NUREG/CR-4002
PNL-5226

Development and Application of Econometric Demand and Supply Models for Selected Chesapeake Bay Seafood Products

Prepared by L. A. Nieves, R. J. Moe

Pacific Northwest Laboratory
Operated by
Battelle Memorial Institute

Prepared for
U.S. Nuclear Regulatory Commission

NOTICE

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, or any of their employees, makes any warranty, expressed or implied, or assumes any legal liability of responsibility for any third party's use, or the results of such use, of any information, apparatus, product or process disclosed in this report, or represents that its use by such third party would not infringe privately owned rights.

NOTICE

Availability of Reference Materials Cited in NRC Publications

Most documents cited in NRC publications will be available from one of the following sources:

1. The NRC Public Document Room, 1717 H Street, N.W.
   Washington, DC 20555
2. The NRC/GPO Sales Program, U.S. Nuclear Regulatory Commission,
   Washington, DC 20555
3. The National Technical Information Service, Springfield, VA 22161

Although the listing that follows represents the majority of documents cited in NRC publications, it is not intended to be exhaustive.

Referenced documents available for inspection and copying for a fee from the NRC Public Document Room include NRC correspondence and internal NRC memoranda; NRC Office of Inspection and Enforcement bulletins, circulars, information notices, inspection and investigation notices; Licensee Event Reports; vendor reports and correspondence; Commission papers; and applicant and licensee documents and correspondence.

The following documents in the NUREG series are available for purchase from the NRC/GPO Sales Program: formal NRC staff and contractor reports, NRC-sponsored conference proceedings, and NRC booklets and brochures. Also available are Regulatory Guides, NRC regulations in the *Code of Federal Regulations*, and *Nuclear Regulatory Commission Issuances.*

Documents available from the National Technical Information Service include NUREG series reports and technical reports prepared by other federal agencies and reports prepared by the Atomic Energy Commission, forerunner agency to the Nuclear Regulatory Commission.

Documents available from public and special technical libraries include all open literature items, such as books, journal and periodical articles, and transactions. *Federal Register* notices, federal and state legislation, and congressional reports can usually be obtained from these libraries.

Documents such as theses, dissertations, foreign reports and translations, and non-NRC conference proceedings are available for purchase from the organization sponsoring the publication cited.

Single copies of NRC draft reports are available free, to the extent of supply, upon written request to the Division of Technical Information and Document Control, U.S. Nuclear Regulatory Commission, Washington, DC 20555.

Copies of industry codes and standards used in a substantive manner in the NRC regulatory process are maintained at the NRC Library, 7920 Norfolk Avenue, Bethesda, Maryland, and are available there for reference use by the public. Codes and standards are usually copyrighted and may be purchased from the originating organization or, if they are American National Standards, from the American National Standards Institute, 1430 Broadway, New York, NY 10018.

GPO Printed copy price: $6.00

NUREG/CR-4002
PNL-5226

Development and Application of Econometric Demand and Supply Models for Selected Chesapeake Bay Seafood Products

Manuscript Completed: September 1984
Date Published: December 1984

Prepared by
L. A. Nieves, R. J. Moe

Pacific Northwest Laboratory
Richland, WA 99352

Prepared for
TMI Program Office
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555
NRC FIN B2366

ABSTRACT

Five models were developed to forecast future Chesapeake seafood product prices, harvest quantities, and resulting income. Annual econometric models are documented for oysters, hard and soft blue crabs, and hard and soft clams. To the degree that data permit, these models represent demand and supply at the retail, wholesale, and harvest levels. The resulting models have broad applications in environmental policy issues and regulatory analyses for the Chesapeake Bay.

EXECUTIVE SUMMARY

This report provides documentation of econometric models developed for selected major seafood products from the Chesapeake Bay. The research that forms its basis was performed under contract to the U.S. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation.

The purpose of this research was to develop a set of econometric models for specific species or products comprising the bulk of the Chesapeake Bay seafood industry, which could be used to forecast future harvest quantities and prices and to assess effects of various events on these quantities and prices. This aim was achieved through development of annual econometric models for oyster, hard and soft blue crab, and hard and soft clam markets. Specification of these models, while affected by data limitations, was based on expert understanding of Chesapeake Bay seafood harvesting technology, state regulation, and market structures. Price equations were developed for the retail, wholesale, and harvest sectors for oysters and blue crabs. Due to lack of retail price data, only wholesale and harvest sector price equations were developed for hard and soft clams. Supply models were developed for oysters, crabs and hard (but not soft) clams. In most cases, the data permitted model estimation for the period 1960 through 1980. Both statistical and analytical validation techniques were applied to the models with satisfactory results.

The demand and supply models for oysters reflect the interrelatedness of demand and the diversity of Maryland and Virginia supply. While retail, wholesale, and ex-vessel demand are modeled jointly, separate supply models for Virginia and Maryland incorporate differences in oyster ground ownership patterns and state regulations affecting the harvest technology employed.

The two states' blue crab fisheries are less interdependent than the oysters fisheries, so separate economic models were estimated for Virginia and Maryland. These reflect the effects of crab life cycle and migration on harvest in each state as well as differences in harvest gear regulation. Separate models were estimated for hard and soft crabs. Due to data limitations, only an ex-vessel price model was developed for soft crabs.

For hard clams, the model reflects Virginia's small share of the northeastern market. A wholesale price equation was developed for the New York market and ex-vessel price equation for New York and Virginia. The Virginia hard clam supply model reflects ex-vessel prices in New York.

Soft clams are mainly harvested in Maryland and Maine so the demand model reflects that fact. Wholesale prices are developed jointly and ex-vessel prices separately for these two states. Maryland supply is treated as exogenous to the demand model, due to data and information limitations.

Each model can be used to forecast future Chesapeake Bay harvests of the respective product, as well as prices at the relevant market levels. These forecasts are based on forecasts of national income, population, and consumer price indices, as well as on forecasts of local variables which affect the cost of harvest. They can also be used to assess the future impacts of shocks to the corresponding market, such as changes in personal income, changes in prices of other meat products, or changes in consumer preferences for the product.

CONTRIBUTORS

Project Manager: L. A. Nieves

Model Integration and Application: R. J. Moe

Development of Demand and Supply Models:

O. Capps Jr.
Route 4, Box 464
Christiansburg, VA 24073

L. Shabman
1901 Meadowview Drive
Blacksburg, VA 24060

CONTENTS

FIGURES

TABLES

1.0 INTRODUCTION

This report presents econometric models of the four major commercial seafood products from the Chesapeake Bay: oysters, hard and soft blue crabs, hard clams, and soft clams. These simultaneous equation models represent the production and marketing structure of the demand and supply systems for each of these products. Price equations were developed for the retail, wholesale, and ex-vessel, or harvest, levels for oysters and blue crabs. Due to lack of retail price data, price equations were developed only for the wholesale and ex-vessel levels for hard and soft clams. In most cases, the models were estimated from data for the period 1960 through 1980. Due to the nature of available data, all of the models represent compromises between accuracy in capturing the market structures and validity as tools for projecting future changes in these markets.

As discussed in Chapter 2, the research conclusion is that these demand and supply models can be used to project economic trends in the oyster, blue crab, hard clam, and soft clam industries. Specifically, the models are suitable for projecting revenue changes, at each market level, that would result from exogenous changes in either quantity demanded or quantity supplied of each product. Of course, such projections are more likely to be accurate for periods of a few years into the future than for the longer term. Accuracy is also likely to be greater for projections stemming from exogenous changes whose magnitude is within the range of normal fluctuations.

The methodology employed to develop the models is documented in Chapter 3. Considerations that influenced the model specification are discussed first. These considerations include the purpose of the models, economic theory, and the nature of the Chesapeake Bay fishery. A description of the data collection procedures is then followed by a detailed discussion of the techniques employed in model estimation. Chapter 3 ends with a description of the tests and analyses used to validate the models.

Development of the economic models is documented for oysters in Chapter 4, for blue crabs in Chapter 5, for hard clams in Chapter 6, and for soft clams in Chapter 7. The structure of these four chapters is roughly comparable. Each begins with a brief overview of the industry, including market structure and factors affecting production, processing, and consumption. This is followed by sections describing first the rationale for the models and then the results of the estimation. Findings of the model validation effort are described at the close of each chapter. Finally, Chapter 8 discusses the application of these models in simulating economic activity of Chesapeake Bay seafood markets.

2.0 CONCLUSIONS

In brief, this study yielded the following conclusions:

- Economic theory provides a basis for specifying models of seafood product markets, such as those for Chesapeake Bay oysters, crabs, and clams. This theory suggests that such models should consider, the behavior of both buyers and sellers at three market levels: retail, wholesale/processing, and harvest.

- Secondary data available to estimate the parameters of models explaining prices and quantities of Chesapeake Bay oysters, crabs, and clams is limited both in quantity and quality.

- Despite data limitations, adequate models of prices (retail, wholesale, ex-vessel) and harvest quantities of Chesapeake Bay oysters, hard crabs, soft crabs, hard clams, and soft clams can be econometrically estimated. The econometric equations explain 80-90 percent of the variation in the dependent variable (typically one of the three prices of a product, or a component of its Bay harvest), over the 1960-1980 period.

- The econometrically estimated models can be used to forecast future Chesapeake Bay oyster, crab, and clam prices and harvest quantities under assumptions regarding trends affecting the industry. The forecasts from such an exercise appear reasonable, in that forecast values of future prices and harvest quantities of each product are of the same general magnitude as actual 1980 values.

- The estimated models can also be used to forecast or assess changes, in the prices and quantities of each of the Bay products, due to changes in U.S. personal income, U.S. population, consumer prices, wholesale prices, and U.S. seafood consumption. The results of such an exercise also appear reasonable, in that the estimated impacts on Bay prices and quantities of each of these hypothesized changes is of the expected sign and magnitude.

- Finally, the estimated models can be used to forecast or assess changes in the prices and quantities of each of the Bay products resulting from specific changes in the structure of consumer demand for Bay products. Examples of structural changes in consumer demand whose effects can be assessed by the models are changes in tastes, and changes in preferences due to perceived changes in product quality.

3.0 METHODOLOGY DEVELOPMENT

Five econometric models representing the demand for and supply of five Chesapeake Bay seafood products (oysters, hard blue crabs, soft blue crabs, hard clams, and soft clams) were developed in this study. Each model can be used to forecast future Chesapeake Bay harvests of the respective product, as well as the retail, wholesale, and ex-vessel prices of the product; each model can also be used to assess the impacts on future harvests and prices of "shocks" to the corresponding market, such as changes in personal income, changes in the prices of other meat products, or changes in consumer demand for the product. Although we recognize the importance of biological factors on harvests of seafood products, the models are economic in nature; prices and harvest quantities in each model are expressed as functions of other economic variables, such as personal income and the wholesale price index.

Each of these distinct models was developed using a common methodology. For convenience of presentation, this methodology can be seen as comprising four steps or tasks: 1) model specification, 2) data collection, 3) model estimation, and 4) model validation. Model specification involves determining the variables that the model will predict (i.e., the endogenous variables), the form of the equations to predict these variables, and the other variables which influence each endogenous variable (i.e., the variables that appear on the right-hand side of the equation which are used to predict the value of each endogenous variable). This step is based largely on the requirements of the model, economic theory, and specific characteristics of the market or product under study. Data collection involves obtaining historical values for each of the endogenous and exogenous variables identified in the model specification process, so that the parameters or coefficients of the model's equations can be statistically estimated. Model estimation involves obtaining estimates of the parameters of the equations specified in the first step, using data acquired in the second step and econometric or statistical techniques. Model validation involves determining how "good" the estimated model is regarding its accuracy in predicting historical values of the endogenous variables and its consistency with economic theory.

As stated, division of the methodology into four distinct steps is for convenience in presentation only. In actuality, each of these steps is performed simultaneously in an iterative manner. After theoretically specifying the model for a particular product, the researcher may discover that historical data on some of the variables in the model are not available; in such a case, the model must be respecified. During the estimation step, theoretical hypotheses proposed in the model specification step may be rejected, requiring respecification of the model and possibly additional data collection. Model validation may show that the model as estimated does not accurately predict past values of the endogenous variables, or produces forecasts and impact assessments that are inconsistent with economic theory; again, in such a case, the model may have to be reestimated, or even respecified. Each step may have to be repeated a number of times before a satisfactory model is developed.

Nevertheless, each of these four steps involves a specific activity, and it is much easier to describe the methodology as a whole by describing each of these four activities separately, than by describing the simultaneous, iterative nature of the model development methodology in a holistic manner. The chapter is thus divided into four sections. Section 3.1 discusses the process used to specify each of the five Chesapeake Bay seafood product demand/supply models. Section 3.2 describes the data used to estimate the models. The econometric techniques used to estimate the models are discussed in Section 3.3. Finally, the model validation tests or exercises performed on each model are described in Section 3.4.

3.1 MODEL SPECIFICATION

Model specification consists of determining 1) the variables that the model will predict (i.e., the endogenous variables, or those appearing on the left-hand side of one of the equations in the model); 2) the form (e.g., logarithimic, linear or additive) of the equations used to predict these endogenous variables (one equation for each endogenous variable); 3) the explanatory variables of each equation (i.e., the variables hypothesized to influence each endogenous variable, and thus appear on the right-hand side of the equations in the model; for each equation of the model, explanatory variables include exogenous variables that are not predicted or forecast by the model and lagged endogenous variables); and 4) the manner in which these explanatory variables appear in the equation, regarding both the sign (i.e., positive or negative) of each variable's coefficient in the equation and the relative magnitude of the coefficients. As an example of the model specification process, consider the Chesapeake Bay oyster demand and supply model. Based on a number of considerations (discussed below), it was determined that this model should contain an equation that explained the retail price of Chesapeake Bay oysters, and that this equation should be linear in form (i.e., a one-unit change in one of the equation's explanatory variables would have a specific impact on the retail price, which would be the same regardless of the pre-impact levels of the retail price, the particular explanatory variable or any other explanatory variables). It was further determined that the following variables should be included on the right-hand side of this equation as determinants of the Chesapeake Bay retail oyster price: 1) the wholesale price of oysters, 2) the U.S. consumption of oysters, 3) U.S. disposable income, 4) the U.S. consumer price index for meat, fish, and poultry, 5) U.S. population, and 6) time. Finally, the expected signs and relative magnitudes of the impacts of changes in each of these variables on the retail price (i.e., the sign and magnitude of the coefficients of each of these six variables) was determined. Determining the expected signs and magnitudes of the coefficients prior to estimation provides hypotheses to be tested during the estimation and validation steps.

Three types of factors or considerations entered into the model specification process: 1) model requirements, 2) economic theory, and 3) species- and region-specific characteristics not part of general economic theory. These three types of factors will be briefly considered in turn.

3.1.1 Model Requirements

The first factor considered in specifying each model was the purpose of the model; i.e., when completed, what is the model supposed to be able to do? This consideration dictates to a large extent both the endogenous and exogenous variables to be included in each model. In general, each model had to have the capability to forecast future revenue and value added (i.e., income generated) in each of the three market sectors (retail, wholesale, and harvest), and to assess the impacts on these revenues and incomes of "shocks" to the market, such as changes in income, changes in prices of other products, changes in costs, and, particularly, consumer avoidance of the product in question. Such forecasts and impact assessments were to be on an annual basis (i.e., values of all endogenous variables would be annual values), and for at least the 1984-2000 period.

These model requirements combined with economic theory considerations led to development of models which predict annual retail, wholesale, and ex-vessel (harvest) prices for each of the five products, as well as the Chesapeake Bay harvest of each. Also, partly because of these model requirements, the retail price equation for each product contains income, substitute price, and other variables. Thus, each of the models was specified to produce predictions of Chesapeake Bay prices and quantities (and thus, revenues and value added) under alternative scenarios.

3.1.2 Economic Theory of Commercial Fishery Demand and Supply

Commercial fisheries such as those studied here have been analyzed by economists on several occasions and a standard economic approach to modeling seafood markets has been developed. This standard approach was, to the extent appropriate and feasible, employed in specifying the five Chesapeake Bay seafood product supply and demand models.

The approach employed has several key aspects. First, the supply of a particular seafood product is determined completely within the harvest sector; the retail and wholesale sectors merely accept the given supply, they do not determine it. Second, the harvest in a particular year is determined by the costs of harvesting in that year (which the fisherman presumably knows before he begins harvesting) and the ex-vessel prices he received in previous years. It is assumed that individual fishermen use previous prices to form expectations of current prices, which they further use to decide (along with knowledge of current costs) whether or not to participate in the season's harvest; once they have decided to do so, they harvest as much as they can, regardless of the price they are receiving for their harvest. These two factors together imply that demand and supply can be modeled separately, since the current price has no effect on current supply.

Third, consumer demand for a particular seafood product is price-dependent; i.e., instead of the market price determining the quantity purchased, with the quantity purchased variable and the price fixed (at a market-clearing level), it is assumed that in seafood markets, a fixed quantity (determined by the harvest sector) of the product reaches the market, and this quantity is priced to clear the market. Thus, the dependent variable in the consumer (retail) demand equation is not the quantity of a particular seafood product purchased, but the retail price of that product; as in traditional demand theory, however, prices of substitute (e.g., other meat, poultry, and fish products) products, income, and other economic and demographic factors influence the dependent variable.

Fourth, and finally, the traditional approach to modeling seafood markets assumes that retail, wholesale, and ex-vessel prices are all determined simultaneously; i.e., each price appears on the right-hand side of the equations explaining the other prices. This simultaneous determination of prices is in large part due to the fact that the price equation for each sector is in reality not a demand equation for that sector but a reduced form equation for the sector, a combination of the corresponding demand and supply functions: the wholesale price equation, for example, is a combination of the equation explaining the demand for wholesale seafood (which is determined largely by the retail demand, as represented by the retail price) and the supply of wholesale seafood (which is determined largely by the cost of producing seafood at the wholesale level as represented by the ex-vessel price, which is the cost of the raw input used in the wholesale sector). Together, along with consideration of the model requirements, these four factors led to development of models in which 1) supply and demand sectors are modeled separately; 2) supply or harvest is determined primarily by harvest costs and the previous year's ex-vessel prices; and 3) the demand submodel comprises a set of three simultaneous equations, explaining the corresponding retail, wholesale, and ex-vessel prices.

3.1.3 The Chesapeake Bay Commercial Fishery

Model requirements and economic theory together were used to determine the overall structure of each of the five models; i.e., they determined the types of variables to be included in each model, as well as how in general these variables would relate to one another. Final specification of the variables and functional relationships depended in large part, however, upon consideration of factors peculiar to the species under consideration, the importance of the Chesapeake Bay harvest of these species relative to harvests from other regions, and a number of other economic and institutional factors. In general, these factors fill in the "holes" that model requirements and economic theory cannot fill; for example, they determine whose disposable income should appear in the retail price equations as a determinant of consumer demand. These factors are discussed in the first section of each of the succeeding chapters (one devoted to each seafood product); here, their impact on the specification of each model is described.

All five of the seafood products considered in this study have markets which extend outside of the Chesapeake Bay area; i.e., each product is sold not only in the Maryland-Virginia-Washington, D.C. area, but elsewhere in the United States. The retail and, to a lesser but still significant extent, wholesale prices for Chesapeake Bay seafood products are set in national markets; retail demand is thus in part determined by national disposable income, the national average prices of other goods, and other national economic and demographic variables.

The structure of the ex-vessel market varies considerably, depending on species. Chesapeake Bay oysters are relatively homogeneous; i.e., Maryland-harvested oysters and Virginia-harvested oysters are largely indistinguishable. Because of this, ex-vessel prices for oysters harvested in the two states are nearly identical. Only one ex-vessel price equation is needed for the oyster model. On the other hand, ex-vessel prices of hard blue crabs harvested in the two states differ (due to factors such as meat quality and season of harvest). Hence, two ex-vessel price equations, one for each state, must be included in the hard blue crab model. Each of the remaining products is harvested primarily in only one of the two states.

The structure of the commercial harvest of each product also has an impact on the corresponding model specification. Vastly different institutions are present in the Virginia and Maryland oyster harvest sectors; thus, separate submodels of the supply in each state are required. Even within a state, moreover, there exist distinct institutional and technological arrangements in the oyster industry: in Maryland, for example, oyster harvest takes place on both publicly and privately owned grounds, and several harvest methods are utilized in the publicly owned beds. The harvest from each ownership class and by each equipment class must be modeled separately, since each is subject to different regulations, costs, and incentive structures.

Moreover, the structure of each product's harvest sector requires that harvest be divided into 1) effort, represented by number of fishermen, or number of fishing craft; and 2) productivity, or harvest per unit of effort. This is required because it is effort, and apparently effort alone, that is determined by economic factors such as the previous year's prices. Productivity appears to be determined by weather and other factors that are difficult to identify. These two components, effort and productivity, thus must be modeled separately; otherwise, each model may overestimate the impacts on supply of a change in the previous period's price.

Considerations such as these make each of the five models much larger and more complicated than model requirements and economic theory alone would suggest. For some products, due to the nature of demand, one Chesapeake Bay ex-vessel price exists; for other products, there are two or more ex-vessel prices. For some products (oysters, crabs), ex-vessel prices are determined by the Chesapeake Bay harvest as well as wholesale and retail prices; for other products, the Chesapeake Bay portion of the total national harvest is so small that the Chesapeake Bay ex-vessel price is determined in part by ex-vessel prices in other states (New York for hard clams, Maine for soft clams). Finally, the institutional, technological, and economic variations in supply require that each model contain more than one simple harvest equation; the oyster model, for example, predicts harvest in each of eight state/ownership/equipment classes, with effort and productivity predicted separately (instead of just their multiplicative product, total harvest) in three of these classes. The final specification of each of the models that account for considerations such as these, are described in the following chapters.

3.2 DATA COLLECTION

Collecting historical data for each of the variables identified in the model specification step was required to estimate the parameters of the equations. This was a straightforward although laborious task. Fisheries-specific information on prices was collected from the Shellfish Market Review and the Fishery Statistics of the United States, both published annually (or more frequently) by the National Marine Fisheries Service, a division of the U.S. Department of Commerce. Harvest and effort data were collected from the latter source, and also from various publications of the Virginia Marine Resources Commission and the Maryland Department of Natural Resources. Data on national income, interest rates, consumer price indices, and other national economic and demographic variables were obtained from various Department of Commerce and Department of Agriculture publications. In general, annual data for the 1960-1981 period were obtained.

As noted in the introduction to this chapter, the data collection process can often be performed iteratively with the model specification step. In this study, the lack of data on several important variables required respecification of several of the models. First, for the soft crab model, data series for retail and wholesale prices were not available; the demand submodel in this model therefore consists of just an ex-vessel price equation.

Similarly, in both the hard clam and soft clam models, retail price services were unavailable, and each model had to be respecified without a retail price equation. For all three of these models, the equation explaining the price in the highest remaining market (ex-vessel for soft crabs, wholesale for clams) was adapted to include a number of variables representing consumer demand; the soft clam wholesale price equation, for example, includes national income as a variable, even though in the model specification step this variable was not found to be an important determinant of wholesale prices; it is not contained in the oyster or hard blue crab wholesale price equations.

Second, data on those variables hypothesized to determine harvest sector productivity were in large part either not available or not available in a convenient form. Reliable data on the stocks of each species, for example, were not available.

3.3 MODEL ESTIMATION

As a result of iteratively performing the first two steps of the methodology, each of the five models was operationally specified (i.e., specified in such a way that the data to estimate were available) and the data were collected to estimate its parameters. Each of the models contained two submodels, one predicting Chesapeake Bay harvest or supply of the associated product, the second a demand model which explained a set of market prices. Each of the equations in each of the supply submodels was a single, independent equation; harvest is not determined simultaneously with any other variable. However, each of the demand submodels (except for soft crabs, which contains only one equation) is simultaneous in structure; retail prices influence wholesale prices, as do ex-vessel prices; wholesale prices influence both retail and ex-vessel prices. All three prices are thus determined together.

3.3.1 Estimation of Supply Submodels

Given this model structure, and the data available to estimate the model parameters, specific statistical techniques are called for. Because the equations of the supply submodels are non-simultaneous, their parameters can be estimated using ordinary least squares (OLS), the most basic parameter estimation technique. Each of the supply equations was, in fact, estimated using this procedure. However, several of these equations were plagued by severe multicollinearity. As described by Hoerl and Kennard (1970), multicollinearity results when the explanatory variables in a particular regression equation are correlated not only with the dependent (left-hand side) variable (as intended) but also with each other. When two or more variables are strongly correlated, the OLS technique cannot accurately distinguish the effect of changes in one variable on the dependent variable from the effect of changes in the other variable, because the set of mutually correlated explanatory variables in effect appear as a single variable. Thus, although OLS produces unbiased estimates of the equations parameters, these estimates are highly uncertain, as reflected in large coefficient standard errors. Use of such coefficient estimates in forecasting and, particularly, in impact analysis may yield predictions which are also highly uncertain. To insure against multicollinearity and resulting coefficient uncertainty, two statistics, the variance-decomposition proportions and the variance inflation factors (Belsley, Kuh, and Welsch 1980), were calculated for each equation to determine whether or not serious multicollinearity was present. These sample statistics for each equation were compared to established multicollinearity critical points; if the statistic exceeded the critical point, steps were used to overcome the effects of multicollinearity.

Specifically, in such cases, ridge regression was employed. This statistical technique, a variant of the ordinary least squares method, adjusts the OLS parameter estimates to take into account the effect of multicollinearity on the OLS estimates. The resulting coefficient estimates are biased, but the extent of this bias can be calculated; more importantly, the coefficient variance can be reduced by using ridge regression to such an extent that the mean squared error of the coefficient estimates (the coefficient variance plus the square of the bias) is smaller than the corresponding OLS estimates; i.e., on average, the ridge regression coefficient estimates are "closer" to the true parameter values than are the OLS coefficient estimates. This improvement can generally occur only when the sample multicollinearity statistics exceed their critical points.

In addition, because the equations were estimated using time-series data, the residuals or errors of each equation (both OLS- and ridge regression-estimated) were tested for the presence of autocorrelation, utilizing the standard Durbin-Watson (D-W) and Durbin h statistics. Calculated D-W's were compared to established critical points to determine whether or not autocorrelation was serious. In general, if autocorrelation is present, parameter estimates not adjusted to reflect its presence can, have large variances or standard errors, which may make the coefficient estimates virtually useless in forecasting or impact assessment. For equations with severe autocorrelation, as represented by the D-W, which were estimated using OLS, the equations were reestimated using Cochrane-Orcutt (a technique which adjusts the OLS estimates to account for autocorrelation) producing coefficient estimates that are, again, slightly biased but which have much smaller standard errors and thus smaller mean square errors. For equations estimated using ridge regression, the D-W statistic was calculated; however, since statistical packages which combine ridge regression with the Cochrane-Orcutt method are not available, these equations were not reestimated.

3.3.2 Estimation of Demand Submodels

Even in the absence of multicollinearity and/or autocorrelation, ordinary least squares could not be used to estimate the parameters of the demand submodels because of the simultaneous structure of these submodels. In the situation where two or more variables are jointly determined in a set of structural equations, as is the case here (where the retail price determines the wholesale price, and the wholesale price determines the retail price, etc.) OLS produces coefficient estimates that are biased (i.e., the expected value of the parameter estimate is not the true parameter value). To overcome this bias, the two-stage least squares (2SLS) estimation technique was employed to estimate the parameters of four of the five demand submodels (the soft crab demand submodel, comprising one equation, was estimated using OLS). This commonly employed statistical technique produces coefficient estimates that are assymptomtically unbiased (i.e., unbiased for very large samples), and that are also typically less biased for finite samples than are the corresponding OLS coefficient estimates.

However, 2SLS estimation was also plagued by severe multicollinearity in most cases. To overcome this, the variance-decomposition proportions and variance-inflation factors sample statistics were again computed for each structural equation (i.e., each second-stage equation, as contrasted to the first-stage equations, which are merely auxiliary equations used to create new variables used in the second-stage equations that are of interest to the analyst); again, these sample statistics were compared to their critical points, and equations with severe multicollinearity were reestimated using a combined 2SLS-ridge regression technique.

Finally, Durbin-Watson statistics were calculated for each of the equations to check for the presence of autocorrelation. The Cochrane-Orcutt method was not employed to adjust the coefficient estimates for autocorrelation, since the 2SLS-ridge regression technique was used for nearly all of the demand equations and no statistical computation package which combines ridge regression with the Cochrane-Orcutt method was available.

3.4 MODEL VALIDATION

The final step of the methodology was to validate each of the models estimated in the third step. These models were validated or tested in two ways: first, the accuracy of the model in predicting historical values of the endogenous variables was assessed; second, the ability of the model to produce "reasonable" forecasts of the future values of the model's endogenous variables under alternative exogenous-variable scenarios was assessed. Included in this second set of tests were a number of experiments in which a particular model would forecast future values under two scenarios, which differed only in the value assigned to a single exogenous variable; in this manner, short- and long-term "impact" multipliers were calculated for each model, and the reasonableness of both the sign and magnitude of the multipliers considered. Each of these two types of validation exercises is considered in turn below.

3.4.1 Goodness-of-Fit Tests

For each model, several exercises were performed to determine how well the individual equations of the model and the model as a whole were able to replicate history.

First, as part of the estimation process, the correlation coefficient (R^2) for each equation was calculated. This statistic represents the proportion of the historical sample variance of the equation's dependent (left-hand side) variable that is "explained" by the equation, when the actual historical values of the equation's right-hand side variables are inserted into the equation. The R^2 statistic, ranging in value from zero to one, measures how well each equation, when considered in isolation from all other equations of the model, predicts past values of the dependent variable.

Second, for each model, two backcasts were performed, and backcast statistics calculated for each. In a backcast, the model is set up as it would be to forecast future values of the model's endogenous variables, and the model is then simulated for the historical period, producing predicted or "backcast" (as contrasted to "forecast" or future values) for the historical period. Actual values of the model's exogenous variables are used to assign values to the endogenous variables via the equations; however, when an endogenous variable appears on the right-hand side of another equation in the model, the predicted value not the actual value, is used. Two types of backcasts were performed. In the first, called a static backcast, when previous values (i.e., lagged values) of the model's endogenous variables appear on the right-hand side of an equation in the model, the actual past value, not the predicted past value, is used. In the second, called a dynamic backcast, when previous values of such a lagged endogenous variable appear on the right-hand side of an equation, the model's prediction of that variable (from the simulation) is used. For example, the previous period's ex-vessel price is one determinant of each period's number of tong-using harvesters in Maryland public grounds (i.e., effort). In the static backcast, the actual values of last period's price would be used to predict this period's effort, while in the dynamic backcast the simulated value (i.e., the value predicted by the oyster ex-vessel price equation) would be used to evaluate the equation. Thus, dynamic backcasts in some sense reflect how the model can be expected to operate in forecasting; if the model performs well in a dynamic backcast, it can be expected to perform reasonably well (i.e., predict reasonably accurately) in the future. The converse is also true. One simplification is that for the dynamic backcast the actual values of the model's exogenous variables are known and are used, while for forecasting this is not typically the case; moreover, the model ought to backcast reasonably well since its parameters were estimated using data for the backcast period and thus reflect the relationships among the variables that actually were in effect but do not reflect the relationships that may be in effect in the future (if the relationships change). Static backcasts, on the other hand, do not display how the model would operate in a forecasting situation (unless the model is actually static, i.e., does not contain any lagged dependent variables); by comparing the results of a static backcast with those from a dynamic backcast, however, an analyst can identify the sources of predictive inaccuracy. If the accuracy of the two models differs substantially between the two exercises, for example, then the equations of the model with dynamic elements (i.e., lagged endogenous variables) may be highly inaccurate and the predicted values from these equations may be causing inaccuracy in other equations of the model (where they appear on the right-hand side of an equation).

For each of the two backcasts, each model, and each endogenous variable within the model, a number of backcast summary statistics were computed. First, the mean square error (MSE) was computed for each endogenous variable. This statistic is the sum over all of the backcast years of the squared differences between the actual and the predicted values of the corresponding endogenous variable, all divided by the number of backcast periods. This statistic (and its root, the root mean square error, RMSE) indicate the "average" amount that the model "missed" the true value of the corresponding endogenous variable. The analyst can use this statistic to determine if the model predicts a particular variable accurately enough to be useful. The relative change mean square error (RCMSE) statistic was also calculated; this statistic is calculated in a manner similar to the mean square error, except the percentage difference between the actual period-to-period percentage change and the predicted period-to-period percentage change is substituted. This statistic can be transformed into Theil's U_2 statistic, and decomposed into Theil's U_m, U_r, and U_d statistics. U_2 is calculated by comparing the model's root RCMSE to the root RCMSE that a naive extrapolation model (which always predicted that period's value was equal to last period's actual value) would produce; if U_2 is less than one, the model under consideration predicts past period-to-period changes in the values of the endogenous variable in question more accurately than would the so-called naive model. Conversely, if U_2 is greater than one, the model's predictions are less accurate than those of the naive model. U_m measures the proportion of the RCMSE that is due to bias (i.e., consistent over- or under-prediction of the actual relative or percentage change), U_r measures the proportion of the RCMSE that is due to consistent over- or under-reaction of the model to exogenous variable changes, and U_d is the proportion of the RCMSE that is due to mere noise. The sum of these three statistics equals one. Generally, the closer to zero that the MSE, root MSE, RCMSE, root RCMSE, U_2, U_m, and U_r for a particular variable are, the better the model is in terms of predicting that particular variable; if any of the first five of these summary statistics are unusually high, it indicates that the model cannot be expected to accurately predict these variables in the future under any conditions; if the latter two are unusually high, it indicates that the model is misspecified. In either case, further estimation or even respecification of the model may be required.

3.4.2 Impact Analysis Tests

For each model, several tests were also performed to determine how well the model could assess the impacts of changes in the exogenous variables. In contrast to the goodness-of-fit tests, in which quantitative summary statistics could be computed for each model/endogenous variable and compared to established "critical points," these tests are largely qualitative. In each test, the change in the future values of each of the model's endogenous variables associated with a specific change in one of the model's exogenous variables was calculated. The direction, the magnitude, and (in some types of tests) the duration of the impacts were considered in determining whether the structure of the model and the individual parameter estimates were consistent with economic theory and intuition. In cases where the impacts were inconsistent with this criteria, equations were reestimated and/or the model was respecified.

The first type of these tests was performed as part of the estimation process. The sign and magnitude of each coefficient estimate were checked for consistency with economic theory; because coefficients of the "wrong" sign or magnitude might produce impact assessments that would be deemed unreliable, the equations containing such coefficients were typically reestimated in an alternative form, or completely respecified.

In the second type of test, the "analytically derived reduced form" of each model was computed; this form of the model reorganizes the variables and the parameter estimates of the model so that each of the model's endogenous variables is made a function of only exogenous variables. The coefficients of this form of the model, which are more algebraic transformations of the estimated coefficients of the original structural model, represent current-period impact multipliers; i.e., they measure the change in the value of each of the model's endogenous variables in a given period associated with a one-unit increase in the same period in a particular exogenous variable. Such impact multipliers take into account both direct and indirect effects; for example, the impact multiplier of U.S. oyster consumption on the wholesale oyster price accounts for the effects of 1) consumption on the retail price, 2) the retail price on the wholesale price, 3) the wholesale price back on the retail price, 4) the retail price back on the wholesale price, etc., as well as 5) the retail and wholesale prices on the ex-vessel price, 6) the ex-vessel price on the wholesale price, etc. The signs and magnitudes of these impact multipliers were also checked for consistency with economic theory and intuition.

