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Pulsed Generic Advertising: The Case of Common Property

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Abstract *Regulation of fisheries production together with public promotion of fisheries products offer a potentially profitable environment for fishermen. Yet production restrictions are usually insufficient to prevent entry, causing depletion of the resource base and dissipation of long-run profits from promotion. Shorter run gains may be possible, providing producer response to advertising is not instantaneous.*

Lagged biological and economic responses appear to provide a rationale for pulsed advertising. Moreover, a pulsed advertising policy is shown to mitigate the adverse effects on the resource base which would normally accompany expansion of consumption without direct production control.

Keywords Generic promotion, oysters, common property, pulsed advertising.

Introduction

Almost ninety percent of U.S. fishery production comes from capture fisheries (USDA). These capture fisheries are managed under the jurisdiction of either the federal government or individual states, depending on whether or not the majority of the harvest is within three miles of a state's coastline. The political economy of fisheries management at both the state and federal level has resulted in an industry structure, in most cases, based on free entry. Entry restrictions proposed by economists to protect both the resource and its potential economic rents have been discarded in favor of a morass of protective regulations which conserve the stock but restrict neither entry nor expansion.[1]

Other programs related to the fishing industry, at both the federal and state level, are often treated separately from the fisheries management and stock conservation efforts. For example, in Maryland, the Office of Seafood Marketing is currently in the Maryland Department of Agriculture, while regulation of fish harvesting is under the jurisdiction of the Maryland Department of Natural Resources. At the Federal level, there is little coordination within the National Marine Fisheries Service between the division responsible for fisheries manage-

[1] A notable exception is the surf clam fishery which has had a moratorium on entry of new vessels since 1977. There have also been severe restrictions on the number of hours a surf clam vessel may fish over the course of the season. A landings rights program is currently being implemented.

ment (including the largely autonomous Regional Fishery Management Councils) and those involved with industry development. Therefore, it is not surprising that Federal and state programs aimed at generic promotion of seafood products have shown little consideration for the problems associated with the open access exploitation of a common property resource.

The most recent example of this was the passage of the Fish and Seafood Promotion Act of 1986 (P.L. 99-659). The Act provides Federal funds for generic promotion of seafood through 1990, but more importantly, provides the enabling legislation to allow the seafood industry to assess its members on a continuing basis for the cost of generic advertising. The legislation also allows the industry to set quality standards in a similar manner to other agricultural marketing orders. Interestingly, in the Section 202, Findings, of the Act, it is mentioned that:

> "(6) many fish species are underutilized by the United States fishing industry because of underdeveloped markets."

There is no mention in the findings that the major problem facing the U.S. fishing industry continues to be the depressed conditions of many stocks due to overharvest, and the overcapitalization in most segments of the fishing industry.

The issues related to the social desirability of advertising of branded products and generic products have been discussed in the economics literature (*e.g.*, Scherer, 1980; Nichols, 1985). On the producer side, it is clear that long-term gains to advertising are dissipated by new entry and expansion of output. Therefore, advertising is most beneficial to producers when there is some restriction on flow-to-market. These restrictions may be due to monopoly power for branded products, and may be facilitated by agricultural marketing orders for generic products. With an open-access fishery, short-term gains from higher prices due to generic advertising are dissipated by a combination of an expansion in output and higher costs of production due to a further depletion of the stock in order to expand output. If the fish stock is biologically overharvested, expanded fishing effort may actually lower the harvest in the long-run, but the price rise caused by lower production will still be offset by higher fishing costs. Fishing effort regulations adopted to capture the economic rent of the fishery resource could also have the effect of preserving long-term gains from generic advertising of fishery products.

Whether or not consumers are better off due to advertising will depend on the content of the advertising, information or deception, and on whether or not welfare is measured using *ex ante* or *ex post* advertising tastes (Dixit and Norman; Scherer, 1980 pp. 376–405). However, in common-property fisheries, the likelihood of consumer losses due to advertising is greater because of the possibility of biological overharvest. Even when the advertising is pure information, the resulting demand shift may result in higher prices and less production. McConnell and Strand (1989) demonstrate this effect when a shift in demand due to improved water quality, analogous to an increase in advertising, results in decreased consumer surplus.

In this paper we develop the framework for determining the optimal promotional strategy for fisheries conditional on the omnipresent free entry management regime, aware that such strategies may diverge considerably from the solutions which restrict production and fishing effort. Optimization is based solely on producer benefits. Others may argue that promotion programs that are either directly or indirectly supported by the government should have consumer benefits measured as well. We have chosen to ignore these because of the controversy discussed earlier about how they should be measured, and also to reflect the reality that these programs, although sometimes explicitly stated otherwise, are not designed with the consumer's welfare in mind. The Fish and Seafood Promotion Act establishes a National Fish and Seafood Promotion Council where 14 of the 15 voting members represent the producing industry and the 15th member shall be:

> "(F) one member-at-large who is either a person professionally engaged in the dissemination of information pertaining to the nutritional benefits and preparation of fish and fish products or a person who is a member of an organized labor union and has expertise in the United States fisheries."

This member is the nearest to a "consumer" representative on the Council.

A conceptual model of generic advertising with a common property resource base is developed, accounting for the dynamics of advertising and demand, capital formation in the fishing industry, and the fish stock. First-order conditions arising from optimal advertising strategies are used to examine the economic trade-offs between higher immediate industry profits versus eventual unwanted capital. The likely time delays in the system suggest a potential solution of cyclical advertising expenditures. Depending on the behavior of the cycle, pulsing of advertising over a period of substantial duration may be observed.

Data from the Maryland oyster industry was used to apply and test the conceptual model. Recent events, principally the decimation of Maryland's oyster stocks due to disease, would confound the results and are not included in the analysis. Relevant biological and economic parameters of the Maryland industry are estimated econometrically, and these results are applied to a numerical analysis of optimal intertemporal advertising strategies.

