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A Note on Optimal Effort in the Maldivian Tuna Fishery

H. F. CAMPBELL

Department of Economics
University of Tasmania
Hobart, Tasmania 7001
Australia

R. K. LINDNER

University of Western Australia
Nedlands, Western Australia

Abstract *This note argues that spatial considerations and travel costs should be taken into account in devising tax/subsidy regulations for island-based tuna fisheries. In particular, the effect of a landings tax on distant fishing grounds should be considered when setting the level of the tax. A fuel subsidy is suggested as a means of offsetting the impact of the landings tax on marginal grounds.*

Introduction

In a recent paper Sathiendrakumar and Tisdell (1987) propose a tax on landings as a means of achieving an optimal level of effort in the Maldivian tuna fishery. They describe the fishery as being conducted within a range of 25 km from the atoll reef, and elsewhere they explain that because of the lack of ice the boats travel to and from the fishing grounds each day that they fish (Sathiendrakumar and Tisdell 1986). Travel cost is obviously an important consideration in this fishery but Sathiendrakumar and Tisdell (ST) make no provision for it in their model. The purpose of this note is to show that the "optimal" tax calculated by ST is excessive for most areas of the fishery, and to suggest alternative and more efficient ways of regulating the fishery.

The ST Model

As explained by ST, it is unlikely that the tuna stock in the region will be affected by the fishing effort of the Maldives. Assuming that applying increasing amounts of effort to a fixed stock of fish results in diminishing marginal productivity of effort, the catch/effort relationship can be expressed as

$$h = a - be^{-kE} \tag{1}$$

where h is the rate of harvest, E is the rate of effort, and a, b, and k are positive constants. For estimation purposes, ST allow $a \neq b$ because they are interested in obtaining an approximation to the relationship over the relevant range. If, however, a zero level of effort is to correspond to a zero level of harvest, it is necessary to restrict $a = b$ and we will employ this restriction in our analysis.

ST choose E to maximize the following expression.

$$\pi = ph - cE \tag{2}$$

where p is the price of tune determined in world markets, t is the proportionate ad valorem tax, and c is the unit cost of effort. Because ST note in their earlier paper that fisheries contribute 45% of Maldivian employment, we might question the assumption that the opportunity cost of effort is independent of the level of effort devoted to the fishery. (This point was made by Geoff Waugh in discussion with one of the authors.) However, because the focus of this note is the importance of travel costs, we will continue to assume that all inputs are supplied to the fishery at parametric prices. Because the equilibrium level of effort in an open-access fishery is determined by the zero-profit condition, the optimal tax in the ST model is the solution to

$$p(1 - t)\, h(E^*) - cE^*$$

where E^* is the level of effort that maximizes profit.

Travel Costs

The travel costs incurred by a vessel are of two kinds: the opportunity cost of time and the cost of fuel while traveling at speed to and from the chosen fishing ground. We assume that a vessel costs C_1 per day to operate plus the cost of travel at speed. The cost of a day's operations when ground i is chosen is;

$$C_i = C_1 + 2C_2d_i \tag{3}$$

where C_2 is the cost per kilometer of traveling at speed, and $2d_i$ is the length of the return trip to ground i. If the vessel travels at S kilometers per hour and the length of the working day is N hours, the proportion of the day spent fishing is

$$V_i = \frac{N - (2/S)d_i}{N} \tag{4}$$

Combining (3) and (4) gives an expression for the cost per unit of effective effort in ground i:

$$r_i = \frac{NS(C_1 + 2C_2d_i)}{NS - 2d_i} \tag{5}$$

where, for simplicity, we assume C_1, C_2, N, and S to be exogenous.