Finally, the third type of test of each model's impact analysis capabilities involved simulating the model for the 1980-1990 period using alternative scenarios. First, a base-case forecast was developed in which all of the model's exogenous variables were assigned their 1979 values for the entire 1980-1990 period. Second, a forecast was developed in which the intermediate goods and services index (IIGS), a measure of costs incurred by the wholesale industry, was assigned a value for the 1980-1990 period that exceeded its 1979 (base-case) value by 10 percent, with all other exogenous variables assigned their 1979 values. Additional forecast scenarios were developed in which 1) U.S. population (a determinant of retail demand) was assigned a value percent above its 1979 value, 2) U.S. disposable income was assigned a value 10 percent higher than its 1979 value, and 3) the U.S. Consumer price index was assigned a value 10 percent higher than its 1979 value. For each of these tests, the differences between the base- and alternative-scenario forecasts of 1980-1990 values of each of the model's endogenous variables were calculated and analyzed to insure, again, that the model was consistent with both economic theory and intuition. In general, these two criteria would suggest that the impact of such moderate changes would be rather small (i.e., the model must not be explosive) and that the impacts of such one-time, sustained impacts should be rather short-lived (i.e., that the model is not dynamically unstable).

4.0 ECONOMIC MODELS OF THE OYSTER INDUSTRY

This chapter documents the development of economic models for the demand and supply of Chesapeake Bay oysters. An explanation of the industry structure is provided first in Section 4.1. This discusses major environmental factors that have affected the industry and describes product flows and relationships between various industry sectors. The demand and supply models developed for Bay oysters are presented and explained in the second section. This is followed, in the third section, by presentation of the estimation results. Techniques used to validate the oyster model are discussed in the final section.

4.1 BACKGROUND

The Chesapeake Bay oyster (Crassostrea virginica) industry has two main levels: harvesting and intermediate handling (which consists of processing and distribution activities). Factors affecting oyster growth and harvesting are discussed first, in this section followed by a discussion of the processing sector and product flows to retail markets.

4.1.1 Overview of Oyster Production

The Chesapeake Bay in Maryland and Virginia has long been a primary producer of oysters for the U.S. market. In the past two decades, however, the Bay region has experienced substantial declines in production. In 1955 Chesapeake Bay production was 59.5 percent of total U.S. production. By 1980 the Bay's production had declined to 46.4 percent of the U.S. total (see Table 4.1).

Though declining, total Bay production has remained important in the U.S. market. However, the states of Maryland and Virginia have, over time, reversed their respective positions of importance as producers of Bay oysters. Until the mid-1960s Virginia accounted for as much as 59 percent of Bay production (see Table 4.1). However, during the 1960s, the onslaught of MSX disease in Virginia's highly saline waters, in conjunction with a severe price/cost squeeze on private oyster growers, caused a rapid decline in Virginia production (Haven et al., 1981). Meanwhile, more favorable environmental conditions in Maryland, coupled with an extensive Maryland effort to increase oyster production by planting of shell and seed oysters, brought forth significant increases in Maryland production (Kennedy et al., 1981).

Despite these production shifts, oyster shucking operations continue to be located primarily in Virginia. As state production has declined, Virginia oyster processors have had to import oysters from other states (primarily Maryland) to utilize processing capacity (see Table 4.2). Clearly, there exists now, and has long existed, an interdependency between the oyster industries

TABLE 4.1. Maryland and Virginia Oyster Harvests, and Shares of Total U.S. and Bay Harvests, Selected Years

	Maryland			Virginia		
Year	Harvest (thousands of lb)	Percent U.S.	Percent Bay	Harvest (thousands of lb)	Percent U.S.	Percent Bay
1955	17,272	26	44	21,955	33	56
1960	11,771	24	44	15,340	31	56
1965	8,620	19	41	12,568	28	59
1970	16,625	36	67	8,043	18	33
1975	16,403	35	72	6,237	13	28
1980	14,944	30	66	7,846	16	34

Source: U.S. Department of Commerce, National Marine Fisheries Service, Fishery Statistics of the United States, selected years, unpublished data.

TABLE 4.2. Virginia Oyster Handlings, Selected Years (Bushels)

Year	Virginia Harvest	Imports for Processing	Total Handlings
1956	4,579,299	-0-	4,579,299
1960	3,659,811	-0-	3,659,811
1965	2,390,479	356,494	2,746,973
1970	1,753,589	2,092,519	3,846,108
1975	1,167,396	1,636,292	2,803,688
1980	1,620,706	1,679,680	3,300,386

Source: Virginia Marine Resources Commission, Annual Reports for 1981-1982.

of Maryland and Virginia. This interdependency is explicitly recognized in the economic models of the Chesapeake Bay oyster industry presented in this chapter.

The harvest sectors of Maryland and Virginia differ because of the property rights structure of the oyster grounds. While both states have both public and private grounds, the public sector is more important in Maryland and the private in Virginia. Private grounds are usually productive only if planted with seed oysters. The seed oysters are left for two to four years to grow to maturity. They are then generally harvested by oyster dredges. Individual oyster planters in both states can lease such grounds for planting; however, private plantings in Virginia are far more important than in Maryland. Indeed, in the 1950s private planters in Virginia accounted for most of the Virginia harvest. In Maryland private planters have always accounted for a small proportion of total state production (see Table 4.3).

TABLE 4.3. Maryland and Virginia Harvest from Public and Private Grounds Selected Years (thousands of lb)

	Maryland		Virginia	
Year	Public	Private	Public	Private
1955	13,444	3,832	3,896	18,058
1960	10,003	1,667	3,996	11,344
1965	6,614	1,506	4,440	8,128
1970	15,946	678	3,110	4,933
1975	15,720	683	2,992	3,245
1980	14,472	472	4,716	3,437

Source: U.S. Department of Commerce, National Marine Fisheries Service, Fishery Statistics of the United States, selected years.

The public oyster grounds of both states are open to harvest by any person who holds a license. Licenses can be purchased for a nominal fee. The oysters available for harvest are wild stocks that grow on natural oyster bars. In both states the ability of the natural bars to support such wild stocks is enhanced by state repletion (or propagation) programs. In these repletion programs, oyster shell and seed are planted to increase the public ground's oyster populations. However, the number of harvestable oysters will fluctuate with the prior year's "spat" (larval oyster) setting on available shell and other hard surfaces. The spat set varies with a variety of environmental conditions, including salinity and water quality.

Minimum restrictions on oyster harvest from the public grounds exist in both states. In Maryland, harvest is primarily by hand tongs. Dredging by skipjack sailcraft is permitted under limited conditions with an upper limit on daily catch. Patent tongs are also permitted in limited areas. In Virginia, hand tong harvest is permitted on all public grounds. However, some of the public grounds are too deep to be accessible by hand tong. In these inaccessible areas, the Virginia Marine Resources Commission may permit harvest by patent tong or oyster dredge.

The harvest of oysters by the Chesapeake Bay "waterman" is an activity bound by tradition. As a result, watermen vary their fishing effort only slowly in response to changing economic forces and biological productivity. Furthermore, as a result of the regulatory environment coupled with the traditional nature of the harvest sector, the harvest practices have changed little over time. These factors are considered in the design of the harvest supply models presented in this chapter.

4.1.2 Overview of Processing and Consumption

As shown in Figure 4.1, distribution of harvested oysters to consumers involves an intermediate handling system composed of processors and distributors. While the intermediate handling system includes some wholesale

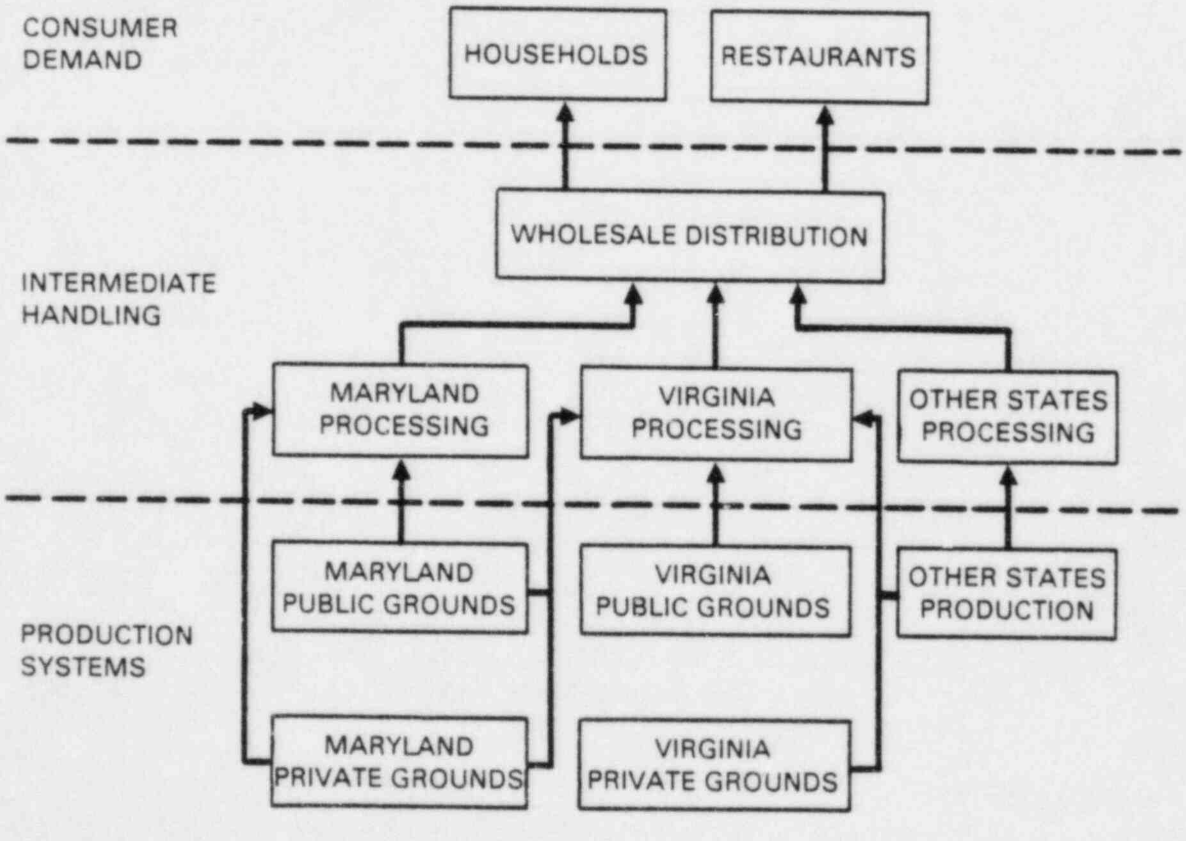


FIGURE 4.1. Product Flow from Chesapeake Bay Oyster Production

distributors of shucked oyster meats, the shucking plants that remove oyster meats from the shells and pack the meats into containers are most important. The shucking process continues to operate as it has over the past several decades. The oysters are opened by hand using minimum-wage employees who are quite skilled at the shucking process. A minimum amount of capital is needed for cleaning and preparing the oysters for packing in containers. Indeed, the predominant costs for a shucking plant are the oysters themselves, plus labor. As was previously noted, Virginia processing continues to dominate the Bay region's processing output despite the decline in Virginia harvest (see Table 4.4). To support this production level, Virginia oyster shuckers have imported oysters from other states, primarily Maryland.

TABLE 4.4. Volume of Shucked Oysters from Maryland and Virginia, Selected Years (thousands of gal)

Year	Maryland	Virginia	Virginia's Percent of Bay Total
1955	1684	2385	59
1960	1099	1631	60
1965	674	1239	65
1970	765	1920	71
1975	799	1904	70

Source: U.S. Department of Commerce, National Marine Fisheries Service, Fishery Statistics of the United States, selected years.

As depicted in Figure 4.1, most harvested oysters move to shucking plants where the oyster meats are packed in containers for further distribution to wholesale distributors and retail outlets both within and beyond the Chesapeake Bay region. Although no quantity estimates are available, a large share of Chesapeake Bay production is shipped outside the region. Also, a substantial part of consumption occurs in restaurants rather than in homes. In these restaurants and away from the Bay region, the Bay's production faces competition from oysters produced in other areas. The equations used to model the resulting demand and supply system for Chesapeake Bay oysters are discussed in the following section.

4.2 DEMAND AND SUPPLY SYSTEM

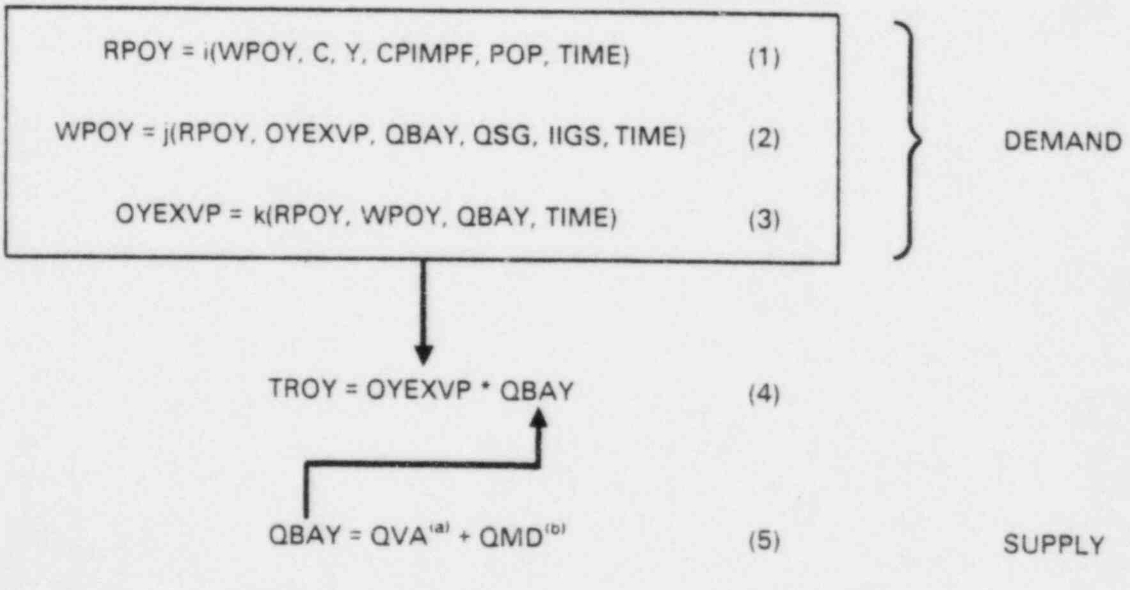
Figure 4.2 shows the demand and supply system estimated for the Chesapeake Bay oyster industry. The demand equations (1) to (3) show that prices at ex-vessel, wholesale and retail levels are simultaneously determined and depend upon a number of exogenous variables, including landings from the Chesapeake Bay. Landings are treated as exogenous to the demand system because within the supply equations, harvest effort responds to ex-vessel prices with a time lag.

Total harvest revenue (TROY) is the product of Bay harvest and ex-vessel price at each time period (Equation 4). The development of ex-vessel prices is explained in the following section on Chesapeake Bay oyster demand. Total Bay harvest or landings is the sum of Virginia and Maryland harvests.

$$QBAY = QVA + QMD \qquad (5)$$

where

QBAY = landings in the Chesapeake Bay (millions of pounds)
QVA = landings in Virginia (millions of pounds)
QMD = landings in Maryland (millions of pounds).



(a) QVA DEVELOPED IN FIGURE 4.4
(b) QMD DEVELOPED IN FIGURE 4.5

FIGURE 4.2. Demand and Supply System for Chesapeake Bay Oysters

Due to their differences, the models for Virginia and Maryland harvests are explained separately in the sections that follow on Virginia harvest supply and on Maryland harvest supply.

4.2.1 Chesapeake Bay Oyster Demand

Because of the interdependency between Maryland and Virginia in oyster processing and distribution, a single system of demand equations is developed for Chesapeake Bay oysters. Equations (1) to (3) in Figure 4.2 represent this demand system. Prices at three separate levels of the oyster industry (corresponding to Figure 4.1) are explained: consumer or retail level, intermediate or wholesale and processor level, and production or ex-vessel level.

$$\text{RPOY} = i(\text{WPOY}, C, Y, \text{CPIMPF}, \text{POP}, \text{TIME}) \quad (1)$$

$$\text{WPOY} = j(\text{RPOY}, \text{OYEXVP}, \text{QBAY}, \text{QSG}, \text{IIGS}, \text{TIME}) \quad (2)$$

$$\text{OYEXVP} = k(\text{RPOY}, \text{WPOY}, \text{QBAY}, \text{TIME}) \quad (3)$$

where:

RPOY = nominal retail price of oysters (standards) at Baltimore, Maryland (dollars per pound)

C = total consumption of U.S. oysters including western oysters and imports (millions of pounds)

Y = nominal total disposable personal income in the United States (billions of dollars)

CPI = consumer price index of meat, poultry, and fish (1967 = 100)

WPOY = nominal wholesale price of oysters (standards) at Norfolk, Virginia (dollars per pound)

QBAY = landings in the Chesapeake Bay (millions of pounds)

QSG = landings in the South Atlantic and the Gulf (millions of pounds)

IIGS = index of intermediate goods and services (1967 = 100)

OYEXVP = nominal ex-vessel price of oysters, weighted average value of Maryland and Virginia landings (dollars per pound)

POP = civilian population of the United States (millions)

TIME = time trend.

The relationships among ex-vessel, wholesale and retail prices depend upon consumer demand, product supply and costs of marketing (Gardner 1975; Heien 1980). Specifically, retail price influences wholesale and ex-vessel price, wholesale price influences retail and ex-vessel price, and ex-vessel price influences wholesale price. The interdependent nature of oyster price determination constitutes a simultaneous system in which the endogenous variables are the market prices at the three levels in the marketing chain. However, it does not follow from this that prices at the three levels necessarily change together.

The time divisions used in this analysis are probably the major contributors to the simultaneity of the determination of price levels. With data for short time units, a recursive or causal chain system for price determination might be more appropriate than a simultaneous equation system. However, in this case, the data interval corresponds to one year, and hence, the simultaneous system is preferable.

Implicit in this system is a price dependent demand (Fox 1953; Waugh 1964) for oysters. Chesapeake Bay landings in any time period are not responsive to current ex-vessel prices because harvest effort (labor and seed planting) responds to price with a time lag. A similar logic is presumed to apply to landings outside the Bay region which also may respond to prices with a time lag. Thus, landings and total consumption in any year are treated as being exogenous when estimating the parameters in the model. Total consumption is set equal to total U.S. landings plus imports (Table 4.5).

It is hypothesized that in the retail price equation, the coefficient on consumption is negative, reflecting the usual inverse relationship to price. The coefficient on income is hypothesized to be positive, reflecting the fact that oysters are normal goods. CPIMPF is an index used to measure the price of substitute products such as meat, poultry, fish, and shellfish. As such, it is hypothesized to be positively related to the retail price of oysters. Also, similarly to income and prices of substitute products, time and population are hypothesized to be positively related to retail price. The wholesale price is also expected to be positively related to retail price.

At the wholesale level, it is hypothesized that Bay landings and South Atlantic and Gulf landings have inverse impacts on the wholesale price. Therefore, the coefficients are expected to be negative. The unavailability of

TABLE 4.5. Landings of Oysters, by Area and Type, Annual, 1960-1980 (meat weight in thousands of pounds)

	Eastern Oysters							
Year	Chesapeake	South Atlantic	Gulf	Other	Total	Pacific	Western	Total
1960	27,111	4,119	16,098	1,654	48,982	10,983	45	60,010
1961	27,500	3,984	18,240	2,389	52,113	10,154	38	62,305
1962	19,939	3,850	18,838	2,670	45,297	10,714	26	56,037
1963	18,274	4,837	24,139	1,417	48,667	9,746	31	58,444
1964	22,098	3,527	23,385	1,556	50,566	9,934	34	60,534
1965	21,188	4,082	19,156	1,105	45,531	9,117	40	54,688
1966	21,232	3,657	17,182	1,338	43,409	7,779	35	51,223
1967	25,798	3,160	21,747	1,526	52,231	7,682	44	59,957
1968	22,679	2,965	26,739	1,749	54,132	7,696	58	61,886
1969	22,157	1,830	19,765	1,491	45,243	9,916	40	52,199
1970	24,668	1,626	17,714	1,620	45,628	7,915	59	53,602
1971	25,557	1,846	20,266	2,169	49,838	8,048	52	57,938
1972	24,066	1,868	18,260	3,473	47,667	8,362	29	56,058
1973	25,400	1,656	14,914	3,363	45,333	6,576	22	51,931
1974	25,021	1,841	14,878	3,385	45,125	5,030	21	50,176
1975	22,640	1,585	19,295	3,878	47,398	5,807	22	53,227
1976	20,964	1,704	21,569	3,773	48,010	6,354	31	54,395
1977(a)	17,929	1,847	18,081	2,579	40,436	5,590	(b)	46,026
1978(a)	21,531	2,138	18,212	3,302	45,183	5,800	(b)	50,983
1979(a)	20,428	2,441	15,289	4,167	42,325	5,756	(b)	48,081
1980(a)	21,906	NA	NA	NA	42,439	6,642	(b)	49,081

(a) Preliminary.

(b) Landings of western oysters included with landings of Pacific oysters.

Note: Figures may not add to total because of rounding.

Source: Shellfish Market Review (1981).

time-series data on wholesale cost components led to the use of the index of intermediate goods and services (IIGS) as a proxy variable for marketing costs other than raw materials. IIGS is an index developed by the USDA to measure trends in marketing costs for the food processing sector. As such, it can be assumed to represent costs in the oyster processing sector. Ex-vessel prices, which are the raw material costs, are expected to be positively related to wholesale price. Retail price is also hypothesized to be positively related to wholesale price. The coefficient on the time trend variable is hypothesized to be positive, reflecting a general upward price trend over the period.

In the ex-vessel price equation it is expected that landings will be inversely related to price. Coefficients on wholesale price and retail price are expected to be positive. The time trend variable is expected to be negative to reflect the stagnant historical pattern of ex-vessel prices over the time period (Figure 4.3).

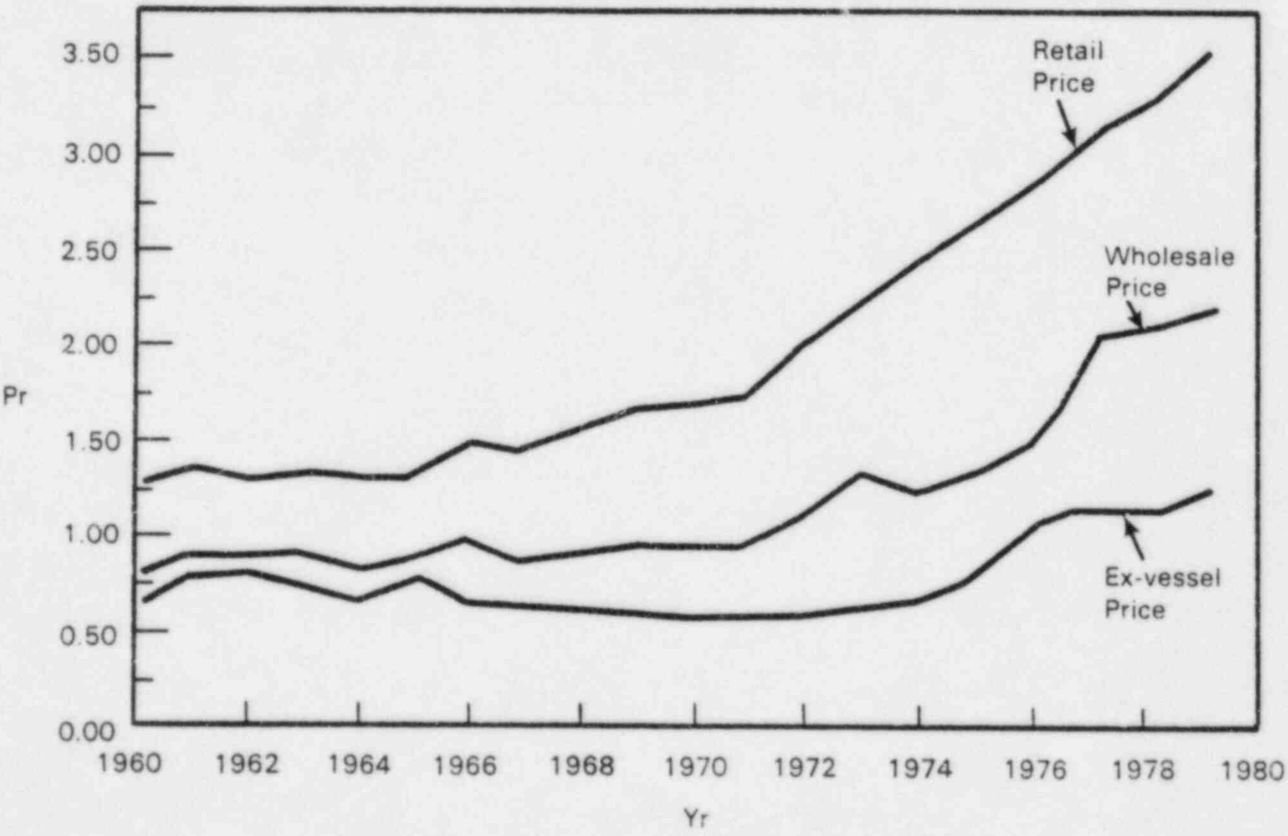


FIGURE 4.3. Retail, Wholesale, and Ex-Vessel Prices for Oysters (1960 to 1979)

Source: Shellfish Market Review (1981).

4.2.2 Virginia Harvest Supply

Equations (6) to (12) in Figure 4.4 represent the Virginia harvest supply model. The total Virginia harvest is the sum of harvested quantities from both public and private grounds.

$$QVA = QVAPRV + QVAPUB \tag{6}$$

where

QVA = Virginia landings (millions of pounds)
QVAPRV = harvest from Virginia private grounds (millions of pounds)
QVAPUB = harvest from Virginia public grounds (millions of pounds).

Because of the different property rights, production input requirements, and harvest methods on public versus private grounds, separate supply equations are developed for private grounds harvest (7 to 9) and for public grounds harvest (10 to 12).

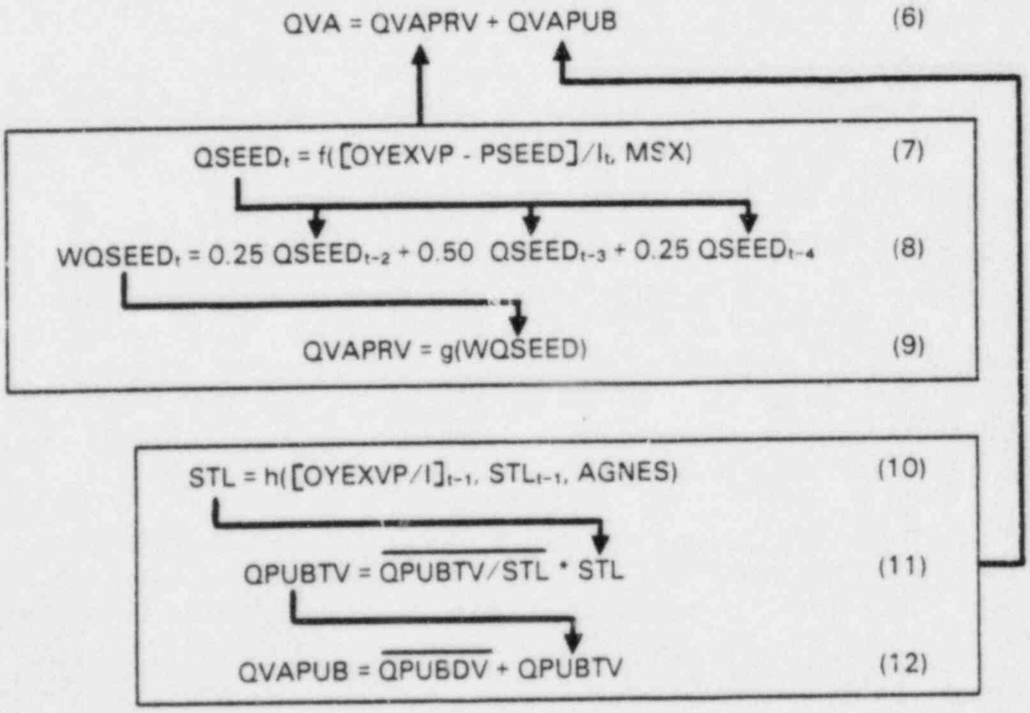


FIGURE 4.4. Virginia Oyster Harvest Supply

Virginia Private Grounds Production

Production of oysters from private beds requires the planting of seed oysters in prior years. Without such planting private beds will be unproductive. The seed planting decision responds to both economic incentives and biological conditions. Specifically, seed planting will depend upon the price of market oysters, the price of seed oysters, the cost of capital and the threat of MSX disease killing seed oysters planted. Equation (7) represents the effect of the economic and biological factors.

$$QSEED_t = f([OYEXVP - PSEED]/I_t, MSX) \tag{7}$$

where

$QSEED_t$ = seed planted on private beds in Virginia (bushels)

OYEXVP = ex-vessel price for market oysters (dollars per pound of meat)

PSEED = price of seed oysters (dollars per bushel)

I = interest rate on lowest denomination long-term commercial loans

MSX = dummy variable for years immediately following the 1959-1960 outbreak of MSX disease

t = current year.

Seed costs represent a substantial share of the total costs of production for the private planter. The market price to seed price differential is a convenient rule-of-thumb often used to evaluate seed planting profitability in the industry (Haven et al., 1981). The potential profitability represented by this difference will vary with the cost of capital (i.e., seed investment cost). This relationship is represented by the first term in Equation (7). Projected profitability is expected to positively enhance seed planting.

The MSX dummy variable represents the fact that for several years after MSX entered the Bay in 1959, the tradition-bound watermen continued planting seed. However, over time, reductions in seed planting occurred with the realization that on many private grounds seed oysters would not survive to maturity. A second factor accounted for by the MSX variable is that shortly after the MSX outbreak, for reasons that remain unexplained, James River seedbed productivity (spat setting) experienced an abrupt decline. (The James River is the area where most of Virginia's seed oysters are harvested.) The resultant negative shift in seed planting levels after 1965 is reflected by the MSX variable in Equation (7).

Once planted, seed grows to mature, market-size oysters in two to four years. A general growth pattern consistent with oyster biology is shown in Equation (8) where 25 percent of planted seed is expected to mature in two years, 50 percent in three years and the remaining 25 percent in year four.

$$WQSEED_t = .25\ QSEED_{t-2} + .50\ QSEED_{t-3} + .25\ QSEED_{t-4} \tag{8}$$

where

$WQSEED_t$ = weighted quantity of previous seed plantings expected to mature to market size in current year t.

$QSEED_{t-n}$ = seed planted n years before t, where n = 2, 3 and 4.

The private grounds harvest (QVAPRV) of market oysters in the current time period will be positively related to previous years' seed plantings (WQSEED). The relationship between such plantings and harvest is depicted in Equation (9). A one-to-one relationship of seed to harvest is not expected due to natural mortality and inefficiencies in harvest methods. Thus,

$$QVAPRV = g(WQSEED) \tag{9}$$

where

QVAPRV = harvest of oysters from private grounds in Virginia (millions of pounds)

WQSEED = weighted quantity of previous seed plantings.

Virginia Public Grounds Production

Oysters harvested from public grounds must be taken from a population whose size fluctuates primarily with the environmental conditions that affect spat setting and survival from attacks of predators and disease (Haven et al., 1981; Kennedy et al., 1981). In addition, public repletion programs can be undertaken to enhance the likelihood of large harvestable populations being available. Therefore, unlike the private grounds where prior seed plantings dictate current harvest, public grounds harvest is primarily determined by the level of the wild stock and the amount of harvest effort utilized to harvest the stock.

Harvest effort consists of the combination of labor with a particular gear. Hand tong gear is the least labor efficient, but to protect the resource, much of the public ground harvest effort is limited to hand tongs. While patent tongs are more labor efficient, their use is restricted to deeper waters where hand tongs cannot be used and to areas where market size oysters are widely scattered. Use of patent tongs generally falls and rises with the size of the populations in these deeper waters. Oyster dredges are the most labor efficient harvest method and are used extensively on private grounds. However, dredge use on public grounds is severely limited. In fact, since 1961, dredge use has only been permitted in two areas. Dredges are being used there to "mine" an oyster population that has grown up over the past 50 years but which is not reproducing itself at a rate equal to the rate of harvest. Once this population is depleted, dredge use on public beds would be expected to fall.

Tong effort is expected to respond to economic forces. This effort response model is shown as Equation (10).

$$STL = h([OYEXVP/I]_{t-1}, STL_{t-1}, AGNES) \tag{10}$$

where

STL = sum of patent tong and hand tong licenses
OYEXVP = ex-vessel price for market oysters (dollars per pound of meat)
I = interest rate for lowest denomination long-term commercial loans
t = current year
AGNES = effect of hurricane Agnes on effort.

Harvest effort is measured by the number of licenses issued each year. While licenses will tend to misstate effort because not all persons with licenses will fish and/or because some will fish more intensively than others, it is the best available measure of effort for the Virginia harvest. The first argument in Equation (10) suggests that license numbers will respond positively to the profitability of oystering in the previous year. Profitability is measured as the price of oysters in relation to the costs of harvest as represented by the interest rate. The second argument suggests that the tradition-bound watermen adjust only partially in the short run to changes in profitability. This slowness in adjustment is represented by the lagged dependent variable. Finally, after hurricane Agnes in 1972, a number of watermen stayed away from the industry because many oysters were killed by the storm. They returned three years later when the oyster populations recovered.

Tong harvest (patent and hand tong) is a product of the number of tongs licensed and the harvest-per-tong. Thus, Equation (11), from Figure 4.4 is,

$$QPUBTV = \overline{QPUBTV/STL} * STL \tag{11}$$

where

$QPUBTV$ = harvest by tong from public grounds in Virginia (millions of pounds)

$\overline{QPUBTV/STL}$ = reported harvest per tong license from public grounds in Virginia (millions of pounds)

STL = licenses for hand and patent tong use on public grounds in Virginia.

Harvest per tong license is expected to vary with exogenous environmental and management factors.

The harvest by dredge is limited and would be expected to occur only in response to infrequent regulatory grants of permission to dredge public grounds. Therefore no economic supply model for dredge harvest is formulated.

Total harvest from Virginia's public grounds is the sum of tong plus dredge harvest. Thus,

$$QVAPUB = \overline{QPUBDV} + QPUBTV \tag{12}$$

where

$\overline{QPUBDV}$ = reported harvest by dredge from public grounds in Virginia (millions of pounds)

$QPUBTV$ = harvest by tong from public grounds in Virginia (millions of pounds)

$QVAPUB$ = total harvest from Virginia public grounds (millions of pounds).

4.2.3 Maryland Harvest Supply

Equations (13) to (16) in Figure 4.5 represent the Maryland harvest supply model. The total harvested oyster supply is the sum of landings by tong and dredge from public grounds and landings from private grounds. This summation is shown in Equation 13.