Empirical results suggest that under the conditions of the Maryland oyster fishery from 1967–1980, constant levels of advertising are suboptimal in raising fisherman's incomes. Instead, a cyclical pattern (or pulsed strategy) will be optimal. This pulse strategy does not arise from "wearout" (Simon, 1992) or linearity (Clark, 1976) phenomena, but rather from initial conditions and the trade-off between capital necessary for profit and capital that ultimately reduces the fish stock. Advertising is only undertaken when fishing effort is relatively low and the resource base built up. When potential production is high, advertising is introduced. The resultant high incomes attract effort and drive down the fish stock, making continued high levels of advertising counterproductive. Reducing advertising leads to exit and subsequent resource recovery. The cycle dampens after several reversals.

Optimal Advertising in a Common Property Fishery

We extend the previous work of Nerlove and Arrow (1962) and of Schmalensee (1972) by addressing the nature of optimal advertising strategies in industries harvesting a common property resource. Recognizing the intrinsic dynamic nature of advertising, these authors argue that advertising is a form of investment affecting both current and future demand for a product. Combining this aspect of advertising with the biological stock growth and capital accumulation on the supply side causes complex dynamic strategies.

Demand is considered to be a function of consumers' perception of the product where this perception is reflected in their stock of goodwill for the product. The stock of goodwill is augmented by advertising but decays over time. Thus goodwill at time t equals:

$$G_t = \delta G_{t-1} + g(A_{t-1}). \tag{1}$$

The parameter δ reflects the carryover of goodwill from one period to the next ($0 \leqslant \delta \leqslant 1$), and $g(\cdot)$ relates advertising expenditures to goodwill. Since it is reasonable to expect diminishing returns to advertising, $\partial g/\partial A > 0$ and $\partial^2 g/\partial A^2 < 0$ are assumed. The stock of goodwill in any time period (G) and exogenous factors (Z) affect the price consumers are willing to pay for (Q) of the product. Thus, the inverse demand function can be expressed as:

$$P_t = D(Q_t, G_t, Z_t). \tag{2}$$

Following an approach frequently employed in fisheries biology and economics (*e.g.*, Bell, 1972), but more generally applicable, we present all inputs used in production by one index which we call effort (E).[2] Thus, effort measures both capital and its utilization. The degree of utilization of capital in a given time period will likely depend on current price (P_t). The availability of capital in that time period with depend on the capital stock, built as a function of expected future returns. A naive expectations approach is used to model the determination of desired capital stock levels. Previous periods prices (P_{t-1}) and resource stock levels (X_{t-1}) are used in the capital formation decision to yield a total effort response equation of the following general form.[3]

$$E_t = k(P_t, E_{t-1}, X_{t-1}, P_{t-1}) \tag{3}$$

where the common property situation implies no central control over effort levels. The supply of product at time t is determined by effort and the size of the resource stocks:

$$Q_t = h(E_t, X_t). \tag{4}$$

Stock sizes changes with natural growth, f(X), and with harvests, so that the resource stock in time t can be expressed as:

$$X_t = f(X_{t-1}) - Q_{t-1}. \tag{5}$$

[2] Squires discusses the restrictive nature of using E as an index of production inputs, but its use here greatly decreases data requirements and allows us to proceed with an analysis of generic promotion.

[3] As an anonymous reviewer pointed it, this specification does not depend directly on profits, and therefore, does not guarantee a steady state equilibrium with zero profits as would be predicted by theory. Due to lack of cost data it is not possible to calculate profits from the data set. As a next best approach, we use this specification as a proxy for behavioral response to profits. When prices and stock are such that profits would be positive effort enters, but lower prices and stocks leading to negative profits result in exit of effort.

The function f(X) is assumed to be concave and increasing over an open interval $(O,\overline{X})$ where $\overline{X}$ is the size of the equilibrium unfished population.

The central authority is assumed to exercise effective control over only one decision variable, advertising expenditures (A). This is consistent with the existing seafood promotion act and the realities of separation of seafood promotion activities from resource management programs at both the state and federal level. The objective is to maximize the present value of the stream of net returns to harvesting minus agency advertising costs, where for any period t the objective function is:[4]

$$P_t(Q_t,G_t,Z_t) \cdot Q_t(E_t,X_t) - C(E_t) - A_t. \tag{6}$$

Costs of production are represented by $C(E_t)$ and are increasing in effort. Since advertising is measured in terms of real expenditures, A_t equals the cost of advertising as well.

The authority's decision problem can be characterized in a discrete-time optimal-control framework (Burt and Cummings, 1970). It can be expressed as a LaGrangian maximization of the form:[5]

$$\begin{aligned} L = \max \sum_{t=0}^{T} & [P_t(Q_t,G_t,Z_t) \cdot Q_t(E_t,X_t) - C(E_t) - A_t)\beta^t \\ & - \lambda_t\beta^t(X_t - f(X_{t-1}) + Q_{t-1}) - \mu_t\beta^t(E_t - k(P_t,E_{t-1},X_{t-1},P_{t-1})) \\ & - \gamma_t\beta^t(G_t - \delta G_{t-1} - g(A_{t-1}))] \end{aligned} \tag{7}$$

where $\beta = 1/(1 + \rho)$, and ρ is the real discount rate.

The multipliers, λ, μ, and γ are, respectively, the implicit current values of a marginal unit of resource stock, capital stock and goodwill. Maximization of L with respect to A_t for all t yields the following set of first-order conditions for optimization:

$$\gamma_{t+1}\beta\partial \frac{G_{t+1}}{\partial A_t} - 1 = 0 \tag{C1}$$

$$\gamma_t = Q_t \frac{\partial P_t}{\partial G_t} + \gamma_{t+1}\beta\delta + \mu_{t=1}\beta \frac{\partial E_{t+1}}{\partial P_t}\frac{\partial P_t}{\partial G_t} + \mu_t \frac{\partial E_t}{\partial P_t}\frac{\partial P_t}{\partial G_t} \tag{C2}$$

[4] We assume capital is perfectly malleable, and therefore, need only be concerned with the operating cost of effort and not the rental cost of capital and depreciation (Clark et al., 1979). Later in the empirical analysis we will argue that there is a delayed response in capital accumulation or removal. Most fishermen, particularly Maryland watermen, are adaptable to switching fishing effort to other fisheries because of the large natural variation in fish stocks. These alternatives allow malleability, but behaviorally, the watermen are modeled as adjusting partially.

