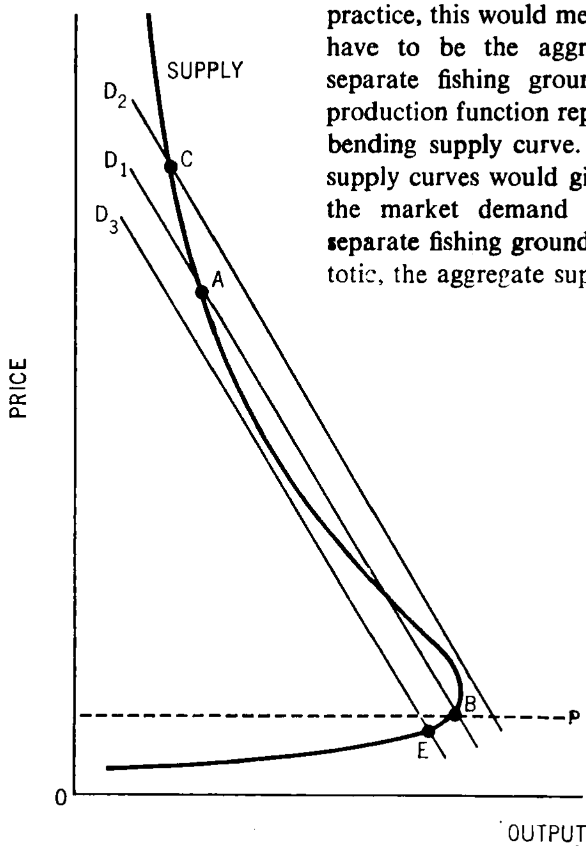

FIG. 3

[9] This is a point of practical significance, though it does violate the assumption of fixed technology and factor proportions stipulated above. It raises the possibility of a change or shift in the supply curve.

be the same. The aggregate supply curve, then, would also be backward-bending, though the relative positions of the component curves could impart some irregularity to its shape.

In any economically viable fishery the existence of a point of equilibrium of supply and demand may be assumed. An economically non-viable fishery would exhibit a demand schedule covering a price range entirely below that of the supply schedule. But as long as demand extends to a price level at which supply is forthcoming, an intersection of the demand and supply curves is indicated. This is so because of the asymptotic nature of the supply curve, qualified only by the indivisibility of the smallest unit of output, which gives practical assurance that the supply curve will extend to higher price ranges than the demand curve and thus intersect. This conclusion runs counter to a presentation by Turvey, in which he postulated a demand curve lying entirely above the corresponding supply curve.[10] In this dilemma he made the (unsupported) suggestion that output would remain at the maximum sustainable yield.

The best known examples of backward-bending supply curves are short-run labour supply curves, particularly relevant to underdeveloped countries. The cause of the backward slope in such curves is the dominance of income effect over substitution effect with a changing wage rate. Vatter contends that changes along such backward-sloping supply schedules will be irreversible and therefore questions whether such curves are true supply curves.[11] The backward slope of the supply curve for the fishing industry has a quite different origin. It is a long-run, rather than short-run phenomenon and results from the interaction of two conditions largely peculiar to the fishing industry. One is the common property nature of, and related free entry to, the fisheries. The other is the biological law of renewal in the fish stock under conditions of exploitation. Generally, there appears no reason why a movement along the fishing industry's long-run supply curve should not be reversible. It is true that an expansion-related technological change is likely to be irreversible, but this is a case of a supply curve shift, rather than a movement along the curve. One might consider the effects of an irreversible backward-sloping supply schedule

[10] Ralph Turvey, 'Introduction', in R. Turvey and J. Wiseman (eds.), *The Economics of Fisheries*, F.A.O., 1957, pp. vii-xii. Turvey uses a function derived by a different route, but from the same ingredients as the long-run supply curve described in this article. He proceeds by considering first a series of long-run supply curves, each particular to a given stable fish population. On each curve the single point is selected for which output (catch) equals the sustainable yield of the fish population assumed. By drawing the locus of the points thus selected a curve is achieved with the same definitional base and the same geometrical price/output expression as the long-run supply curve of this paper. A similar curve is used by James A. Crutchfield and Arnold Zellner in *Economic Aspects of the Pacific Halibut Fishery*, Fishery Industrial Research, Vol. 1, No. 1, U.S. Government Printing Office, 1963, pp. 16-7.

[11] Harold G. Vatter has summarized much of the literature on this subject in 'On the Folklore of the Backward-Sloping Supply Curve,' *Industrial and Labour Relations Review*, Vol. 14, July 1961, pp. 478-86.

for the labour component of the fishing industry's production function. But as Vatter points out, the backward-sloping labour supply is a rare phenomenon—with no apparent occurrence in fishing. Furthermore, it is a short-run phenomenon, with no apparent relevance to the long-run supply schedule of the fishing industry.

In the long-run—the long time necessary to establish economic equilibrium in the fishing effort and biological balance in the fish population—there are bound to be intermittent shifts in demand. Many markets for fish products, especially where they are international in extent, are subject to significant demand changes from year to year, or more frequently. This is related to the interaction with markets for competing fish products that are partial substitutes. At the same time, the fishing industry in many places is characterized by stable relationships for factor inputs—a tradition-bound and immobile labour force and slow technological change.[12] These circumstances lend some practical significance to the confrontation of a stable supply curve by a shifting demand curve, as is suggested in Figure 3.

