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An Econometric Model for American Lobster

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Abstract *An econometric model for the wholesale and ex-vessel markets of American lobster,* Homarus americanus, *was developed to determine the market impact of proposed increases in the minimum size for American lobster. Prices were found to be inflexible with respect to landing, imports, and income (i.e., the price flexibilities were less than one) in both wholesale and ex-vessel markets. The size of lobster has a statistically significant effect on wholesale and ex-vessel prices and revenues. On average, wholesalers pass along 52% of any price changes to lobstermen. The ex-vessel price impact of a given change in supply is about the same as for changes in either landings or imports. Any changes in public policies leading to increases in total landings of American lobster and/or decreases in the proportion of small lobsters in the landings would result in increases in gross revenues to fishermen and wholesalers. While the long-term impact would be favorable, the short-term market impact of increases in the minimum size for lobster would be uncertain.*

Introduction

The American lobster fishery is one of the major fisheries on the U.S. Atlantic coast. In 1986, U.S. landings of American lobster, *Homarus americanus*, were 46 million pounds with an ex-vessel value of about $120 million. The lobster fishery employed about 13,000 fishermen (both full- and part-time) and about 10,000 boats in 1982.

Government management policies have been implemented in the fishery because it utilizes a common property resource. The most important regulation is the minimum size which is regulated in all of the major lobster producing states and in the EEZ. Under this regulation, lobsters must measure at least $3\frac{3}{16}$ inches along the carapace; however, biologists have recommended that the minimum size be increased to $3\frac{1}{2}$ or possibly 4 inches for conservation purposes. This recommendation has not been implemented in part because of its unknown impact on lobster markets.

Most economic studies of the lobster fishery have relied on bioeconomic models to analyze management policies: e.g., Bell (1972), Dow et al (1975), Smith (1977), Acheson and Reidman (1982), and Richardson and Gates (1986). Because of the overemphasis on bioeconomic modelling in theses studies, individual components of economic models often are neither given the proper consideration nor

fully documented. For example, Acheson and Reidman's failure to recognize the price effect of changes in the mix of lobster sizes in their economic models might have biased their estimates of policy impacts. Richardson and Gates recognized this problem and adopted the economic model develop by Wang and Kellogg (1984) to improve their bioeconomic analysis. Richardson and Gates state that Wang and Kellogg's demand equations "are particularly useful because they incorporate the influence of average weight in determining wholesale and ex-vessel prices. Inclusion of the quality effect is important both for correct price prediction and for correct calculation of consumer surplus variation" (362).

Further, the lack of documentation of the economic models used in these bioeconomic analyses cited above makes it difficult to use these models as a basis for developing other models in the future. This study represents the first attempt to include lobster sizes explicitly in the model specification and the first study of a multi-equation model for the U.S. lobster market. Two later studies which further built on this approach are Wang and Kellogg (1986) and Botsford et al. (1986). Wang and Kellogg used a choice model to analyze demand relationships among various sizes of lobsters. The authors conclude that small lobsters are complements to both medium and large lobsters, while the medium and large lobsters are substitutes. In the Botsford study, the ex-vessel price of a particular lobster size is specified as a function of landings of that size, landings of other sizes, and other variables. The study indicates that landings of small lobsters but not of the other sizes explain the variation in ex-vessel prices of all size categories.

This article documents the first multi-equation model for the U.S. lobster market with special recognition of the price effects of size regulations. Section II briefly describes the market for American lobsters. Section III presents a market model including model specification, estimation, and findings. A summary is presented Section IV.

Markets for American Lobster

On average, U.S. landings account for about 50% of total consumption. In 1986, the landings were about 46 million pounds in comparison to imports of about 38 million pounds. Most American lobster is imported live and all imports of live American lobster are from Canada. Although it is impossible to determine the exact amount of live lobster imports because they are combined with frozen lobster products in the census import data, it is believed that frozen lobsters are only a small part of these imports.