[5] We suppress the initial and terminal condition constraints to improve readability. However, the application implicitly takes them into consideration.

$\mu_t =$

$$\frac{\left[\left(Q_t \frac{\partial P_t}{\partial Q_t} + P_t\right) \frac{\partial Q_t}{\partial E_t} - \frac{\partial C}{\partial E_t}\right] + \mu_{t+1}\beta\left[\frac{\partial E_{t+1}}{\partial E_t} + \frac{\partial E_{t+1}}{\partial P_t} \frac{\partial P_t}{\partial \delta Q_t} \frac{\partial Q_t}{\partial E_t}\right] - \lambda_{t+1}\beta \frac{\partial Q_t}{\partial E_t}}{1 - \frac{\partial E_t}{\partial P_t} \frac{\partial P_t}{\partial Q_t} \frac{\partial Q_t}{\partial E_t}} \tag{C3}$$

$$\lambda_t = \left(Q_t \frac{\partial P_t}{\partial Q_t} + P_t\right) \frac{\partial Q_t}{\partial X_t} + \lambda_{t+1}\beta\left(\frac{\partial X_{t+1}}{\partial X_t} - \frac{\partial Q_t}{\partial X_t}\right) + \mu_t \frac{\partial E_t}{\partial P_t} \frac{\partial P_t}{\partial Q_t} \frac{\partial Q_t}{\partial X_t} - \mu_{t+1}\beta \left(\frac{\partial E_{t+1}}{\partial P_t} \frac{\partial P_t}{\partial Q_t} \frac{\partial \delta Q_t}{\partial X_t} + \frac{\partial E_{t+1}}{\partial X_t}\right) \tag{C4}$$

for all t, in addition to the three constraints (1), (3) and (5) and a non-negative constraint on A_t for all t.

With one control and three state variables, simplification of the above conditions is difficult, but their interpretation is relatively easy. Conditions (C1) and (C2) together describe the optimal path for advertising and goodwill, conditional on the scarcity values of effort and resource stocks. Condition (C1) has the interpretation that in any time period the marginal cost of advertising (which equals one, since advertising is measured in expenditures) should equal the present value in that time period of all future net benefits generated by the increment in advertising. These net benefits accrue through the effect of advertising on goodwill in the next time period.

Condition (C2), the expression for the marginal scarcity value of goodwill, provides information as to the components of these net benefits. The first term captures the direct effect on revenues in the current period of increasing goodwill and thus shifts out demand. The second term captures the scarcity value of that portion of goodwill which is carried over to the next period, where δ is the proportion of goodwill carried forward. The final terms reflect the marginal scarcity value of present and all future effort attracted to the fishery by the current increase in price generated by the increment in goodwill. These terms are unique to the common property setting and represent an unusual cost of advertising. Increasing advertising provides economic incentives for entry of new effort, where effort is likely already to be employed at inefficiently high levels. This common property effect is translated into expected negative values for μ, the scarcity value of effort.

Condition (C3) provides an expression for the scarcity value of effort. The term $1/[1 - (\partial E_t/\partial P_t)(\partial P_t/\partial Q_t)(\partial Q_t/\partial E_t)]$ is present only because of the concurrent effect of effort on price and price on effort. This term is less than one and serves to dampen the magnitude of the remainder of the expression since a round of increased effort depresses price through increased harvests and so leads to a simultaneous reduction in effort. The term approaches one in the short run when adjustments of effort by producers are more difficult.

The sign of the marginal scarcity value of effort can be determined by assessing the three terms in the numerator of equation (C3). The first term represents marginal net revenues from increasing effort. In a competitive industry this should be negative because excessive effort is dissipating the potential economic rent of the resource stock. The second term reflects the scarcity value of the effort carried over to the next period. The third term captures the marginal user cost associated with the resource stock, adversely affected by increased effort. Embodied in this term are the stock externalities which are not taken into account by individual producers in a common property fishery. The marginal value of stock is derived in condition (C4).

The important dynamic features of conditions (C2–C4) are highlighted when they are written in the general form:

$$Y_t = V^{-1}Y_{t+1} \tag{8}$$

where Y_t is the 3×1 vector of LaGrangian multipliers in our problem, and V is a 3×3 matrix reflecting intertemporal movements in Y_t. The solution for Y_t can be characterized as:

$$Y_t = BD^t_\psi B^{-1}Y_o \tag{9}$$

where D^t_ψ is a diagonal matrix (3×3) of the characteristic roots (ψ) of V, and B is a matrix (3×3) whose columns are the characteristic vectors of A (Chow, 1975). If some characteristic roots are complex numbers (*i.e.*, $\psi_i = a_i \pm b_i \sqrt{-1}$), then their contribution to the solution can be represented as a harmonic function of the form $sr^t \cos(\theta + \omega t)$ where sr^t represents the amplitude; θ/ω, the phase shift; and $\omega/2\pi$, the frequency. If $|r| < 1$, then the solution is a dampened cycle.

A Statistical Model of the Maryland Oyster Industry

Until its recent decimation by disease, the Maryland oyster fishery was the most important economic component of the Maryland seafood industry. Regulated to conserve stock through inefficient means (Christy, 1964), the industry uses the same technologies as in the 1880's. A campaign to promote the Maryland oyster was instituted in 1967 on the heels of a major effort to rebuild the overharvested oyster stock through public replenishment of oyster stocks. Although not entirely directed towards oysters, Maryland's Seafood Development Program spent $1.5 million between 1967 and 1980 to assist the oyster industry in marketing its increased production. Program funds, however, were cut by 50% in 1981 to $115,000. Funds continued to diminish throughout the remainder of the 1980's until 1989 when a major enhancement brought funds back to the 1981 levels. However, the period of 1967–1980 offers a perfect situation in which to test the operational value of our conceptual model.

