THE INTERACTION OF ECONOMIC, BIOLOGICAL, AND LEGAL FORCES IN THE MIDDLE ATLANTIC OYSTER INDUSTRY

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ABSTRACT

Economic, environmental, and legal forces are contributing factors in the decline of the Middle Atlantic oyster industry. This paper determines the interactions and importance of these forces by quantifying and integrating some of the relevant variables into a supply and demand model of the oyster industry. The statistical results yield significant and expected parameter values with useful information on price and income demand elasticities. Also implications of common property legal frameworks on resource utilization are revealed. The main conclusions are that efforts to rehabilitate the industry by cleaning up pollution, replacing cultch, and encouraging legal private property rights may have large social values.

The historically important Middle Atlantic oyster industry is currently recognized as having many of the symptoms of a declining industry. Economic, biological, and legal forces are contributing causal factors in the fishery's decline. This paper attempts to integrate some of these variables into an estimable supply and demand model explaining oyster price and output movements over time for the region. Economic and biological variables are directly included in the model while the legal dimension is focused on indirectly by comparing empirical results for data generated from different common property structures.

The multidimensional approach reveals information on price and income elasticities, substitutability relationships, and the effect a common property regulatory framework has on resource overutilization and depletion. The regional orientation taken in this paper, rather than a national or international focus, provides a departure from much of the traditional fishery analysis and enables the effects of alternative property right structures between states to be observed.[2]

The impact property rights structure has on economic efficiency and biological growth has been discussed widely in the theoretical literature of fishery modelling.[3] Less however has been written on empirical analyses of the effects property rights have on economic and biological efficiency.[4] Consensus among the discussants is that common property leads to overexploitation of fish stocks and perhaps extinction of a species. Common property right systems result in less efficient resource allocation than private right systems since the former do not ensure that the total costs of an individual harvester's exploitation of the resource are borne fully by him. Private property internalizes the costs of the harvester's actions thereby forcing the producer to bear not only all of the costs of his actions but also to capture all of the benefits.

MIDDLE ATLANTIC OYSTER FISHERY

The American Eastern oyster represents the resource base of both the Gulf and Atlantic coasts oyster industries. Following a brief mobile larval stage, the oyster connects permanently to a firm subaqueous material such as rock or shell deposits.

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[2]Recent empirical work confined primarily to economic factors and directed towards species and regions different from our analysis includes Bell (1968), Doll (1972), and Waugh and Norton (1969).

[3]Much has been written in fishery economics on the effects of biological stock depletion due to common property legal structures. Some of the earlier treatments that are still widely referred to can be found in Gordon (1954) and Scott (1955). For more recent theoretical analyses see Fullenbaum et al. (1972), and Smith (1969). In the context of this literature, common property means that any member of a community has the right to harvest the fish stock.

[4]Notable exceptions in the fishery literature where the effects of legal ownership frameworks have been quantified include Bell (1972) and O'Rourke (1971). For example Bell estimates the redundant effort employed in the American lobster fishery which is subject to common property. He concludes that approximately 50% of current fishing effort is required to achieve economic efficiency.

Also the authors, in an unpublished paper (Efficiency and Property Rights in the U.S. Oyster Industry, 1974), estimate that in 1969 oystermens' income would have increased by almost 50% if all coastal states had relied on leasing of oyster beds.

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Its habitat is the intermediate salinity waters of the seacoast's intertidal zone and of inland rivers and bays. Water current, temperature, and biological productivity, in addition to salinity, are determinants of the resource productivity of a given parcel of subaqueous land.

The property right structure characterizing oyster grounds varies widely among states. Courts have granted rights to subaqueous land to the people of each state for their own common use. State legislatures exercise these rights. The federal government has been granted the right to a 3-mile coastal zone and Congress in turn has ceded back to the states land and resource use rights within this zone.[5] States have responded in similar ways to the exercise of their rights to the oyster resource. In general, natural oyster beds have been set aside as a common fishery for state residents,[6] whereas other submerged land parcels are available for private leasing. However, great variation among the states exists in the proportion of area and quality of land set aside for public or common use versus private use depending on how broadly administrators define the term "natural oyster bed."[7] An examination of the proportion of oyster catch by weight on private grounds to total catch by state reveals ratios ranging from a maximum of 1 to 0 for certain states in recent years. Within the Middle Atlantic region the two states with property rights in Delaware Bay (i.e., Delaware and New Jersey) can be characterized as essentially private property states, whereas Maryland and Virginia, which share the Chesapeake Bay, have significantly lower private to total catch ratios.[8]