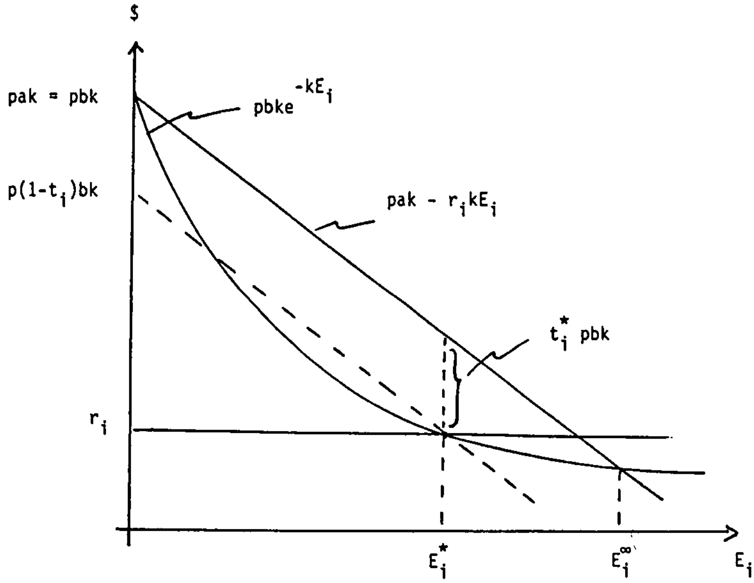

Figure 1 Solutions to $pbke^{-kE_i} = pak - kr_i; E_i$.

The Revised Model

We can now consider the tax that will produce an optimal level of effort in fishing ground i. The optimal level of effort is given by the solution to

$$\frac{\partial \Pi_i}{\partial E_i} = pbke^{-kE_i} - r_i = 0 \tag{6}$$

The optimal tax on harvest in fishing ground i is given by the solution to

$$p(1 - t_i)(a - be^{-kE_i^*}) - r_iE_i^* = 0 \tag{7}$$

where $E_i^* = (1/k)\ \ln(pbk/r_i)$. In the absence of a tax the open access equilibrium level of effort in ground i, E_i^∞, is given by the solution to

$$pbke^{-kE_i} = pak - kr_iE_i \tag{8}$$

The solutions are illustrated in Figure 1 where it can be seen that $E_i^\infty > E_i^*$ when there is no landings tax. From (7) it can seen that the optimal tax in ground i is

$$t_i^* = \frac{1 - r_iE_i^*}{p(a - be^{-kE_i^*})} \tag{9}$$

If landing taxes are to be used to obtain all the potential rent from the fishery, it is clear from (9) that a different tax will be required on harvest from each ground. It can be shown that $\partial t_i^*/\partial r_i < 0$, indicating that the optimal tax will be highest in the closest ground. The extensive margin of the fishery is where the optimal level of effort tends to zero. From (6) this occurs where $r_m = pbk$. This means that the optimal tax on landings in the farthest ground is

$$t_m^* = 1 - \lim_{E^* \to 0} \frac{pbkE_i^*}{p(a - be^{-kE_i^*})}$$

Using l'Hopital's rule, the optimal value of t_m^* can be seen to be zero. In the closest ground, the value of r_i becomes c_1 and the optimal tax becomes the one calculated in the ST paper.

Policy Alternatives

It is clear that the policy recommended by ST will not distribute effort optimally over the fishing grounds. Marginal grounds will be excluded from the fishery because of the tax, and in those grounds that are fished effort will be too low except in areas directly adjacent to the atoll reef. A policy of imposing a landings tax differentiated by area of harvest may be difficult, it not impossible, to operate. If a single tax on landings is to be used it should be one that trades off efficiency gains in the nearby fishing grounds against losses in the distant grounds. This will be a lower tax than the one recommended in the ST paper. A policy that is potentially more efficient than a single-tax policy is one that offsets the effect of the single tax on the amount of effort applied to distant grounds by means of a subsidy on the price of boat fuel. Such a subsidy would reduce the unit cost of effective effort, r_i, by a greater amount for distant than for nearby grounds, thereby encouraging the exploitation of distant grounds. Before this potentially more efficient tax/subsidy scheme could be introduced additional research on travel costs would be required.

References

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