Estimates of the biological and economic parameters of the theoretical structure must be obtained prior to calculating a solution to the dynamic optimization problem: In order to make these parameter estimates from available data, it is necessary to provide specificity and functional form to the general equations of the previous section.

Changes in the resource stock variable are captured by a typical discrete approximation (Hilborn, 1979):

$$X_t = (1 + r)X_{t-1} - (r/k)X^2_{t-1} - Q_{t-1} \tag{10}$$

where r is a biological growth parameter, and k is the equilibrium of the unfished population.[6] We assume a production relationship of the form:

$$Q_t = qE_tX_t \tag{11}$$

where the parameter q reflects the proportion of the stock harvested by a unit of effort. Since there are no measures of the standing stock of oysters over the time period of interest, equations (10) and (11) are combined to yield the estimating equation:

$$R_t = (1 + r)R_{t-1} - (r/qk)(R^2_{t-1}) - qQ_{t-1} + n_t \tag{12}$$

where $R_t = Q_t/E_t$ represents relative stock abundance and n_t is a random disturbance term.[7]

The second equation in the system describes the determination of the level of fishermen's inputs, E. Fishermen are expected to alter their capital utilization in response to current prices and to alter their capital stock in response to expectations of returns based on past prices and yields (reflected in relative abundance). These expected returns affect their desired effort level, which is given by:

$$E^*_t = \beta_o + B_1P_t + B_2P_{t-1} + \beta_3R_{t-1} + v_t. \tag{13}$$

Fishermen typically do not completely and immediately adjust effort to desired levels. The change in effort can be described by the partial adjustment model.[8]

$$E_t - E_{t-1} = \phi(E^*_t - E_{t-1}) + w_t. \tag{14}$$

Combining (13) and (14):

$$E_t = \phi B_o + (1 - \phi)E_{t-1} + \phi\beta_1P_t + \phi\beta_2P_{t-1} + \phi\beta_3R_{t-1} + s_t \tag{15}$$

where the error terms s_t meets the Gauss-Markov assumptions if v_t and w_t do.

The third transition equation cannot be estimated directly because goodwill is unobservable. However, from equation (1), G_t can be expressed in terms of past advertising levels as:

[6] As a reviewer has pointed out, this is not the best discrete time approximation of the logistic growth function. It is however, an approximation of an appropriate growth function and can easily be estimated with linear regression techniques.

[7] As pointed out by a reviewer, this specification introduces the potential for bias into the estimation if, as hypothesized, E_t and E_{t-1} are related. Unfortunately, there is no way around this problem because there is no independent estimate of stock size available.

[8] Alternative behavioral assumptions (*e.g.*, rational expectations) could be proposed for the watermen's behavior. Institutional constraints limit watermen's ability to borrow so that investment must generally come from recent years' profits. Additionally, the inflexible nature of human capital in fishing precludes rapid disinvestment. These arguments make a short-term lagged adjustment model far more realistic that a rational expectations model for fishing firms.

$$G_t = \sum_{i=0}^{\infty} \delta^i g(A_{t-1-i}). \tag{16}$$

Making a substitution for goodwill in a linear demand function allows us to express demand as:

$$Q_t = \alpha_o + \alpha_1 P_t + \alpha_2 \left[\sum_{i=0}^{\infty} \delta^i g(A_{t-1-i}) \right] + \alpha_3 Z_t + u_t \tag{17}$$

where Z_t represents other exogenous variables. Estimation of this equation requires a Koyck transformation which yields:

$$Q_t = \alpha_o(1 - \delta) + \delta Q_{t-1} + \alpha_1(P_t - \delta P_{t-1}) + \alpha_2 g(A_{t-1}) + \alpha_3(Z_t - \delta Z_{t-1}) + m_t. \tag{18}$$

An iterative procedure was used to estimate a value for δ which would be consistent throughout the equation. Note that m_t equals $\mu_t - \delta\mu_{t-1}$ and is first order serially correlated if the μ_t of (17) are independent.

Equations (12), (15), and (18) yield a system which is compatible with the theoretical model and can be estimated using available data. Published annual data on harvest, value of harvest and total boat days for Maryland oysters were available for the 1965 through 1976 seasons (Cabraal, 1978). Unpublished data on harvest, value of harvest, and boat days by gear type were made available from Maryland's Department of Natural Resources for the 1975 through 1981 seasons. State expenditures on seafood marketing since 1968 were available, although funds targeted specifically for oysters could not be determined. Since oysters constituted the major focus of this marketing program, total expenditures represented a good approximation.

In addition to the variables discussed above, two other factors were considered. First, evidence suggests that demand in the 1976 and 1977 oyster seasons was affected by publicity on the closure of the James River due to kepone contamination (Swartz and Strand, 1981). A binary variable is included in the price equation to capture this effect. A second institutional factor is taken into account in the effort equation. In addition to season and gear restrictions, effort on oyster stocks was regulated for many years by county residency requirements (Powers, 1970). These requirements, however, were struck down in late 1971 (Bruce *vs.* Director, Department of Chesapeake Bay Affairs), with a resulting increase in mobility (Lewis and Strand, 1978).

The definition and measurement of the preceding data is summarized as follows:

R_t relative abundance of oysters or catch per unit effort in season t, measured in bushels per tong day, mean = 18.7;

E_t effort in season t measured in millions of tong boat days per season, mean = .122;

Q_t harvest in season t measured in millions of bushels, mean = 2.27;
P_t average price in season t measured in 1967 dollars per bushel, mean = \$3.69 per bushel;
A_{t-1} Maryland Seafood Marketing Division expenses in the fiscal year prior to the fishing season, measured in millions of 1967 dollars, mean = \$.104;
Z_t binary variable for James River closure, value is one for 1975–1976 and 1976–1977 season, zero otherwise;
D_t binary variable identifying the years in which county residency requirements were in effect, one for each season through 1970–1971, zero for post 1970–1971 seasons;
DP_t the difference between P_t and δP_{t-1};
DZ_t the difference between Z_t and δZ_{t-1}.