The supply of lobster is highly seasonal. Domestic landings peak in August and September and are generally at their lowest in the winter months. In contrast to the seasonal pattern of domestically landed lobsters, imports peak in May and June and are at their lowest in September and October. This pattern of imports is partially caused by Canadian fishing regulations which prohibit Canadian fishermen from landing newly molted lobsters in the summer when U.S. landings are high and prices relatively low.

The differences in the seasonal supply patterns of Canadian- and U.S.-caught lobster are thought to stabilize prices. Ex-vessel prices vary seasonally, from a low in early autumn to a high in midwinter. Prices fall in mid-April as total supply rises from winter lows. Different sizes of lobsters command different prices. Gen-

erally, per pound prices increase as size increases up to a threshold size of about three pounds. The smallest lobsters, called chicken lobsters, weigh about one pound and have the lowest price per pound.

Wholesale prices for lobsters are largely determined by the demand for lobster in restaurants, where about 60% of lobster is consumed (Consumer Survey, National Marine Fisheries Service, 1969). However, it is difficult to identify a retail price for restaurants because menu prices include many cost components other than the lobster itself. Retail prices at fish stores are also not a reliable indicator of consumer demand because these stores comprise a smaller part of the market than do restaurants. Data on retail prices are generally not available.

In general, small lobsters, less than 1¼ lbs. are preferred by restaurants, caterers, and retailers who want to pay the lowest possible price per lobster. Medium lobsters, those between 1¼ and 2½ lbs., tend to be consumed in the higher priced restaurants and at home. Lobsters weighing more than 2½ lbs. are bought primarily for home consumption. Lobsters greater than 3 lbs. may be processed for meat as well as sold for home consumption or to a few specialty restaurants. The premium price paid for "select lobsters" weighing between 1¼ and 2½ lbs. may be an indication of consumer preference for lobsters of this size.

An estimated 40-50% of Maine inshore landings are composed of lobsters less than 1¼ lbs. and about 40-50% are between 1¼ and 2 lbs. The median weight is between 1⅛ and 1⅕ lbs. An estimated 35% of the landings from offshore areas are small, 22% medium, and 43% large (over 2 lbs.) lobsters.

The Boston wholesale market is thought to be the market center for lobsters. Although market concentration ratios are not known, it is believed that almost one half of the wholesale market is handled by about four Boston firms. These wholesalers handle both domestic landings and imported lobsters.

A Market Model for American Lobster

Model Specification

The main purpose of modelling the lobster market is to evaluate the impact of possible changes in the size limits on American lobster markets. Because changes in the size limits affect total landings and the size distribution of the landings, the impact of proposed size regulations can be traced through changes in two variables representing the landings and the size distribution. Other factors, such as income, inventories, and tourism were also considered in the model.

Because of the lack of some data at the retail level, this model is limited to two market levels: the wholesale and the ex-vessel. Although the retail market is excluded from this model, factors affecting the retail markets are included in the wholesale market model in a manner consistent with the theory of derived demand.

Wholesale Market

Given quantities of domestic and imported lobsters available at the wholesale level, the price which the wholesale buyer is willing to pay is a function of the mix of lobster size, his inventory, and the price he receives in the retail market.

The price received by the wholesaler is, in turn, determined by consumer income, seasonal consumption patterns, and the price of related products.

The wholesale price (PW), therefore, is specified as a function of the percentage of small lobster in the supply (PCTS), domestic landings (LUS), imports (CAN), inventories (QL1), real disposable income (DPI), and seasonal demand (SD1 and SD2) as indicated in equation (1). The hypothesized relationship between the dependent variable and each explanatory variable is shown by the sign of the explanatory variable: a positive sign (+) indicates a direct relationship, whereas a negative sign (−) shows an inverse relationship.

$$PW = f(-PCTS, -LUS, -CAN, -QL1, +DPI, -SD1, -SD2) \quad (1)$$

The percentage of small lobsters (PCTS), calculated by using the ratio of the weight of small lobsters in the supply to the total weight of supply, measures the effects of changes in the size distribution which is associated with changes in the carapace limit regulation.[1] The impact of the percent of small lobsters on the wholesale price (PW) is postulated to be inverse because small lobsters command a lower per pound price at the market place.