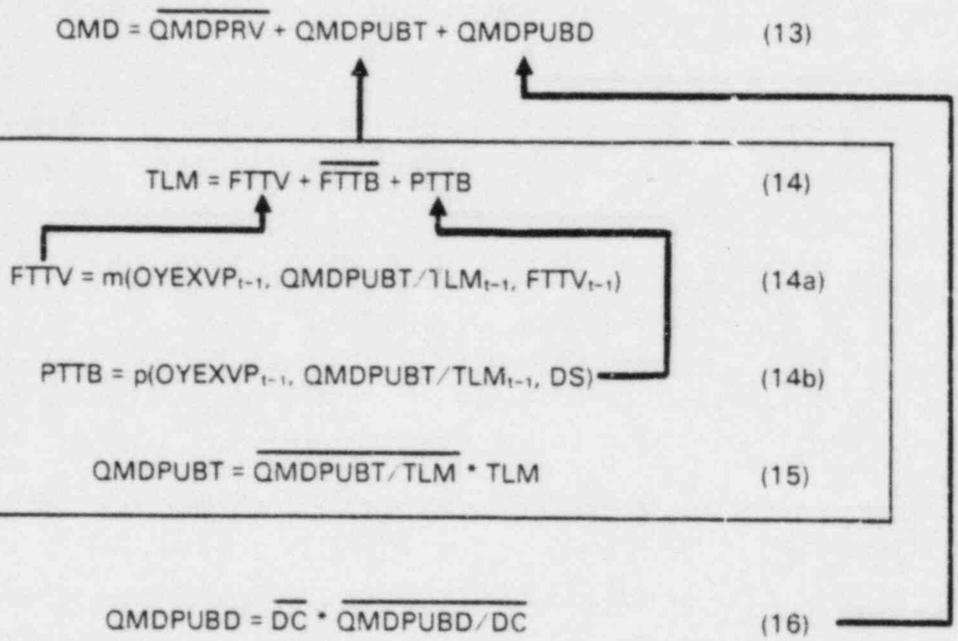


FIGURE 4.5. Maryland Oyster Harvest Supply

$$QMD = \overline{QMDPRV} + QMDPUBT + QMDPUBD \tag{13}$$

where

QMD = Maryland landings (millions of pounds)

$\overline{QMDPRV}$ = reported harvest from Maryland private grounds (millions of pounds)

QMDPUBT = tong harvest from Maryland public grounds (millions of pounds)

QMDPUBD = dredge harvest from Maryland public grounds (millions of pounds).

As in Virginia, different models are developed for private versus public production.

Maryland Private Grounds Production

Since 1962 Maryland private production has declined from 15.1 percent of state production to less than 5 percent (see Table 4.6). Because its contribution to total Maryland harvest is so small, a supply model for Maryland private harvest is not developed. Instead, the private harvest is treated as being determined exogenously from the general economic forces in the demand and supply model.

Maryland Public Grounds Production

Maryland public grounds are harvested by hand tong, patent tong and oyster dredge when such dredges are hauled by skipjack sailing vessels. Supply models for each of these harvest methods will be discussed in turn.

The hand and patent tong harvest from Maryland public grounds has, in recent years, exceeded the total production of the state of Virginia. This has arisen from a number of years in which the spat set has been very successful. Much of this success can be attributed to a concerted state oyster propagation program that grew dramatically beginning in the mid-1960s. Evidence of this success is shown in Table 4.7 where total public harvest and harvest per tong laborer are shown.

The number of tong laborers is expected to respond to economic forces. Tong effort in Maryland is divided according to craft used by the tonger and the share of income earned by all fishing for each fisherman. Thus, total tong labor in Maryland (TLM) equals the sum of full-time tong laborers on vessels (FTTV), full-time tong laborers on boats (FTTB) and part-time tong laborers on boats (PTTB).

$$TLM = FTTV + \overline{FTTB} + PTTB \tag{14}$$

where

TLM = total tong labor
$FTTV$ = full-time tong labor on vessels
$\overline{FTTB}$ = reported full-time tong labor on boats
$PTTB$ = part-time tong labor on boats.

There were few part-time tongers on vessels so these were added to FTTV. Data reported by the National Marine Fisheries Service were used because license

TABLE 4.6. Maryland Private and Public Production of Oysters (million pounds)

Year	QMDPRV	QMDPUBD	QMDPUBT	QMD
1960	--	--	--	11.771
1961	--	--	--	10.337
1962	--	--	--	8.139
1963	1.348	1.629	4.779	7.756
1964	1.145	1.028	5.776	7.949
1965	1.506	0.823	5.791	8.120
1966	1.437	1.586	8.767	11.790
1967	1.840	3.173	11.717	16.730
1968	0.899	2.136	11.838	14.873
1969	0.812	2.232	11.776	14.820
1970	0.678	1.983	13.963	16.624
1971	1.364	3.273	12.480	17.117
1972	0.929	2.436	15.687	19.052
1973	0.407	2.407	17.609	20.423
1974	0.452	1.804	16.029	18.285
1975	0.683	1.283	14.436	16.402
1976	0.700	1.123	13.057	14.880
1977	0.358	1.186	11.483	13.027
1978	0.503	1.439	12.432	14.374
1979	0.410	1.283	13.236	14.929
1980	--	--	--	14.788

QMDPRV: Maryland landings from private grounds.
QMDPUBD: Maryland landings from public grounds by dredge.
QMDPUBT: Maryland landings from public grounds by patent and hand tong.
QMD: Total Maryland landings of oysters.

TABLE 4.7. Total Harvest and Harvest per Tong Laborer in Maryland, 1962-1980 (thousands of pounds)

Year	Total Tong Harvest	Harvest Per Tong Laborer
1962	5,334	1.277
1963	4,779	1.221
1964	5,776	1.258
1965	5,791	1.587
1966	8,767	2.202
1967	11,717	2.681
1968	11,838	3.699
1969	11,776	2.911
1970	13,962	3.335
1971	12,480	2.715
1972	15,087	4.125
1973	17,608	4.361
1974	16,028	3.598
1975	14,435	3.148
1976	13,057	2.372
1977	11,483	2.578
1978	12,432	2.955
1979	11,699	3.177
1980	13,236	NA

Source: 1962-1976 data for total tong harvest from *Fishery Statistics of the United States*; 1977-on from unpublished sources in National Marine Fisheries Service.

data for Maryland were not available over time. Separate equations were constructed for two categories of Maryland tong labor.

Although it would be expected that FTTB would respond also to changes in profitability, the data series for FTTB showed little variation throughout the period of analysis. The only change in FTTB appears as a one-time shift in reported FTTB in the early 1970s. This most likely reflects a change in data collection procedures.

The profitability of tonging effort is established by the difference between prices received for oysters and the non-labor costs of harvest. In turn, costs of harvest depend upon the cost of inputs and their productivity. [In Virginia, labor productivity (catch per license) did not change over the period of analysis, so ex-vessel price relative to an interest rate variable accurately measured profitability.] In Maryland, state repletion programs rapidly increased labor productivity (see Table 4.7) and, in turn, served to reduce harvest cost over time. Therefore profitability of hand tonging was hypothesized to be related to ex-vessel prices and labor productivity. The following equations were used to model tong labor in Maryland.

$$\mathrm{FTTV} = m(\mathrm{OYEXVP}_{t-1}, \mathrm{QMDPUBT/TLM}_{t-1}, \mathrm{FTTV}_{t-1}) \tag{14a}$$

$$\mathrm{PTTB} = p(\mathrm{OYEXVP}_{t-1}, \mathrm{QMDPUBT/TLM}_{t-1}, \mathrm{DS}) \tag{14b}$$

where

FTTV = full-time tong labor on vessels

PTTB = part-time tong labor on boats

OYEXVP_{t-1} = lagged ex-vessel price of oysters (dollars per pound)

$\mathrm{QMDPUBT/TLM}_{t-1}$ = lagged average harvest per tong laborer

DS = dummy variable shift equal to 1 for 1966, 1967, 1968 and 0 otherwise

t = year.

Equation (14a) suggests that FTTV will respond positively to both OYEXVP_{t-1} and $\mathrm{QMDPUBT/TLM}_{t-1}$ as measures of profitability of hand tonging. The lagged dependent variable suggests that FTTV adjusts only partially in the short run to changes in profitability.

Equation (14b) argues that PTTB responds positively to changes in profitability in the preceding period (OYEXVP_{t-1} and $\mathrm{QMDPUBT/TLM}_{t-1}$). A lagged dependent variable is not included because entry and exit of part-time fishermen would be expected to occur rapidly. The dummy variable DS is included to reflect an unusually high level of reported PTTB for 1966, 1967 and 1968. There was no obvious explanation for these high values.

Tong harvest for Maryland is shown in Equation (15) as the product of the number of tong laborers in the fishery and the catch per tonger. (It should be noted that in recent years oyster divers have also entered the fishery. These divers have been licensed as if they were tongers and each diver is treated in these data as equivalent to one tonger). Harvest per tonger is treated as exogenous to the model since it is primarily determined by environmental conditions and oyster propagation programs. Thus, Equation (15) states:

$$\text{QMDPUBT} = \overline{\text{QMDPUBT/TLM}} * \text{TLM} \tag{15}$$

where

QMDPUBT = harvest by tong from Maryland public grounds

$\overline{\text{QMDPUBT/TLM}}$ = reported harvest per tong laborer from public grounds in Maryland (millions of pounds)

TLM = number of tong laborers in Maryland.

Of all the traditional symbols of the Chesapeake Bay watermen perhaps none is as well recognized as the skipjack. The skipjack is a sail-powered craft that has been used to take oysters by dredge in Maryland for nearly 100 years. Before the turn of the century, sail dredging was responsible for significant depletion of Maryland's oyster resources. As a result, dredging has been heavily regulated. Today there is a maximum daily harvest limit on skipjack harvest. Furthermore, no motorized power may be used except if the skipjack is pushed (on certain days) by another motorized craft. The result of these regulations has been to make investments in new skipjack construction unprofitable. In addition, limitations on income from oystering have resulted in many skipjacks being poorly maintained and therefore withdrawn from use over time. Table 4.8 illustrates how the number of skipjacks harvesting oysters has declined since 1950. These trends are treated as being exogenous to both the economic and biological factors that influence the industry. Thus, for Equation (16),

$$\text{QMDPUBT} = \overline{\text{QMDPUBT/TLM}} * \text{TLM} \tag{16}$$

where

QMDPUBD = dredge harvest from Maryland public grounds (millions of pounds)

TABLE 4.8. Sail Powered Dredge Craft in Maryland, 1950-1982

Year	Sail Dredge
1950	113
1955	85
1960	61
1965	46
1970	39
1975	29
1980	32

Source: U.S. Department of Commerce, National Marine Fishery Service, Fishery Statistics of the United States; and Michael Burch, Tidewater Administration, personal communication, January 11, 1983.

$\overline{QMDPUBD/DC}$ = reported harvest on Maryland public grounds by skipjacks, per skipjack

$\overline{DC}$ = reported skipjack dredge craft in each year.

In Equation (16) harvest by skipjack dredge craft is the product of catch per skipjack and skipjack numbers. Catch per skipjack is established exogenously as a function of environmental conditions affecting oyster populations and regulations on skipjack harvest.

4.3 ESTIMATION RESULTS

Results of the model estimation are presented in this section. The supply models are discussed separately, first Virginia and then Maryland. Presentation of the estimated demand equations concludes this section.

4.3.1 Supply Models

The Virginia and Maryland supply models were estimated with annual data taken from the post-MSX period, generally 1960 to 1981. Collinearity problems were present in the FTTV equation (14a) for Maryland and ridge regression procedures were used. All other equations were estimated using ordinary least squares procedures. Data used in the estimation are listed in Appendix A-1.

Virginia Supply Models

Table 4.9 provides the results for the estimation of Equations (7), (9) and (10). The R^2, t and D-W statistics are all reported. All signs are as hypothesized and the statistical properties of each equation are satisfactory, with the possible exception of a serial correlation problem in Equation (7). As will be discussed later, the dynamic backcasts, which include this equation, were quite satisfactory. This lends support to use of Equation (7) without a serial correlation correction.

TABLE 4.9. Virginia Oyster Supply Model Estimation Results

$$\text{QSEED} = 1651.437^{*} + 40.605767^{*}\,[(\text{OYEXVP-PS})/(\text{I})] - 705.888^{*}\,\text{MSX} \tag{7}$$

$R^2 = 0.6123$
D-W = 1.143

(Estimated with annual data for 1960 to 1980)

$$\text{QVAPRV} = .128324 + .005380787^{*}\,\text{WQSEED} \tag{9}$$

$R^2 = 0.8586$
D-W = 2.198

(Estimated with annual data for 1960 to 1980)

$$\text{STL} = 396.518^{*} + 71.835663^{*}\,[(\text{OYEXVP/I})_t] + .4999959^{*}\,\text{STL}_{t-1} - 494.09^{*}\,\text{AGNES}_t \tag{10}$$

$R^2 = 0.8264$
D-W = 1.640

(Estimated with annual data for 1962 to 1980)

---

* Significant at 5 percent level.

Maryland Supply Models

Table 4.10 presents the results for the estimation of Equations (14a) and (14b). All signs are as hypothesized and the statistical properties of both equations are satisfactory.

4.3.2 Demand Model

The demand model was estimated using annual data for 1960 to 1980. Data used in the estimation are described in Appendix A-1. Based on order and rank conditions, equations in the model are overidentified. Attempts to estimate the simultaneous equation system using the traditional methods of two-stage and three-stage least squares were plagued by deleterious collinearity problems. The presence of collinearity in the first stage and the second stage regressions was confirmed by examination of the singular value decomposition of the data matrix, the variance-decomposition proportions, and the variance inflation factors (Belsley, Kuh, and Welsch, 1980). According to Belsley, Kuh, and Welsch, strong variable intercorrelations, which ultimately lead to degradation of structural parameter estimates, exist in the case of condition indices in

TABLE 4.10. Maryland Oyster Supply Model Estimation Results

$$\mathrm{FTTV} = -133.99062^{*} + 157.833756^{*}\ \mathrm{OYEXVP}_{t-1} + 75641.8199^{*}\ \mathrm{QMDPUBT/TLM}_{t-1} + .6994450534^{*}\ \mathrm{FTTV}_{t-1} \qquad (14a)$$

[Used ridge regression with K = 0.10]

R^2 = .97493
D-W = 2.004

(Estimated using 1962 to 1979 annual data)

$$\mathrm{PTTB} = 86.788606 + 385.556^{*}\ \mathrm{DS} + 631.530^{**}\ \mathrm{OYEXVP}_{t-1} + 201187^{*}\ \mathrm{QMDPUBT/TLM}_{t-1} \qquad (14b)$$

R^2 = .5048
D-W = 1.373

(Estimated using 1962 to 1979 annual data)

---

* Significant at 5 percent level.
** Significant at 10 percent level.

excess of 30, variance-decomposition proportions in excess of 0.5, and variance inflation factors in excess of 10 (see Appendix B.1). These various measures not only provide reference points to determine the seriousness of the collinearity problem but also pinpoint the variables that share in the collinearity. Also, these measures constitute generalizations of the traditional detection devices of collinearity, namely, the use of pairwise correlation coefficients of the data matrix and the use of eigenvalues and eigenvectors of the matrix of correlation coefficients. Not surprisingly, due to the nature of the data, almost all the variables in the simultaneous equation model participate in the collinearity.

To overcome the effects of collinearity in the simultaneous equation system, this study employs the adaptation of ridge regression with two-stage least squares (Capps, 1982; Vinod and Ullah, 1982; and Maasoumi, 1980). Although successfully used in economic research to reduce the effects of collinearity in single-equation applications (Brown, 1973; Brown and Beattie, 1975; Vinod, 1976; Watson and White, 1976; Moscardi and deJanvry, 1977; Belongia, 1979), the use of ridge regression in conjunction with simultaneous systems has rarely been previously attempted. However, the adaptation of ridge regression with two-stage least squares provides a reasonably straightforward method to potentially improve the structural estimation of simultaneous models.

In this application, the ridge regression modification occurs in the second-stage estimations, where the emphasis lies with structural estimation. The first-stage estimations are oriented towards obtaining predictions of right-hand side endogenous variables, wherein each endogenous variable is expressed as a function of all predetermined variables in the models. Consequently, given the emphasis on prediction rather than on structural estimation in the first-stage estimations, the ridge regression modification to circumvent the collinearity problem occurs only in the second-stage estimations.

In brief, the procedure entails the addition of small positive increments, k-values, to the correlation matrices of the second-stage equations. The selection of the k-values for the respective equations is based on the Ridge Trace (Hoerl and Kennard, 1970). The Ridge Trace is a plot of the structural coefficients versus various k-values. The choice of the k-values is indicated by the point at which the structural coefficients begin to stabilize. A drawback to this criterion rests on the fact that the k-value selection process is subjective.

The interaction of ridge regression with two-stage least squares reduces the effects of collinearity, thereby making it possible to partition the separate effects of the various factors influencing the nominal price at each level of the marketing chain. Structural parameter estimates of the equations are exhibited in Table 4.11. The standard errors of the coefficients of each equation are placed in parentheses below the coefficients. Although conventional

TABLE 4.11. Demand Estimation: Chesapeake Bay Oyster Industry

	Retail Price (RPOY)	Wholesale Price (WPOY)	Ex-Vessel Price (OYEXVP)
Intercept	-0.6186	0.3393	0.5927*
	(0.3584)	(0.2140)	(0.1415)
RPOY	--	0.1720*	0.1348*
		(0.1732E-01)	(0.2010E-01)
WPOY	0.6250*	--	0.3714*
	(0.5564E-01)		(0.4706E-01)
OYEXVP	--	0.5434*	--
		(0.8665E-01)	
QBAY	--	-0.5195E-02	-0.1332E-01*
		(0.4910E-02)	(0.5219E-02)
QSG	--	-0.8241E-02	--
		(0.4325E-02)	
IIGS	--	0.1605E-02*	--
		(0.3574E-03)	
TIME	0.1700E-01*	0.1290E-01*	-0.1870E-01*
	(0.2445E-02)	(0.2977E-02)	(0.4181E-02)
C	-0.7191E-03	--	--
	(0.3702E-02)		
Y	0.4650E-03*	--	--
	(0.3288E-04)		
CPIMPF	0.5237E-02*	--	--
	(0.7357E-03)		
POP	0.3971E-02*	--	--
	(0.1578E-02)		
R^2	0.9908	0.9881	0.9197
D-W	0.7703	1.2658	1.0085
U	0.6647	0.7621	1.1532
K^2	0.10	0.05	0.05

---

* Indicates significance.

tests of significance are not exactly applicable to parameters obtained from estimating simultaneous equation models, the estimated structural parameter is judged to be significantly different from zero when the ratio of the parameter estimate to the associated estimate of standard error is greater than two.

All estimated coefficients in the model have signs consistent with prior theoretical expectations. The model explains approximately 99 percent of the variation in the retail and wholesale prices of oysters and over 90 percent of the variation in ex-vessel price. The conventional goodness-of-fit statistic, R^2, for each of the three equations is the square of the Pearson product-moment coefficient of actual and predicted prices.

Durbin (1957) and Malinvaud (1970) have suggested that the conventional single-equation Durbin-Watson statistic be used to check for serial correlation of disturbances in the simultaneous equation setting. The appropriate number of degrees of freedom is (K,T) where K is the number of predetermined variables used in the first-stage estimations and T is the number of observations. For this application, $K = 8$, and $T = 21$. The Durbin-Watson statistics are 0.7703 for the retail price equation, 1.2658 for the wholesale price equation and 1.0085 for the ex-vessel price equation. The null hypothesis of no autocorrelation is not rejected for any of the equations.

Overall, the Theil U_2 statistics for the market price equations indicate that the model is unequivocally better than the naive, no extrapolation model. The U_2 statistic for the no extrapolation model is unity. While no rigorous test has been developed to judge whether the difference between two U_2 coefficients is statistically significant, all but one of the U_2 coefficients of the model are much lower than the U_2 coefficients of the naive no extrapolation model. The range of the U_2 coefficients for the retail, wholesale, and ex-vessel price equations range from 0.6647 to 1.1532.

Traditionally, the calculation of the Theil U_2 statistic rests on the difference between the predicted and actual changes. However, since the model predicts the levels of market prices for oysters, predicted changes are calculated using differences between the predicted values for a period and the actual values of the previous period. According to Stekler (1968, p. 439), this approach is often used in ex-post evaluations.

In summary, the retail price of oysters is responsive to the wholesale price; income; the general price level for meat, poultry, fish and shellfish; population; and the time trend. The key determinants of the wholesale price of oysters are the retail price, the ex-vessel price, the time trend, and marketing costs. The ex-vessel price of oysters in the Bay is responsive to Bay landings, the retail price, the wholesale price, and the time trend.

The impact of exogenous variables on prices at each market level are determined from the analytically derived, reduced form equations. These are reported in Table 4.12. In turn, impact multipliers in terms of percentage changes are reported in Table 4.13.

TABLE 4.12. Analytically Derived Reduced Form Equations for Chesapeake Bay Oysters

$$\begin{aligned}\text{RPOY} = {} & -0.124665 - 0.0120494\ \text{QBAY} - 0.00798671\ \text{QSG} + 0.00155547\ \text{IIGS} \\ & + 0.0236945\ \text{TIME} - 0.000890018\ \text{C} + 0.000575522\ \text{Y} \\ & + 0.00648174\ \text{CPIMPF} + 0.00491484\ \text{POP}\end{aligned}$$

$$\begin{aligned}\text{WPOY} = {} & 0.790295 - 0.0192791\ \text{QBAY} - 0.0127787\ \text{QSG} + 0.00248876\ \text{IIGS} \\ & + 0.0107112\ \text{TIME} - 0.000273468\ \text{C} + 0.000176836\ \text{Y} \\ & + 0.00199159\ \text{CPIMPF} + 0.00151014\ \text{POP}\end{aligned}$$

$$\begin{aligned}\text{OYEXVP} = {} & 0.869411 - 0.0221045\ \text{QBAY} - 0.00582263\ \text{QSG} + 0.001134\ \text{IIGS} \\ & - 0.0115278\ \text{TIME} - 0.00022154\ \text{C} + 0.000143257\ \text{Y} \\ & + 0.00161342\ \text{CPIMPF} + 0.00122339\ \text{POP}\end{aligned}$$

$$\begin{aligned}\text{QVA}_t = {} & 9.014354741 + \text{QPU BDV}_t - 3.798232974\ \text{MSX}_t \\ & + .054622746\ (\text{OYEXVP-PSEED/I})_{t-2} + .109245492\ (\text{OYEXVP-PSEED/I})_{t-3} \\ & + .054622746\ (\text{OYEXVP-PSEED/I})_{t-4} + 396.518\ (\text{QPUBTV/STL})_t \\ & + 71.835663\ (\text{QPUBTV/STL})_t(\text{OYEXVP/I})_{t-1} \\ & + .499959\ (\text{QPUBTV/STL})_t(\text{STL}_{t-1}) - 494.09\ (\text{QPUBTV/STL})_t(\text{AGNES}_t)\end{aligned}$$

$$\begin{aligned}\text{QMD}_t = {} & \text{QMDPRV}_t + \text{QMDPUBD}_t + (\text{QMDPUBT/TLM})_t\ [-47.202014 + 789.363756\ \text{OYEXVP}_{t-1} \\ & + \text{FTTB}_t + 276828.8199\ (\text{QMDPUBT/TLM})_{t-1} + 385.556\ \text{DS}_t + .694450534\ \text{FTTV}_{t-1}]\end{aligned}$$

TABLE 4.13. Impact Multipliers[a] for Estimated Oyster Model Variables

Variable	Retail Price (RPOY)	Wholesale Price (WPOY)	Ex-Vessel Price (OYEXVP)
QBAY	-0.1310	-0.3647	-0.6176
QSG	-0.0863	-0.2403	-0.1617
IIGS	0.1025	0.2853	0.1920
TIME	0.1251	0.0984	-0.1564
C	-0.0329	-0.0175	-0.0210
Y	0.2270	0.1213	0.1452
CPIMPF	0.3744	0.2000	0.2394
POP	0.4806	0.2568	0.3073

(a) Impact multipliers in terms of percentage changes (at the sample means).

4.4 MODEL VALIDATION

Validation of the models beyond the traditional statistical tests, includes: 1) development of static backcasts using only the demand model; 2) development of reduced form equations of the supply and demand models to conduct dynamic backcasts; and 3) "shocking" the demand system to evaluate forecast sensitivity to changes in key exogenous factors. On the basis of the static and dynamic backcast evaluations the econometric model is satisfactorily stable. (See Tables 4.14 to 4.17 for results and test statistics.)

The model validation process terminates with the examination of forecast sensitivity to changes in key exogenous factors. Initially, base case forecasts are obtained for the period 1980 to 1990 by fixing all exogenous variables at 1979 levels. Then the model is shocked by adjusting the 1979 levels of disposable income; the general price level of meat, poultry, and fish; population; and the index of intermediate goods and services. The model is relatively insensitive to changes in the respective exogenous variables (see Tables 4.18 to 4.22).

TABLE 4.14. Static Backcasts for the Oyster Model (1960 to 1980)

Year	RPOY	PRPOY	WPOY	PWPOY	OYEXVP	POYEXVP
1960	1.31	1.16375	0.80	0.74497	0.71	0.64644
1961	1.40	1.18535	0.87	0.72653	0.79	0.61862
1962	1.33	1.33233	0.87	0.88423	0.80	0.77902
1963	1.39	1.34239	0.90	0.86139	0.75	0.77537
1964	1.33	1.36053	0.82	0.82851	0.71	0.69597
1965	1.33	1.48706	0.85	0.90845	0.78	0.73613
1966	1.51	1.61092	0.94	0.97038	0.68	0.75654
1967	1.47	1.56004	0.86	0.86243	0.67	0.63007
1968	1.56	1.62978	0.91	0.90017	0.67	0.67633
1969	1.68	1.83185	0.96	1.05298	0.63	0.74858
1970	1.72	1.86904	0.95	1.07255	0.61	0.70871
1971	1.75	1.84055	0.96	1.03301	0.62	0.65965
1972	2.01	1.98613	1.09	1.12116	0.63	0.71317
1973	2.23	2.30343	1.30	1.28356	0.66	0.77979
1974	2.44	2.43894	1.26	1.38444	0.70	0.82187
1975	2.59	2.62116	1.37	1.45893	0.80	0.88712
1976	2.83	2.73638	1.54	1.52873	1.04	0.93221
1977	3.14	2.91491	1.84	1.69155	1.11	1.03847
1978	3.30	3.14957	1.90	1.72171	1.11	1.00214
1979	3.55	3.58543	1.98	2.03583	1.24	1.24144
1980	3.85	3.75841	2.17	2.05651	1.31	1.16894

RPOY, PRPOY: Actual and backcast values of retail price of oysters.
WPOY, PWPOY: Actual and backcast values of wholesale price of oysters.
OYEXVP, POYEXVP: Actual and backcast values of ex-vessel price of oysters.

TABLE 4.15. Static Backcast Evaluations of the Oyster Model (1960 to 1980)

Variable	Retail Price (RPOY)	Wholesale Price (WPOY)	Ex-Vessel Price (OYEXVP)
MSE	0.01311	0.00791	0.00828
RMSE	0.11451	0.0889	0.0910
U_1	0.3249	0.3793	0.5282
U_2	0.6647	0.7621	1.1532
U_m	0.0034	0.0005	0.0010
U_r	0.2485	0.2082	0.4298
U_d	0.7481	0.7911	0.5690

TABLE 4.16. Dynamic Backcasts for the Oyster Model

Year	OYEXVP	POYEXVP	QVA	PQVA	QMD	PQMD
1960	0.71	--	15.340	--	11.771	--
1961	0.79	--	17.163	--	10.337	--
1962	0.80	--	11.800	--	8.139	--
1963	0.75	--	10.518	--	7.756	--
1964	0.71	0.75353	14.147	11.6800	7.949	7.8398
1965	0.78	0.74816	12.568	12.4862	8.120	8.1631
1966	0.68	0.78200	9.443	7.7484	11.790	12.3431
1967	0.67	0.66461	9.068	7.3440	16.730	16.9073
1968	0.67	0.71709	7.805	6.4400	14.873	14.4135
1969	0.63	0.72872	7.436	7.8114	14.820	15.2353
1970	0.61	0.73480	8.043	6.4050	16.624	17.0947
1971	0.62	0.70313	8.391	6.0025	17.117	17.6069
1972	0.63	0.72413	4.996	5.1465	19.052	18.4286
1973	0.66	0.77197	4.978	4.7942	20.423	20.9561
1974	0.70	0.84216	6.737	5.3940	18.285	18.7182
1975	0.80	0.93613	6.237	4.6469	16.402	15.7976
1976	1.04	0.98988	6.085	5.0075	14.880	13.3723
1977	1.11	1.01685	4.985	6.2993	13.027	12.5973
1978	1.11	1.00822	8.087	7.8688	14.374	14.3266
1979	1.24	1.06844	8.197	7.9988	14.929	16.0177
1980	1.31	--	7.846	8.4060	14.788	--

Year	QBAY	PQBAY	ACTREV	PREREV	STL	PSTL
1960	--	--	--	--	4566	--
1961	--	--	--	--	3742	--
1962	--	--	--	--	2957	--
1963	18.274	--	13.7055	--	3915	--
1964	22.096	19.5198	15.6882	14.7087	3772	3700.69
1965	20.688	20.6493	16.1366	15.4490	3648	3675.16
1966	21.233	20.0915	14.4384	15.7117	3981	4232.18
1967	25.798	24.2513	17.2847	16.1175	4370	4436.13
1968	22.678	20.8535	15.1943	14.9538	4768	4582.92
1969	22.256	23.0467	14.0213	16.7945	4045	4187.65
1970	24.667	23.4998	15.0469	17.2675	4187	4328.16
1971	25.508	23.6094	15.8150	16.6005	4596	4776.43
1972	24.048	23.5752	15.1502	17.0715	3796	3645.16
1973	25.401	25.7503	16.7647	19.8785	4038	4160.24
1974	25.022	24.1121	17.5154	20.3064	4455	4575.39
1975	22.639	20.4445	18.1112	19.1388	4585	4393.04
1976	20.965	18.3798	21.8036	18.1938	5055	4471.31
1977	18.012	18.8967	19.9933	19.2150	4454	4287.34
1978	22.461	22.1954	24.9317	22.3779	4207	4190.98
1979	23.126	24.0165	28.6762	25.6602	3682	3984.85
1980	22.624	--	--	--	2533	--

TABLE 4.16. (contd)

Year	QMDPUBT	PQMDPUBT	RPOY	PRPOY	WPOY	PWPOY
1960	--	--	1.31	--	0.80	--
1961	--	--	1.40	--	0.87	--
1962	--	--	1.33	--	0.87	--
1963	4.779	--	1.39	--	0.90	--
1964	5.776	5.6668	1.33	1.39389	0.82	0.87892
1965	5.791	5.8341	1.33	1.49403	0.85	0.91898
1966	8.767	9.3201	1.51	1.62567	0.94	0.99268
1967	11.717	11.8943	1.47	1.58006	0.86	0.89267
1968	11.838	11.3785	1.56	1.65340	0.91	0.93586
1969	11.776	12.1913	1.68	1.82033	0.96	1.03558
1970	13.963	14.4337	1.72	1.88415	0.95	1.09539
1971	12.480	12.9699	1.75	1.86575	0.96	1.07109
1972	15.687	15.0636	2.01	1.99248	1.09	1.13076
1973	17.609	18.1421	2.23	2.29890	1.30	1.27671
1974	16.029	16.4622	2.44	2.45070	1.26	1.40221
1975	14.436	13.8316	2.59	2.64957	1.37	1.50186
1976	13.057	11.5493	2.83	2.76981	1.54	1.57923
1977	11.483	11.0533	3.14	2.90238	1.84	1.67261
1978	12.432	12.3846	3.30	3.15310	1.90	1.72704
1979	13.236	14.3247	3.55	3.48517	1.98	1.88433
1980	--	--	3.85	--	2.17	--

QVA, PQVA: Actual and backcast values of Virginia landings of oysters (millions of pounds).

QMD, PQMD: Actual and backcast values of Maryland landings of oysters (millions of pounds).

QBAY, PQBAY: Actual and backcast values of Chesapeake Bay landings of oysters (millions of pounds).

ACTREV, PREREV: Actual and backcast values of dockside value of Chesapeake Bay oysters (millions of dollars).

STL, PSTL: Actual and backcast values of tong licenses.

QMDPUBT, PQMDPUBT: Actual and backcast values of Maryland landings by tong (millions of pounds).