The results of the three-stage least-squares estimation of the system are presented in Table 1.[9] Most coefficients have expected signs and are at least twice the magnitude of their standard errors. The exceptions are in the effort equation where the coefficients on contemporaneous price and lagged relative abundance are less than twice their respective standard errors. The insignificance of the current price coefficient is not surprising since the largest variations in effort would be brought about by changes in the capital stock, requiring at least one year to accomplish. Variations in the utilization of existing capital stock are more likely to be affected by random events (*e.g.*, weather) than by short-run responses to price. Once having rigged their boats and thus having made a commitment to oystering, watermen do not have many comparable employment alternatives during the oyster season. The insignificance of relative abundance suggests that the effect of stock levels on effort decisions is also negligible. This seems realistic since the common property nature of the fishery introduces considerable uncertainty into the relationship between present stocks and future yields to any individual fisherman. The effort equation also supports the argument that fishermen do not respond immediately to changes in economic incentives. A little more than

[9] Because the observation set approach is undersized (Theil, 1971, p. 532), parameters in the nonlinear function $g(A_{t-1})$ could not be estimated simultaneously with the parameters of the rest of the system. Instead, we chose several different functional forms for $g(A_{t-1})$, all of which were consistent with the *a priori* requirements that $\partial g/\partial A > 0$ and $\partial^2 g/\partial A^2 < 0$. We proceeded to test the robustness of the other system coefficients over choice of functional form and ranges of non-linear parameters. The three functional forms chosen for $g(\cdot)$ were $(1 - \exp(\nu A_{t-1}))$, the semi-log form (A_{t-1}^{γ}), and the logistic $(1/(1 + \exp A))$. Parameters ranged from -4 to -1.2 for ν and $-.2$ to $-.95$ for γ. In no case did the re-specification alter substantially any coefficients other than the coefficient on $g(A_{t-1})$ in equation (18). Changes in the specification of $g(A_{t-1})$ within our set of alternative functional forms merely amounted to changes in the scaling of unobservable goodwill and did not alter the rest of the system. We then tested the effect of re-specification of the optimal solution. Although there were slight deviations from the time paths described below, the nature of the solutions remained the same. As more data become available, a more accurate specification of $g(A_{t-1})$ will be possible through maximum likelihood estimation. However, we are confident that the choice of functional form for $g(A_{t-1})$ did not substantially affect our results. The necessity of obtaining biological estimates precluded using an approach similar to the one used by Rausser and Hochman (1979) in their analysis of the orange industry. Our formulation is also easily adapted to explore socially efficient advertising levels since demand parameters are directly obtained.

half the desired change in effort ($\phi = .57$) is accomplished by the end of the first year.

From the resource stock equation, we derive estimates of the biological parameters discussed above. The catchability coefficient (q) is estimated at 4.87 for a million tong days. At effort levels of around 100,000 boat days, an estimated 49% of the fish populations is being harvested annually. The oyster growth coefficient (r) is 1.42; this parameter is key to providing stability to the population growth equation. In the case where $1 < r \leq 2$, the unexploited population follows a damped oscillation around k (Conrad and Clark, 1987). The estimated size of the unfished population (k) is about 9 million bushels.[10]

Finally, from the demand equation we can derive estimates of consumers' response to price and advertising levels as well as the amount of carryover in goodwill (δ). The derived value of the carryover parameter is .23, which suggests that most of the goodwill generated by advertising is dissipated by the second year. The short-run price elasticity of demand is calculated as -0.92 at the mean, which agrees favorably with a recent study by Cheng and Capps, 1988 which yielded an elasticity of -1.13.

Optimal Advertising of a Common Property Resource: The Maryland Oyster

Before presenting the optimal advertising strategies and their implications, a brief review of the time paths generated by open-access fishing is useful. Movements to a new competitive equilibrium following exogenous disturbances in a common property fishery are thought to be cyclical (Christy, 1964). For example, following a shock which raises prices, effort will increase and result in increased harvests. The increased harvests have two effects on the system: it tends to depress price; and it drives down the resource stocks, eventually reducing yield. This leads to reduced effort, reduced harvests, and resulting higher prices and yields. The cyclical effect is enhanced by the lags in both behavioral and biological response. As we have empirically estimated above, effort does not respond immediately to changes in economic signals. Because major changes in fishing effort levels require investment or disinvestment, effort responds gradually to economic incentives. Additionally, fish stocks make take several years to fully respond to changes in effort as stocks are overfished or being rebuilt.

We consider the objective of maximizing producer returns to the State of Maryland's seafood promotion effort and use the conceptual model, together with the empirical results, to establish optimal strategies for oyster advertising. A secondary objective of the State's promotion were returns to the State's \$.35-per-bushel tax to buyers. Thus the discounted net promotion benefits in period t are given by:

$$NB_t = \beta^t(Q_t(P_t + .35) - C(E_t) - A_t) \tag{19}$$

[10] This is substantially less than the fifteen million bushels or more that were taken in the late 1800's. Some of the difference can be rationalized by the loss in habitat in the upper Bay caused by siltation of once-productive oyster bends and by substantial lowering of water quality in the Bay.

Table 1
Estimated[1] Coefficients for Maryland Oyster Model

Equation	Explanatory Variables										
	R_{t-1}	R^2_{t-1}	Q_{t-1}	P_t	P_{t-1}	DP_t	$g(A_{t-1})^2$	E_{t-1}	D_t	DZ_t	Constant
Resource	2.422	−0.34	−4.872								2.866
Abundance (R_t)	(.543)[3]	(.011)	(2.042)								(3.665)
Capital Stock (E_t)	−.0003			−.015	.018			.430	−0.12		.067
	(.001)			(.012)	(.006)			(.160)	(.004)		(.078)
Demand (Q_t)	.288					−.566	2.366			.167	3.20
	(.137)					(.188)	(1.063)			(.057)	(.750)

[1] Three-stage least squares estimation was used with endogenous variables R_t, E_t, P_t, Q_t and DP_t.
[2] $g(A_{t-1})$ defined as $(1\text{-}\exp(-.8A_{t-1})$, see text footnote 9.
[3] Standard errors in parentheses.

where Q_t and P_t are derived from the estimated equations as:

$$Q_t = 4.87E_tX_t \tag{20}$$

$$P_t = 7.26 - 8.52E_tX_t + 4.16G_t. \tag{21}$$

Operating costs $C(E_t)$ are estimated based on Smith at a constant cost of $77 per boat day (in 1967 dollars). A real interest rate of 7 percent was chosen for the calculations.[11] Net benefits are measured in 1967 dollars.