Domestic landings (LUS) and imports (CAN) are postulated to impact inversely on the price. However, the degree of price impact is postulated to be different because of differences in shelf life between domestic landings and imported lobsters and differences in other product characteristics such as quality and the supply reliability.

Inventory behavior can affect wholesale prices because live lobsters can be stored for several months before being sold. Inventory levels of the wholesale buyers tend to be high for a period (t) if the landings and imports are high in the immediately previous period (t − 1). To capture the effects of inventory changes, wholesale supply lagged one period (QL1) is included as an explanatory variable.

Seasonal variables (SD1, SD2) are used to capture seasonal demand and consumption patterns in the price equation. Seasonal demand may be caused partially by seasonal patterns in tourism and recreational activities. The seasonal variables were constructed by grouping months together in the following way: December through March; June through September; and the remaining months–April, May, October, and November. The rationale for these groupings is that lobster is largely consumed in restaurants and that restaurant visits in New England peak in the summer months and September. Restaurant visits are low in December through March and are at a medium level in the spring and autumn.

Ex-Vessel Market

Since demand in the U.S. ex-vessel market is derived from demand in the wholesale market, wholesale price (PW) is included in the specification of ex-vessel demand. It is postulated that the ex-vessel price (PX) is determined by the price received at the wholesale level (PW) and total landings (LUS).

$$PX = f(+PW, -LUS) \quad (2)$$

Model Estimation and Empirical Results

The model is estimated with monthly data from March 1974 to June 1979.[2] Data on prices and income are in real terms. Equation (1) is estimated with an ordinary

least squares procedure, and equation (2) is fitted using two-stage least squares. The empirical equations for a linear model are presented in equations (3) and (4) below, and the equations for a logarithmic model are also available from the authors. The linear model is shown because it can be easily used to calculate social surplus.

Wholesale Market

The empirical wholesale price equation is presented as Equation (3). Based on the values of the t, R^2, and Durbin-Watson statistics, the equation had a high overall explanatory power. Also, the coefficients of the explanatory variables were statistically significant with the expected signs.

$$\begin{aligned} PW = {} & 559.5515 - \underset{(-2.67)^*}{2.2915}\ PCTS - \underset{(-2.69)^*}{15.6}\ LUS - \underset{(-8.44)^*}{4.79}\ CAN - \underset{(-4.70)^*}{22.1}\ QL1 \\ & + \underset{(1.63)^{**}}{0.1081}\ DPI - \underset{(-3.97)^*}{71.3818}\ SD1 - \underset{(6.34)^*}{78.8642}\ SD2 \end{aligned} \tag{3}$$

$$R^2 = 0.73 \qquad D\text{-}W = 1.91^*$$

* significant at the 5% level
** significant at the 10% level

The coefficient for PCTS shows that a 1% decrease of small lobsters in total supply would increase the wholesale price by 2.29 cents per pound (1979 dollars). An increase in the minimum size of lobsters would cause a decrease in PCTS and thereby an increase in wholesale prices. It must be noted, however, that this statement is valid only for marginal changes within the historical experience of the market.[3]

The wholesale price flexibility with respect to U.S. landings is less than one (Table 1). The revenue effect relative to changes in landings is also presented in this table. For example, a 1% decrease in January landings would cause the price to rise by 0.02% but would cause a 0.98% decrease in wholesale revenues. It is important to note that increases in the minimum size are likely to decrease landings in the short term but would increase them in the long term. The short-term loss must be balanced against the long-term gain in order to determine whether there are any benefits from increasing the minimum size.

The wholesale price flexibility with respect to imported lobsters is also less than one (Table 2). Revenue impacts caused by changes in imports are also shown in this table. For example, if imports in January increased by 1%, the wholesale price would drop by 0.14%, and wholesale revenues would increase by 0.86%.