Private property rights in oystering tend to promote efficiency in several ways. First, exclusive user rights provide incentives for firms to pursue a policy of investing in cultch and maintaining it at a desired level as influenced by market conditions. Second, congestion and overexploitation of the oyster resource is unlikely to occur since there is no pressing need to harvest quickly so as to not lose the resource's benefits. Finally, a communal property structure tends to lower efficiency by requiring the use of obsolete technology in order to prevent depletion of the resource stock. Inefficient technology often takes the form of obsolete capital regulated into use by legislative codes. In general, states relying on common property right structures tend to impose greater restrictions on the use of capital than private property states.[9]

Between 1947 and 1968 the annual U.S. domestic oyster harvest declined from 63.1 to 55.6 million pounds. Imports increased from an insignificant 111 thousand pounds to 15.5 million pounds during the same years. Accounting for inventory changes, total consumption of oyster meat consequently expanded by 8.2 million pounds. Concurrently, both ex-vessel and wholesale prices rose. Between 1950 and 1968 ex-vessel prices rose 38% and wholesale prices rose 89%.[10]

Significant regional differences in oyster catch trends characterize the post-World War II period. In general, the Gulf region has increased its landings while landings in the Middle Atlantic region (defined to include the states of New York, New Jersey, Delaware, Maryland, and Virginia) have declined by 45%. Delaware and New Jersey harvests especially have fallen dramatically, no doubt in large part due to disease which affected stocks beginning in 1958. It is during this period of both relative and absolute decline that we shall estimate the underlying factors explaining changes in quantities and prices for the Middle Atlantic oyster industry.

MODEL

Economic variables such as prices and quantities are generally explained by economists through the use of supply and demand models. Prices and quantities are determined through the equilibration of supply and demand forces which incorporate the effects of various predetermined

[5]See Power (1970) for a detailed description of court decisions involving rights to submerged land.

[6]Legislative codes usually prohibit nonresidents from entering the industry. See Power (1970:216-223) for a discussion of the constitutionality of these restrictions.

[7]Maryland, for example, classifies a natural bed as one such that the natural growth of oysters ". . . is of such abundance that during the preceding five years the public has resorted to them for livelihood," Power (1970:220). Courts reportedly view one individual declaration of one day's work in a 5 yr period as sufficient evidence of the existence of a natural bed. Most states employ a less restrictive definition for a natural bed.

[8]It is useful to note that private property rights may be institutionally arranged in a multitude of ways. The usual manner of leasing subaqueous lands to a relatively few individuals is by no means the only way of introducing private property, and in fact is often objected to as prejudicial to individual freedom. A more acceptable arrangement pointed out by a reviewer may be for states to assume control of beds and issue permits to harvest a given quantity of oysters.

[9]For example, in the predominantely common property right state of Maryland power dredging is prohibited in the harvest of oysters. Consequently any dredging takes place through the use of sail-powered craft called skipjacks, the newest of which is around 50 yr old.

[10]All data presented in this section are from *Fishery Statistics of the United States*, Bureau of Commercial Fisheries. National retail price data are not readily available.

(independent) variables on the endogenous (dependent) variables price and quantity. A general application of this methodology to any commodity would specify that quantity supplied (Q_s) is dependent on input cost factors, prices of goods related in supply, and price of the product. Quantity demand (Q_d) is usually hypothesized to depend on current price, income, and prices of related goods in demand.

When specifying such a model for oyster markets several modifications to the supply specification of the above general framework are employed. Although from supply theory input factors include technological, environmental, and biological variables, data limitations restrict the inclusion to a single biological factor, the MSX disease.[11] It is hypothesized that the protozoan oyster parasite commonly referred to as the MSX disease has a negative impact on the oyster industry during the period of analysis. Also since no strong relationships between the production of oysters and other goods is readily apparent, we omit prices of related goods from the oyster supply relationship.

The last modification of the supply relationship for oysters and probably the most unique feature of the model is the hypothesis that quantity supplied is a function of price lagged 1 yr rather than current price. As in the case of agricultural commodities, quantity supplied of oysters can be considered a function of past price and natural phenomena and hence fixed in the short run. In the fishery case a fixed supply is usually based on the presence of lags in generating fishing effort (e.g. securing capital and making occupational choices). Lagged price can be expected to positively influence current fishing effort.[12] In fishery estimation with annual data however, the assumption of such long lags in adjusting fishing effort may be inappropriate and the inclusion of lagged price as a determinant of effort will likely be a weak determinant of supply.