The intertemporal optimization problem then is:

$$\begin{aligned}\text{Max } L^* = \sum_{t=0}^{128} \beta^t[&NB_t + \lambda_t(X_t + .58 - 2.42X_{t-1} + .17X_{t-1}^2 - 4.87E_tX_t)\\ &+ \gamma_t(G_t - .23G_{t-1} - (1 - e^{-.8A_{t-1}})\\ &+ \mu_t(E_t - .003 - .43E_{t-1} - 0.18P_{t-1}) + \phi_t(A_t - .5)]\\ &+ \lambda_0(X_0 - 3.26) + \gamma_0(G_0) + \mu_0(E_0 - .128).\end{aligned} \tag{22}$$

The initial conditions are obtained from actual 1967 data. Terminal-value functions are not included because the 128-year time horizon precludes concern over terminal values. In addition, reducing the time horizon from 128 to 64 years caused no effect on the optimal time path for the first 20 years. We assume managers will not ''disadvertise'' and will be constrained by a maximum advertising budget of $500,000, twice the size of their largest previous level of advertising. Numerical solutions were obtained on a Univac 1180 using the DUAL non-linear optimization program (Electrical Engineering Department, University of California at Berkeley).

The optimal time path is illustrated for the first 20 years in Figure 1, and the actual values are presented in Table 2. Advertising expenditures cycle twice before converging to about $200,000 per year. An optimal strategy was consistent with postponing advertising until 1970, and then advertising heavily for four years, followed by three years of low expenditures and then a fairly long period of moderate advertising. The solution contrasts with actual State expenditures which began in 1967 at $100,000, reached a peak in 1975, and have fallen steadily since then.

The value of the objective function with actual and optimal advertising is also presented in Table 2. Optimal advertising increased the net present value of producer and State returns to advertising by almost $1.1 million dollars over the 14 year period for which there was actual data on State expenditures.

The nature of the solution prescribed for this problem is a pulsed form of advertising. From a mathematical perspective, this implies that the solution to conditions (C1)–(C4) has imaginary characteristics roots causing the cyclical pat-

[11] This rate approximates the rate suggested by the Water Resource Council guidelines in discounting benefits.

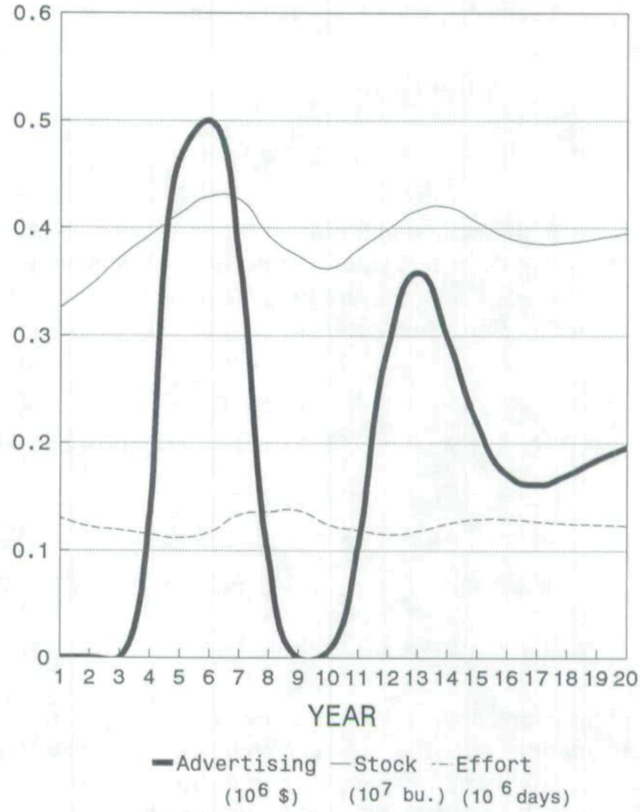

Figure 1. Optimal levels of advertising with corresponding levels of stock and effort.

tern. From a heuristic perspective, the nature of the solution follows from the fact that (1) advertising is most worthwhile when landings are large and price is depressed, and (2) advertising has the indirect effect of attracting capital. To move from the initial state to the optimal steady state, the model first allows stocks to build, causing production to rise, prices to fall, and effort to exit the industry. By not advertising in the first few periods, effort is reduced from 130,000 boat days to 112,000, while stock is rising to over four million bushels. Advertising is pulsed just before the natural growth in stock reaches its peak of 3.25 million bushels per year (at a standing stock level of about 4.13 million bushels). At this point, harvest can be large without dramatic depletion of the resource. Net revenues climb as price remains high and catch per boat day increases. Eventually, as stocks fall (see Figure 1) advertising is relaxed causing effort to exit the industry and stocks to rebuild. The optimal path prescribes a second pulse in advertising just prior to the second peak in natural growth, again creating positive net revenues.