RPOY, PRPOY: Actual and backcast retail prices of oysters

WPOY, PWPOY: Actual and backcast wholesale prices of oysters

TABLE 4.17. Dynamic Backcast Evaluations of the Oyster Model (1960 to 1980)

Variable	Retail Price (RPOY)	Wholesale Price (WPOY)	Ex-Vessel Price (OYEXVP)
MSE	0.01456	0.01063	0.01052
RMSE	0.1206	0.1031	0.1025
U_1	0.3292	0.4032	0.5293
U_2	0.6918	0.8590	1.2331
U_m	0.0900	0.0797	0.1042
U_r	0.1469	0.1948	0.3769
U_d	0.7629	0.7253	0.5188

Variable	Virginia Landings (QVA)	Maryland Landings (QMD)	Chesapeake Bay Landings (QBAY)
MSE	1.9275	0.4044	2.1892
RMSE	1.3883	0.6359	1.4796
U_1	0.3556	0.1446	0.2906
U_2	0.7590	0.3119	0.6049
U_m	0.4045	0.0017	0.3351
U_r	0.0424	0.3812	0.0853
U_d	0.5529	0.6169	0.5794

Variable	Chesapeake Bay Revenue (TROY)	Total Tong Labor (TLM)	Maryland Public Grounds Tong Harvest (QMDPUBT)
MSE	4.6111	48658.5033	0.4044
RMSE	2.1473	220.5867	0.63597
U_1	0.4819	0.2460	0.1664
U_2	0.9497	0.5115	0.3580
U_m	0.0069	0.0000	0.0017
U_r	0.2131	0.1469	0.3220
U_d	0.7798	0.8530	0.6761

TABLE 4.18. Base Case Forecasts for the Oyster Model

Year	POYEXVP	PQVA	PQMD	PQBAY	PREREV	PSTL	PQMDPUBT	PRPOY	PWPOY
1980	1.05692	7.99879	16.0177	24.0165	25.3834	3984.85	14.3247	3.50887	1.89504
1981	1.04167	8.31606	15.8671	24.1831	25.1908	3942.95	14.1741	3.53041	1.90249
1982	1.03308	8.22753	15.8238	24.0513	24.8470	3930.91	14.1308	3.55581	1.91578
1983	1.02380	8.15131	15.7994	23.9507	24.5208	3924.14	14.1064	3.58080	1.92846
1984	1.01168	8.20426	15.7731	23.9773	24.2574	3916.81	14.0801	3.60415	1.93865
1985	1.00092	8.20426	15.7387	23.9430	23.9649	3907.24	14.0457	3.62829	1.95003
1986	0.99007	8.20426	15.7082	23.9124	23.6750	3898.75	14.0152	3.65238	1.96134
1987	0.97923	8.20426	15.6774	23.8816	23.3857	3890.19	13.9844	3.67647	1.97265
1988	0.96839	8.20426	15.6466	23.8509	23.0970	3881.63	13.9536	3.70057	1.98397
1989	0.95755	8.20426	15.6159	23.8201	22.8089	3873.07	13.9229	3.72466	1.99528
1990	0.94671	8.20426	15.5851	23.7894	22.5216	3864.51	13.8921	3.74875	2.00659

TABLE 4.19. Effects on Oyster Model Forecasts of IIGS Increasing by Ten Percent

Year	POYEXVP	PQVA	PQMD	PQBAY	PREREV	PSTL	PQMDPUBT	PRPOY	PWPOY
1980	1.08361	7.99879	16.0177	24.0165	26.0246	3984.85	14.3247	3.54549	1.95363
1981	1.06667	8.31606	15.9428	24.2589	25.8763	3964.02	14.2498	3.56605	1.95960
1982	1.05820	8.22753	15.8947	24.1223	25.5261	3950.65	14.2017	3.59151	1.97298
1983	1.04891	8.15131	15.8707	24.0220	25.1968	3943.96	14.1777	3.61650	1.98566
1984	1.03678	8.20426	15.8443	24.0486	24.9332	3936.63	14.1513	3.63985	1.99585
1985	1.02602	8.20426	15.8099	24.0142	24.6392	3927.06	14.1169	3.66399	2.00723
1986	1.01518	8.20426	15.7794	23.9837	24.3477	3918.57	14.0864	3.68808	2.01854
1987	1.00434	8.20426	15.7486	23.9529	24.0568	3910.00	14.0556	3.71217	2.02985
1988	0.99350	8.20426	15.7179	23.9221	23.7666	3901.45	14.0249	3.73626	2.04117
1989	0.98266	8.20426	15.6871	23.8914	23.4770	3892.89	13.9941	3.76036	2.05248
1990	0.97181	8.20426	15.6563	23.8606	23.1881	3884.33	13.9633	3.78445	2.06379

TABLE 4.20. Effects on Oyster Model Forecasts of Population Increasing by Five Percent

Year	POYEXVP	PQVA	PQMD	PQBAY	PREREV	PSTL	PQMDPUBT	PRPOY	PWPOY
1980	1.07040	7.99879	16.0177	24.0165	25.7072	3984.85	14.3247	3.56304	1.91168
1981	1.05430	8.31606	15.9053	24.2214	25.5366	3953.59	14.2123	3.58409	1.91839
1982	1.04577	8.22753	15.8596	24.0872	25.1896	3940.88	14.1666	3.60952	1.93173
1983	1.03648	8.15131	15.8354	23.9867	24.8618	3934.15	14.1424	3.63451	1.94440
1984	1.02436	8.20426	15.8091	24.0133	24.5983	3926.82	14.1161	3.65786	1.95459
1985	1.01360	8.20426	15.7747	23.9789	24.3050	3917.25	14.0817	3.68200	1.96597
1986	1.00275	8.20426	15.7441	23.9484	24.0143	3908.76	14.0511	3.70609	1.97728
1987	0.99191	8.20426	15.7134	23.9176	23.7242	3900.20	14.0204	3.73018	1.98860
1988	0.98107	8.20426	15.6826	23.8869	23.4347	3891.64	13.9896	3.75428	1.99991
1989	0.97023	8.20426	15.6518	23.8561	23.1459	3883.08	13.9588	3.77837	2.01122
1990	0.95939	8.20426	15.6211	23.8253	22.8578	3874.52	13.9281	3.80246	2.02253

TABLE 4.21. Effects on Oyster Model Forecasts of Income Increasing by Ten Percent

Year	POYEXVP	PQVA	PQMD	PQBAY	PREREV	PSTL	PQMDPUBT	PRPOY	PWPOY
1980	1.08018	7.99879	16.0177	24.0165	25.9420	3984.85	14.3247	3.60232	1.92375
1981	1.06345	8.31606	15.9331	24.2491	25.7878	3961.31	14.2401	3.62300	1.92991
1982	1.05496	8.22753	15.8856	24.1131	25.4385	3948.11	14.1926	3.64846	1.94328
1983	1.04567	8.15131	15.8615	24.0128	25.1096	3941.41	14.1685	3.67345	1.95596
1984	1.03355	8.20426	15.8352	24.0394	24.8460	3934.08	14.1422	3.69680	1.96615
1985	1.02279	8.20426	15.8008	24.0050	24.5522	3924.51	14.1078	3.72094	1.97753
1986	1.01195	8.20426	15.7702	23.9745	24.2609	3916.01	14.0772	3.74503	1.98884
1987	1.00111	8.20426	15.7395	23.9437	23.9702	3907.45	14.0465	3.76912	2.00015
1988	0.99027	8.20426	15.7087	23.9130	23.6802	3898.90	14.0157	3.79321	2.01147
1989	0.97942	8.20426	15.6779	23.8822	23.3908	3890.34	13.9849	3.81731	2.02278
1990	0.96858	8.20426	15.6472	23.8514	23.1021	3881.78	13.9542	3.84140	2.03409

TABLE 4.22. Effects on Oyster Model Forecasts of CPIMPF Increasing by Ten Percent

Year	POYEXVP	PQVA	PQMD	PQBAY	PREREV	PSTL	PQMDPUBT	PRPOY	PWPOY
1980	1.08821	7.99879	16.0177	24.0165	26.1351	3984.85	14.3247	3.63461	1.9336
1981	1.07098	8.31606	15.9559	24.2719	25.9948	3967.66	14.2629	3.65500	1.9393
1982	1.06252	8.22753	15.9070	24.1345	25.6435	3954.05	14.2140	3.68047	1.9527
1983	1.05323	8.15131	15.8830	24.0343	25.3137	3947.38	14.1900	3.70546	1.9654
1984	1.04111	8.20426	15.8566	24.0609	25.0501	3940.04	14.1636	3.72881	1.9756
1985	1.03035	8.20426	15.8222	24.0265	24.7557	3930.47	14.1292	3.75295	1.9870
1986	1.01951	8.20426	15.7917	23.9959	24.4640	3921.98	14.0987	3.77704	1.9983
1987	1.00867	8.20426	15.7609	23.9652	24.1728	3913.42	14.0679	3.80113	2.0096
1988	0.99782	8.20426	15.7301	23.9344	23.8823	3904.86	14.0371	3.82523	2.0209
1989	0.98698	8.20426	15.6994	23.9036	23.5925	3896.30	14.0064	3.84932	2.0322
1990	0.97614	8.20426	15.6686	23.8729	23.3033	3887.75	13.9756	3.87341	2.0435

5.0 ECONOMIC MODELS OF THE BLUE CRAB INDUSTRY

Development of economic models for the demand and supply of blue crabs from the Chesapeake Bay is discussed in this chapter. An overview of the industry structure and the blue crab life cycle is provided in the "Background" section. In the second section the demand and supply models developed for Virginia and Maryland are presented and explained. Model estimation results are presented in the third section, followed by a fourth section explaining techniques applied to validate the models.

5.1 BACKGROUND

Together, the Maryland and Virginia portions of the Chesapeake Bay account for a major portion of U.S. blue crab production. Within the Bay region, Virginia has consistently produced more of the total harvest than Maryland (see Table 5.1). Virginia's dominance can be attributed to a longer harvest season, arising from the migrating patterns of the blue crab, and to the different harvest gear used in the two states. The blue crab life cycle and harvesting methods are discussed below. Processing and consumption are described in the following section.

5.1.1 Overview of Blue Crab Production

Blue crabs (Callinectes sapidus) are harvested as both "hard" crabs and "soft" crabs. Hard crabs have a hardened exoskeleton and are steamed prior to having the meat picked out or to being marketed as whole steamed crabs. Those crabs with soft shells (i.e., harvested in the period just after molting) are marketed, after removal of gills and viscera, to be eaten whole. Figure 5.1 illustrates how blue crabs reach the consumer either as soft crabs--tracing the left side of the figure; or, as hard crabs--tracing the right side of the figure.

The annual harvest of crabs is dependent upon the population stock in any year and the harvest gear used. Population stocks of blue crabs are thought to be dependent upon a number of environmental variables including salinity, water temperature, and wind direction at particular seasons (affecting movement of larval crabs). However, at this time, understanding of the blue crab life cycle is incomplete, thus precluding a definitive assessment of the relative importance of different environmental variables upon crab populations. It does appear, though, that recruitment to the future population is independent of current population stock size. This stock-independent recruitment means that current harvest effort has virtually no effect on future population sizes and need not be considered in a bio-economic model of crab harvest (Martin-Marietta 1980a).

TABLE 5.1. Blue Crab Production Shares for Maryland and Virginia

	Maryland		Virginia		Bay
Year	Percent U.S.	Percent Bay	Percent U.S.	Percent Bay	Percent U.S.
1960	17.9646	26.2500	40.5354	59.2308	44.3182
1961	18.0406	29.7739	37.7422	62.2890	47.7996
1962	18.5198	35.9484	34.0098	66.0180	54.4541
1963	11.9294	32.5610	28.7892	73.1204	44.5307
1964	14.7846	33.8601	30.3873	69.5938	48.6540
1965	19.1575	30.2743	38.7324	61.2082	49.4611
1966	18.2092	38.1859	32.2774	67.6876	56.7586
1967	16.9579	37.8097	30.9685	69.0479	54.7586
1968	8.2254	39.4665	17.2399	82.7196	47.7113
1969	17.3953	25.4218	40.5891	59.3175	42.8571
1970	17.1492	29.1671	36.9955	62.9214	46.3549
1971	17.4883	32.0637	35.2842	64.6915	49.5641
1972	15.9200	32.9186	32.6139	67.4375	48.8136
1973	14.3143	26.8344	34.7052	65.0604	41.2454
1974	16.5288	27.3432	37.6504	62.2840	43.9008
1975	18.0134	25.8337	41.0558	58.8799	43.8753
1976	16.8371	22.3241	42.9867	56.9956	39.1681
1977	15.1916	28.0158	35.7434	65.9167	42.5019
1978	12.0044	26.0883	31.5401	68.5437	38.0808
1979	16.2429	28.0694	38.8592	62.0487	42.0157
1980	15.5028	23.0950	40.1597	59.8270	38.8829

Source: Fishery Statistics of the U.S., selected years.

However, the life cycle movement of crabs in the Bay does affect the opportunities for harvest in the two states. The highly saline waters of the lower Bay in Virginia provide a suitable habitat for egg extrusion and larval hatching that occurs in spring. After several molts, the larvae become bottom dwelling and begin to migrate up the Bay to less saline waters more conducive to the growth that occurs during the months of warmer weather. Growth involves a series of molts that provide opportunities for the harvest of "peeler" and

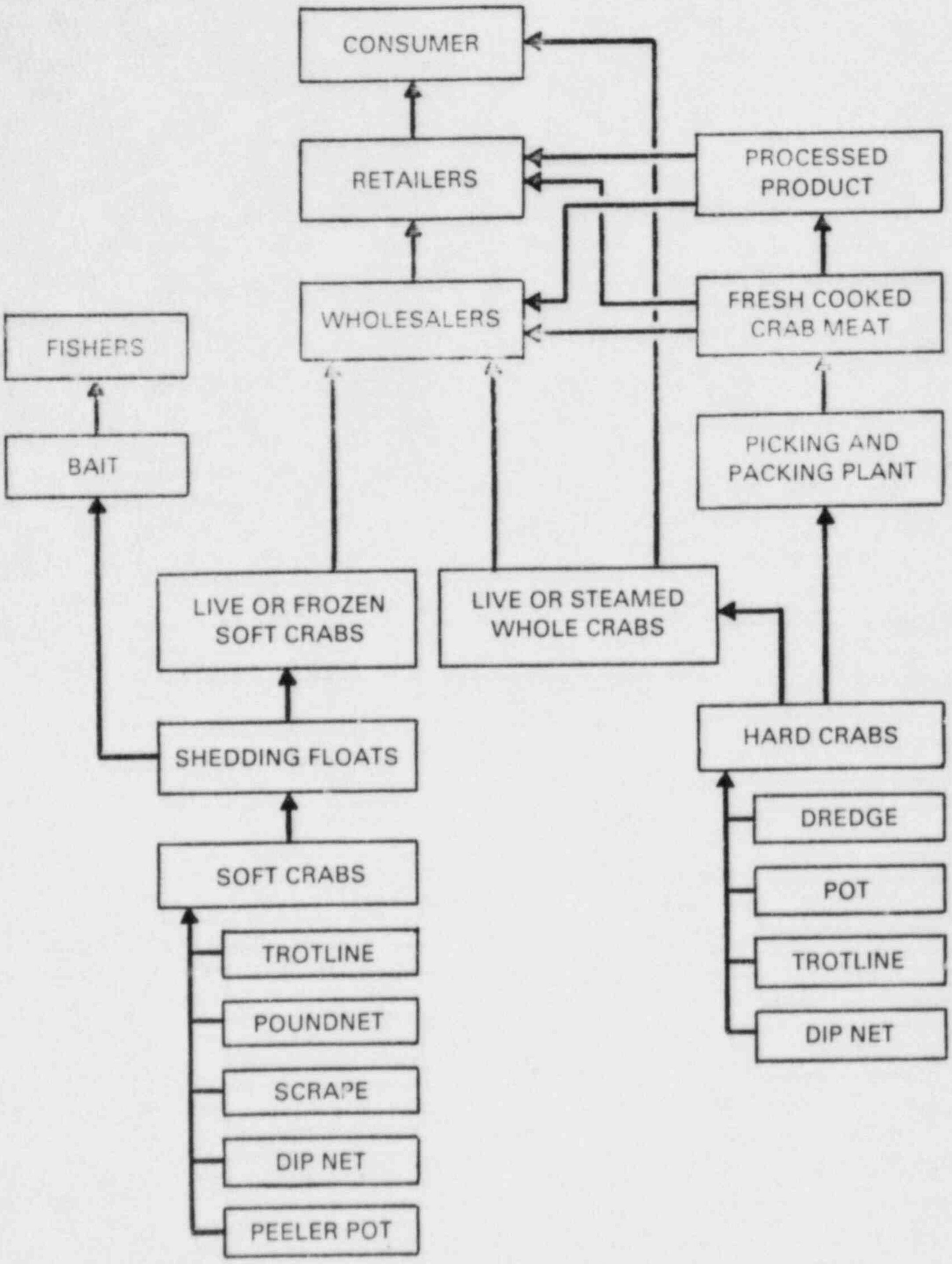


FIGURE 5.1. Product Flow from Chesapeake Bay Blue Crab Production (adapted from Van Engel et al. 1972)

soft crabs. In the fall, the female crabs migrate to the lower Bay and spend the winter buried in bottom sediments in a semi-dormant state. Male crabs remain in the upper Bay in the deeper channels. During the first year crabs are too small for harvest; they do not reach commercial size until the second year of life.

The seasonal behavior of the blue crab dictates the commercial harvest possibilities. First, soft crab harvest is confined to months when molting occurs. Second, the sensitivity to temperature and the migration patterns mean that Virginia's harvest season extends over a longer period than Maryland's. Third, the movement of male crabs into deeper waters in winter all but precludes their catch during winter months. However, a winter crab dredge fishery can exist in Virginia where the semi-dormant female crabs are harvested.

In recognition of the life cycle, and in response to different regulations, crab harvest gear differs between the two states. In general, five different gear types are used in the fishery: pots, trotlines, dredges, poundnets, and scrapes (illustrated in Figure 5.2). The crab pot is the predominant hard crab harvest gear and accounts for about two-thirds of total landing volume. Soft and peeler crabs are also caught in pots as an incidental catch. More recently some fishermen have developed a "peeler pot" designed exclusively for capture of soft crabs. In recent years pots have become the sole gear type used in Virginia for the summer hard crab harvest season, totally replacing trotlines. Trotline use continues in Maryland because Maryland state law prohibits use of crab pots in several areas of the Bay. In Virginia hard crabs are also harvested during the winter by dredge gear in limited areas of the lower Bay. Maryland does not permit use of crab dredges.

Poundnets and scrapes are specialized gear for soft crab harvest. Scrapes are dragged along the bottom in areas where soft crabs may be found after molting, usually in beds of submerged grass. Poundnets trap crabs in grassy areas where molting is likely to occur. The predominant soft crab gear in Virginia has been poundnets, while the predominant soft crab gear in Maryland has been scrapes. Despite rapidly rising retail prices in recent years, soft crab production has fallen in both states as a result of adverse environmental conditions that have caused a decline in aquatic vegetation. The decline in aquatic vegetation has reduced the productivity of some soft-crab harvest gear. Also, the declining total soft crab harvest is evident.

5.1.2 Overview of Processing and Consumption

Processing (or intermediate handling) of hard and soft crabs also differs a great deal. Hard crabs enter the marketing chain in several ways. A large, but undetermined, portion of the catch enters the "basket trade" where trucker/retailers buy crabs from the dockside to sell directly to the public and restaurants. In addition, wholesalers purchase crabs to sell as live crabs or to steam prior to sale.

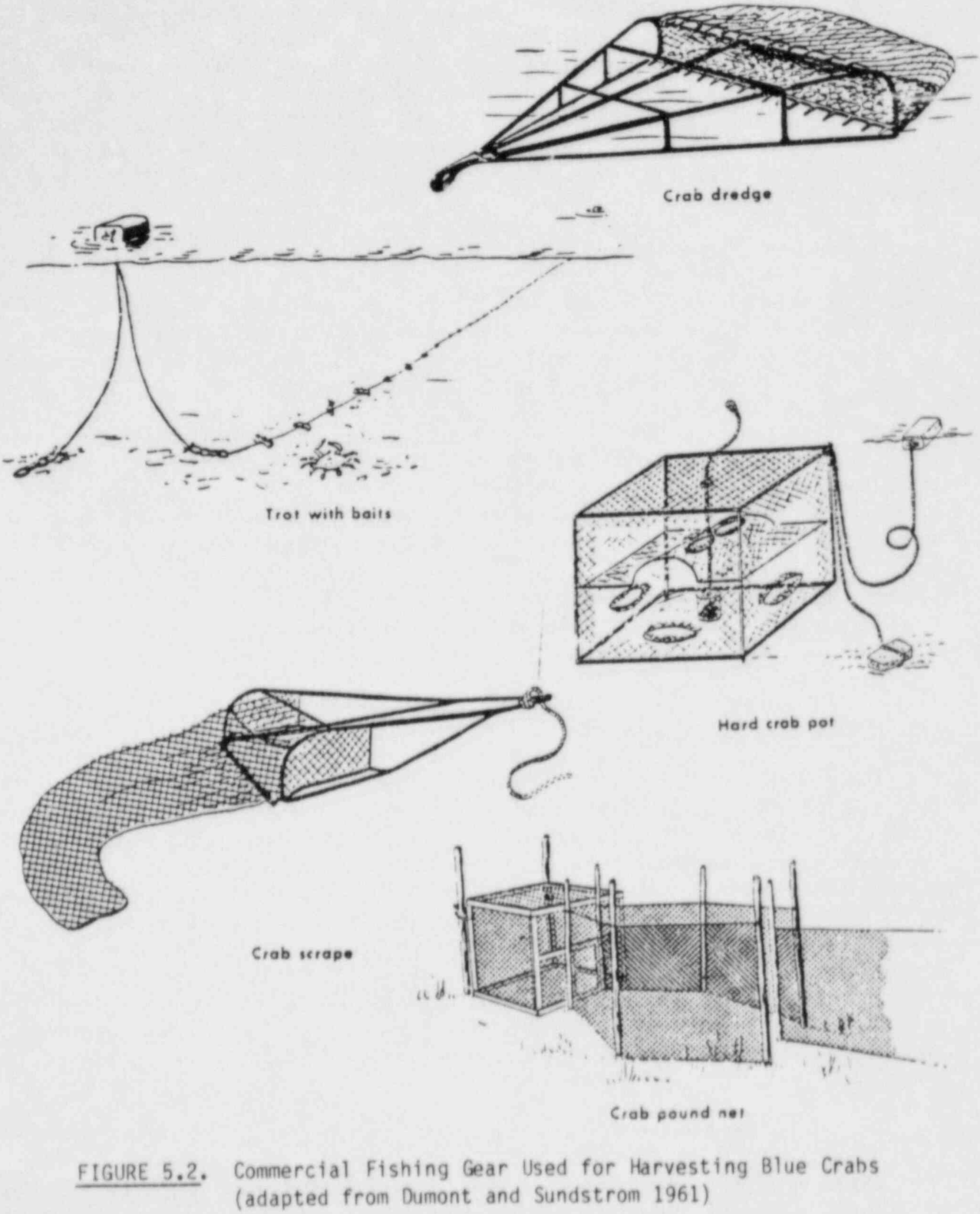


FIGURE 5.2. Commercial Fishing Gear Used for Harvesting Blue Crabs (adapted from Dumont and Sundstrom 1961)

The foundation of the "intermediate handling" sector is the picking process. In this process, cooked crab meat is removed from the shell either by hand or machine and then canned, pasteurized, frozen, left as fresh meat or processed further into specialty products. Picked meat comes in grades, with the highest quality being "backfin" followed by "flake" and "claw." In the intermediate handling sector the primary costs are for the crabs themselves. This is true even for the processing operations where raw materials are about 40 percent of costs.

Soft crabs are usually harvested as "peelers," i.e., as crabs beginning the molting process. Peeler crabs are then retained in specially designed shedding tanks or shedding floats until they have completed their molt. The whole live crab is then packed and sold to wholesalers and at retail. More recently soft crabs have been frozen before distribution. Soft crab handling requires careful management and some capital investment.

Although the two states share a common body of water, the blue crab fisheries are less economically interdependent than the oyster fisheries. Each state has adequate processing capacity to handle its own landings, and market channels for Virginia and Maryland blue crabs are best described as similar rather than interrelated. Ex-vessel prices for hard blue crabs and soft crabs in the two states illustrate this separation since prices generally move together but are by no means identical for the two states (see Table 5.2). Therefore, separate economic models of blue crab fisheries in Maryland and Virginia are estimated to model the Bay-wide fishery.

5.2 DEMAND AND SUPPLY SYSTEMS

It was suggested in the background discussion that Maryland and Virginia blue crab harvests follow similar but not identical marketing channels. Because Maryland and Virginia demands are expected to differ (see ex-vessel price differences in Table 5.2), separate demand models for each state were developed. However, a comparison of the models indicates that a common structure exists between the hard crab models in that prices at three separate levels of the industry are explained: consumer/retailer, intermediate or wholesaler/processor level, and ex-vessel level. In both Maryland and Virginia soft crab price data exist only at the ex-vessel level. Therefore, a single price-dependent, ex-vessel demand equation for soft crabs was formulated for each state. In this section, the Virginia blue crab industry models are presented first, followed by the comparable models for Maryland.

5.2.1 Virginia Blue Crab Demand and Supply

Figure 5.3 shows the demand and supply models to be estimated for Virginia's blue crab fishery. In Figure 5.3 the demand equations (1) to (3) show that ex-vessel, wholesale and retail prices for hard crabs and crab meat

TABLE 5.2. Average Crab Prices (Cents per Pound) Received in Virginia and Maryland

	Hard Crabs		Soft Crabs	
Year	Virginia	Maryland	Virginia	Maryland
1960	4.8	5.7	26.6	22.0
1961	4.4	5.5	26.1	22.8
1962	4.7	6.4	32.0	20.0
1963	5.6	6.8	30.2	35.7
1964	6.8	7.5	44.8	36.1
1965	7.4	7.1	42.2	34.1
1966	6.0	7.3	36.3	38.5
1967	5.0	7.0	38.7	38.0
1968	11.2	11.9	38.0	47.3
1969	9.4	8.3	33.7	41.2
1970	5.6	7.5	37.1	42.2
1971	7.7	8.6	45.9	47.9
1972	7.7	8.5	47.7	48.0
1973	10.1	14.4	47.9	50.6
1974	10.1	17.1	48.0	56.5
1975	14.1	18.1	49.0	53.0
1976	19.5	23.8	69.0	72.0
1977	18.0	24.3	81.4	120.1
1978	19.0	24.3	113.7	137.4
1979	17.0	23.0	94.0	113.2
1980	18.0	23.8	105.4	118.1

Source: National Marine Fisheries Service, Fishery Statistics of the U.S., 1960-1976; Annual Landings Bulletins, 1977-1980.

are simultaneously determined and depend upon a number of exogenous variables, including Virginia harvest. Equation (4) is an ex-vessel price equation for soft crabs. Equations (5) and (6) are auxiliary price equations showing that annual ex-vessel prices are related to the summer, or pot, price and the

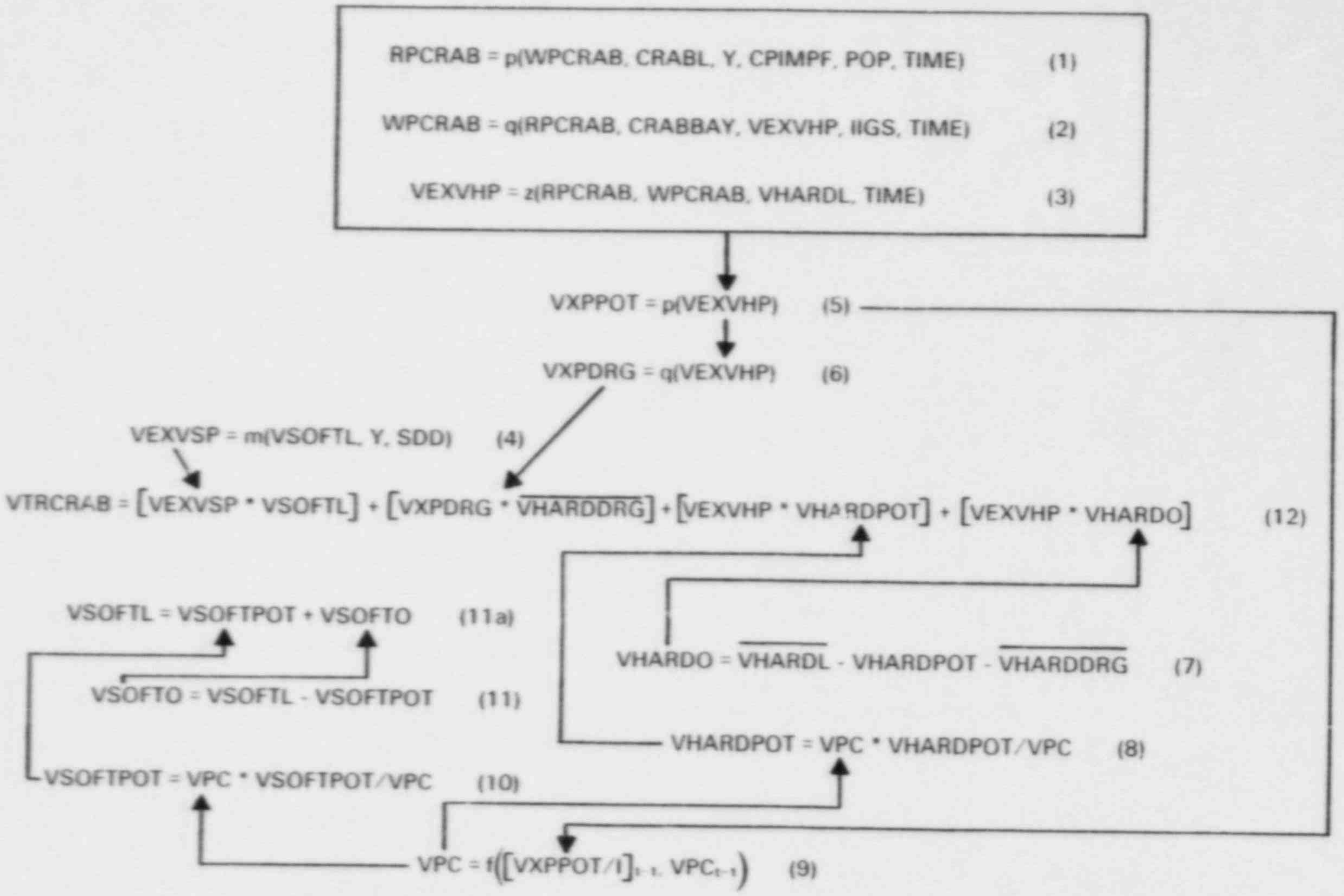


FIGURE 5.3. Demand and Supply System for Virginia Blue Crabs

winter, or dredge, price. Landings are treated as exogenous to the demand equations because landings either do not respond in a significant way to price [Equations (7) and (11a)] or because they respond with a one-period lag [Equations (8) and (10)]. Total harvest revenue [Equation (12)] is the product of Virginia harvest of hard and soft crab landings and the appropriate ex-vessel price at each time period.

Equations (7) to (11) in Figure 5.3 represent the Virginia harvest supply model. Separate supply models are considered for the different harvest gear types. Virginia crab harvest revenue is modeled in Equation 12.

Hard Crab Demand

The relationship among ex-vessel, wholesale, and retail prices depends upon consumer demand, product supply, and costs of marketing. Specifically, retail price influences wholesale and ex-vessel price, wholesale price influences retail and ex-vessel price, and ex-vessel price influences wholesale price. The interdependent nature of crab price determination constitutes a simultaneous system in which the endogenous variables are the respective market prices at various levels of the marketing chain.

Implicit in this structure is a price dependent demand system for blue crabs. National, Bay and individual state landings in any period are not modeled as responsive to current ex-vessel crab price because harvest effort responds to price with a time lag. Therefore, landings in any year are treated as exogenous when estimating parameters in the models.

The equations in the demand model are specified as follows:

$$\text{RPCRAB} = p\ (\text{WPCRAB, CRABL, Y, CPIMPF, POP, TIME}) \tag{1}$$

$$\text{WPCRAB} = q\ (\text{RPCRAB, VEXVHP, CRABBAY, IIGS, TIME}) \tag{2}$$

$$\text{VEXVHP} = z\ (\text{RPCRAB, WPCRAB, VHARDL, TIME}) \tag{3}$$

where

RPCRAB = retail price of blue crab meat at Baltimore (dollars per pound)

WPCRAB = wholesale price of blue crab meat at New York (dollars per pound)

CRABL = landings of hard blue crabs in U.S. (thousands of pounds)

Y = disposable income in U.S. (billions of dollars)

CPIMPF = consumer price index for meat, poultry and fish (1967 = 100)

POP = civilian population in the United States

TIME = time trend

VEXVHP = ex-vessel price in Virginia (dollars per pound)

CRABBAY = landings of blue crabs in Chesapeake Bay (thousands of pounds)

IIGS = index of intermediate goods and services (wholesale and processing cost index)

VHARDL = reported landings of hard blue crabs in Virginia.

It is hypothesized that in the retail price equation the coefficients on WPCRAB, Y, CPIMPF, POP and TIME are positive. The coefficient on CRABL is expected to be negative. At the wholesale level, positive coefficients are hypothesized for RPCRAB, VEXVHP, IIGS and TIME. A negative coefficient is expected on CRABBAY. In the ex-vessel price equation it is expected that Virginia landings will be inversely related to price. Coefficients on wholesale price, retail price and time are expected to be positive.

Soft Crab Demand

In the soft crab demand equation [Equation (4) in Figure 5.3] disposable income in the United States is incorporated as a demand shifter. Also, a dummy variable is included to represent a substantial change in reported price levels that occurred in 1975. Landings within the state are the other argument in the equation. Thus:

$$\text{VEXVSP} = m\ (\text{Y, VSOFTL, SDD}) \qquad (4)$$

where

VEXVSP = Virginia ex-vessel price of soft crabs (dollars per pound)

Y = U.S. disposable income (billions of dollars)

VSOFTL = Virginia soft crab landings (thousands of pounds)

SDD = dummy variable for price levels (1960 to 1975 = 0; 1976 to 1980 = 1).

Virginia Hard Crab Harvest Supply

From the period 1960 to 1980, hard crabs were harvested by three gear types in Virginia. Trotlines (and other miscellaneous gear) ceased to be significant contributors to the harvest by the 1970s and are represented as exogenous contributors to supply in Equation (9):

$$\text{VHARDO} = \overline{\text{VHARDL}} - \text{VHARDPOT} - \overline{\text{VHARDDRG}} \tag{7}$$

where

VHARDO = harvest of hard crab by gear other than pots and dredges in Virginia

$\overline{\text{VHARDL}}$ = reported harvest of hard crabs by all gear in Virginia

VHARDPOT = harvest of hard crabs by crab pots in Virginia

$\overline{\text{VHARDDRG}}$ = reported harvest of hard crabs by dredges in Virginia.

Dredge harvest will depend upon the available crab population stocks and the level of effort, as represented by dredge fishing craft operating during a given season. Table 5.3 shows annual numbers of dredge fishing craft in Virginia. The dredge season extends over December to February, however, seasonal effort data are not reported. To test the hypothesis that there has been a decline in dredge crab harvest from 1960 to 1980, a model was estimated to include the following arguments:

$$\overline{\text{VHARDDRG}} = f(\text{VHARDSUM}, \text{YR})$$

where

$\overline{\text{VHARDDRG}}$ = reported dredge harvest in Virginia

VHARDSUM = summer harvest of hard crabs in a year to represent size of crab population available for winter harvest YR = year.

TABLE 5.3. Number of Fishing Crafts Using Various Gear Types by State

Year	MPC(a)	MTC(b)	MPNSC(c)	VPC(d)	VDC(e)	VPNSC(f)
1960	502	1,926	231	1,295	184	438
1961	558	2,201	240	1,037	246	479
1962	718	2,153	240	1,004	214	451
1963	589	2,040	232	1,145	224	524
1964	616	2,091	230	1,309	201	507
1965	748	2,500	211	1,292	178	414
1966	805	2,643	192	1,231	156	425
1967	843	2,640	130	1,097	154	517
1968	779	2,772	121	1,179	201	349
1969	843	2,918	206	1,207	175	419
1970	1,013	4,941	104	1,328	191	337
1971	1,102	6,326	331	1,066	179	275
1972	1,002	6,300	330	1,110	169	273
1973	913	5,775	327	1,083	215	228
1974	1,278	7,626	288	1,599	154	380
1975	1,223	8,082	285	1,544	163	351
1976	1,326	8,676	285	1,581	119	382
1977	1,512	11,679	277	1,617	154	485
1978	1,714	9,623	181	1,860	166	551
1979	1,766	13,517	188	2,075	165	551
1980	1,762	8,574	169	--	--	--

(a) Maryland crafts using pots.
(b) Maryland crafts using trotlines.
(c) Maryland crafts using poundnets and scrapes.
(d) Virginia crafts using pots.
(e) Virginia crafts using dredges.
(f) Virginia crafts using poundnets and scrapes.

Source: Fishery Statistics of the U.S., selected years.

The results of the model were as follows:

$$\overline{\text{VHARDDRG}} = \underset{(8581.940)}{20417.416^{*}} + \underset{(0.09365)}{.20045}\ \text{VHARDSUM}^{*} - \underset{(95.574985)}{244.087}\ \text{YR}^{*}$$

$R^2 = 0.5287$

D-W = 1.816

Despite rising prices for crabs, dredge effort is declining. This is probably due to increasing costs, unsatisfactory working conditions in winter weather, and the regulatory environment. The strong downward trend in dredge harvest over the period 1960-1980 suggested that dredge harvest be treated as exogenous in the model.