An additional rationale is therefore necessary for including price lagged 1 yr as a determinant of supply. We hypothesize that lagged price has a negative impact on current supply due to a depletion effect. In fishery production not only current effort, but current biological stock determines current production. If current biological stock is negatively related to past effort, then variables explaining past effort may bear a strong relation to current supply. Price lagged 1 yr (or alternatively distributed lags of past prices if data were plentiful) may be closely related to past effort. Accordingly we hypothesize that price lagged 1 yr is a proxy for past levels of effort and thus negatively related to current biological stock. Also if the negative relationship that lagged price has on current biological stock is strong enough to offset the positive relationship lagged price has on current fishing effort, the net impact of lagged price on current supply might be negative.

Furthermore we expect the negative depletion effect of lagged price to be stronger in fisheries subject to common property. Thus lagged price is likely to have a slight positive effect on supply in fisheries subject to private property due to the positive effort effect. For fisheries subject to common property the negative depletion effect is expected to offset the positive effort effect yielding a negative relationship between lagged price and quantity supplied.

The structural equations and equilibrium condition of the fixed supply model applied to oyster markets are written below with expected parameter signs appearing above each explanatory variable.

$$\text{Supply } Q_s = S(\overset{-}{\text{MSX}}, \overset{\pm}{P}_{t-1})$$

$$\text{Demand } Q_d = D_1(\overset{-}{P}, \overset{+}{I}, \overset{+}{P_r})$$

$$\text{Equilibrium conditions } Q_s = Q_d = Q$$

where MSX, P_{t-1}, P, I, and P_r are the MSX disease, price lagged 1 yr, current price, income, and the price of a related good, respectively. In the supply equation a negative relationship with MSX is hypothesized a priori, and lagged price may be positive or negative depending on the intensity of depletion. In demand, current price is expected to have a negative effect according to the law of

[11]Little technological change has occurred during the period of analysis due in part to state regulation mandating old technologies as a conservation device. Environmental factors such as pollution and siltation have doubtless had a negative impact on oyster supplies, but unfortunately little systematic and consistent information is available through time.

[12]We note that although lagged price may positively affect current effort the total effect on current harvest (i.e. supply) depends on what effect lagged price has on the current biological stock of the resource. For reasons explained below the net affect of lagged price on current supply might actually be negative if stocks have been reduced to the point of depletion. For an example of the short-run supply assumption (i.e., supply is independent of current price) in the fishery area, see Bell (1968). It should be noted that Bell's empirical work is quite successful using monthly data.

demand, the income effect is positive if oysters are a normal good, and the related good (poultry) is most likely a substitute for oysters.

Since the fixed supply assumption removes the simultaneity from the model, both the supply and demand functions can be interpreted as reduced forms, and estimated directly by ordinary least squares regression techniques without regard to problems of identification. The demand function is solved for its only endogenous variable, price, and estimated in this form. The reduced form equations estimated later in the paper are written below.

$$\text{Supply } Q = S\,(\overset{-}{\text{MSX}}, \overset{+}{P}_{t-1})$$

$$\text{Demand } P = D_2\,(\overset{+}{I}, \overset{+}{P}_r, \overset{-}{Q})$$

where Q is predetermined.

In addition to conclusions concerning parameter signs and elasticity values, implications of property right structures are revealed in the model. It is hypothesized that in states relying more heavily on common property rather than private leasing of subaqueous beds, the depletion effect should be greater. The lagged price variable in supply should thus have a negative coefficient value for common property right areas.

DATA

Regression analyses are performed on the above model for the Middle Atlantic and Delaware Bay regions. The Middle Atlantic region is defined to include the five contiguous coastal states of Virginia, Maryland, Delaware, New Jersey, and New York. This region includes the productive subaqueous resources of Chesapeake Bay, Delaware Bay, and part of Long Island Sound. The Delaware Bay area includes the states of Delaware and New Jersey only. We anticipate depletion to be a more important factor in the regional analyses which are dominated by the high production levels of Maryland and Virginia. These Chesapeake Bay states (especially Maryland) rely to a greater extent on common property than do the Delaware Bay states. The latter states allow much more extensive private leasing, and hence supply a greater proportion of their oysters from private leaseholds which may be expected a priori to be less subject to overfishing with the ensuing depletion.