The wholesale price with respect to income is less than one for all months (Table 3), indicating that aggregate economic activity contributes to the variation of lobster prices.[4]

The results also show that seasonal demand patterns represented by the variables SD1 and SD2 have a statistically significant effect on wholesale prices. These variables reflect seasonal differences in demand for lobster caused by tourism, lifestyle, etc. The higher demand from June through September would cause the wholesale price to be about 71 cents higher than in the period January through March, other things being equal.

Table 1
Percent Changes in Both Wholesale Price and Wholesale Revenues, with respect to a One-Percent *Decrease* from the Average Level of Monthly Landings (1974–1979)[1]

Month	Wholesale Price Flexibility with Respect to Landings	Percent Change in Wholesale Revenue
January	+0.02	−0.98
February	+0.01	−0.99
March	+0.01	−0.99
April	+0.03	−0.97
May	+0.09	−0.91
June	+0.09	−0.91
July	+0.16	−0.84
August	+0.21	−0.79
September	+0.23	−0.77
October	+0.17	−0.83
November	+0.15	−0.85
December	+0.07	−0.93
Average	+0.10	−0.90

[1] Estimated at mean values of the sample data

Table 2
Percent Changes in Both Wholesale Prices and Wholesale Revenues, with Respect to a One-Percent *Increase* in the Average Level of Imports by Month (1974–1979)[1]

Month	Percent Changes in Wholesale Price	Percent Change in Wholesale Revenue
January	−0.14	+0.86
February	−0.07	+0.93
March	−0.09	+0.91
April	−0.13	+0.87
May	−0.42	+0.58
June	−0.40	+0.60
July	−0.24	+0.76
August	−0.10	+0.90
September	−0.03	+0.97
October	−0.02	+0.98
November	−0.02	+0.98
December	−0.19	+0.81
Average	−0.15	+0.85

[1] Estimated at the mean values of the sample data

Table 3
Percent Changes in Wholesale Prices with respect to a One-Percent *Increase* in Income by Month (1974–1979)[1]

Month	Wholesale Price Flexibility with Respect to Income
January	+0.38
February	+0.36
March	+0.35
April	+0.51
May	+0.47
June	+0.44
July	+0.41
August	+0.44
September	+0.39
October	+0.47
November	+0.42
December	+0.19
Average	+0.40

[1] Estimated at the mean values of the sample data

These empirical findings are comparable to those derived from the aggregate demand equation in the Wang and Kellogg study (1986). However, other compatible data are not available from this study for comparison with the Wang and Kellogg study (1986) and the Botsford study (1986). While comparison between the two latter studies might be possible, such a comparison is beyond the scope of this paper.

Ex-Vessel Price

The empirical equation for ex-vessel price (4) has an R^2 value of 0.87, indicating that this specification explains 87% of the variation in the ex-vessel price of American lobsters.

$$PX = 70.2297 - \underset{(-9.41)^*}{15.5\ LUS} + \underset{(8.82)^*}{0.5246\ PW} \qquad (4)$$

$R^2 = 0.87 \qquad$ D-W $= 1.31^*$

* significant at the 5% level

The ex-vessel price flexibility with respect to ex-vessel landings is less than one, indicating that ex-vessel revenues vary directly with landings (Table 4). This implies that an increase in the minimum size, causing a decrease in short-run land-

Table 4
Percent Changes in Ex-vessel Price and Revenue to Lobstermen with Respect to a One-Percent *Decrease* from the Average Level of *Monthly Landings* by Month (1974–1979)[1]

Month	Ex-vessel Price Flexibility with Respect to Landings	Percent Change in Revenue to Lobstermen
January	+0.03	−0.97
February	+0.02	−0.98
March	+0.02	−0.98
April	+0.04	−0.96
May	+0.13	−0.87
June	+0.13	−0.87
July	+0.28	−0.72
August	+0.43	−0.57
September	+0.48	−0.52
October	+0.51	−0.49
November	+0.26	−0.74
December	+0.11	−0.89
Average	+0.20	−0.80

[1] Estimated at the mean values of the sample data

ings, would lead to an increase in ex-vessel prices and a decrease in lobstermen's revenues.