Harvest of hard crabs by pots is represented by Equations (8) and (9). Equation (9) suggests that Virginia crab pot effort, as measured by the number of fishing crafts using pots, varies with the previous year's price received for crabs caught from pots (which includes both hard and soft crabs) and with the cost of harvest, which is represented by an interest rate variable. Slowness in adjusting to changing prices is represented by the lagged dependent variable. Such slow adjustment occurs because of the traditional commitment to fishing of the Chesapeake Bay watermen and because annual fluctuations in natural crab populations (and in harvest) are expected, so that watermen remain in the fishery during years of bad harvest as well as good. Effort is measured as the number of craft using pots, since this is considered to be a better measure of effort than labor. Thus Equation (9) states:

$$\text{VPC} = f([\text{VXPPOT}/I]_{t-1}, \text{VPC}_{t-1}) \qquad (9)$$

where

VPC = Virginia pot craft (sum of vessels and boats)

VXPPOT = ex-vessel price for crabs caught in pots

I = interest rate on lowest denomination long-term commercial loans

t = year.

Hard crab harvest by pots is the product of the number of craft using pots and the catch per pot craft, which depends primarily upon population stock levels. Catch per pot craft, which fluctuates substantially over the period 1960 to 1980, is exogenous. Equation (8) is the hard crab pot harvest equation.

$$VHARDPOT = VPC * VHARDPOT/VPC \tag{8}$$

where

VHARDPOT = total harvest of hard crabs by pots in Virginia

VPC = number of pot craft in Virginia

VHARDPOT/VPC = Virginia hard crab catch per pot craft as computed from reported data.

Virginia Soft Crab Harvest Supply

Soft crab harvest occurs 1) from use of poundnet and scrape gear directed solely to the harvest of peeler and soft crabs, 2) as an incidental catch from baited crab pots, and 3) as harvest from "peeler" pots. Equation (10) shows soft crab harvest as a product of soft crab catch per pot craft and number of pot crafts. Number of pot crafts is from Equation (9), explained above. Soft crab harvest per pot craft depends upon the population of crabs in any year, the willingness of crabbers to segregate their catch between peeler and hard crabs, and the use of peeler pots. Catch of soft crabs per pot craft is therefore considered to be an exogenous variable. Thus:

$$VSOFTPOT = VPC * VSOFTPOT/VPC \tag{10}$$

where

VSOFTPOT = harvest of soft crabs by pots in Virginia

VPC = number of crafts using crab pots in Virginia

VSOFTPOT/VPC = harvest of soft crabs per pot craft in Virginia as computed from reported data.

Equation (10) shows harvest of soft crabs by gear other than pots--primarily poundnets and scrapes.

$$\text{VSOFTO} = \text{VSOFTL} - \text{VSOFTPOT} \tag{11}$$

where

VSOFTO = harvest of soft crabs by poundnets and scrapes in Virginia
VSOFTL = harvest of soft crabs in Virginia by all gear
VSOFTPOT = harvest of soft crabs by pots in Virginia.

In fact, soft crab harvest will depend upon the available population stocks and the amount of effort, as represented by poundnet and scrape fishing craft operating during a given season. Table 5.4 shows annual numbers of poundnet and scrape craft since 1960. Despite rapidly escalating soft crab prices, the amount of soft crab effort depicted by Table 5.4 appears to represent a downward trend. To test the hypothesis that soft crab landings from poundnets and scrapes have been in decline, soft crab harvest for years since 1960 was estimated as a function of time.

$$\text{VSOFTO} = h\ (\text{YR})$$

where

VSOFTO = Virginia soft crab harvest from gear other than pots
YR = year.

The results of the estimation were as follows:

$$\text{VSOFTO} = 3272.485^{*} - 38.497403^{*}\ \text{YR}$$

$$(419.055) \quad (5.964226)$$

$$R^2 = 0.6868$$

$$\text{D-W} = 1.750$$

The apparent absence of a positive relationship between poundnet and scrape effort and soft crab price and between the downward trend in soft crab harvest

TABLE 5.4. Virginia Landings by Gear Type (thousands of lb)

Year	VHARDL(a)	VHARDPOT(b)	VSOFTTRT(c)	VHARDDRG(d)	VSOFTL(e)	VSOFTPN(f)	VSOFTPOT(g)	VSOFTSCR(h)
1960	39,270	26,949	1,650	10,545	1,553	789	494	200
1961	43,976	31,605	3,065	9,083	1,535	878	361	178
1962	53,671	36,855	3,564	13,033	1,319	777	272	204
1963	46,139	27,471	1,959	16,525	928	500	239	107
1964	51,569	35,580	2,588	13,135	978	375	369	140
1965	50,558	38,864	1,894	9,434	1,078	561	420	39
1966	63,694	41,063	5,387	15,244	1,028	419	365	156
1967	54,824	36,079	1,840	14,978	1,201	661	288	211
1968	44,834	30,976	2,569	9,873	793	274	319	151
1969	33,633	22,929	2,014	7,695	1,950	267	1,074	500
1970	42,409	28,120	2,536	10,559	900	132	394	316
1971	47,807	35,250	1,124	10,962	691	222	369	100
1972	48,555	36,012	155	12,349	852	214	391	247
1973	36,629	27,718	18	8,881	978	167	615	196
1974	40,796	32,713	0	8,083	806	173	553	80
1975	34,798	30,226	53	4,462	754	249	405	100
1976	25,762	19,670	0	6,091	761	361	345	55
1977	37,177	31,004	--	6,124	695	--	476	--
1978	36,054	29,448	--	6,606	605	--	331	--
1979	39,834	32,681	--	7,106	1,052	--	552	--
1980	37,691	28,265	--	9,406	633	--	327	--

(a) Total Virginia landings of hard blue crabs.
(b) Virginia landings of hard blue crabs by pots.
(c) Virginia landings of hard blue crabs by trotlines.
(d) Virginia landings of hard blue crabs by dredges.
(e) Total Virginia landings of soft crabs.
(f) Virginia landings of soft crabs by poundnets.
(g) Virginia landings of soft crabs by pots.
(h) Virginia landings of soft crabs by scrapes.

Source: Fishery Statistics of the U.S., selected years.

from poundnets and scrapes suggested that soft crab harvest be treated as exogenous in the model.

5.2.2 Maryland Blue Crab Demand and Supply

The demand and supply equations for Maryland's blue crab industry are shown in Figure 5.4. Because of similarities in production, marketing, and consumption between Virginia and Maryland, the Maryland model is similar in structure to that for Virginia described above. Indeed, Equations 13 through 18 are virtually equivalent in structure.

The demand Equations (13) to (15) show that ex-vessel, wholesale, and retail prices for hard crabs and crab meat are simultaneously determined and depend upon a number of exogenous variables, including Maryland harvest. Equation (16) is an ex-vessel price equation for soft crabs. Equations (17) and (18) are auxiliary price equations showing that ex-vessel hard crab prices differ by gear type. Landings are treated as exogenous to the demand equations because landings either do not respond in a significant way to price [Equations (19) and (26a)] or because they respond with a one-period lag [Equations (20), (21), (24), and (25)]. Total harvest revenue [Equation (27)] is the product of Maryland hard and soft crab landings and their respective prices in each time period.

Maryland Harvest Supply

Equations (19) to (26a) represent Maryland harvest supply for blue crabs. As for Virginia, separate consideration is given to hard and soft crabs. In contrast with Virginia, Maryland gear types consist of pots and trotlines rather than pots and dredges.

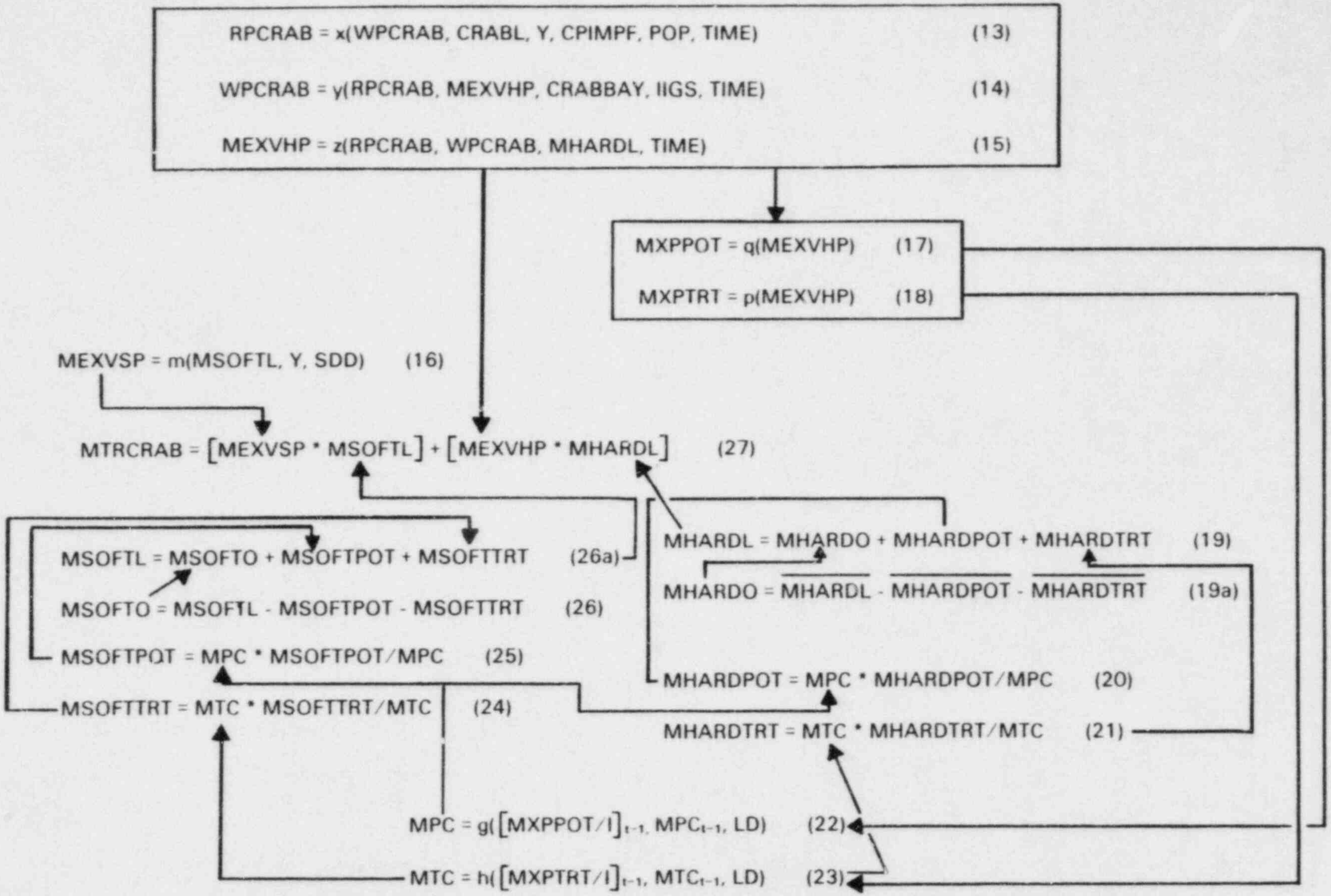
Maryland Hard Crab Harvest Supply

Hard crabs were primarily harvested in Maryland by pots and trotlines during the period of 1960 to 1980. In addition, other gear provided some residual level of hard crab harvest. Landings by gear type are shown in Table 5.5. Equation (19a) in Figure 5.4 depicts the residual catch from other gear, which is represented as an exogenous contributor to supply.

$$\text{MHARDO} = \overline{\text{MHARDL}} - \overline{\text{MHARDPOT}} - \overline{\text{MHARDTRT}} \tag{19a}$$

where

MHARDO = harvest of hard crabs by gear other than pots and trotlines in Maryland



$\text{RPCRAB} = x(\text{WPCRAB, CRABL, Y, CPIMPF, POP, TIME})$ (13)

$\text{WPCRAB} = y(\text{RPCRAB, MEXVHP, CRABBAY, IIGS, TIME})$ (14)

$\text{MEXVHP} = z(\text{RPCRAB, WPCRAB, MHARDL, TIME})$ (15)

$\text{MXPPOT} = q(\text{MEXVHP})$ (17)

$\text{MXPTRT} = p(\text{MEXVHP})$ (18)

$\text{MEXVSP} = m(\text{MSOFTL, Y, SDD})$ (16)

$\text{MTRCRAB} = [\text{MEXVSP} * \text{MSOFTL}] + [\text{MEXVHP} * \text{MHARDL}]$ (27)

$\text{MSOFTL} = \text{MSOFTO} + \text{MSOFTPOT} + \text{MSOFTTRT}$ (26a)

$\text{MSOFTO} = \text{MSOFTL} - \text{MSOFTPOT} - \text{MSOFTTRT}$ (26)

$\text{MSOFTPOT} = \text{MPC} * \text{MSOFTPOT}/\text{MPC}$ (25)

$\text{MSOFTTRT} = \text{MTC} * \text{MSOFTTRT}/\text{MTC}$ (24)

$\text{MHARDL} = \text{MHARDO} + \text{MHARDPOT} + \text{MHARDTRT}$ (19)

$\text{MHARDO} = \overline{\text{MHARDL}} - \overline{\text{MHARDPOT}} - \overline{\text{MHARDTRT}}$ (19a)

$\text{MHARDPOT} = \text{MPC} * \text{MHARDPOT}/\text{MPC}$ (20)

$\text{MHARDTRT} = \text{MTC} * \text{MHARDTRT}/\text{MTC}$ (21)

$\text{MPC} = g([\text{MXPPOT}/\text{I}]_{t-1}, \text{MPC}_{t-1}, \text{LD})$ (22)

$\text{MTC} = h([\text{MXPTRT}/\text{I}]_{t-1}, \text{MTC}_{t-1}, \text{LD})$ (23)

FIGURE 5.4. Demand and Supply System for Maryland Blue Crabs

TABLE 5.5. Maryland Landings by Gear Type (thousands of lb)

Year	MHARDL[a]	MHARDPOT[b]	MHARDTRT[c]	MSOFTL[d]	MSOFTPN[e]	MSOFTPOT[f]	MSOFTSCR[g]
1960	26,875	15,446	11,222	2,788	0	329	2,324
1961	26,646	13,854	12,597	2,692	0	257	2,303
1962	27,650	14,883	12,573	3,892	0	334	3,398
1963	16,904	8,481	8,321	2,109	0	198	1,783
1964	22,517	12,061	10,362	3,499	0	265	3,067
1965	31,993	17,592	14,254	2,695	212	338	1,994
1966	30,373	16,188	14,051	1,885	189	190	1,359
1967	24,589	12,834	11,634	2,187	190	255	1,559
1968	9,344	5,003	4,264	1,002	50	123	724
1969	23,014	13,053	9,813	2,251	203	162	1,741
1970	24,935	14,283	10,496	1,579	167	103	1,212
1971	26,075	15,394	10,549	1,530	107	156	1,171
1972	23,482	13,725	9,640	1,575	113	107	1,275
1973	19,539	11,476	7,944	1,515	126	127	1,194
1974	24,661	15,449	9,091	1,821	195	101	1,438
1975	24,264	15,649	8,499	1,655	200	154	1,232
1976	19,430	12,918	6,425	1,475	175	157	1,074
1977	20,159	13,629	6,440	1,164	--	81	--
1978	16,540	12,731	3,799	869	--	286	--
1979	24,819	19,790	4,956	947	--	411	--
1980	25,300	21,601	3,610	1151	--	613	--

(a) Total Maryland landings of hard blue crabs.
(b) Maryland landings of hard blue crabs by pots.
(c) Maryland landings of hard blue crabs by trotlines.
(d) Total Maryland landings of soft crabs.
(f) Maryland landings of soft crabs by poundnets.
(g) Maryland landings of soft crabs by pots.
(h) Maryland landings of soft crabs by scrapes.

Source: <u>Fishery Statistics of the U.S.</u>, selected years.

$\overline{\text{MHARDL}}$ = reported harvest of hard crabs by all gear in Maryland

$\overline{\text{MHARDPOT}}$ = reported harvest of hard crabs by crab pots in Maryland

$\overline{\text{MHARDTRT}}$ = reported harvest of hard crabs by trotlines in Maryland.

Harvest of hard crabs by pots is represented by Equations (26) and (22) in Figure 5.4. Equation (22) suggests that Maryland crab pot effort, as measured by the number of fishing crafts using pots, varies with the lagged price received from crabs caught from pots (which includes both hard and soft crabs) and the lagged cost of harvest which is represented by an interest rate variable. Slowness in adjusting to changing prices is represented by the lagged dependent variable. A dummy variable is also included to represent the fact that Maryland licensing requirements for crab fishermen were changed in 1970 resulting in an apparently substantial increase in harvest effort. Thus, Equation (22) states:

$$\text{MPC} = g\ ([\text{MXPPOT}/I]_{t-1}, \text{MPC}_{t-1}, \text{LD}) \tag{22}$$

where

MPC = Maryland pot craft (sum of vessels plus boats)

MXPPOT = ex-vessel price for crabs caught in pots

I = interest rate on lowest denomination long-term commercial loans

LD = licensing dummy; 1970 to 1976 = 1 and 1960 to 1969 = 0

t = year.

Hard crab harvest by pots is the product of the number of craft using pots and the catch per pot craft. Catch per pot craft, which depends primarily upon population stock levels and therefore fluctuates over the period 1960-1980, is exogenous. Equation (20) is the hard crab pot harvest equation.

$$\text{MHARDPOT} = \text{MPC} * \text{MHARDPOT/MPC} \tag{20}$$

where

MHARDPOT = total harvest of hard crabs by pots in Maryland

MPC = number of pot craft in Maryland

MHARDPOT/MPC = Maryland hard crab catch per pot craft as computed from reported data.

Equations (21) and (23) are for the Maryland trotline fishery. The structure of the two equations is based upon the same justifications offered in the Maryland pot fishery. Thus effort is represented by:

$$MTC = h\ [MXPTRT/I]_{t-1},\ MTC_{t-1},\ LD) \qquad (23)$$

where

MTC = craft using trotlines in Maryland

MXPTRT = ex-vessel price of crabs caught by trotlines in Maryland

I = interest rate on lowest denomination short-term commercial loans.

LD = licensing dummy; 1970 to 1976 = 1 and 1960 to 1969 = 0

t = year.

Trotline harvest is developed in Equation 21.

$$MHARDTRT = MTC * MHARDTRT/MTC \qquad (21)$$

where

MHARDTRT = harvest of hard crabs by trotline in Maryland

MTC = number of craft using trotlines in Maryland

MHARDTRT/MTC = catch of hard crabs per trotline craft in Maryland as computed from reported data.

Maryland Soft Crab Harvest Supply

Soft crab harvest consists of poundnet and scrape gear harvest of peeler and soft crabs and incidental catch from crab pots and trotlines. Total soft crab harvest is a product of soft crab catch per pot craft and number of pot crafts [Equation (25)] and a product of soft crab catch per trotline craft and number of trotline crafts [Equation (24)]. Number of pot craft is from Equation (22) and number of trotline craft is from Equation (23), both as explained above. Soft crab catch per craft (either pot or trotline) depends upon the population of soft and peeler crabs in any year and the willingness of crabbers to segregate their catch between soft/peeler and hard crabs. Catch of soft crabs per pot craft and per trotline craft is, therefore, considered to be an exogenous variable. For trotline crafts the harvest equation is:

$$MSOFTTRT = MTC * MSOFTTRT/MTC \qquad (24)$$

where

MSOFTTRT = Maryland harvest of soft crabs by trotlines

MTC = Maryland craft using trotlines

MSOFTTRT/MTC = Maryland harvest of soft crabs by trotlines per trotline craft as computed from reported data.

Similarly, for pot crafts the equation is:

$$MSOFTPOT = MPC * MSOFTPOT/MPC \qquad (25)$$

where

MSOFTPOT = Maryland harvest of soft crabs by pots

MPC = Maryland craft using pots

MSOFTPOT/MPC = Maryland harvest of soft crabs by pots per pot craft as computed from reported data.

Equation (26) shows the harvest of soft crabs by gear other than pots and trotlines--primarily poundnets and scrapes.

$$\text{MSOFTO} = \text{MSOFTL} - \text{MSOFTPOT} - \text{MSOFTTRT} \qquad (26)$$

where

MSOFTO = harvest of soft crabs by poundnets and scrapes in Maryland
MSOFTL = harvest of soft crabs in Maryland by all gear
MSOFTPOT = harvest of soft crabs by pots in Maryland
MSOFTTRT = harvest of soft crabs by trotlines in Maryland.

Soft crab harvest will depend upon the available population stocks and the amount of effort, as represented by poundnet and scrape craft, operating during a given season. Table 5.3 (page 5.12) shows annual numbers of poundnet and scrape craft since 1960 in Maryland. Despite rapidly escalating prices, the amount of soft crab effort shown in Table 5.3 does not change significantly over time and could represent a downward trend. To test the hypothesis that soft crab landings from poundnets and scrapes have been in decline, soft crab harvest from these years was estimated as a function of time.

$$\text{MSOFTO} = f\ (\text{YR})$$

where

MSOFTO = Maryland soft crab harvest from gear other than pots
YR = year.

The results of this model were as follows:

$$\text{MSOFTO} = 8868.907^{*} - 103.828^{*}\ \text{YR}$$

$$(1190.46) \quad (16.94329)$$

$$R^2 = 0.6640$$

$$\text{D-W} = 2.361$$

The apparent absence of a relationship between poundnet/scrape effort and soft crab prices and the downward trend in soft crab harvest suggested that soft crab harvest be treated as exogenous in the model.

5.3 ESTIMATION RESULTS

This section presents the model estimation results. Supply models for Virginia and Maryland are described first, followed by the demand models for both states.

5.3.1 Supply Models

Virginia and Maryland supply models were estimated using annual data for the period 1960 to 1980. In each case, ordinary least squares procedures were used and no significant statistical problems were encountered. Appendix A.2 includes the data used in these models.

Virginia Supply Models

Table 5.6 provides the results from the estimation of Equation (9), Figure 5.3. The R^2, standard errors and D-W statistics are reported. Signs are as hypothesized and the statistical properties are satisfactory.

Maryland Supply Models

Table 5.7 presents the results for estimation of Maryland Equations (22) and (23), Figure 5.4. The R^2, standard errors and D-W statistics are reported. Signs are as hypothesized. The statistical properties of the equations are satisfactory.

5.3.2 Demand Models

Based on order and rank conditions, all equations in the hard blue crab demand models are overidentified. Attempts to estimate the simultaneous equation system using the traditional methods of two-stage and three-stage least squares were plagued by deleterious collinearity problems. Therefore, ridge regression procedures were used. (See discussion of the technique in section on oyster demand models). Collinearity diagnostics are reported in Appendix B.2.

TABLE 5.6. Virginia Blue Crab Supply Estimation Results

$$VPC = 177.568 + 229.553^{*} (VXPPOT/I)_{t-1} + 0.673774^{*} VPC_{t-1} \qquad (9)$$

(222.363) (101.532) (0.217826)

$R^2 = 0.7290$

D-W = 2.020

---

* Significant at 5 percent level.

TABLE 5.7. Maryland Blue Crab Supply Estimation Results

$$\begin{array}{llll} \text{MPC} = & \underset{(70.350703)}{132.610^{*}} + \underset{(71.270516)}{195.102^{*}}\ \text{LD} & + \underset{(51.608562)}{174.854^{*}}\ (\text{MXPPOT/I})_{t-1} & (22) \\ & & + \underset{(0.134737)}{.546777}\ \text{MPC}_{t-1} & \end{array}$$

$$R^2 = 0.9499$$
$$\text{D-W} = 2.382$$

$$\begin{array}{llll} \text{LOG MTC}_t{}^{(a)} = & \underset{(1.167901)}{5.182914^{*}} + \underset{(0.149019)}{0.671714^{*}}\text{LOG LD}_t & + \underset{(0.174318)}{0.365689^{*}}\text{LOG } (\text{MXPTRT/I})_{t-1} & \\ & & + \underset{(0.153562)}{0.328321^{*}}\text{LOG } (\text{MTC}_{t-1}) & (23) \end{array}$$

$$R^2 = 0.9568$$
$$\text{D-W} = 2.580$$

---

* Significant at 5 percent level.

(a) The log-log formulation of this model increased the statistical validity of the estimates as compared to the linear formulation.

Results of the hard blue crab demand models are presented in Tables 5.8 and 5.9. Standard errors are shown in parentheses below the structural parameter estimates. Although conventional tests of significance are not exactly applicable to parameters obtained from estimating simultaneous equation models, the estimated structural parameter is judged to be significantly different from zero when the ratio of the parameter estimate to the associated estimate of standard error is greater than two.

In these models retail price responds at a statistically significant level to changes in all variables except population and CPIMPF. All estimated coefficients in the wholesale price equation are statistically significant. State landings are not statistically significant in the Maryland ex-vessel price equation; however, all variables are statistically significant in the Virginia model. Landings changes do affect wholesale and ex-vessel prices and so, through the system, Maryland ex-vessel prices are affected by state landings.

All estimated coefficients have signs as expected. The models explain over 90 percent of the variation in all prices. The R^2 statistic shown for each equation is the square of the Pearson product-moment coefficient of actual and predicted prices.

TABLE 5.8. Demand Estimation: Chesapeake Bay Hard Blue Crab Industry, Virginia Fishery

	Retail Price (RPCRAB)	Wholesale Price (WPCRAB)	Ex-Vessel Price (VEXVHP)
INTERCEPT	-0.5961 (0.1089E+01)	0.7831* (0.3833)	0.6263E-01* (0.2332E-01)
WPCRAB	0.5107* (0.5949E-01)	--	0.1236E-01* (0.1898E-02)
RPCRAB	--	0.2279* (0.2101E-01)	0.1145E-01* (0.1687E-02)
VEXVHP	--	0.5058E+01* (0.1038E+01)	--
CRABL	-0.6635E-05* (0.4001E-05)	--	--
Y	0.9476E-03* (0.1102E-03)	--	--
CPIMPF	0.1068E-01* (0.2138E-02)	--	--
POP	0.5630E-02 (0.4849E-02)	--	--
CRABBAY	--	-0.1094E-04* (0.4529E-05)	--
IIGS	--	0.3675E-02* (0.1029E-02)	--
VHARDL	--	--	-0.9157E-06* (0.4224E-06)
TIME	0.2479E-01* (0.6671E-02)	0.5336E-01* (0.9657E-02)	0.1225E-02* (0.6017E-03)
R^2	0.98321	0.97451	0.92412
D-W	0.5676	1.2798	1.0710
U_2	1.0952	0.7688	0.7367
K	0.10	0.15	0.15

---

* Significant at 5 percent level.

TABLE 5.9. Demand Estimation: Chesapeake Bay Hard Blue Crab Industry, Maryland Fishery

	Retail Price (RPCRAB)	Wholesale Price (WPCRAB)	Ex-Vessel Price (MEXVHP)
INTERCEPT	-0.5961 (0.1089E+01)	0.8867* (0.3654)	0.2360E-01 (0.1736E-01)
WPCRAB	0.5107* (0.5949E-01)	--	0.1885E-01* (0.1871E-2)
RPCRAB	--	0.2375* (0.2449E-01)	0.1668E-01* (0.1551E-02)
MEXVHP	--	0.4780E+01* (0.7809)	--
CRABL	-0.6635E-05* (0.4001E-05)	--	--
Y	0.9476E-03* (0.1102E-03)	--	--
CPIMPF	0.1066E-01* (0.2138E-02)	--	--
POP	0.5630E-02 (0.4849E-02)	--	--
CRABBAY	--	-0.1146E-04* (0.4370E-03)	--
IIGS	--	0.2423E-02* (0.1163E-02)	--
MHARDL	--	--	-0.6052E-06 (0.6167E-06)
TIME	0.2479E-01* (0.6671E-02)	0.5148E-01* (0.1076E-01)	0.1990E-02* (0.5782E-03)
$\bar{R}^2$	0.98321	0.97931	0.96140
D-W	1.4600	1.2339	0.6130
U_2	0.6720	0.7661	0.9516
K^2	0.10	0.10	0.15

---

* Significant at 5 percent level.

Durbin (1957) and Malinvaud (1970) have suggested that the conventional single-equation Durbin-Watson statistic be used to check for serial correlation in simultaneous equation systems. The appropriate number of degrees of freedom is (K,T) where K is the number of predetermined variables and T is the number of observations. For this application, $K = 8$ and $T = 21$. In the demand analysis for the Virginia crab fishery, the Durbin-Watson statistics are 0.5676 for the retail price equation, 1.2798 for the wholesale price equation, and 1.0710 for the ex-vessel price equation. The magnitudes of the Durbin-Watson statistics for the demand equations in the Maryland fishery are 1.4600, 1.2339 and 0.6130 for the retail, wholesale and ex-vessel equations. Positive autocorrelation apparently exists in the retail price equation of the demand model for the Virginia fishery and the ex-vessel equation of the demand model for the Maryland fishery. Serial correlation persists despite the circumvention of severe collinearity problems. No algorithm exists to circumvent both collinearity and serial correlation problems simultaneously either in single-equation or multi-equation settings. In this application, since collinearity is deemed to be the more severe problem, only corrections to reduce the impacts of this problem were employed.

On the basis of the Theil U_2 statistics of the market price equations in the Maryland and Virginia crab fisheries, the demand model for hard blue crabs is unequivocally better than the naive, no extrapolation model. The U_2 statistic of the no extrapolation model is unity. While no rigorous test has been developed to judge whether the difference between two U_2 coefficients is statistically significant, all but one of the respective U_2 coefficients of the models are much lower than the U_2 coefficients of the naive no extrapolation model. The U_2 coefficients for the respective equations in the model for the Virginia hard blue crab fishery and the model for the Maryland hard blue crab fishery range from 0.6720 to 1.0952.

Traditionally, the calculation of the Theil U_2 statistic rests on the difference between predicted and actual changes. However, since the model predicts the levels of market prices for hard blue crabs, predicted changes are calculated using differences between the predicted values for a period and the actual values of the previous period, while actual changes are calculated using differences between the actual values for a period and the actual values of the previous period. According to Stekler (1968, p. 439), this approach is often used in ex-post evaluations.

Table 5.10 presents the results for the soft crab demand models for Virginia and Maryland. The R^2, standard errors and D-W statistics are reported. Signs are as hypothesized and the statistical properties of the equation are satisfactory.

Table 5.11 presents the results of the Maryland and Virginia auxiliary price equations which describe the relationship between the annual ex-vessel

TABLE 5.10. Demand Equations for Soft Crabs in Maryland and Virginia

Virginia

$$\mathrm{VEXVSP} = \underset{(0.088596)}{0.309922^{*}} - \underset{(0.00005369568)}{0.000077123^{*}}\ \mathrm{VSOFTL} + \underset{(0.0000726212)}{0.0002798987^{*}}\ Y \tag{4}$$

$$+ \underset{(0.067186)}{0.273649^{*}}\ \mathrm{SDD}$$

$R^2 = 0.9403$
D-W = 1.913

Maryland

$$\mathrm{MEXVSP} = \underset{(0.151234)}{0.341762^{*}} - \underset{(0.00004194181)}{0.0000659044^{*}}\ \mathrm{MSOFTL} + \underset{(0.0001241687)}{0.0003184357^{*}}\ Y \tag{16}$$

$$+ \underset{(0.103741)}{0.385145^{*}}\ \mathrm{SDD}$$

$R^2 = 0.9244$
D-W = 1.898

---

* Significant at 5 percent level.

price of hard blue crabs and the primary harvest gear for each state. The dredge harvest price for Virginia should be viewed as a seasonal price difference since dredges are used only in the winter months. The R^2, standard error, and D-W statistics for the price equations are presented.

Tables 5.12 and 5.13 present the reduced form equations for Virginia and Maryland. It is from these equations that the impact multipliers are developed. Impact multipliers (Tables 5.14 and 5.15) measure the effect of a one-unit change in a particular exogenous variable upon the endogenous variable in the same time period. To illustrate, ceteris paribus, a billion dollar increase in nominal disposable income would increase the retail price of hard blue crabs by approximately 0.10 cents per pound.

Not surprisingly, in terms of percentage changes, blue crab landings, disposable income, the general price level of meat, poultry and fish, and population dominate in influencing retail price. Marketing costs, blue crab landings, and the general price level of meat, poultry and fish have salient impacts on the wholesale price and the respective ex-vessel prices in Maryland

TABLE 5.11. Auxiliary Blue Crab Price Equations for Maryland and Virginia

Virginia

$$\text{VXPPOT} = \underset{(0.001651824)}{0.00347615^{*}} + \underset{(0.014468)}{0.998132^{*}}\ \text{VEXVHP} \tag{5}$$

$R^2 = 0.9960$
D-W = 1.812

$$\text{VXPDRG} = \underset{(0.007236086)}{-0.00606526} + \underset{(0.063379)}{1.141758^{*}}\ \text{VEXVHP} \tag{6}$$

$R^2 = 0.9447$
D-W = 2.453

Maryland

$$\text{MXPPOT} = \underset{(0.003457796)}{-0.0062105} + \underset{(0.023679)r}{1.091823^{*}}\ \text{MEXVHP} \tag{17}$$

$R^2 = 0.9911$
D-W = 1.128

$$\text{MXPTRT} = \underset{(0.004321431)}{0.005893091^{*}} + \underset{(0.029593)}{1.004965^{*}}\ \text{MEXVHP} \tag{18}$$

$R^2 = 0.9838$
D-W = 1.081

---

* Significant at 5 percent level.

and Virginia. Because the inverse of the own-price flexibility is the lower limit of the own-price elasticity (Houck 1966), retail, wholesale, and ex-vessel demand functions for hard blue crabs in the Chesapeake Bay are price elastic.

5.4 MODEL VALIDATION

Validation of the models, beyond the statistical tests reported previously, included 1) development of static backcasts using only the demand system for hard blue crabs, 2) development of reduced form equations for dynamic backcasts, and 3) "shocking" the demand system to evaluate forecast sensitivity to changes in the exogenous variables.

Static backcasts (Table 5.16) were developed for the period 1960 to 1980 using the analytically derived reduced form equations for the hard blue crab

TABLE 5.12. Analytically Derived Reduced Form Equations for Virginia Blue Crabs

$$\begin{aligned}\mathrm{RPCRAB} = {} & 0.00363394 - 7.8586\mathrm{E}{-06}\ \mathrm{CRABL} + 0.00112235\ \mathrm{Y} + 0.0126495 \\ & \mathrm{CPIMPF} + 0.00666824\ \mathrm{POP} - 7.0587\mathrm{E}{-06}\ \mathrm{CRABBAY} + 0.00237117 \\ & \mathrm{IIGS} - 2.9884\mathrm{E}{-06}\ \mathrm{VHARDL} + 0.0677881\ \mathrm{TIME}\end{aligned}$$

$$\begin{aligned}\mathrm{WPCRAB} = {} & 1.17434 - 2.3959\mathrm{E}{-06}\ \mathrm{CRABL} + 0.000342175\ \mathrm{Y} + 0.00385651 \\ & \mathrm{CPIMPF} + 0.00203297\ \mathrm{POP} - 0.000013822\ \mathrm{CRABBAY} + 0.00464298 \\ & \mathrm{IIGS} - 5.8516\mathrm{E}{-06}\ \mathrm{VHARDL} + 0.0841944\ \mathrm{TIME}\end{aligned}$$

$$\begin{aligned}\mathrm{VEXVHP} = {} & 0.0771864 - 1.1959\mathrm{E}{-07}\ \mathrm{CRABL} + 0.0000170802\ \mathrm{Y} + 0.000192503 \\ & \mathrm{CPIMPF} + 0.000101479\ \mathrm{POP} - 2.5166\mathrm{E}{-07}\ \mathrm{CRABBAY} + 0.0000845371 \\ & \mathrm{IIGS} + 0.0000010222\ \mathrm{VHARDL} + 0.00304182\ \mathrm{TIME}\end{aligned}$$

$$\begin{aligned}\mathrm{VSOFTL} = {} & \mathrm{VSOFTO}_t + [(\mathrm{VSOFTPOT}/\mathrm{VPC}_t)\ (177.568 + 229.553\ \mathrm{VXPPOT}/I_t \\ & + 0.673774\ \mathrm{VPC}_{t-1})]\end{aligned}$$

$$\begin{aligned}\mathrm{VHARDL} = {} & \mathrm{VHQDRG}_t + \mathrm{VHARDO}_t + [(\mathrm{VHARDPOT}/\mathrm{VPC}_t)\ (177.568 + 229.553\ \mathrm{VXPPOT}/I_t \\ & + 0.673774\ \mathrm{VPC}_{t-1})]\end{aligned}$$

fisheries of Maryland and Virginia (Tables 5.12 and 5.13). The U_m, U_r, and U_d proportions (components of the MSE decompositions) indicate that the model performs very adequately in the backcast evaluation (Table 5.17). For optional predictors, the U_m and U_r proportions tend toward zero, and the U_d proportion tends toward unity in the backcast process.