Solution of the control model generates shadow prices for the three stock variables (see Table 2). It is interesting to note that the shadow value for effort is negative throughout, indicating that the industry remains overcapitalized. Since the objective function includes only producer welfare and State tax revenues, the negative shadow value implies overcapitalization in the sense that excessive effort erodes the present value of industry net returns, not necessarily net social returns. The initial low scarcity value for good will resulting initially in no advertising

Table 2
Comparison of Actual and Optimal Advertising Expenditures and Shadow Prices

Period	Actual Advertising	Optimal Advertising	Change in Net Benefits	Shadow Price λ	Shadow Price μ	Shadow Price γ
1	\$98,000	0	+\$98,000	4.83	−119.93	.01
2	\$94,000	0	−\$541,000	3.80	−108.42	.42
3	\$86,000	0	−\$273,600	3.29	−98.30	.35
4	\$107,000	\$132,000	−\$498,500	2.96	−96.34	.77
5	\$151,000	\$465,000	+\$197,600	2.92	−83.97	.70
6	\$163,000	\$500,000	+\$2,121,700	2.58	−89.20	1.3
7	\$175,000	\$372,000	+\$1,974,400	2.88	−80.49	.72
8	\$163,000	\$93,000	+\$1,089,400	2.61	−78.58	.63
9	\$117,000	0	−\$1,143,100	2.57	−69.29	.20
10	\$123,000	\$6,000	−\$1,191,200	2.17	−63.26	.28
11	\$131,000	\$104,000	−1,252,000	1.93	−58.26	.37
12	\$109,000	\$290,000	−\$528,300	1.76	−53.90	.49
13	\$106,000	\$358,000	+780,700	1.64	−52.15	.57
14	\$47,000	\$298,000	+1,047,900	1.63	−50.18	.48

reflects an imbalance between resource stock and effort. In this situation, goodwill does more harm in attracting unwanted effort than it helps by raising price. During the first few periods as stocks grow and effort declines, the scarcity value of goodwill increases, eventually promoting non-zero optimal levels of advertising.

Sensitivity Analysis

The optimal control solution suggests the desirability of cyclical advertising over the initial periods. Three factors appear critical in determining the degree and timing of the cycle: the negative scarcity value of capital, the long-term effectiveness of advertising, and the growth rate of the resource stock. Particularly important with respect to the negative scarcity value of capital is the speed of adjustment of capital (ϕ of equation (15)). In addition, the long-term effectiveness of advertising is primarily dependent on the carryover of goodwill (δ in equation (18)). Finally, the growth rate parameter (r in equation (12)) signals the responsiveness of the resource to changing harvest levels.

Figure 2 depicts the optimal time paths of advertising with various deviations in key parameters. First (see Figure 2a) we consider a change in ϕ, the capital adjustment parameter, from the estimated value of .57 to alternative values of .7 and .4. It is clear from equation (15) that a change in ϕ affects not only the level of carryover of capital stock from one period to the next, but also the responsiveness of effort to price. A higher value of ϕ indicates a more rapid response. At high rates of adjustment, effort reacts quickly to low initial prices and exits, allowing for early advertising. However, because effort responds more dramatically to price increases as well, large amounts of advertising are not possible because they draw in too much effort too quickly. Thus, changes in ϕ cause both changes in phase angle and changes in amplitude of the cyclical pattern. With the

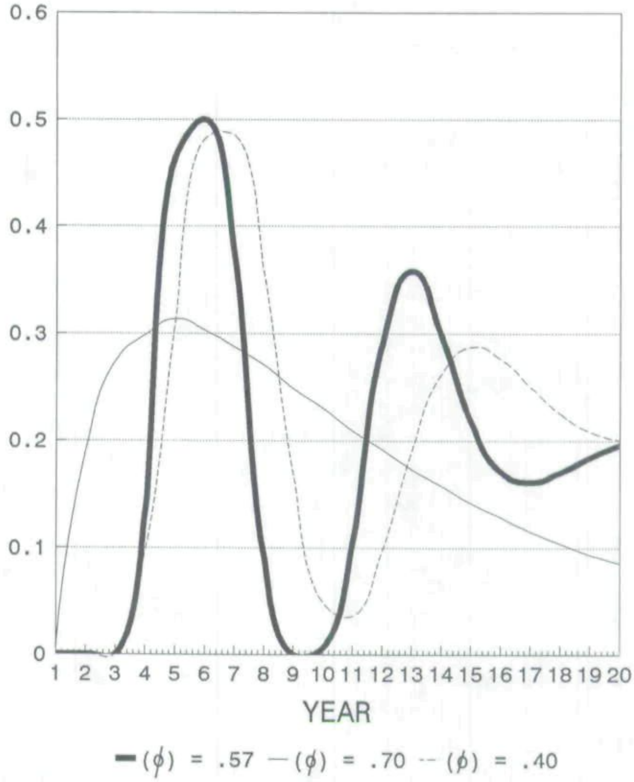

Figure 2a. Optimal advertising levels assuming different levels of effort adjustment (ϕ).

1967 initial conditions of high effort and low stocks, low value of ϕ cause advertising to be postponed. However, once undertaken, greater amplitudes in the cycle are optimal since effort is less responsive to price changes.

Figure 2b illustrates the effect of variations in the carryover in the stock of goodwill. While there is a slight frequency difference among the three cycles, the major difference is amplitude. Large rates of decay in goodwill (*i.e,* smaller values of δ and thus smaller carryovers) are associated with larger amplitudes. Here, high decay rates prevent advertising from having a sustained effect on price, causing pulsing to be more effective in increasing returns without drawing in effort. The final steady-state level of advertising is higher with less carryover of goodwill because the implicit costs of excessive effort are smaller. This suggests the rather perverse result that for a common property resource, lower levels of advertising when product identification through promotion lasts for a long time. This result is especially interesting since it suggests that if the errors in equation (15) are serially correlated and hence we are overvaluing, optimal strategies should be at even higher levels and more intensively pulsed than we have prescribed.