Time series annual data on quantities landed (in pounds) and implicit prices are obtained from *Fishery Statistics of the United States* (1940-1970) compiled by the Bureau of Commercial Fisheries of the U.S. Department of Commerce and the U.S. Department of the Interior. Data on the price of a related commodity in demand (i.e., the price of poultry) and personal income are obtained from the Bureau of Labor Statistics (U.S. Department of Labor) and the *Survey of Current Business* (U.S. Department of Commerce), respectively. The biological variable representing the MSX disease included in the oyster supply function of the model was obtained from site sampling of oysters in the Delaware River.[13] The regions of consumption and production are not identical in that the consumption area includes a somewhat larger area. Precise definitions of the variables used are given below.

- Q Quantity per capita of oyster landings (measured as pounds per person) for Delaware Bay includes Delaware and New Jersey, and regional quantities include the five states of Delaware, New Jersey, Maryland, Virginia, and New York. Population refers to the seven-state region including New York, Pennsylvania, New Jersey, Delaware, Maryland, District of Columbia, and Virginia.
- P Price of oysters measured in dollars per pound (meat weight).
- P_{t-1} Price of oysters lagged 1 yr.
- MSX Biological variable referring to a protozoan oyster parasite commonly called the MSX disease.
- I Personal income per capita (deflated by the Consumer Price Index for all items) for the seven-state region including New York, Pennsylvania, New Jersey, Delaware, Maryland, District of Columbia, and Virginia.
- P_{ch} National average price per pound for chickens (live weight).

EMPIRICAL RESULTS

We now turn to a brief discussion of the detailed findings, and conclude with some general remarks and policy implications. Tables 1 and 2 present the

[13]The average annual prevalence of the MSX disease in a test sample of oysters in the Delaware River was obtained from H. Haskin of Rutgers University. These percentages were zero before 1957 and exceeded 50% in some later years.

TABLE 1.–Middle Atlantic supply and demand regressions.

Equation	Endogenous variable	Constant	Predetermined variables MSX	I^3	P_{ch}	P_{t-1}	Q^3	Statistics[1] R^2 DW	Elasticities[2] Price Income
Supply	Q^3	1.733	−0.581			−1.202		0.85	
			(−3.14)*			−(6.29)*		0.48	
Supply	ln Q^4	−0.136	−1.001			−0.319		0.68	
			(−3.60)*			−(3.05)*		0.39	
Demand	P	0.802		0.00002	0.010		−0.507	0.54	1.0
				(0.20)	(4.12)*		(−3.14)*	0.76	0.1
Demand	ln P^4	−14.110		1.582	0.425		−0.421	0.53	2.4
				(3.28)*	(2.59)*		(−1.50)	0.64	3.8

[1] R^2 and DW refer to the unadjusted coefficient of determination and the Durbin-Watson statistic for autocorrelation, respectively.

[2] The formulae used in calculating price and income elasticities are $\frac{-dQ}{dp} \cdot \frac{P}{Q}$ and $\frac{dQ}{dI} \cdot \frac{I}{Q}$, respectively. In the regressions not utilizing logarithms mean values of variables are used to fix the point elasticities.

[3] Quantity and Income are measured in per capita form.

[4] All variables are measured in natural logarithms except MSX.

* Refers to statistical significance at the 0.05 level.

TABLE 2.–Delaware Bay supply and demand regressions.

Equation	Endogenous variable	Constant	Predetermined variables MSX	I^3	P_{ch}	P_{t-1}	Q^3	Statistics[1] R^2 DW	Elasticities[2] Price Income
Supply	Q^3	0.223	−0.409			0.003		0.70	
			(−8.05)*			(0.22)		0.77	
Supply	ln Q^4	−1.718	−4.317			−0.155		0.66	
			(−5.99)*			(−0.77)		0.98	
Demand	P	0.165		0.0003	0.008		−1.169	0.55	3.4
				(3.18)*	(2.43)*		(−2.42)*	1.06	4.1
Demand	ln P^4	−18.290		2.090	0.407		−0.170	0.66	5.9
				(5.04)*	(2.51)*		(−2.51)*	1.24	12.3

[1] R^2 and DW refer to the unadjusted coefficient of determination and the Durbin-Watson statistic for autocorrelation, respectively.