Reduced forms of the demand and supply models were incorporated into a simulation model to develop dynamic backcasts (Tables 5.18a and b). As shown in Tables 5.19a and b, the U_m, U_r and U_d proportions as well as the Theil U_1 and U_2 coefficients for the respective equations in the Maryland and Virginia

TABLE 5.13. Analytically Derived Reduced Form Equations for Maryland Blue Crabs

$$\begin{aligned}\mathrm{RPCRAB} = {} & -0.0441843 - 8.0659\mathrm{E}{-06}\ \mathrm{CRABL} + 0.00115196\ \mathrm{Y} + 0.0129832 \\ & \mathrm{CPIMPF} + 0.00684416\ \mathrm{POP} - 7.8112\mathrm{E}{-06}\ \mathrm{CRABBAY} + 0.00165154 \\ & \mathrm{IIGS} - 1.9512\mathrm{E}{-06}\mathrm{MHARDL} + 0.0716412\ \mathrm{TIME}\end{aligned}$$

$$\begin{aligned}\mathrm{WPCRAB} = {} & 1.0807 - 2.8018\mathrm{E}{-06}\ \mathrm{CRABL} + 0.000400153\ \mathrm{Y} + 0.00450996 \\ & \mathrm{CPIMPF} + 0.00237744\ \mathrm{POP} - 0.000015295\ \mathrm{CRABBAY} - 3.8206\mathrm{E}{-06} \\ & \mathrm{MHARDL} + 0.00323388\ \mathrm{IIGS} + 0.0917392\ \mathrm{TIME}\end{aligned}$$

$$\begin{aligned}\mathrm{MEXVHP} = {} & 0.0432343 - 1.8735\mathrm{E}{-07}\ \mathrm{CRABL} + 0.0000267576\ \mathrm{Y} + 0.000301573 \\ & \mathrm{CPIMPF} + 0.000158975\ \mathrm{POP} - 4.1861\mathrm{E}{-07}\ \mathrm{CRABBAY} + \\ & 0.0000885062\ \mathrm{IIGS} - 7.0976\mathrm{E}{-07}\ \mathrm{MHARDL} + 0.00491426\ \mathrm{TIME}\end{aligned}$$

$$\begin{aligned}\mathrm{MSOFTL} = {} & \mathrm{MSOFTO}_t + [(\mathrm{MSOFTPOT}/\mathrm{MPC}_t)\ (132.610 + 195.102\ \mathrm{LD}_t + 174.854\ \mathrm{MXPPOT}/\mathrm{I}_t \\ & + 0.546777\ \mathrm{MPC}_{t-1})] + [(\mathrm{MSOFTTRT}/\mathrm{MTC}_t)\ (\mathrm{MEXVHP}_t(5.182914 \\ & + 0.671714\ \mathrm{LD}_t)\ (0.365689\ \mathrm{MXPTRT}/\mathrm{I}_t)\ (0.328321\ \mathrm{MTC}_{t-1})]\end{aligned}$$

$$\begin{aligned}\mathrm{MHARDL} = {} & \mathrm{MHARDO}_t + (\mathrm{MHARDPOT}/\mathrm{MPC}_t)\ (132.610 + 195.102\ \mathrm{LD}_t + 174.854\ \mathrm{MXPPOT}/\mathrm{I}_t \\ & + 0.546777\ \mathrm{MPC}_{t-1}) + [(\mathrm{MHARDTRT}/\mathrm{MTC}_t)\ (\mathrm{MEXVHP}_t(5.182914 \\ & + 0.671714\ \mathrm{LD}_t)\ (0.364589\ \mathrm{MXPTRT}/\mathrm{I}_t)\ (0.328321\ \mathrm{MTC}_{t-1})]\end{aligned}$$

crab fisheries indicate very reasonable predictive performance on the part of the "full" supply and demand model. In short, on the basis of the static and dynamic backcast evaluations, the econometric model seems stable.

The model validation process terminates with the examination of forecast sensitivity to changes in key exogenous variables. Initially, base case forecasts are obtained for the period 1980 to 1990, fixing all exogenous variables

TABLE 5.14. Price Impact Multipliers for Estimated Hard Blue Crab Model Variables

Virginia Fishery

Variable	Retail Price (RPCRAB)	Wholesale Price (WPCRAB)	Ex-Vessel Price (VEXVHP)
CRABL	-7.8586E-06 (-0.3606)	-2.3959E-06 (-0.1453)	-1.1959E-07 (-0.1694)
Y	0.00112235 (0.2935)	0.000342175 (0.1182)	0.0000170802 (0.1377)
CPIMPF	0.0126495 (0.4839)	0.00385651 (0.1950)	0.000192503 (0.2273)
POP	0.00666824 (0.4318)	0.00203247 (0.1740)	0.000101479 (0.2028)
CRABBAY	-7.0587E-06 (-0.3158)	-0.000013822 (-0.4539)	-2.5166E-07 (-0.2425)
IIGS	0.00237117 (0.1035)	0.00464298 (0.2679)	0.0000545371 (0.1139)
VHARDL	-2.8884E-06 (-0.2467)	-5.8516E-06 (-0.4020)	-1.0222E-06 (-0.5925)
TIME	0.0677881 (0.2371)	0.0841944 (0.3894)	0.00304182 (0.3285)

Impact multipliers in terms of percentage changes are in parentheses.

at 1980 levels. Then the model is shocked by adjusting the 1980 levels of disposable income; the general price level of meat, poultry, and fish; population; and the index of intermediate goods and services. The base case forecasts, as well as the forecasts associated with changes in the aforementioned exogenous factors, are exhibited in Tables 5.20 to 5.24. These show that the model is relatively insensitive to changes in the respective exogenous variables.

TABLE 5.15. Impact Multipliers for Estimated Hard Blue Crab Model Variables

Maryland Fishery

Variable	Retail Price (RPCRAB)	Wholesale Price (WPCRAB)	Ex-Vessel Price (MEXVHP)
CRABL	-8.0659E-06 (-0.3701)	-2.8018E-06 (-0.1699)	-1.8735E-07 (-0.2100)
Y	0.00115196 (0.3010)	0.000400153 (0.1382)	0.0000267576 (0.1708)
CPIMPF	0.0129832 (0.4967)	0.00450996 (0.2281)	0.000301573 (0.2818)
POP	0.00684416 (0.4432)	0.00237744 (0.2035)	0.000158975 (0.2515)
CRABBAY	-7.8112E-06 (-0.3362)	-0.000015295 (-0.5065)	-4.1861E-07 (-0.2779)
IIGS	0.00165154 (0.0721)	0.0032388 (0.1866)	0.0000885062 (0.0943)
MHARDL	-1.9512E-06 (-0.1320)	-3.8206E-06 (-0.2146)	-7.0976E-07 (-0.2381)
TIME	0.0716412 (0.2506)	0.0917392 (0.4243)	0.00491426 (0.4200)

Impact multipliers in terms of percentage changes are in parentheses.

TABLE 5.16. Static Backcasts for the Blue Crab Model (1960 to 1980)

Year	WPCRAB[a]	VEXVHP[b]	MEXVHP[c]	PMRPCRAB[d]	PVRPCRAB[e]	PMWPCRAB[f]	PVWPCRAB[g]	PMEXVHP[h]	PVEXVHP[i]	RPCRAB[j]
1960	1.12	0.050802	0.056893	1.21887	1.69602	0.92006	1.02960	0.046999	0.055221	1.47
1961	0.86	0.044229	0.054980	1.31021	1.79792	0.96433	1.04107	0.051486	0.053132	1.20
1962	1.06	0.046990	0.064014	1.34098	1.87288	0.90469	0.93484	0.052257	0.044247	1.41
1963	1.16	0.055181	0.067972	1.65953	2.05745	1.34429	1.33851	0.074351	0.060795	1.64
1964	1.21	0.065660	0.071368	1.58759	2.05588	1.23059	1.22574	0.069600	0.054836	1.79
1965	1.22	0.073658	0.078611	1.59209	2.13945	1.16740	1.21163	0.064740	0.057151	1.81
1966	1.14	0.057085	0.072927	1.74782	2.32863	1.15713	1.12381	0.070114	0.046592	1.64
1967	1.30	0.053863	0.069950	2.14216	2.62502	1.56476	1.52252	0.089866	0.065330	1.80
1968	1.95	0.109894	0.115903	2.76315	3.05682	2.21894	2.11974	0.123771	0.089861	2.70
1969	1.94	0.094431	0.095724	2.84603	3.21531	2.25074	2.26849	0.119470	0.104814	2.53
1970	1.64	0.056262	0.083698	2.73869	3.16300	2.15002	2.14241	0.116609	0.095067	2.09
1971	1.90	0.077436	0.094765	2.67625	3.13386	2.11960	2.09634	0.116294	0.089974	2.41
1972	2.58	0.080857	0.100588	2.98570	3.41692	2.33944	2.28812	0.129159	0.096264	2.89
1973	3.21	0.110459	0.142535	3.77069	4.11135	2.93039	2.89706	0.157768	0.125029	3.87
1974	2.98	0.104128	0.164389	3.83215	4.24936	2.95425	2.95637	0.158133	0.124082	3.88
1975	3.32	0.144146	0.176228	4.38225	4.76757	3.33333	3.35262	0.176685	0.142096	4.12
1976	4.09	0.197850	0.236078	4.87957	5.17807	3.78443	3.80663	0.198399	0.162917	5.17
1977	4.67	0.181000	0.243330	4.87778	5.22753	3.73751	3.72074	0.199033	0.152380	6.00
1978	4.08	0.188000	0.243810	5.47192	5.78598	4.10908	4.06970	0.220098	0.165617	5.40
1979	4.10	0.167000	0.230420	5.89295	6.29876	4.22067	4.21663	0.226234	0.170225	5.74
1980	4.41	0.180000	0.238300	6.28115	6.69943	4.52474	4.56007	0.240139	0.182332	6.46

(a) Actual wholesale price
(b) Actual Virginia ex-vessel price
(c) Actual Maryland ex-vessel price
(d) Backcast of retail price from Maryland model
(e) Backcast of retail price from Virginia model
(f) Backcast of wholesale price from Maryland model
(g) Backcast of wholesale price from Virginia model
(h) Backcast of Maryland ex-vessel price
(i) Backcast of Virginia ex-vessel price
(j) Actual retail price

TABLE 5.17. Static Backcast Evaluations of the Hard Blue Crab Models (1960 to 1980)

Virginia Fishery

Variable	Retail Price (RPCRAB)	Wholesale Price (WPCRAB)	Ex-Vessel Price (VEXVHP)
MSE	0.3248	0.0926	0.0003
RMSE	0.5699	0.3043	0.0182
U_1	0.4381	0.3990	0.3808
U_2	1.0952	0.7688	0.7367
U_m	0.5732	0.0001	0.0002
U_r	0.0261	0.1113	0.0950
U_d	0.4006	0.8884	0.9046

Maryland Fishery

Variable	Retail Price (RPCRAB)	Wholesale Price (WPCRAB)	Ex-Vessel Price (MEXVHP)
MSE	0.1223	0.0919	0.0004
RMSE	0.3497	0.3032	0.0204
U_1	0.3500	0.3915	0.4394
U_2	0.6720	0.7661	0.9516
U_m	0.0010	0.0009	0.0005
U_r	0.0626	0.1267	0.3611
U_d	0.9363	0.8722	0.6382

TABLE 18a. Dynamic Backcasts for the Virginia Blue Crab Model

Year	VHARDL	PVHARDL	VSOFTL	PVSOFTL	VEXVHP	PVEXVHP	VEXVSP	PVEXVSP	VXPPOT	PVXPPOT	VXPDRG	PVXPDRG
1960	39270	39270.0	1553	1553.00	0.050802	0.055221	0.28203	0.287933	0.052290	0.058594	0.059554	0.056983
1961	43976	51207.6	1535	1617.60	0.044229	0.053132	0.26906	0.286743	0.046549	0.056509	0.044369	0.054599
1962	53671	57053.0	1319	1343.96	0.046990	0.044247	0.31766	0.313725	0.049317	0.047640	0.045884	0.044454
1963	46139	43605.3	928	905.96	0.055181	0.060795	0.34375	0.352708	0.059112	0.064158	0.054100	0.063348
1964	51569	48569.8	978	946.90	0.065660	0.054836	0.45297	0.359217	0.071713	0.058210	0.060678	0.056544
1965	50558	50378.0	1078	1076.06	0.073658	0.057151	0.41373	0.359081	0.077869	0.060521	0.070702	0.059188
1966	63694	65447.0	1028	1043.58	0.057085	0.046592	0.36673	0.372298	0.062566	0.049981	0.049396	0.047132
1967	54824	57580.8	1201	1223.01	0.053863	0.065330	0.37302	0.368012	0.052218	0.068684	0.065429	0.068526
1968	44834	44218.9	793	786.67	0.109894	0.089861	0.38714	0.406884	0.114907	0.093169	0.102400	0.096534
1969	33633	34733.4	1950	2001.54	0.094431	0.104814	0.35590	0.332012	0.106112	0.108094	0.098116	0.113607
1970	42409	41043.0	900	880.86	0.056262	0.095067	0.37222	0.433984	0.060847	0.098366	0.056161	0.102479
1971	47807	56406.2	691	781.02	0.077436	0.089974	0.46310	0.457596	0.081305	0.093282	0.077905	0.096663
1972	48555	50868.9	852	877.12	0.080857	0.096264	0.47535	0.466558	0.081257	0.099560	0.091910	0.103845
1973	36629	40395.9	978	1061.58	0.110459	0.125029	0.50511	0.480819	0.109660	0.128271	0.141651	0.136687
1974	40796	32791.1	806	670.68	0.104128	0.124082	0.49256	0.533512	0.108038	0.127326	0.115922	0.135606
1975	34798	33988.1	754	743.15	0.144146	0.142096	0.51061	0.556760	0.146126	0.145306	0.165397	0.156174
1976	25762	25567.0	761	757.58	0.197850	0.162917	0.72273	0.856642	0.204796	0.166089	0.207848	0.179947
1977	37177	38216.0	695	710.95	0.181000	0.152380	0.84400	0.893448	0.187612	0.155572	0.209000	0.167916
1978	36054	34307.0	605	585.36	0.188000	0.165617	1.13700	0.946630	0.184330	0.168784	0.168350	0.183030
1979	39834	35914.5	1052	985.80	0.167000	0.170225	0.94000	0.962022	0.168350	0.173383	0.215000	0.188290
1980	37691	--	633	--	0.180000	0.182332	1.05400	--	0.162960	0.185468	0.215000	0.202114

VHARDL, PVHARDL: actual and backcast of Virginia landings of hard blue crabs.

VSOFTL, PVSOFTL: actual and backcast of Virginia landings of soft crabs.

VEXVHP, PVEXVHP: actual and backcast of Virginia ex-vessel price of hard blue crabs.

VEXVSP PVEXVSP: actual and backcast of Virginia ex-vessel price of soft crabs.

VXPPOT, PVXPPOT: actual and backcast of Virginia ex-vessel price of crabs by pot gear.

VXPDRG PVXPDRG: actual and backcast of Virginia ex-vessel price of crabs by dredge gear.

Note: Dynamic backcasts for actual and wholesale prices are essentially equivalent to the static backcasts.

TABLE 18b. Dynamic Backcasts for the Maryland Blue Crab Model

Year	MHARDL	PMHARDL	MSOFTL	PMSOFTL	MEXVHP	PMEXVHP	MEXVSP	PMEXVSP	MXPPOT	PMXPPOT	MXPTRT	PMXPTRT
1960	26875.0	26875.0	2788	2788.00	0.056893	0.046999	0.21915	0.26927	0.060222	0.045105	0.058236	0.053126
1961	26646.0	25251.5	2692	2676.24	0.054980	0.051486	0.22845	0.28095	0.058182	0.050003	0.056339	0.057635
1962	27650.0	25252.2	3892	3833.74	0.064014	0.052257	0.20041	0.21135	0.067030	0.050845	0.065322	0.058410
1963	16904.0	18832.5	2109	2148.14	0.067972	0.074351	0.35609	0.32845	0.074433	0.074967	0.072131	0.080613
1964	22517.0	25429.6	3499	3550.76	0.071368	0.069600	0.36268	0.24692	0.080886	0.069781	0.071795	0.075839
1965	31993.0	29757.5	2695	2657.31	0.078611	0.064740	0.34100	0.31698	0.075739	0.064474	0.090890	0.070954
1966	30373.0	28093.8	1885	1860.01	0.072927	0.070114	0.38462	0.38171	0.076444	0.070341	0.075990	0.076355
1967	24589.0	22686.5	2187	2152.81	0.069950	0.089866	0.37952	0.37328	0.075636	0.091907	0.074674	0.096205
1968	9344.0	9632.6	1002	1009.19	0.115903	0.123771	0.46108	0.45459	0.127000	0.128926	0.120302	0.130279
1969	23014.0	23577.2	2251	2257.77	0.095724	0.119470	0.41448	0.39372	0.086871	0.124230	0.115187	0.125957
1970	24935.0	26099.9	1579	1586.33	0.083698	0.116609	0.42432	0.45565	0.077228	0.121106	0.097348	0.123081
1971	26075.0	26466.4	1530	1533.29	0.094765	0.116294	0.47778	0.47725	0.089646	0.120762	0.109425	0.122764
1972	23482.0	28029.9	1575	1606.61	0.100588	0.129159	0.47746	0.49104	0.087623	0.134808	0.124729	0.135693
1973	19539.0	25611.4	1515	1567.22	0.142536	0.157768	0.50561	0.52605	0.147979	0.166044	0.142249	0.164445
1974	24661.0	22331.2	1821	1805.84	0.164389	0.158133	0.56562	0.53597	0.173248	0.166443	0.156520	0.164811
1975	24264.0	24208.1	1655	1657.37	0.176228	0.176685	0.52447	0.57856	0.184142	0.186698	0.168948	0.183455
1976	19430.0	19387.0	1475	1475.07	0.236078	0.198399	0.72949	1.00683	0.244665	0.210406	0.236529	0.205277
1977	20159.3	18432.6	1164	1149.66	0.243330	0.199033	1.20110	1.06606	0.251960	0.211098	0.244170	0.205914
1978	16590.1	16674.3	869	870.52	0.243810	0.220098	1.37470	1.13394	0.268690	0.234097	0.257520	0.227084
1979	24819.2	22461.1	947	905.71	0.230420	0.226234	1.13230	1.18427	0.249560	0.240797	0.238390	0.233250
1980	25300.6	24701.3	1151	1131.75	0.238300	0.240139	1.18110	1.23241	0.263030	0.255979	0.262960	0.247225

MHARDL, PMHARDL: actual and backcast of Maryland landings of hard blue crabs.
MSOFTL, PMSOFTL: actual and backcast of Maryland landings of soft crabs.
MEXVHP, PMEXVHP: actual and backcast of Maryland ex-vessel price of hard blue crabs.
MEXVSP PMEXVSP: actual and backcast of Maryland ex-vessel price of soft crabs.
MXPPOT, PMXPPOT: actual and backcast of Maryland ex-vessel price of crabs by pot gear.
MXPTRT PMXPTRT: actual and backcast of Maryland ex-vessel price of crabs by trotline gear.

Note: Dynamic backcasts for retail and wholesale prices are essentially equivalent to the static backcasts.

TABLE 5.19a. Dynamic Backcast Evaluations for the Virginia Blue Crab Model (1960 to 1980)

	Retail Price Hard Blue Crabs (RPCRAB)	Wholesale Price Hard Blue Crabs (WPCRAB)	Ex-Vessel Price Hard Blue Crabs (VEXVHP)
MSE	0.3249	0.0926	0.0003
RMSE	0.5700	0.3043	0.0182
U_1	0.4379	0.3987	0.3896
U_2	1.0953	0.7689	0.7452
U_m	0.5733	0.0001	0.0002
U_r	0.0261	0.1115	0.0921
U_d	0.4005	0.8882	0.9075

	Soft Crab Landings (VSOFTL)	Hard Blue Crab Landings (VHARDL)	Ex-Vessel Price for Dredge Landings (VXPDRG)
MSE	3506.3507	15278779.07	0.0003
RMSE	59.2144	3908.8078	0.0196
U_1	0.0721	0.2362	0.3723
U_2	0.1445	0.5016	0.6947
U_m	0.1733	0.0245	0.0000
U_r	0.0977	0.2475	0.0205
U_d	0.7289	0.7279	0.9794

	Ex-Vessel Price for Pot Landings (VXPPOT)	Ex-Vessel Price Soft Crabs (VEXVSP)
MSE	0.0003	0.0043
RMSE	0.0190	0.0659
U_1	0.3745	0.3053
U_2	0.7212	0.6173
U_m	0.0002	0.0040
U_r	0.0911	0.1406
U_d	0.9086	0.8552

TABLE 5.19b. Dynamic Backcast Evaluations of the Maryland Blue Crab Models (1960 to 1980)

	Retail Price Hard Blue Crabs (RPCRAB)	Wholesale Price Hard Blue Crabs (WPCRAB)	Ex-Vessel Price Hard Blue Crabs (MEXVHP)
MSE	0.1223	0.0920	0.0004
RMSE	0.3497	0.3033	0.0204
U_1	0.3497	0.3725	0.4394
U_2	0.6720	0.7662	0.9515
U_m	0.0010	0.0009	0.0003
U_r	0.0626	0.1269	0.3612
U_d	0.9363	0.8720	0.6383

	Soft Crab Landings (MSOFTL)	Hard Blue Crab Landings (MHARDL)	Ex-Vessel Price for Pot Landings (MXPPOT)
MSE	917.5196	5658238.145	0.0006
RMSE	30.2905	2378.7051	0.0250
U_1	0.1097	0.1846	0.4437
U_2	0.0394	0.3645	0.9469
U_m	0.0090	0.0001	0.0007
U_r	0.0040	0.0117	0.3487
U_d	0.9869	0.9881	0.6504

	Ex-Vessel Price for Trotline Landings (MXPTRT)	Ex-Vessel Price Soft Crabs (MEXVSP)
MSE	0.0003	0.0095
RMSE	0.0186	0.0978
U_1	0.3981	0.3350
U_2	0.8343	0.6903
U_m	0.0001	0.0005
U_r	0.2597	0.1873
U_d	0.7401	0.8121

TABLE 5.20. Base Case Forecasts for the Blue Crab Model

Year	PMSOFTL	PMHARDL	PMEXVHP	PMXPPOT	PMXPTRT	PMEXVSP	PMRPCRAB	PMWPCRAB
1980	1151.00	25,300.6	0.240139	0.255979	0.247225	1.23115	6.28115	4.52474
1981	1075.90	22,667.0	0.245054	0.261345	0.252163	1.23609	6.35279	4.61648
1982	1078.36	22,756.9	0.249968	0.266710	0.257102	1.23593	6.42443	4.70822
1983	1080.82	22,846.5	0.254882	0.272076	0.262041	1.23577	6.49607	4.79996
1984	1083.26	22,935.7	0.259796	0.277441	0.266979	1.23561	6.56772	4.89170
1985	1085.70	23,024.6	0.264711	0.282807	0.271918	1.23545	6.63936	4.98344
1986	1088.14	23,113.2	0.269625	0.288172	0.276857	1.23529	6.71100	5.07518
1987	1090.56	23,201.5	0.274539	0.293538	0.281795	1.23513	6.78264	5.16692
1988	1092.98	23,289.6	0.279453	0.298903	0.286734	1.23497	6.85428	5.25866
1989	1095.39	23,377.3	0.284368	0.304269	0.291673	1.23481	6.92592	5.35040
1990	1097.79	23,464.8	0.289282	0.309634	0.296611	1.23465	6.99756	5.44214

Year	PVSOFTL	PVHARDL	PVEXVHP	PVXPDRG	PVXPPOT	PVEXVSP	PVRPCRAB	PVWPCRAB
1980	633.00	37,691.8	0.182331	0.202113	0.185467	1.04464	6.69943	4.56006
1981	787.050	37,906.8	0.185373	0.205586	0.188503	1.03276	6.76722	4.64426
1982	788.063	37,966.8	0.188415	0.209059	0.191539	1.03268	6.83501	4.72845
1983	789.077	38,026.8	0.191457	0.212532	0.194575	1.03261	6.90280	4.81264
1984	790.090	38,086.8	0.194499	0.216005	0.197611	1.03253	6.97058	4.89684
1985	791.103	38,146.8	0.197540	0.219478	0.200648	1.03245	7.03837	4.98103
1986	792.116	38,206.8	0.200582	0.222951	0.203684	1.03237	7.10616	5.06523
1987	793.129	38,266.7	0.203624	0.226424	0.206720	1.03229	7.17395	5.14942
1988	794.142	38,326.7	0.206668	0.229897	0.209756	1.03222	7.24174	5.23362
1989	795.155	38,386.7	0.209708	0.233370	0.212792	1.03214	7.30952	5.31781
1990	796.169	38,446.7	0.212750	0.236843	0.215828	1.03206	7.37731	5.40201

TABLE 5.21. Effects on Blue Crab Model Forecasts of IIGS Increasing by Ten Percent

Year	PMSOFTL	PMHARDL	PMEXVHP	PMXPPOT	PMXPTRT	PMEXVSP	PMRPCRAB	PMWPCRAB
1980	1151.00	25,300.6	0.242523	0.258582	0.249620	1.23115	6.32575	4.61174
1981	1077.10	22,710.7	0.247437	0.263947	0.254559	1.23602	6.39739	4.70348
1982	1079.55	22,800.4	0.252352	0.269313	0.259498	1.23585	6.46903	4.79522
1983	1082.01	22,889.8	0.257266	0.274678	0.264436	1.23569	6.54068	4.88696
1984	1084.45	22,978.9	0.262180	0.280044	0.269375	1.23553	6.61232	4.97870
1985	1086.88	23,067.6	0.267095	0.285409	0.274314	1.23537	6.68396	5.07044
1986	1089.31	23,156.1	0.272009	0.290775	0.279252	1.23521	6.75560	5.16218
1987	1091.73	23,244.3	0.276923	0.296140	0.284191	1.23505	6.82724	5.25392
1988	1094.15	23,332.2	0.281837	0.301506	0.289130	1.23489	6.89888	5.34566
1989	1096.55	23,419.8	0.286752	0.306871	0.294068	1.23473	6.97052	5.43740
1990	1098.95	23,507.1	0.291666	0.312237	0.299007	1.23458	7.04216	5.52914

Year	PVSOFTL	PVHARDL	PVEXVHP	PVXPDRG	PVXPPOT	PVEXVSP	PVRPCRAB	PVWPCRAB
1980	633.000	37,691.8	0.184607	0.204711	0.187738	1.04464	6.76337	4.68493
1981	787.808	37,951.7	0.187649	0.208184	0.190774	1.03270	6.83116	4.76912
1982	788.821	38,011.7	0.190690	0.211657	0.193810	1.03263	6.89895	4.85331
1983	789.834	38,071.7	0.193732	0.215130	0.196846	1.03255	6.96674	4.93751
1984	790.848	38,131.7	0.196774	0.218603	0.199883	1.03247	7.03452	5.02170
1985	791.861	38,191.6	0.199816	0.222076	0.202919	1.03239	7.10231	5.10590
1986	792.874	38,251.6	0.202858	0.225549	0.205955	1.03231	7.17010	5.19009
1987	793.887	38,311.6	0.205899	0.229022	0.208991	1.03224	7.23789	5.27429
1988	194.900	38,371.6	0.208941	0.232495	0.212027	1.03216	7.30568	5.35848
1989	795.913	38,431.6	0.211983	0.235968	0.215063	1.03208	7.37346	5.44268
1990	796.927	38,491.6	0.215025	0.239441	0.218099	1.03200	7.44125	5.52687

TABLE 5.22. Effects on Blue Crab Model Forecasts of Population Increasing by Five Percent

Year	PMSOFTL	PMHARDL	PMEXVHP	PMXPPOT	PMXPTRT	PMEXVSP	PMRPCRAB	PMWPCRAB
1980	1151.00	25,300.6	0.241915	0.257918	0.249009	1.23115	6.35759	4.55130
1981	1076.79	22,699.5	0.246829	0.263283	0.253948	1.23604	6.42923	4.64304
1982	1079.25	22,789.3	0.251743	0.268649	0.258886	1.23587	6.50087	4.73477
1983	1081.70	22,878.7	0.256658	0.274014	0.263825	1.23571	6.57251	4.82651
1984	1084.15	22,967.8	0.261572	0.279380	0.268764	1.23555	6.64415	4.91825
1985	1086.58	23,056.7	0.266486	0.284745	0.273702	1.23539	6.71579	5.00999
1986	1089.01	23,145.2	0.271400	0.290111	0.278641	1.23523	6.78743	5.10173
1987	1091.43	23,233.4	0.276315	0.295476	0.283580	1.23507	6.85907	5.19347
1988	1093.85	23,321.3	0.281229	0.300842	0.288518	1.23491	6.93071	5.28521
1989	1096.25	23,408.9	0.286143	0.306207	0.293457	1.23475	7.00236	5.37695
1990	1098.66	23,496.3	0.291057	0.311573	0.298396	1.23460	7.07400	5.46869

Year	PVSOFTL	PVHARDL	PVEXVHP	PVXPDRG	PVXPPOT	PVEXVSP	PVRPCRAB	PVWPCRAB
1980	633.000	37,691.8	0.183465	0.203407	0.186598	1.04464	6.77390	4.58276
1981	787.428	37,929.2	0.186506	0.206880	0.189634	1.03273	6.84169	4.66696
1982	788.441	37,989.2	0.189548	0.210353	0.192670	1.03266	6.90948	4.75115
1983	789.454	38,049.1	0.192590	0.213826	0.195706	1.03258	6.97727	4.83535
1984	790.467	38,109.1	0.195632	0.217299	0.198743	1.03250	7.04505	4.91954
1985	791.480	38,169.1	0.198674	0.220772	0.201779	1.03242	7.11284	5.00374
1986	792.493	38,229.1	0.201716	0.224245	0.204815	1.03234	7.18063	5.08793
1987	793.507	38,289.1	0.204757	0.227718	0.207851	1.03226	7.24842	5.17213
1988	794.520	38,349.1	0.207799	0.231191	0.210887	1.03219	7.31621	5.25632
1989	795.533	38,409.1	0.210841	0.234664	0.213923	1.03211	7.38399	5.34051
1990	796.546	38,469.0	0.213883	0.238137	0.216959	1.03203	7.45178	5.42471

TABLE 5.23. Effects on Blue Crab Model Forecasts of Income Increasing by Ten Percent

Year	PMSOFTL	PMHARDL	PMEXVHP	PMXPPOT	PMXPTRT	PMEXVSP	PMRPCRAB	PMWPCRAB
1980	1151.00	25,300.6	0.245014	0.261301	0.252123	1.28915	6.49100	4.59764
1981	1078.34	22,756.2	0.249928	0.266667	0.257062	1.29394	6.56264	4.68938
1982	1080.80	22,845.7	0.254842	0.272032	0.262001	1.29378	6.63429	4.78112
1983	1083.25	22,935.0	0.259757	0.277398	0.266939	1.29362	6.70593	4.87286
1984	1085.68	23,023.9	0.264671	0.282763	0.271878	1.29346	6.77757	4.96460
1985	1088.12	23,112.5	0.269585	0.288129	0.276817	1.29330	6.84921	5.05634
1986	1090.54	23,200.8	0.274499	0.293494	0.281755	1.29314	6.92085	5.14808
1987	1092.96	23,288.8	0.279414	0.298860	0.286694	1.29298	6.99249	5.23982
1988	1095.37	23,376.6	0.284328	0.304225	0.291633	1.29282	7.06413	5.33155
1989	1097.77	23,464.1	0.289242	0.309591	0.296571	1.29266	7.13577	5.42329
1990	1100.17	23,551.3	0.294156	0.314956	0.301510	1.29250	7.20742	5.51503

Year	PVSOFTL	PVHARDL	PVEXVHP	PVXPDRG	PVXPPOT	PVEXVSP	PVRPCRAB	PVWPCRAB
1980	633.000	37,691.8	0.185443	0.205666	0.188573	1.09563	6.90389	4.62240
1981	788.087	37,968.2	0.188485	0.209139	0.191609	1.08367	6.97168	4.70659
1982	789.100	38,028.2	0.191526	0.212612	0.194645	1.08359	7.03947	4.79078
1983	790.113	38,088.2	0.194568	0.216085	0.197681	1.08352	7.10725	4.87498
1984	791.126	38,148.1	0.197610	0.219558	0.200717	1.08344	7.17504	4.95917
1985	792.139	38,208.1	0.200652	0.223031	0.203753	1.08336	7.24283	5.04337
1986	793.152	38,268.1	0.203694	0.226504	0.206789	1.08328	7.31062	5.12756
1987	794.166	38,328.1	0.206736	0.229977	0.209826	1.08320	7.37841	5.21176
1988	795.179	38,388.1	0.209777	0.233450	0.212862	1.08313	7.44620	5.29595
1989	796.192	38,448.1	0.212819	0.236923	0.215898	1.08305	7.51398	5.38014
1990	797.205	38,508.1	0.215861	0.240396	0.218934	1.08297	7.58177	5.46434

TABLE 5.24. Effects on Blue Crab Model Forecasts of CPIMPF Increasing by Ten Percent

Year	PMSOFTL	PMHARDL	VMEXVHP	PMXPPOT	PMXPTRT	PMEXVSP	PMRPCRAB	PMWPCRAB
1980	1151.00	25,300.6	0.246206	0.262603	0.253321	1.23115	6.54232	4.61547
1981	1078.94	22,777.9	0.251120	0.267968	0.258260	1.23589	6.61396	4.70721
1982	1081.39	22,867.4	0.256034	0.273334	0.263199	1.23573	6.68560	4.79895
1983	1083.84	22,956.6	0.260949	0.278699	0.268137	1.23557	6.75724	4.89068
1984	1086.27	23,045.4	0.265865	0.284065	0.273076	1.23541	6.82889	4.98242
1985	1088.70	23,133.9	0.270777	0.289430	0.278015	1.23525	6.90053	5.07416
1986	1091.13	23,222.2	0.275691	0.294796	0.282953	1.23509	6.97217	5.16590
1987	1093.54	23,310.2	0.280606	0.300161	0.287892	1.23493	7.04381	5.25764
1988	1095.95	23,397.8	0.285520	0.305527	0.292831	1.23477	7.11545	5.34938
1989	1098.35	23,485.3	0.290434	0.310892	0.297769	1.23462	7.18709	5.44112
1990	1100.75	23,572.4	0.295348	0.316258	0.302708	1.23446	7.25873	5.53286

Year	PVSOFTL	PVHARDL	PVEXVHP	PVXPDRG	PVXPPOT	PVEXVSP	PVRPCRAB	PVWPCRAB
1980	633.000	37,691.8	0.186204	0.206534	0.189332	1.04464	6.95389	4.63764
1981	788.340	37,983.2	0.189246	0.210007	0.192368	1.03266	7.02168	4.72183
1982	789.353	38,043.2	0.192287	0.213480	0.195404	1.03259	7.08947	4.80603
1983	790.366	38,103.2	0.195329	0.216953	0.198440	1.03251	7.15725	4.89022
1984	791.380	38,163.1	0.198371	0.220426	0.201477	1.03243	7.22504	4.97442
1985	792.393	38,223.1	0.201413	0.223899	0.204513	1.03235	7.29283	5.05861
1986	793.406	38,283.1	0.204455	0.227372	0.207549	1.03227	7.36062	5.14280
1987	794.419	38,343.1	0.207496	0.230845	0.210585	1.03219	7.42841	5.22700
1988	795.432	38,403.1	0.210538	0.234318	0.213621	1.03212	7.49619	5.31119
1989	796.445	38,463.1	0.213580	0.237792	0.216657	1.03204	7.56398	5.39539
1990	797.458	38,523.1	0.216622	0.241265	0.219693	1.03196	7.63177	5.47958

6.0 ECONOMIC MODELS OF THE HARD CLAM INDUSTRY

This chapter documents the development of demand and supply models for hard clams. Industry background is provided in the first section. This includes an overview of clam production, processing and consumption. The second section describes the models and provides the rationale for their structure. Estimation results are presented in the third section and details of model validation in the fourth.