The most dramatic effects occur when changes in the growth rate parameter are introduced. Figure 2c illustrates how a change from our estimated 1.42 to 1.30 reduces the cyclic nature and level of advertising dramatically. Moreover, a rise in the value to 1.52 causes optimal advertising to be immediately constrained by the upper bound ($500,000) and to remain constrained throughout the time horizon. This suggest that more rapidly growing fish populations have lower user

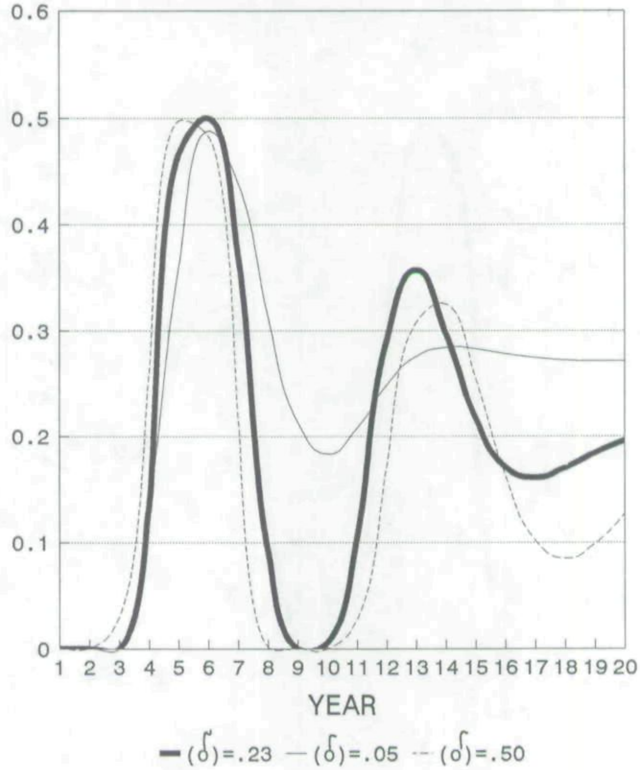

Figure 2b. Optimal advertising levels assuming different levels of goodwill carryover (δ).

costs so that excessive effort is not especially costly and advertising has greater returns. It also suggests that returns to advertising can be enhanced by public stock repletion programs which artificially raise r. Because of the large sensitivity of the results to the value of r it is important to have an unbiased and precise estimate of r prior to instituting any advertising program.

Conclusions and Implications

Our analysis demonstrates the potential for generic advertising to temporarily increase producer returns in a competitive common property resource. By using estimates from a dynamic bioeconomic model of the Maryland oyster industry, we show that certain types of advertising paths result in producer profits, even with a common property resource base. We emphasize that the profits are short-lived, and that the system eventually tends toward a steady-state zero-profit equilibrium. The new steady-state differs from the no advertising scenario due to higher prices and lower fish stocks. The profits obtained in the earlier time periods offset the discounted losses to advertising in the later time periods when industry profits are assumed to be zero and there is a positive advertising expenditure. Suboptimal advertising of the common property resource, for example, heavy advertising when stocks are depleted and price is high, can actually lower industry profits relative to the no advertising scenario.

The optimal pattern of advertising, for the situation illustrated, exhibits damp-

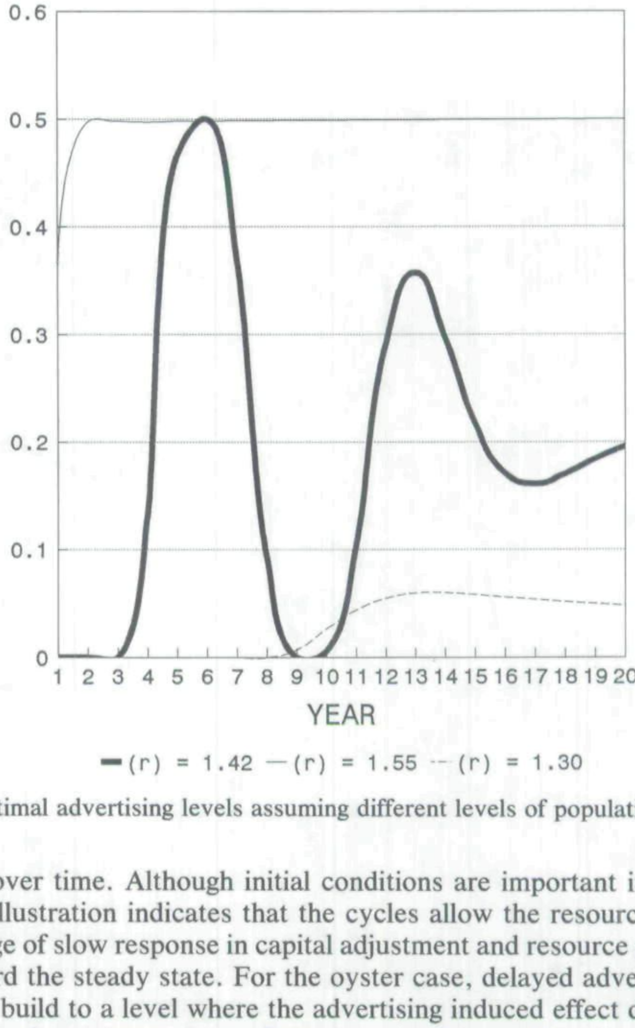

Figure 2c. Optimal advertising levels assuming different levels of population growth (r).

ened cycles over time. Although initial conditions are important in shaping the pattern, the illustration indicates that the cycles allow the resource manager to take advantage of slow response in capital adjustment and resource growth, while moving toward the steady state. For the oyster case, delayed advertising allows the stocks to build to a level where the advertising induced effect does not drastically deplete the resource base. Sensitivity analysis indicates the amplitude, phasing and period of the cycle are indeed sensitive to the rate of adjustment in capital stock and the growth rate of the resource. Variation in the carryover of goodwill does not have a dramatic effect on the optimal time path for advertising.

Cyclical advertising offers a means of indirectly controlling effort, and as such could offer managers an added regulatory tool. Some of the advantages of pulse advertising may be lost, however, if fishermen are aware of advertising plans and come to anticipate the rise in price which accompanies promotional campaigns by adjusting their effort accordingly. In these cases, a rational expectations model similar to the Berck and Perloff model might be desirable. Institutional and environmental uncertainties are likely to discourage this behavior for many fisheries.

The policy prescriptions implied by our model derive from the politically realistic objective of increased short run industry profits. As a result, it is not meant to be an economically efficient strategy. Further gains might be made if effort, in addition to advertising, could be explicitly controlled by a taxing or entry restriction scheme. However, the likelihood of direct effort restrictions in most fisheries is limited. Given the typically constrained decision environment, our analysis and framework provide useful guidance to controlling advertising.

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