Considering demand in this instance to be best represented by a band or bundle of curves (D_2-D_3), it is apparent that there could be an approximate coincidence of demand and long-run supply over a considerable price and output range along the reverse slope of the supply curve. While potentially unstable, equilibrium under these circumstances may be institutionally biased towards the greatest fishing effort (and thus the highest price and lowest output) compatible with the range of possible equilibria. This will result from the irrevocable commitment of productive resources once they are attracted to the industry. At the same time this analysis suggests that with different institutional circumstances a high-output-low-price market equilibrium could be approached at the opposite end of the equilibrium range.

In this connection a few policy measures suggest themselves. In a market confined to one country, the government might enforce price control at a level corresponding to a large output (P in Figure 3). This would be of doubtful appeal in private enterprise oriented economics in peace time. However, one common objection to price control, viz., that it requires the introduction of a system of non-price rationing, need not apply in this instance as there could be a balance or near balance of supply and demand at the controlled price. Perhaps a politically more acceptable method of achieving the same effect would be to establish appropriate prices through a marketing board with monopsony powers.

A common recommendation from economists, designed to achieve optimum exploitation of a fishery resource, is the limitation of fishing effort through licensing restrictions. This would reserve the fishery to a

[12] However, in some instances a destabilizing influence on the supply curve may be imparted by ecological changes affecting fish stocks.

limited number of operators and by thus restricting fishing effort it would set an upper limit to output (OL in Figure 4). The resulting supply curve (S_L) would have zero elasticity at maximum output. The social optimum (by the criterion of marginal cost pricing) would be achieved at that level of output at which demand and marginal social cost are equal. Abstracting from any divergences of private and social cost,[13] a marginal cost curve may be derived from the original supply curve that measures average cost. In Figure 4 marginal cost and demand intersect at N so that OL becomes the socially optimum output at a (marginal cost) price of OR. A maximum rent (NRTU) results which may be enjoyed by operators or transferred to the state through taxes or license fees. Alternatively, optimum output could be achieved through a marketing board controlling the price to fishermen at the level of OT, while selling to the public at price OR. The rent would

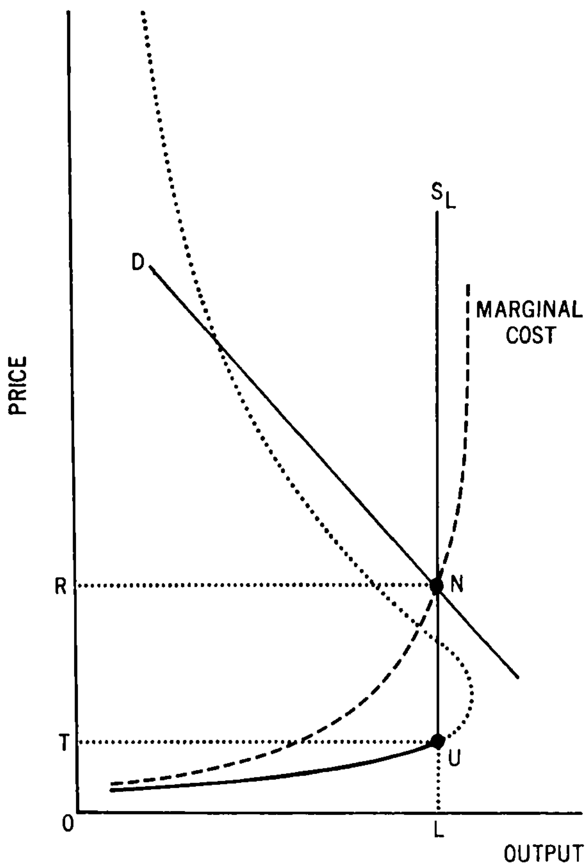

FIG. 4

[13] Where there are divergences of social and private cost (e.g., where intra-marginal factors enjoy a rent owing to lower opportunity costs or where crowding of fishing grounds introduces externalities) the marginal social cost curve would have to allow for an appropriate adjustment.

then accrue to the board. It should be noted, however, that the aim of limiting output to OL would be defeated if the marketing board were to follow the common practice of distributing profits to producers in relation to their respective outputs. This would effectively raise the price received above OT and induce an expansion of effort beyond that required for output OL.

The foregoing also allows a definition to be made of 'overfishing' in terms of demand and supply analysis. In an economic sense any fishing effort beyond that compatible with the achievement of the optimum output OL may be defined as overfishing. Biologists, however, sometimes refer to overfishing as an effort beyond that compatible with a maximum sustainable physical yield (OM in Figure 2).

The analysis of this paper in terms of conventionally stated supply and demand relationships confirms accepted observations regarding the propensity of an unlimited competitive fishery to expand fishing effort beyond the social optimum and to dissipate the rent the resource could yield. It offers new insights by drawing attention to the possibilities of multiple equilibria and the near coincidence, over a wide range, of demand with a negatively sloped supply. It suggests that the deterioration of a fishery through greatly reduced yield (with a correspondingly great price rise) may proceed quite rapidly once rising demand pushes exploitation past the maximum sustainable yield. At the same time, this deterioration might be arrested by appropriate institutional measures with comparative ease, i.e., without creating conditions in which there would be a significant divergence of demand and supply at the operational market price. The possibilities are raised of achieving a social optimum by the interposition of taxes, license fees or marketing board margins between buying and selling prices.

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