6.1 BACKGROUND

The hard clam (Mercenaria mercenaria) harvest from the Chesapeake Bay occurs in Virginia, although in some recent years Maryland has had a small harvest. In a national context, the Virginia harvest represents a small share of the U.S. total and that share has not changed significantly in recent years (see Table 6.1). Therefore, economic modeling of the Chesapeake Bay hard clam fishery includes only Virginia production and must recognize that Virginia historically has not been a primary U.S. producer of hard clams.

6.1.1 Overview of Hard Clam Production

One important feature of the hard clam market is the dominance of Northeastern production, most particularly New York production. Table 6.1 shows that for most years a significant share of total U.S. production came from New York. Virginia clams, which are part of this harvest, are shipped almost exclusively to Northeast markets. Over the period 1960 to 1980, annual production of hard clams in the U.S. was significantly related to New York harvest as the following equations show:

$$\underset{(980.573)}{\mathrm{TUSCL} = 12309.776^{*}} + \underset{(0.141153)}{0.383648^{*}\,\mathrm{CLNY}}$$

$$R^2 = 0.2802$$

$$\text{D-W} = 0.690$$

where

TUSCL = total U.S. clam landings (pounds)
CLNY = New York landings of clams (pounds).

TABLE 6.1. Virginia and New York Share of U.S. Hard Clam Landings

Year	Virginia Percent Share	New York Percent Share
1960	11.1649	26.1343
1961	12.7431	29.3824
1962	12.7115	36.3746
1963	14.4263	36.5545
1964	16.4355	36.1943
1965	16.5315	39.5374
1966	12.1378	42.9457
1967	11.4943	43.6658
1968	12.1159	45.2872
1969	11.7804	46.5272
1970	8.3110	49.3662
1971	11.0224	51.2961
1972	8.2833	52.6218
1973	9.3347	49.9565
1974	9.4550	53.4901
1975	7.2581	57.8059
1976	5.8573	59.1987
1977	6.6094	55.2360
1978	3.7400	55.3080
1979	5.1394	47.2802
1980	5.6326	36.9835

The harvest of hard clams in Virginia depends upon the harvest gear used and the population stocks to be harvested. State fishery management policy permits only labor-intensive harvest gears such as hand tongs, clam rakes and patent tongs. Of the gears permitted for use, the patent tong is the most labor-efficient and provides the dominant share of the total hard clam harvest.

Harvestable populations of hard clams depend upon natural conditions, without any public management except restrictions on harvest effort. The harvest of hard clams from Virginia waters has shown some decline from 1963 to

1981 (see Table 6.2). Using patent tong licenses over the period as a measure of fishing effort, it is clear that catch per unit of effort in the fishery has trended downward. This decline is most likely due to fishing pressures on the stocks of clams, which are slow to grow to harvestable size. There is no evidence to suggest that catch per unit of effort will return to higher levels unless effort itself is reduced for sufficient time for clam stocks to increase.

6.1.2 Overview of Processing and Consumption

At the "consumer" level, clams are graded into three groups according to size: littlenecks, cherrystones and chowders. Chowder clams are the largest and often are purchased for use in commercial soup production. They have few other uses. However, ocean quahogs may also be used in soup production and are produced in larger quantities than hard clams. As a result, chowder clam prices are the lowest of the three grades.

Littleneck and cherrystone clams are usually marketed in the shell with no processing other than washing and some refrigeration to keep the clams fresh. These size clams command a higher price, with the littleneck clam being the most valuable.

Table 6.3 shows the relative prices for littleneck, cherrystone and chowder clams at the Fulton fish market in New York. While there are significant price differences, the prices of the three grades are hypothesized to move together. To test this hypothesis, the following equations were estimated using annual data for 1960 to 1980:

$$\begin{aligned} \text{CHOWP} &= \underset{(0.258017)}{1.918898^{*}} + \underset{(0.00806)}{0.162304^{*}}\ \text{NECKP} \end{aligned}$$

$$R^2 = 0.9557$$

$$\text{D-W} = 0.585$$

$$\begin{aligned} \text{CHERP} &= \underset{(0.291468)}{4.981529^{*}} + \underset{(0.00910627)}{0.280856^{*}}\ \text{NECKP} \end{aligned}$$

$$R^2 = 0.9804$$

$$\text{D-W} = 0.962$$

TABLE 6.2. Virginia Hard Clam Harvest and Effort

Year	Harvest[a]	Effort[b]	Productivity[c]
1953	873.0	24	36.3750
1954	729.0	29	25.1379
1955	887.0	22	40.3182
1956	796.0	12	66.3333
1957	725.0	8	90.6250
1958	711.0	18	39.5000
1959	1690.0	54	31.2963
1960	1661.0	28	59.3214
1961	1861.0	34	54.7353
1962	1690.0	66	25.6061
1963	2096.0	120	17.4667
1964	2453.0	130	18.8692
1965	2487.0	121	20.5537
1966	1860.0	172	10.8140
1967	1866.0	133	14.0301
1968	1859.0	119	15.6218
1969	1903.0	81	23.4938
1970	1330.7	84	15.8417
1971	1836.5	96	19.1302
1972	1337.6	90	14.8622
1973	1354.2	95	14.2547
1974	1419.1	92	15.4250
1975	1088.3	99	10.9929
1976	893.0	91	9.8132
1977	1021.0	88	11.6023
1978	495.8	79	6.2759
1979	620.0	104	5.9615
1980	753.0	146	5.1575
1981	1110.0	144	7.7083

(a) Virginia landings of hard clams (in thousands of pounds)

(b) Number of patent tong licenses.

(c) Harvest/licenses.

TABLE 6.3. Littleneck, Cherrystone, and Chowder Clam Prices at the Fulton Fish Market in New York

Year	Prices (per bushel)		
	Littleneck	Cherrystone	Chowder
1960	13.44	8.06	4.11
1961	11.75	7.86	4.26
1962	12.44	8.54	4.43
1963	15.00	9.31	4.65
1964	15.95	9.31	4.62
1965	15.37	9.89	4.79
1966	15.06	10.06	4.94
1967	17.08	10.52	4.84
1968	17.25	10.47	5.06
1969	20.02	10.50	5.20
1970	21.66	10.58	5.14
1971	24.66	11.02	5.22
1972	29.09	11.56	5.47
1973	31.62	14.02	5.98
1974	32.57	14.48	6.46
1975	34.50	15.34	6.89
1976	37.99	16.08	8.32
1977	43.03	17.00	9.34
1978	52.45	18.84	10.42
1979	60.51	22.20	12.67
1980	65.01	23.68	12.67

where

CHERP = wholesale price of cherrystone clams at Fulton, New York (dollars per bushel)

CHOWP = wholesale price of chowder clams at Fulton, New York (dollars per bushel)

NECKP = wholesale price of littleneck clams at Fulton, New York (dollars per bushel).

The strong relationship of both chowder and cherrystone prices to littleneck prices is evident.

6.2 DEMAND AND SUPPLY SYSTEM

Figure 6.1 is a schematic diagram of the demand and supply models to be estimated for this fishery. In Figure 6.1 the demand Equations (1) to (3) show that wholesale prices, New York ex-vessel prices and Virginia ex-vessel prices are determined simultaneously and depend upon a number of exogenous variables, including Virginia hard clam landings. Equations (4) and (5) are the supply model equations which indicate that current year's landings depend upon current year fishery effort, which in turn depends upon the last year's prices. This lagged response to price permits landings to be treated as exogenous in the demand system. Total harvest revenue for Virginia (Equation 6) is the product of landings and Virginia ex-vessel price in any period.

6.2.1 Demand Model

Virginia, as well as other Southeastern states, contributes a small share to total U.S. production. The dominance of the Northeastern states, especially New York, suggests that a model of price formation for Virginia hard clams must recognize the supplemental nature of Virginia production.

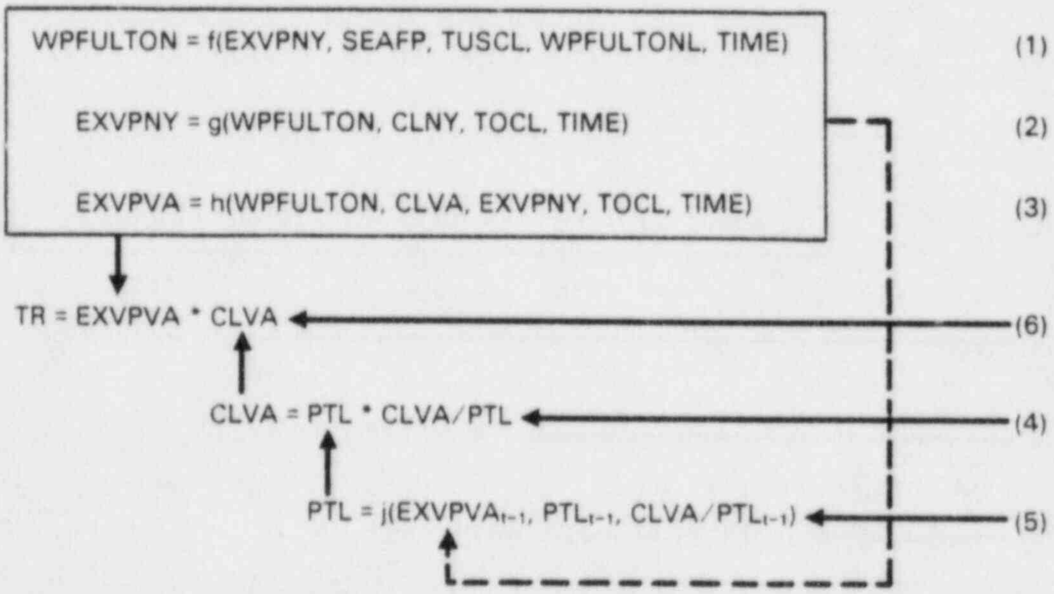


FIGURE 6.1. Demand and Supply System for Virginia Hard Clams

The relationship among ex-vessel, wholesale, and retail prices for clams depends upon consumer demand, product supply, and marketing cost. Retail price influences wholesale price, which in turn influences ex-vessel price. At the same time, ex-vessel price influences wholesale price, which in turn influences retail price. Therefore, prices at the three levels of the marketing system can be said to be simultaneously determined.

For purposes of model construction, specific equations developed for Virginia hard-clam price-dependent demand models must recognize two conditions that alter this general view of simultaneously determined prices. First, there is no price series published for retail hard clam prices. Therefore, only a model limited to wholesale and ex-vessel prices can be constructed. Second, because of the dominance of the New York harvest, wholesale prices would be hypothesized to be interdependent with New York prices. Virginia prices will depend upon the wholesale price levels and the New York ex-vessel price, but there will be no causality from the Virginia price to New York and wholesale prices.

With these qualifications in mind the demand system shown as Equations (1) to (3) was defined.

$$\mathrm{WPFULTON} = f(\mathrm{EXVPNY}, \mathrm{SEAFP}, \mathrm{TUSCL}, \mathrm{WPFULTONL}, \mathrm{TIME}) \tag{1}$$

$$\mathrm{EXVPNY} = g(\mathrm{WPFULTON}, \mathrm{CLNY}, \mathrm{TOCL}, \mathrm{TIME}) \tag{2}$$

$$\mathrm{EXVPVA} = h(\mathrm{WPFULTON}, \mathrm{CLVA}, \mathrm{EXVPNY}, \mathrm{TOCL}, \mathrm{TIME}) \tag{3}$$

where

WPFULTON = wholesale price of hard clams (littlenecks) (dollars per bushel)

EXVPNY = New York ex-vessel price of hard clams (dollars per pound)

EXVPVA = Virginia ex-vessel price of hard clams (dollars per pound)

SEAFP = consumer price index for fish (1967=100)

TUSCL = total landings of hard clams in the United States (pounds)

CLNY = New York landings of hard clams (pounds)

CLVA = Virginia landings of hard clams (pounds)

TOCL = total landings of ocean quahogs (pounds)

WPFULTONL = lag of WPFULTON

TIME = year.

Because of the dominance of the New York harvest, wholesale price is hypothesized to be positively related to the New York ex-vessel price. The seafood price index, a demand shift variable that serves as a proxy for retail demand, is hypothesized to be positively related to the wholesale price. Total clam landings are hypothesized to be negatively related to price, and lagged wholesale price is expected to be positively related to current price. Ex-vessel prices in New York and wholesale prices are simultaneously determined. A positive sign on wholesale price is expected in the New York ex-vessel price equation. New York landings are hypothesized to affect price negatively.

The final factor in the ex-vessel price equation is the quantity of ocean quahogs, a substitute for chowder clams. Normally, the quantity of a substitute commodity is expected to be negatively related to price. In the case of hard clams and ocean quahogs the expected relationship does not occur, since ocean quahogs are substituted for the lowest price chowder clams only. Thus, if ocean quahogs displace chowder clams, the overall price for hard clams would increase due to the culling of low priced chowders from the harvest.

Ex-vessel prices in Virginia are simultaneously determined with ex-vessel prices in New York. These prices are expected to be inversely related. Virginia ex-vessel prices should be positively related to wholesale price and directly related to Virginia landings. The argument about ocean quahog landings is the same as in the New York equation.

6.2.2 Supply Model

Although hard clams are harvested by a number of gear types, in Virginia the gear type that accounts for the largest share of the harvest is the patent tong. Therefore, Equation (4) reflects the dominance of this gear by representing the total Virginia clam harvest as the product of the number of patent tong licenses and the harvest per license.

$$CLVA = PTL * CLVA/PTL \tag{4}$$

where

CLVA = annual landings of hard clams in Virginia (pounds)

PTL = patent tong license holders

CLVA/PTL = reported hard clam harvest divided by reported number of patent tong licenses.

There is little research available to aid in understanding population dynamics of the hard clam and, therefore, patterns of harvest per unit of effort. In general, there is agreement that, beyond some point, further fishing effort can reduce stock levels, affecting spawning and recruitment (Conrad 1982, Martin-Marietta 1980a). No specific conclusions about the relationship between current effort and future populations of Virginia hard clams have been made to date. Therefore, catch per unit of effort, which will depend upon population levels, is an exogenous variable in the supply model.

The number of patent tong licenses in any year (harvest effort) will depend upon the expectations that clammers have for earnings in the fishery. These expectations are based upon prices and unit harvest cost in the previous year. Harvest costs are determined by the cost of inputs and the productivity of harvest gear. In the hard clam fishery, input costs do not change markedly from year to year because there are few variable costs (primarily fuel) and the craft is frequently used in other fisheries. However, the productivity of the harvest gear has changed significantly over time and this change would be expected to raise harvest costs. Stickiness in adjusting to changing price and cost conditions is also hypothesized. Therefore, Equation (5) states:

$$\mathrm{PTL}_t = j(\mathrm{EXVPVA}_{t-1}, \mathrm{PTL}_{t-1}, \mathrm{CLVA/PTL}_{t-1}) \tag{5}$$

where

PTL = annual patent tong licenses

EXVPVA = ex-vessel price of hard clams in Virginia (dollars per pound)

CLVA/PTL = harvest per patent tong license (gear productivity) in Virginia

t = year.

6.3 ESTIMATION RESULTS

Results of the supply and demand model estimation are briefly discussed in this section.

6.3.1 Supply Model

Virginia supply models for hard clams were estimated using annual data for the years 1963 to 1981. The analysis began with 1963 because the disruption to the whole Chesapeake Bay harvest sector (all species) caused by the MSX oyster disease had dissipated by that time. Data used were taken from the 1982 annual report of the Virginia Marine Resources Commission. Estimates were made using ordinary least squares estimation procedures. Appendix A.3 includes the data used in these models.

Table 6.4 provides the results from the estimation of Equation (5). The R^2, standard errors, and D-W statistics are reported. Signs are as hypothesized and the statistical properties of the equation are satisfactory.

6.3.2 Demand Model

The price-dependent demand equations were estimated from annual data for the years 1960 to 1980. Data used were from the National Marine Fisheries Service and the U.S. Department of Commerce, Bureau of Labor Statistics. Data used are reported in Appendix A.3. Attempts to estimate the hard clam model using traditional methods of two-stage and three-stage least squares procedures were plagued by deleterious collinearity problems. Therefore, ridge regression procedures were used. (See discussion of this technique in section on oyster demand models.) Collinearity diagnostics are reported in Appendix B.3.

TABLE 6.4. Hard Clam Supply Model Estimation Results

$$\begin{aligned} PTL = &\underset{(52.23839)}{-60.61546} + \underset{(15.93133)}{37.85281^{*}}\, EXVPVA_{t-1} \\ &+ \underset{(0.21179)}{0.78182^{*}}\, PTL_{t-1} + \underset{(1.61574)}{3.59445^{*}}\, CLVA/PTL_{t-1} \end{aligned} \qquad (5)$$

$R^2 = 0.4901$

$D\text{-}W = 2.130$

Table 6.5 presents the results for the hard clam demand model. The hypothesized signs were realized and the overall statistical properties of each equation are satisfactory.

TABLE 6.5. Demand Estimation: Virginia Hard Clam Industry

	Wholesale Price (WPFULTON)	New York Ex-Vessel Price (EXVPNY)	Virginia Ex-Vessel Price (EXVPVA)
Intercept	18.1619* (7.8216)	0.6960* (0.2340)	0.4338* (0.1124)
WPFULTON	--	0.01623* (0.00826)	0.00889* (0.00089)
EXVPNY	4.8680* (1.4245)	--	0.1265* (0.0219)
SEAFP	0.05072* (0.01924)	--	--
TUSCL	-0.00125* (0.00049)	--	--
CLNY	--	-0.000097* -(0.000048)	--
CLVA	--	--	-0.000099* (0.000047)
TOCL	--	0.000208* (0.000011)	0.000018* (0.000002)
WPFULTONL	0.2457* (0.1046)	--	--
TIME	0.6438* (0.2026)	0.07722* (0.02146)	0.007053* (0.003847)
R^2	0.9925	0.9726	0.9734
D-W	1.6231	1.6153	1.6897
K	0.01	0.01	0.015

*Indicates significance.

6.4 MODEL VALIDATION

Validation of the model, beyond the statistical tests, included 1) development of static backcasts using only the analytically derived reduced form equations for the demand system (Table 6.6), 2) use of reduced forms from the demand and supply equations for dynamic backcasts, and 3) "shocking" the demand

TABLE 6.6. Analytically Derived Reduced Form Equations for Virginia Hard Clams

$$\begin{aligned}\mathrm{WPFULTON} = {} & 23.3987 + 0.055071\ \mathrm{SEAFP} - 0.0013594\ \mathrm{TUSCL} + 0.266777\ \mathrm{WPFULTONL} \\ & + 1.10718\ \mathrm{TIME} - 0.00514818\ \mathrm{CLNY} + 0.000109782\ \mathrm{TOCL}\end{aligned}$$

$$\begin{aligned}\mathrm{EXVPNY} = {} & 1.07356 + 0.000893803\ \mathrm{SEAFP} - 0.000027063\ \mathrm{TUSCL} + 0.0043248 \\ & \mathrm{WPFULTON} + 0.0951896\ \mathrm{TIME} - 0.000105755\ \mathrm{CLNY} + 0.0000225518\ \mathrm{TOCL}\end{aligned}$$

$$\begin{aligned}\mathrm{EXVPVA} = {} & 0.777922 + 0.000602703\ \mathrm{SEAFP} - 0.000014877\ \mathrm{TUSCL} + 0.00291964 \\ & \mathrm{WPFULTONL} + 0.0289384\ \mathrm{TIME} - 0.0000179553\ \mathrm{CLNY} + 0.0000222889\ \mathrm{TOCL} \\ & - 0.00009912\ \mathrm{CLVA}\end{aligned}$$

system to evaluate forecast sensitivity to changes in exogenous variables. Static backcasts were developed for the period 1960 to 1980 (Table 6.7). The U_m, U_r, and U_d proportions, components of the MSE decomposition, indicate that the model performs adequately in backcast evaluation (Table 6.8). Reduced forms of the demand and supply models were incorporated into a simulation model to develop dynamic backcasts (Table 6.9). The backcast evaluation statistics (Table 6.10) indicate that the model performs adequately. Also, the system was "shocked" to test the forecast sensitivity to changes in exogenous variables. Initially, base case forecasts were obtained for the period 1980 to 1990 by fixing all exogenous variables at 1980 levels. Then, the model was shocked by adjusting the exogenous variable SEAFP upward to determine whether the demand system becomes unstable. Examination of Tables 6.11 and 6.12 suggests that the system is stable.

TABLE 6.7. Static Backcasts for the Hard Clam Model

Year	WPFULTON	PWPFULTON	EXVPNY	PEXVPNY	EXVPVA	PEXVPVA
1960	13.44	--	0.61523	--	0.45515	--
1961	11.75	11.9361	0.58098	0.62880	0.46480	0.45140
1962	12.44	14.2833	0.60505	0.68985	0.48047	0.50295
1963	15.00	13.6455	0.67426	0.71122	0.48282	0.46747
1964	15.95	14.7358	0.76564	0.79746	0.49694	0.45991
1965	15.37	15.7946	0.86567	0.83827	0.53760	0.47780
1966	15.06	16.3652	0.87950	0.86305	0.54301	0.55517
1967	17.08	16.1503	1.00340	0.88859	0.56290	0.56269
1968	17.25	18.9732	1.04037	1.02316	0.56447	0.61430
1969	20.02	19.2170	1.08821	1.06131	0.63058	0.63262
1970	21.66	21.7568	1.13547	1.16478	0.65515	0.75249
1971	24.66	22.7996	1.25828	1.20222	0.76102	0.72866
1972	29.09	26.0047	1.55694	1.32311	0.84454	0.81730
1973	31.62	32.3367	1.50562	1.62639	0.92910	0.91847
1974	32.57	34.3324	1.67234	1.64634	0.93658	0.92732
1975	34.50	36.2941	1.64986	1.70323	0.93903	1.00084
1976	37.99	39.1770	2.00711	1.88158	0.97167	1.15491
1977	43.03	43.7914	2.11755	2.31728	1.29128	1.45440
1978	52.45	51.4318	2.40589	2.69974	1.93871	1.68884
1979	60.51	59.9262	3.07610	3.23858	2.02513	1.97217
1980	65.01	63.9703	4.00065	3.57700	2.26404	2.15311

WPFULTON, PWPFULTON: actual and backcast values of wholesale price of hard clams.

EXVPNY, PEXVPNY: actual and backcast values of ex-vessel price of hard clams at New York.

EXVPVA, PEXVPVA: actual and backcast values of ex-vessel price of hard clams at Virginia.

TABLE 6.8. Static Backcast Evaluations of the Hard Clam Model

	Wholesale Price (WPFULTON)	New York Ex-Vessel Price (EXVPNY)	Virginia Ex-Vessel Price (EXVPVA)
MSE	1.868	0.0225	0.0080
RMSE	1.4025	0.1541	0.0921
U_1	0.1880	0.2646	0.2690
U_2	0.3674	0.5141	0.5104
U_m	0.000009	0.000005	0.0002
U_r	0.0090	0.0405	0.0092
U_d	0.9909	0.9594	0.9905

TABLE 6.9. Dynamic Backcasts for the Hard Clam Model

Year	CLVA	PCLVA	WPFULTON	PWPFULTON	EXVPNY	PEXVPNY	EXVPVA	PEXVPVA
1960	1661.00	1661.00	13.44	--	0.61523	--	0.45515	0
1961	1861.00	--	11.75	11.9361	0.58098	0.62880	0.46480	0.45140
1962	1690.00	--	12.44	14.2833	0.60505	0.68985	0.48047	0.50295
1963	2096.00	1748.61	15.00	13.6455	0.67426	0.71122	0.48282	0.46747
1964	2453.00	2170.41	15.95	14.7358	0.76564	0.79746	0.49694	0.45991
1965	2487.00	2600.88	15.37	15.7946	0.86567	0.83827	0.53760	0.47780
1966	1860.00	1354.70	15.06	16.3652	0.87950	0.86305	0.54301	0.55517
1967	1860.00	1835.33	17.08	16.1503	1.00340	0.88859	0.56290	0.56269
1968	1869.00	1793.57	17.25	18.9732	1.04037	1.02316	0.56447	0.61430
1969	1903.00	2581.33	20.02	19.2170	1.08821	1.06131	0.63058	0.63262
1970	1331.00	1749.11	21.66	21.7568	1.13547	1.16478	0.65515	0.75249
1971	1837.00	1644.16	24.66	22.7996	1.25828	1.20222	0.76102	0.72866
1972	1338.00	1659.90	29.09	26.0047	1.55694	1.32311	0.84454	0.81730
1973	1354.00	1293.64	31.62	32.3367	1.50562	1.62639	0.92910	0.91847
1974	1419.00	1478.22	32.57	34.3324	1.67234	1.64634	0.93658	0.92732
1975	1088.36	1116.04	34.50	36.2941	1.64986	1.70323	0.93903	1.00084
1976	893.30	896.92	37.99	39.1770	2.00711	1.88158	0.97167	1.15491
1977	1020.69	970.97	43.03	43.7914	2.11755	2.31728	1.29128	1.45440
1978	497.24	587.46	52.45	51.4318	2.40589	2.69974	1.93871	1.68884
1979	619.71	469.53	60.51	59.9262	3.07610	3.23858	2.02513	1.97217
1980	753.08	546.96	65.01	63.9703	4.00065	3.57700	2.26404	2.15311

CLVA, PCLVA: actual and backcast values of Virginia landings of hard clams.
WPFULTON, PWPFULTON: actual and backcast values of New York wholesale price.
EXVPNY, PEXVPNY: actual and backcast values of New York ex-vessel price.
EXVPVA, PEXVPVA: actual and backcast values of Virginia ex-vessel price.

TABLE 6.10. Dynamic Backcast Evaluations of the Hard Clam Model (1960 to 1980)

	Wholesale Price (WPFULTON)	New York Ex-Vessel Price (EXVPNY)	Virginia Ex-Vessel Price (EXVPVA)	CLVA
MSE	1.689	0.0225	0.0080	76670.4272
RMSE	1.4025	0.1541	0.0921	276.8942
U_1	0.1880	0.2646	0.2690	0.0935
U_2	0.3674	0.5141	0.5104	0.1927
U_m	0.000009	0.000005	0.0002	0.0036
U_r	0.0090	0.0405	0.0092	0.2585
U_d	0.9909	0.9594	0.9905	0.7378

TABLE 6.11. Base Case Forecasts for the Hard Clam Model

Year	PCLVA	PWPFULTON	PEXVPNY	PEXVPVA
1980	753.080	63.9703	3.57700	2.15311
1981	--	65.0775	3.67219	2.18205
1982	637.565	66.1846	3.76738	2.21099
1983	643.214	67.2918	3.86257	2.23992
1984	648.864	68.3990	3.95776	2.26886
1985	654.513	69.5062	4.05295	2.29780
1986	660.163	70.6134	4.14814	2.32674
1987	665.812	71.7205	4.24333	2.35568
1988	671.462	72.8277	4.33852	2.38461
1989	677.111	73.9349	4.43371	2.41355
1990	682.760	75.0421	4.52890	2.44249

TABLE 6.12. Effects on Hard Clam Model Forecasts of SEAFP Increasing by Ten Percent

Year	PCLVA	PWPFULTON	PEXVPNY	PEXVPVA
1980	753.080	65.7887	3.60652	2.17301
1981	--	66.8959	3.70171	2.20195
1982	641.450	68.0031	3.79690	2.23089
1983	647.099	69.1103	3.89208	2.25983
1984	652.749	70.2174	3.98727	2.28876
1985	658.398	71.3246	4.08246	2.31770
1986	664.048	72.4318	4.17765	2.34664
1987	669.697	73.5390	4.27284	2.37558
1988	675.347	74.6462	4.36803	2.40452
1989	680.996	75.7533	4.46322	2.43345
1990	686.646	76.8605	4.55841	2.46239

7.0 ECONOMIC MODELS OF THE SOFT CLAM INDUSTRY

An economic model of the soft clam industry is described in this chapter. The first section presents background on soft clam production, processing and consumption. Specific demand models are presented in the second section and estimation results in the third. Techniques used in model validation are discussed in the final section.

7.1 BACKGROUND

The soft clam (Mya arenaria) is harvested from the Chesapeake Bay only in Maryland. Nationally, two states provide the bulk of total harvest: Maine and Maryland (Table 7.1). In recent years, Maine production has been substantially larger than that of Maryland. Economic modeling of the Chesapeake Bay soft clam fishery will include only Maryland production.

At the "consumer" level, soft clams are consumed as shucked meats prepared as fried clams or steamed in the shell. A substantial portion of the total harvest is purchased for restaurant use. In recent years, surf clam "strips" (surf clams are harvested by ocean-going vessels along the mid-Atlantic coast) have been substituted for soft clams in frying. Virtually all Maryland clams are sold through the Fulton (New York) wholesale market prior to commercial distribution (Bundy and Williams 1978).

Soft clams are harvested in Maryland by hydraulic escalator dredge, a particularly labor-efficient harvest gear. The size of harvestable populations of soft clams depends solely upon environmental conditions such as temperature and salinity. Environmental conditions affect both reproduction and survival. Because the soft clam is a short-lived species (one to two years) which grows rapidly, fishing effort in the current period has little impact on future harvest (Martin-Marietta 1980b).

The Maryland harvest of soft clams did not begin in earnest until 1960, reaching a peak in the late 1960s. Coincident with the occurrence of Tropical Storm Agnes in 1972, soft clam landings fell dramatically and have continued at low levels (Table 7.2).

Despite this decline, fishing effort (measured by the number of operating clam dredges) has shown little variation in recent years and is not significantly below average levels for the pre-1972 period. As a result, catch per unit of effort declined sharply during the 1970s (Table 7.2).

TABLE 7.1. Share of U.S. Soft Clam Landings from Maryland and Maine (Percent)

Year	Maryland Share	Maine Share
1960	64.9143	24.1753
1961	63.7240	25.0441
1962	72.0200	21.0834
1963	70.3199	18.7820
1964	74.0163	16.3010
1965	67.6866	17.3682
1966	58.7885	25.2370
1967	53.0591	32.3323
1968	53.8098	32.1373
1969	58.6752	30.6728
1970	48.1949	40.7422
1971	47.3127	41.4954
1972	21.4695	67.6581
1973	7.7431	84.1544
1974	24.4240	68.7224
1975	13.5819	71.3647
1976	16.7288	70.3927
1977	16.4561	73.3408
1978	32.5439	59.5283
1979	33.3023	60.4892
1980	21.8708	63.4332

7.2 DEMAND AND SUPPLY SYSTEM

A review of the factors affecting supply in the fishery (effort and population stocks) suggests that soft clam landings are exogenous. First, the population stocks vary with the random forces of nature. Second, other than a one-time shift in dredge numbers after 1972, there appears to be insufficient variation in the data to make effort or supply modeling possible. Therefore, Maryland supply is treated as being exogenous to a system of demand equations.

TABLE 7.2. Harvest and Effort Levels for Soft Clams in Maryland (1960 to 1981)

Year	Harvest (thousands of lb)	Effort[a]	Productivity[b]
1960	5569	199	27.98
1961	4692	281	16.70
1962	6767	238	28.43
1963	6859	276	28.82
1964	8164	213	38.33
1965	7654	207	36.98
1966	7007	211	33.21
1967	5212	226	23.06
1968	5579	214	26.07
1969	7910	273	28.97
1970	6221	277	22.46
1971	5986	292	20.50
1972	1949	183	10.65
1973	668	206	3.24
1974	2098	263	8.00
1975	1246	178	7.00
1976	1751	199	8.80
1977	1654	186	8.89
1978	3450	194	17.78
1979	2883	N/A	N/A
1980	1925	N/A	N/A
1981	1575	N/A	N/A

(a) Operating units (escalator dredge gear).

(b) Catch-per-unit effort (harvest/effort).

Maine and Maryland together account for approximately 97 percent of total U.S. production of soft clams. The relative importance of the two states changed from 1960 to the present, and Maine produces the dominant market share.

At the most general level, the relationship among ex-vessel, wholesale, and retail prices for soft clams depends upon consumer demand, product supply, and marketing costs. Retail price influences wholesale price, which in turn influences ex-vessel price. At the same time, ex-vessel price influences wholesale price, which in turn influences retail price. Therefore, prices at the three respective levels of the marketing system can be said to be simultaneously determined.

Specific price-dependent demand models developed for Maryland soft clams must recognize two conditions which alter this general view of simultaneously determined prices. First, there is no soft clam retail price series published. Consequently, only price interrelationships between the wholesale and ex-vessel sectors can be considered in the modeling process. Second, because the Maine and Maryland harvests comprise the major part of U.S. landings, wholesale prices are potentially interdependent with Maine and Maryland ex-vessel prices. Additionally, Maryland ex-vessel prices are dependent upon Maine ex-vessel prices and wholesale prices and similarly, Maine ex-vessel prices are dependent upon Maryland ex-vessel prices and wholesale prices.