[2] The formulae used in calculating price and income elasticities are $\frac{-dQ}{dp} \cdot \frac{P}{Q}$ and $\frac{dQ}{dI} \cdot \frac{I}{Q}$, respectively. In the regressions not utilizing logarithms mean values of variables are used to fix the point elasticities.

[3] Quantity and Income are measured in per capita form.

[4] All variables are measured in natural logarithms except MSX.

* Refers to statistical significance at the 0.05 level.

empirical results of the supply and demand model applied to oyster data for the years 1940 to 1970 in the Middle Atlantic and Delaware Bay regions. Numerical estimates of the coefficients along with t values in parentheses are obtained through the use of either linear or log linear regression analysis and ordinary least squares as the method of estimation.

In general, parameters have expected signs and are significant for at least the 0.05 level. The coefficient of determination is reasonably high in most regressions indicating that the included predetermined variables explain a large fraction of the variation in the endogenous variables. Since the linear and logarithmic equation forms do not differ greatly there is no evidence of nonlinearities.

In the supply equations the MSX variable displays a strong negative impact on quantity, and is more significant (i.e., larger t values) in the Delaware Bay regressions. Biological evidence indicates that the disease had a greater impact on Delaware Bay production than on Chesapeake Bay production although Virginia was hard hit during much of the period of analysis.

Lagged price has a negative and highly significant impact on supply for the Middle Atlantic region indicating that the depletion effect dominates the effort effect where common property prevails. In contrast the Delaware Bay results indicate that lagged price is not a significant determinant of supply in a private property right structure.

In the price (implicit demand) equations oysters display a significant positive income response in most regressions.[14] Oysters thus appear to be a normal good whose demand is likely to grow as consumer income rises over time. Since the price of chickens is a positive determinant of demand in all regressions, the relationship between the two commodities is one of substitution. The negative coefficient for quantity supports the law of

[14] Preliminary cross sectional analyses conducted by National Marine Fisheries Service Economic Research Laboratory indicate much weaker income effects (and possibly negative) for oysters.

demand indicating demand for oysters to be price-responsive.

In order to determine meaningfully how responsive quantity demanded is to price and income changes, it is useful to investigate the elasticities implied by the statistical results. Tables 1 and 2 indicate high elasticities in both the Middle Atlantic and Delaware Bay regions implying that oysters are price elastic and normal with respect to consumer income responses. If supplies were to increase in the future, one would expect increasing revenues for the oyster industry.[15] Similarly we might expect consumer demand for oysters to increase by larger percentages than real personal income in the future. Efforts to rehabilitate the oyster industry by cleaning up water pollution, discouraging overfishing, and replacing oyster cultch may thus have large social values.

Although the statistical results do lend support to the model, they are certainly not without difficulties. The time series problem of positive serial correlation is present throughout, thus detracting from the reliability of the results. The Durbin-Watson statistics in general indicate either positive autocorrelation or indeterminancy for the Middle Atlantic and Delaware Bay regions respectively using a two-tailed test at the 0.05 level of significance.[16] An additional problem impairing both estimation and prediction is structural change with data over a long time period. Parameters therefore may not remain constant with time series data. Also variables omitted from the model may have caused shifts in the functions over time. All of these problems make prediction hazardous and definitive conclusions should await further testing based on new data sets.

CONCLUSIONS

In general the statistical results support the model of supply and demand forces in the Middle Atlantic oyster industry. Estimates are generated on income and price elasticities of demand and lend optimism to the current rehabilitation efforts directed toward the oyster industry. The MSX disease has clearly had a debilitating effect, however, and must be solved as a condition of successful industry recovery.

The common property characteristics of the industry have also harmed the industry's progress. There exists evidence of overfishing in common property states, and hence less than optimal exploitation of the natural resource stocks. The results indicate that depletion is a much more serious problem for the Chesapeake Bay states than for the Delaware Bay states where private leasing of subaqueous lands is more prevalent. However, the reverse is true concerning the MSX disease characteristics of the regions.

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[15]It has been reported by the Delaware State Department of Natural Resources and Environmental Control that oyster spat count recently have been the highest in several years indicating augmented supplies to be highly probable in the future.

[16]When first differences are used to remove serial correlation, R^2 and t values fall to unacceptably low levels although serial correlation is removed.