The coefficient for wholesale price of 0.5246 indicates that the wholesalers transfer to the lobstermen, on average, 52% of the changes in the wholesale price. These changes in price might be caused by changes in imports, income, or seasonal demand factors.

Finally, with this model, one reviewer has brought to our attention an interesting comparison of ex-vessel price impacts from U.S. landings and imports. The ex-vessel price impact of a given change in supply would be almost the same for changes in either U.S. landings or imports. For example, a one million pound monthly increase in the lobster supply would decrease U.S. ex-vessel prices by about 24 cents (1979 dollars) per pound if the increase is in the landings, and by about 25 cents per pound if the increase is in the imports.

IV. Summary

An increase in the minimum size for lobster would have two short-term effects: a decrease in both total landings as part of supply and the percentage of small lobsters in the supply. However, the long-term effects would be somewhat different: an increase in the total landings but a decrease in the percentage of small lobsters.

The findings indicate that the price flexibility with respect to landings is less

than one in both markets, implying a direct relationship between landings and revenues and that a smaller percentage of small (less than $1\frac{1}{4}$ lbs.) lobsters in the supply is associated with higher prices and revenues. The short-term market impact of increases in the minimum size is ambiguous since the short-term decrease in total landings would lead to lower revenues, whereas the short-term decrease in the percentage of small lobsters would lead to higher revenues.[5] Unlike the short-term impact, the long-term impact would be favorable because both the long-term increase in landings and the long-term decrease in the percentage of small lobsters would be associated with higher revenues.[6]

Other findings of this study are: (1) On average, wholesalers would pass along 52% of any changes in the wholesale prices to lobstermen. (2) The ex-vessel price impact of a given change in supply is almost the same for a change in either landings or imports. (3) Price-flexibilities with respect to both income and imports are less than one.

Notes

1. In this study, the variable, PCTS is defined as the percentage of lobsters which are smaller than $1\frac{1}{4}$ lbs. in the total supply of lobster. To compute the percentage of small lobsters in the supply, landings and import data were combined with biological data on the length frequencies of lobster landings. Length-frequency data collected by the Maine Department of Natural Resources and the length-weight relationships developed by Thomas (1973) were used to estimate the size distribution of landings from the Maine coastal lobster fisheries. Length-frequency data collected by the National Marine Fisheries Service and the length-weight relationships derived by Cooper and Uzmann (1977) were used to estimate the size distribution of U.S. landings from the offshore fisheries. Imports were assumed to have the same length frequencies as the landings from the Maine coastal fisheries.
2. All data, except the values of the PCTS variable, are derived from data published by the U.S. Census Bureau, the National Marine Fisheries Service, and the Maine Division of Marine Resources. The values of the PCTS variable were calculated from unpublished data maintained by NMFS. The data on size distribution are available from the authors.
3. A reviewer pointed out that the relationship between PW and PCTS could be non-linear. Nevertheless, this linear specification represents an approximation of a possible non-linear relationship. Further, this study was not designed to identify optimal sizes of lobsters.
4. Out of his concerns about aggregation bias, a reviewer suggested to list coefficients of disaggregate models, e.g., Wang and Kellogg (1986) and Botsford et al (1986), for comparison. The direct comparison of coefficients is not possible due to differences in model specifications between this study and either of the other two studies.
5. It is impossible to determine the net short-term impacts of an increase in minimum size because the calculation of short-term changes in landings and of the percentages of small lobsters in these landings is not possible at the present time.
6. Because this study emphasizes the estimation of demand parameters, the findings of this study can be used to address some management issues. Bio-economic models, such as the Gates model (1979) and the Richardson and Gates model (1986) are more appropriate for addressing a full range of management issues.

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