With these qualifications in mind, the demand system shown as Equations (1) to (3) follows:

$$\mathrm{WSOFTC} = h\,(\mathrm{WSOFTCL},\ \mathrm{SEAFP},\ \mathrm{TSOCL},\ \mathrm{EXVSOPME},\ \mathrm{EXVSOPMD},\ \mathrm{TIME}) \tag{1}$$

$$\mathrm{EXVSOPME} = f\,(\mathrm{WSOFTC},\ \mathrm{SOCLME},\ \mathrm{TSURCL},\ \mathrm{EXVSOPMD},\ \mathrm{TIME}) \tag{2}$$

$$\mathrm{EXVSOPMD} = g\,(\mathrm{WSOFTC},\ \mathrm{SOCLMD},\ \mathrm{TSURCL},\ \mathrm{EXVSOPME},\ \mathrm{TIME}) \tag{3}$$

where

WSOFTC = wholesale price of soft clams, New York (dollars per bushel)

WSOFTCL = lag (one period of WSOFTC)

EXVSOPME = ex-vessel price of soft clams, Maine (dollars per pound)

EXVSOPMD = ex-vessel price of soft clams, Maryland (dollars per pound)

SEAFP = consumer price index for fish (1967 = 100)

SOCLME = landings of soft clams in Maine (pounds)

SOCLMD = landings of soft clams in Maryland (pounds)

TSOCL = total landings of soft clams in the United States (1000 pounds)

TSURCL = total landings of surf clams in the United States (1000 pounds)

TIME = year.

It is hypothesized that both Maine and Maryland ex-vessel prices positively influence the wholesale price of soft clams at New York. The seafood price index, a demand shift variable which serves as a proxy for retail price, is hypothesized to be positively related to wholesale price. Total soft clam landings are hypothesized to be negatively related to wholesale price, and lagged wholesale price is expected to be positively related to current wholesale price.

A positive sign on wholesale price is expected in both the Maine and Maryland ex-vessel price relationships. Maine landings are hypothesized to negatively affect Maine ex-vessel price and similarly, Maryland landings are hypothesized to negatively affect Maryland ex-vessel prices. Maryland and Maine ex-vessel prices are expected to be directly related. Surf clam landings are hypothesized to negatively influence Maryland and Maine ex-vessel prices because surf clams can be substitutes for soft clams.

7.3 ESTIMATION RESULTS

The price-dependent demand equations were estimated from annual data for the years 1960 to 1980 using simultaneous-equation estimation procedures. Based on the rank and order conditions, all equations were overidentified. Due to the presence of collinearity among predetermined variables, ridge regression techniques for simultaneous equation models were employed to circumvent this ill-conditioning (see Appendix B.4 for collinearity diagnostics in the first- and second-stage estimation). Data used were from the National Marine Fisheries Service and the U.S. Department of Commerce and are reported in Appendix A.4.

Table 7.3 provides the estimation results for the demand system. All signs of the estimated coefficients are as hypothesized. Although conventional tests of significance are not exactly applicable to parameters obtained from estimating simultaneous equation models, the estimated structural parameters are judged to be statistically different from zero when the ratio of the parameter estimate to the associated estimate of standard error is greater than 1.30 (approximately corresponds to alpha = .10).

TABLE 7.3. Demand Estimation: Maryland Soft Clam Industry

	New York Wholesale Price (WSOFTC)	Maine Ex-vessel Price (EXVSOPME)	Maryland Ex-vessel Price (EXVSOPMD)
Intercept	3.0624 (2.4607)	0.3223* (0.0404)	0.5176* (0.1382)
WSOFTC	--	0.0146* (0.0014)	0.0206* (0.0018)
WSOFTCL	0.1991* (0.0626)	--	--
EXVSOPME	4.2486* (1.4391)	--	0.6198* (0.0761)
EXVSOPMD	4.1965* (0.9862)	0.2335* (0.0237)	--
SEAFP	0.0171* (0.0049)	--	--
SOCLME	--	-0.000017* (0.000009)	--
SOCLMD	--	--	-0.000022* (0.000013)
TSOCL	-0.0005* (0.0002)	--	--
TSURCL	--	-0.0000014* (0.0000003)	-0.000004* (0.000001)
TIME	0.5008* (0.1034)	0.0133* (0.0032)	0.0214* (0.0051)
R^2	0.9871	0.9749	0.9745
D-W	1.2917	0.8461	1.3836
K	0.05	0.10	0.10

---

* Indicates significance.

7.4 MODEL VALIDATION

Validation of the model, beyond the statistical tests, included 1) development of static backcasts using analytically derived reduced forms from the demand system (Table 7.4) and 2) "shocking" the demand system to evaluate forecast sensitivity to changes in exogenous variables.

Static backcasts (Table 7.5) were developed for the period 1960 to 1980. The U_m, U_r, and U_d proportions, components of the MSE decomposition, indicate that the model performs adequately in backcast evaluations (Table 7.6). Also the system was "shocked" to test its forecast sensitivity to changes in exogenous variables. Initially, base case forecasts were obtained for the period 1980 to 1990 fixing all exogenous variables at 1980 levels. Then, the model was shocked by adjusting the exogenous variable SEAFP upward to determine whether the system becomes unstable. Examination of results shown in Tables 7.7 and 7.8 suggests that the system is stable.

TABLE 7.4. Analytically Derived Reduced Form Equations for Maryland Soft Clams

WSOFTC = 7.86 + 0.262692 WSOFTCL + 0.0225089 SEAFP
TSOCL + 0.972447 TIME - 0.000181216 SOCLPME - 0.000049272 TSURCL -
0.00017393 SOCLPMD

SOPRME = 0.569365 + 0.00596382 WSOFTCL + 0.000611014 SEAFP - 0.000015106
TSOCL + 0.0434495 TIME - 0.000024166 SOCLME - 0.0000039736 TSURCL -
0.0000098812 SOCLMD

SOPRMD = 0.566304 + 0.00911571 WSOFTCL + 0.000781085 SEAFP - 0.000023089
TSOCL + 0.0684016 TIME - 0.000018717 SOCLME - 0.000077183 TSURCL -
0.000031443 SOCLMD

TABLE 7.5. Static Backcasts for the Soft Clam Model

Year	WSOFTC	PWSOFTC	EXVSOPME	PEXVSOPME	EXVSOPMD	PEXVSOPMD
1960	6.25	--	0.39682	--	0.28623	--
1961	5.68	5.9983	0.43059	0.42651	0.26236	0.26414
1962	5.68	4.9984	0.45129	0.40056	0.19403	0.18954
1963	5.50	5.3582	0.42904	0.41047	0.21854	0.18973
1964	5.45	5.1881	0.45996	0.42218	0.20419	0.18841
1965	5.52	5.7867	0.49084	0.43987	0.20225	0.21902
1966	5.87	6.3766	0.46110	0.45461	0.23548	0.27145
1967	6.77	9.1946	0.46568	0.54741	0.30909	0.44776
1968	7.72	10.2065	0.41657	0.59930	0.33519	0.53333
1969	8.06	8.4878	0.42370	0.52596	0.35398	0.38492
1970	8.83	9.3852	0.47481	0.50453	0.39126	0.37305
1971	10.12	11.7803	0.51314	0.62406	0.50000	0.58573
1972	16.39	15.7347	0.60387	0.71005	0.52078	0.78338
1973	20.04	18.2137	0.78540	0.71893	0.83383	0.80916
1974	18.41	20.0469	0.76414	0.76135	0.84755	0.80534
1975	22.20	21.0396	0.86941	0.82360	0.94222	0.94316
1976	28.33	24.3133	1.01642	1.00775	1.57053	1.29549
1977	29.33	27.1209	1.18341	1.07810	1.55575	1.41031
1978	28.97	29.9285	1.24355	1.22424	1.39129	1.59669
1979	32.43	32.8528	1.44541	1.34345	1.84260	1.78027
1980	35.62	35.0508	1.50705	1.40232	2.19162	1.89114

WSOFTC, PWSOFTC: actual and backcast values of wholesale price of soft clams

EXVSOPME, PEXVSOPME: actual and backcast values of Maine ex-vessel price of soft clams

EXVSOPMD, PEXVSOPMD: actual and backcast values of Maryland ex-vessel price of soft clams

TABLE 7.6. Static Backcast Evaluations of the Soft Clam Model (1960 to 1980)

	New York Wholesale Price (WSOFTC)	Maine Ex-vessel Price (EXVSOPME)	Maryland Ex-vessel Price (EXVSOPMD)
MSE	2.3255	0.00607	0.0187
RMSE	1.5646	0.0799	0.1403
U_1	0.3115	0.4317	0.3534
U_2	0.5868	0.8662	0.6514
U_m	0.00002	0.00004	0.0004
U_r	0.0236	0.3092	0.0178
U_d	0.9763	0.6907	0.9817

TABLE 7.7. Base Case Forecasts for the Soft Clam Model

Year	PWSOFTC	PEXVSOPME	PEXVSOPMD
1980	35.0508	1.40232	1.89114
1981	36.0233	1.44577	1.95954
1982	36.9957	1.48922	2.02794
1983	37.9682	1.53267	2.09634
1984	38.9406	1.57612	2.16474
1985	39.9131	1.61957	2.23314
1986	40.8855	1.66302	2.30155
1987	41.8580	1.70647	2.36995
1988	42.8304	1.74992	2.43835
1989	43.8029	1.79337	2.50675
1990	44.7753	1.83682	2.57515

TABLE 7.8. Effects on Soft Clam Model Forecasts of SEAFP Increasing by Ten Percent

Year	PWSOFTC	PEXVSOPME	PEXVSOPMD
1980	35.7941	1.41920	1.91693
1981	36.7665	1.46265	1.98533
1982	37.7390	1.50610	2.05373
1983	38.7114	1.54955	2.12213
1984	39.6839	1.59300	2.19053
1985	40.6563	1.63645	2.25894
1986	41.6288	1.67989	2.32734
1987	42.6012	1.72334	2.39574
1988	43.5737	1.76679	2.46414
1989	44.5461	1.81024	2.53254
1990	45.5186	1.85369	2.60094

8.0 MODEL APPLICATION

The models described in Chapters 4 through 7 were designed to forecast future Chesapeake Bay seafood product prices, harvest quantities, and resulting income. Forecasts of annual 1980-1990 prices (by retail, wholesale, and harvest market sector), harvests, and revenues (incomes) were generated for each product. These forecasts were generated using the estimated models and the assumption that future (1980-1990) values of all exogenous variables would be equal to their 1979 values (this assumption was made to demonstrate use of the models, and of course does not necessarily generate likely future values of Bay prices, quantities, and revenues).

Likewise, the impacts on annual prices, quantities, and revenues during the 1980-1990 period of changes or "shocks" to U.S. wholesale prices, U.S. consumer prices (for meat, poultry, and fish), U.S. population, and U.S. disposable income were presented for each product in the preceding chapters. Both of these sets of market analyses involve rather straightforward application of the estimated models.

Given their flexibility, the models have a wide range of potential applications. They can be used to assess effects of changes in prices, quantities, and incomes that could result from various fishery enhancement programs. Such programs could include expanded oyster seeding programs, efforts to reduce particular contaminants, efforts to increase submerged aquatic vegetation, and so forth. The models can also be used to evaluate the effects of changes in harvest regulation and similar policy issues.

The models were also designed to assess the impacts on prices, quantities, and (particularly) revenues or incomes due to changes in the structure of consumer demand for Chesapeake Bay seafood products. Examples of such a structural change are changes in tastes (e.g., toward seafood as a substitute for red meat, which has been linked to heart disease) and in institutions (e.g., Roman Catholics no longer avoiding meat on Fridays). Such change could also be induced by consumer avoidance of products in response to a specific event. For example, Swartz and Strand (1981) found that avoidance of Chesapeake Bay seafood products occurred in 1975 following the discovery of kepone in the James River (which feeds into the southern part of the Bay). This product avoidance, manifested as a temporary but sharp drop in retail purchases of selected products, had strong negative impacts on incomes earned by harvesters, wholesalers, and retailers of Chesapeake seafood products, as both prices and the quantities sold fell dramatically for a short period. A discussion of the model application to analysis of structural change is provided below.

The equations of each of the demand models described in Chapters 4 through 7 represent reduced-form demand/supply relationships between market participants at different levels of the marketing chain. For example, the oyster retail price equation summarizes or reflects the demand behavior of final consumers of oysters and the supply behavior of retail firms which sell oysters; the oyster wholesale price equation summarizes the demand behavior of retail firms, which purchase oysters in the wholesale market, and wholesalers, who sell oysters in this market. The parameters of each model's equations thus incorporate the behavior of buyers and sellers of the product at the appropriate market level or, in other words, the structure of demand and supply in each market. Changes in the structure of consumer demand (or the demand and/or supply behavior of other market participants) can be assessed by changing the parameter values of the retail price equation for the product under analysis.

Specific types of structural change will lead to changes in the values of specific parameters. For example, a change in tastes which causes consumers to buy more oysters as their incomes increase (vis-a-vis the "base" case) would increase the coefficient of the income variable in the oyster retail price equation. An institutional change, such as removal of the religious restriction on eating meat on Fridays, might alter the level of demand (i.e., reduce the quantity purchased at each possible price) for a particular seafood product, and would be represented as a reduction in the intercept of the retail price equation for that product. Such an institutional change might also affect the sensitivity of consumption of the product to changes in price, income and other factors; such structural changes could be represented in the models discussed in Chapters 4 through 7 by changes in the coefficients on consumption, income, or the other affected variables appearing in the retail price equation for the product.

The reason for changing the coefficients in the manner just described is that doing so permits the analyst to use the models to assess the changes in retail, wholesale, and ex-vessel prices, harvest quantities, and revenues caused by a particular structural change in consumer demand. The analyst performs such an assessment in four steps. First, the model is simulated (for the product or products of interest) for a particular time period (usually in the future) using the parameter values as previously estimated. This simulation results in "baseline" values of prices, quantities, and revenues, Second, parameter values affected by the hypothesized structural change are identified, as well as the direction and magnitude of these changes. Third, the model is resimulated, using the adjusted parameter values, to obtain "alternative scenario" values of prices, quantities, and revenues. Fourth, the analyst subtracts the alternative scenario values form the baseline values to obtain measures of the impacts of the hypothesized structural change on the prices, quantities, and revenues associated with the product.

REFERENCES

Agricultural Outlook. 1960-1980, various issues. U.S. Department of Agriculture, Econometric and Statistics Service.

Belongia, M. 1979. "Application of Ridge Regression with Verification of New Procedures." Agricultural Economics Research 31:36-39.

Belsley, D. A., E. Kuh and R. W. Welsch. 1980. Regression Diagnostics: Identifying Influential Data and Sources of Collinearity. John Wiley and Sons, New York, New York.

Brown, W. G. 1973. "Effect of Omitting Relevant Variables Versus Use of Ridge Regression in Economic Research." Oregon Agricultural Experiment Station Special Report 394, Corvallis, Oregon.

Brown, W. G. and B. R. Beattie. 1975. "Improving Estimates of Economic Parameters by Use of Ridge Regression with Production Function Application." American Journal of Agricultural Economics 57:21-32.

Bundy, M. and J. Williams. 1978. Maryland's Chesapeake Bay Commercial Fisheries. Coastal Resources Division, Tidewater Administration, Maryland Department of Natural Resources, Annapolis, Maryland.

Capps, O., Jr. 1982. "Treatment of Multicollinearity in Simultaneous Systems of Linear Equations." Staff Paper SP-82-1, Department of Agricultural Economics, Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

Conrad, J. 1982. "Management of a Multiple Cohort Fishery: The Hard Clam in Great South Bay." American Journal of Agricultural Economics 64:3:463-464.

Development Planning and Research Associates, Inc. 1981. "The Maryland Blue Crab and Oyster Processing Industries: The Effects of Government Regulation." Report to National Marine Fisheries Service, Washington, D.C.

Dressel, D. M. and D. R. Whitaker. 1982. "An Economic Profile of the Oyster Industry." Regulations Coordination Branch, Fisheries Development Division, National Marine Fisheries Service, Washington, D.C.

Dumont, W. M. and G. T. Sundstrom. 1961. "Commercial Fishing Gear of the United States." Fish and Wildlife Circular 109. U.S. Department of Interior.

Durbin, J. 1957. "Testing for Serial Correlation in Systems of Simultaneous Regression Equations." Biometrica 370-377.

Fishery Statistics of the United States. U.S. Department of Commerce, National Marine Fisheries Services, 1950-1976.

Fox, K. 1953. The Analysis of Demand for Farm Products. USDA Technical Bulletin No. 1081.

Gardner, B. L. 1975. "The Farm-Retail Price Spread in a Competitive Food Industry." American Journal of Agricultural Economics 57:399-409.

Haven, D., W. Hargis and P. Kendall. 1981. The Oyster Industry of Virginia: Its Status, Problems and Promise. Special Paper No. 4, Virginia Institute of Marine Science, Gloucester Point, Virginia.

Heien, D. M. 1980. "Markup Pricing in a Dynamic Model of the Food Industry." American Journal of Agricultural Economics 62:10-18.

Hoerl, A. E. and R. W. Kennard. 1970. "Ridge Regression: Applications to Nonorthogonal Problems." Technometrics 12:69-82.

Houck, J. P. 1966. "A Look at Flexibilities and Elasticities." Journal of Farm Economics 48:225-232.

Kennedy, V. S. and L. L. Breish. 1981. Maryland's Oysters: Research and Management. Sea Grant Publication UM-SG-TS-81-04, University of Maryland, College Park, Maryland.

Maassoumi, E. 1980. "A Ridge-Like Method for Simultaneous Estimation of Simultaneous Equations." Journal of Econometrics 12:161-176.

Malinvaud, E. 1970. Statistical Methods of Econometrics, Rand McNally and Company, Chicago, Illinois.

Martin-Marietta Corporation. 1980a. A Review and Evaluation of Fisheries Stock Management Models. Prepared for the Tidewater Administration, Maryland Department of Natural Resources, Annapolis, Maryland.

Martin-Marietta Corporation. 1980b. Applicability of Fisheries Stock Models in Management. Prepared for the Tidewater Administration, Maryland Department of Natural Resources, Annapolis, Maryland.

Moscardi, E. and A. de Janvry. 1977. "Attitudes Toward Risk Among Peasants: An Econometric Approach." American Journal of Agricultural Economics 59:710-716.

Shellfish Market Review. 1981. U.S. Department of Commerce, National Marine Fisheries Service, Washington, D.C.

Statistical Abstracts of the U.S. 1960-1980. U.S. Department of Commerce, Bureau of the Census, Washington, D.C.

Stekler, H. O. 1968. "Forecasting with Econometric Models: An Evaluation." Econometerica 36:437-463.

Suttor, R. E. and T. D. Carrigan. 1970. "The Chesapeake Bay Oyster Fisheries: An Econometric Analysis." Agricultural Experiment Station MP 740, University of Maryland, College Park, Maryland.

Swartz, D. G. and I. Strand. 1981. "Avoidance Costs Associated with Imperfect Information: The Case of Kepone." Land Economics 57:2139-150.

Theil, H. and J. C. G. Boot. 1962. "The Final Form of Econometric Equation Systems." Review of the International Statistical Institute, 136-152.

Van Engel, W. A. 1972. "The Crab Industry." Chapter V of A Study of the Commercial and Recreational Fisheries of the Eastern Shore of Virginia, Accomack, and Northampton Counties: History Review and Recommendations for Improvements. G. Burrell, Jr., M. Castagna and R. K. Diaz, eds. Special Report in Applied Marine Science and Ocean Engineering, January 1972. No. 20:94-116. Virginia Institute of Marine Science, Gloucester Point, Virginia.

Vinod, H. D. 1976. "Application of New Ridge Regression Methods to a Study of Bell Systems Scale Economics." Journal of the American Statistical Association 71:835-841.

Vinod, H. D. and A. Ullah. 1982. Recent Advances in Regression Methods. Marcel Dekker, Inc., New York, New York.

Virginia Marine Resources Commission. 1982. Annual Reports for 1981 and 1982.

Watson, D. E. and K. J. White. 1976. "Forecasting the Demand for Money Under Changing Term Structure of Interest Rates: An Application of Ridge Regression." Southern Economic Journal 43:1096-1105.

Waugh, F. V. November 1964. Demand and Price Analysis. Technical Bulletin No. 1316, U.S. Department of Agriculture, Economic Research Service, ESAD.

APPENDIX A

DATA FOR ECONOMIC MODELS OF THE OYSTER, BLUE CRAB, HARD CLAM, AND SOFT CLAM FISHERIES IN THE CHESAPEAKE BAY

APPENDIX A.1

DATA FOR OYSTER MODELS

APPENDIX A

DATA FOR ECONOMIC MODELS OF THE OYSTER, BLUE CRAB, HARD CLAM, AND SOFT CLAM FISHERIES IN THE CHESAPEAKE BAY

Numbers in parentheses over data columns in the following tables indicate the data source.

DATA SOURCE KEY

1. Fishery Statistics of the United States, selected years, and unpublished data from the National Marine Fisheries Service
2. Shellfish Market Review, selected years
3. U.S. Department of Agriculture
4. U.S. Department of Commerce
5. Virginia Marine Resources Commission
6. Artificial Construct

TABLE A.1-1. Data for Oyster Demand Analysis

(6) Year	(2) RPOY	(2) WPOY	(2) OYEXVP	(6) TIME	(2) C	(4) Y	(4) POP	(4) CPIMPF	(2) QBAY	(2) QSG	(3) IIGS	(6) DS
1960	1.31	0.80	0.71	1	74.099	349.35	180.75	90.285	27.111	20.641	94.875	--
1961	1.40	0.87	0.79	2	78.099	362.90	183.75	90.435	28.500	22.747	94.525	--
1962	1.33	0.87	0.80	3	71.299	383.90	186.60	91.475	19.939	23.630	94.750	--
1963	1.39	0.90	0.75	4	78.499	402.77	189.30	90.140	18.274	28.937	94.500	0
1964	1.33	0.82	0.71	5	74.399	437.02	191.95	88.670	22.098	27.259	94.675	0
1965	1.33	0.85	0.78	6	70.299	472.13	194.35	94.545	21.188	25.362	96.601	0
1966	1.51	0.94	0.68	7	71.299	510.40	196.60	102.590	21.232	23.929	99.750	1
1967	1.47	0.86	0.67	8	86.899	544.52	198.75	99.995	25.798	26.363	100.000	1
1968	1.56	0.91	0.67	9	86.399	563.17	200.75	102.320	22.679	30.308	102.500	1
1969	1.68	0.96	0.63	10	78.399	630.42	202.75	110.835	22.157	23.415	106.475	0
1970	1.72	0.95	0.61	11	74.799	685.95	204.65	105.490	24.668	19.930	110.375	0
1971	1.75	0.96	0.62	12	75.699	742.80	207.10	94.740	25.557	22.618	114.050	0
1972	2.01	1.09	0.63	13	86.799	801.30	208.85	103.775	24.066	21.978	119.100	0
1973	2.23	1.30	0.66	14	75.799	903.07	210.40	130.015	25.400	17.050	134.700	0
1974	2.44	1.26	0.70	15	75.399	983.63	211.90	132.260	25.621	17.158	160.075	0
1975	2.59	1.37	0.80	16	73.799	1086.65	213.55	144.300	22.640	22.173	174.875	0
1976	2.83	1.54	1.04	17	78.499	1184.35	215.20	145.445	20.964	23.272	182.925	0
1977	3.14	1.84	1.11	18	74.699	1303.00	216.85	144.550	17.929	19.927	194.225	0
1978	3.30	1.90	1.11	19	84.899	1458.40	218.55	168.825	21.531	20.349	209.000	0
1979	3.55	1.98	1.24	20	76.099	1623.72	220.45	193.990	20.428	17.729	235.425	0
1980	3.85	2.17	1.31	21	70.099	1821.70	222.75	201.160	21.906	18.102	268.800	--

TABLE A.1-2. Summary Statistics for Oyster Demand Analysis

Variable	N	Mean	Standard Deviation	Minimum Value	Maximum Value
YR	21	1970.00000000	6.20483682	1960.0000000	1980.0000000
RPOY	21	2.08190476	0.82067423	1.3100000	3.8500000
WPOY	21	1.19714286	0.43581123	0.8000000	2.1700000
OYEXVP	21	0.81047619	0.21499945	0.6100000	1.3100000
TIME	21	11.00000000	6.20483682	1.0000000	21.0000000
C	21	76.96566667	5.25350677	70.0990000	86.8990000
Y	21	821.48452381	440.90904536	349.3500000	1821.7000000
POP	21	203.60952381	12.55309343	180.7500000	222.7500000
CPIMPF	21	120.27809524	34.52434523	88.6700000	201.1600000
QBAY	21	22.76600000	2.68171303	17.9290000	27.5000000
QSG	21	22.51795238	3.70819144	17.0500000	30.3080000
IIGS	21	137.24761905	53.20977877	94.5000000	268.8000000
DS	17	0.17647059	0.39295262	0.0000000	1.0000000

TABLE A.1-3. Data for Oyster Supply Analysis

Year	QSEED	PSEED	I	AGNES	WQSEED	TLM	STL	MSX	QVAPUB	QVAPRV
1960	2588	0.85	0.060	0	--	4566	4423	0	3.996	11.344
1961	1481	0.75	0.059	0	--	3742	3703	0	3.195	13.968
1962	1656	0.88	0.059	0	--	2957	2952	0	1.431	10.369
1963	1092	1.22	0.059	0	--	2759	2759	0	1.993	8.525
1964	802	1.58	0.059	0	1801.50	3205	3205	0	3.329	10.818
1965	667	1.62	0.059	0	1471.25	3164	3164	0	4.440	8.128
1966	983	1.14	0.066	0	1160.50	3285	3285	1	4.804	4.639
1967	818	1.49	0.066	0	840.75	2282	2282	1	4.066	5.002
1968	743	1.28	0.073	0	779.75	2267	2267	1	3.966	3.839
1969	587	1.55	0.091	0	862.75	1920	1920	1	4.236	3.200
1970	489	1.64	0.089	0	840.50	1704	1704	1	3.110	4.933
1971	723	1.51	0.075	0	722.75	1695	1695	1	2.853	5.538
1972	532	1.97	0.075	1	601.50	1189	1189	1	1.879	3.117
1973	440	1.85	0.098	1	572.00	1259	1255	1	2.330	2.648
1974	528	2.32	0.118	0	616.75	1601	1591	1	3.250	3.487
1975	379	1.90	0.096	0	556.75	1813	1800	1	2.992	3.245
1976	536	1.86	0.089	0	485.00	1870	1829	1	2.749	3.336
1977	454	1.49	0.074	0	468.75	1728	1704	1	3.134	1.851
1978	402	1.94	0.098	0	455.50	2346	2285	1	5.086	3.001
1979	515	2.11	0.116	0	476.25	2675	2452	1	4.845	3.352
1980	322	2.35	0.183	0	461.50	2533	2382	1	4.704	3.142

QVA	QPUBTV	QMDPRV	QMDPUBT	QMDPUBD	QMD	FTTV	FTTB	PTTB	QVAPUBD
18.340	3.5353	--	--	--	11.771	--	--	--	0.4607
17.163	3.1950	--	--	--	10.337	--	--	--	0.0000
11.800	1.4310	--	--	--	8.139	--	--	--	0.0000
10.518	1.9930	1.348	4.779	1.629	7.756	334	2724	857	0.0000
14.149	3.3290	1.145	5.776	1.028	7.949	327	2586	859	0.0000
13.568	4.4400	1.506	5.791	0.823	8.120	276	2511	861	0.0000
9.442	4.8040	1.437	8.767	1.586	11.790	280	2647	1054	0.0000
9.068	4.0660	1.840	11.717	3.173	16.730	280	2757	1333	0.0000
7.806	3.9660	0.899	11.838	2.136	14.873	312	2779	1677	0.0000
7.437	4.1150	0.812	11.776	2.232	14.820	389	2802	854	0.1210
8.044	3.1100	0.678	13.963	1.983	16.624	468	2802	917	0.0000
8.440	2.8530	1.364	12.480	3.273	17.117	549	3094	953	0.0000
5.014	1.8790	0.929	15.687	2.436	19.052	621	2070	1105	0.0000
4.977	2.3300	0.407	17.609	2.407	20.423	725	2137	1176	0.0000
6.737	3.2050	0.452	16.029	1.804	18.285	770	2391	1294	0.0450
6.436	2.9480	0.683	14.436	1.283	16.402	797	2357	1431	0.0440
6.085	2.6220	0.700	13.057	1.123	14.880	836	2462	1757	0.1270
4.485	2.8180	0.358	11.483	1.186	13.027	814	2218	1422	0.3160
8.687	3.9920	0.503	12.432	1.439	14.374	845	2083	1279	1.0940
8.197	3.6850	0.410	13.236	1.283	14.929	825	1751	1106	1.1600
7.846	3.6620	--	--	--	14.788	--	--	--	1.042

TABLE A.1-4. Summary Statistics for Oyster Supply Analysis

Variable	N	Mean	Standard Deviation	Minimum Value	Maximum Value
YR	21	1970.00000000	6.20483682	1960.0000000	1980.0000000
QSEED	21	797.00000000	538.12006095	322.0000000	2588.0000000
PSEED	21	1.58571429	0.45322810	0.7500000	2.3500000
I	21	0.08390476	0.02945149	0.0590000	0.1830000
AGNES	21	0.09523810	0.30079260	0.0000000	1.0000000
WQSEED	17	774.92647059	380.59435185	455.5000000	1801.5000000
TLM	21	2407.61904762	859.32871919	1189.0000000	4566.0000000
STL	21	2373.61904762	839.23908847	1189.0000000	4423.0000000
MSX	21	0.71428571	0.46291005	0.0000000	1.0000000
QVAPUB	21	3.44704762	1.04604591	1.4310000	5.0860000
QVAPRV	21	5.59438095	3.46731685	1.8510000	13.9680000
QVA	21	9.05423809	3.41062460	4.9770000	17.1630000
QPUBTV	21	3.23706190	0.87237405	1.4310000	4.8040000
QMDPRV	17	0.91005882	0.45371349	0.3580000	1.8400000
QMDPUBT	17	11.81505882	3.65602632	4.7790000	17.6090000
QMDPUBD	17	1.81317647	0.71953329	0.8230000	3.2730000
QMD	21	13.91361905	3.79066761	7.7560000	20.4230000
FTTV	17	555.76470588	232.54073015	276.0000000	845.0000000
FTTB	17	2480.64705882	346.13273126	1751.0000000	3094.0000000
PTTB	17	1172.64705882	286.12583359	854.0000000	1757.0000000
QVAPUBD	21	0.20998571	0.39045214	0.0000000	1.1600000

APPENDIX A.2

DATA FOR BLUE CRAB MODELS

TABLE A.2-1. Data for Blue Crab Demand Analysis

Year	(1) VHARDL	(1) VSOFTL	(1) MHARDL	(1) MSOFTL	(1) VEXVHP	(1) MEXVHP	(1) VEXVSP	(1) MEXVSP
1960	39,270.0	1,553.0	26,875.0	2,788.0	0.050802	0.056893	0.28203	0.21915
1961	43,976.0	1,535.0	26,646.0	2,692.0	0.044229	0.054980	0.26906	0.22845
1962	53,671.0	1,319.0	27,650.0	3,892.0	0.046990	0.064014	0.31766	0.20041
1963	46,139.0	928.0	16,904.0	2,109.0	0.055181	0.067972	0.34375	0.35609
1964	51,569.0	978.0	22,517.0	3,499.0	0.065660	0.071368	0.45297	0.36268
1965	50,558.0	1,078.0	31,993.0	2,695.0	0.073658	0.078611	0.41373	0.34100
1966	63,694.0	1,028.0	30,373.0	1,885.0	0.057085	0.072927	0.36673	0.38462
1967	54,824.0	1,201.0	24,589.0	2,187.0	0.053863	0.069950	0.37302	0.37952
1968	44,834.0	793.0	9,344.0	1,002.0	0.109894	0.115903	0.38714	0.46108
1969	33,633.0	1,950.0	23,014.0	2,251.0	0.094431	0.095724	0.35590	0.41448
1970	42,409.0	900.0	24,935.0	1,579.0	0.056262	0.083698	0.37222	0.42432
1971	47,807.0	691.0	26,075.0	1,530.0	0.077436	0.094765	0.46310	0.47778
1972	48,555.0	852.0	23,482.0	1,575.0	0.080857	0.100588	0.47535	0.47746
1973	36,629.0	978.0	19,539.0	1,515.0	0.110459	0.142535	0.50511	0.50561
1974	40,796.0	806.0	24,661.0	1,821.0	0.104128	0.164389	0.49256	0.56562
1975	34,798.0	754.0	24,264.0	1,655.0	0.144146	0.176228	0.51061	0.52447
1976	25,762.0	761.0	19,430.0	1,475.0	0.197850	0.236078	0.72273	0.72949
1977	37,177.7	695.3	20,159.3	1,163.6	0.181000	0.243330	0.84400	1.20110
1978	36,054.7	605.2	16,590.1	868.9	0.188000	0.243810	1.13700	1.37470
1979	39,834.0	1,052.1	24,819.2	946.9	0.167000	0.230420	0.94000	1.13230
1980	37,691.8	632.7	25,300.6	1,151.0	0.180000	0.238300	1.05400	1.18110

(2) CRABL	(2) CRABBAY	(2) RPCRAB	(2) WPCRAB	(6) TIME	(4) Y	(4) POP	(4) CPIMPF	(3) IIGS
149,600	66,300	1.47	1.12	1	349.35	180.75	90.285	94.875
147,700	70,600	1.20	0.86	2	362.90	183.75	90.435	94.525
149,300	81,300	1.41	1.06	3	383.90	186.60	91.475	94.750
141,700	63,100	1.64	1.16	4	402.77	189.30	90.140	94.500
152,300	74,100	1.79	1.21	5	437.02	191.95	88.670	94.675
167,000	82,600	1.81	1.22	6	472.13	194.35	94.545	96.600
166,800	94,100	1.64	1.14	7	510.40	196.60	102.590	99.750
145,000	79,400	1.80	1.30	8	544.52	198.75	99.995	100.000
113,600	54,200	2.70	1.95	9	563.17	200.75	102.320	102.500
132,300	56,700	2.53	1.94	10	630.42	202.75	110.835	106.475
145,400	67,400	2.09	1.64	11	685.95	204.65	105.490	110.375
149,100	73,900	2.41	1.90	12	742.80	207.10	94.740	114.050
147,500	72,000	2.89	2.58	13	801.30	208.85	103.775	119.100
136,500	56,300	3.87	3.21	14	903.07	210.40	130.015	134.700
149,200	65,500	3.88	2.98	15	983.63	211.90	132.260	160.075
134,700	59,100	4.12	3.32	16	1,086.65	213.55	144.300	174.875
115,400	45,200	5.17	4.09	17	1,184.35	215.20	145.445	182.925
132,700	56,400	6.00	4.67	18	1,303.00	216.85	144.550	194.225
138,200	52,600	5.40	4.08	19	1,458.40	218.55	168.825	209.000
152,800	64,200	5.74	4.10	20	1,623.72	220.45	193.990	235.425
163,200	63,000	6.46	4.41	21	1,821.70	222.75	201.160	268.800

TABLE A.2-2. Summary Statistics for Blue Crab Demand Analysis

Variable	N	Mean	Standard Deviation	Minimum Value	Maximum Value
YR	21	70.000000	6.2048368	60.00000	80.00000
VHARDL	21	43,318.200000	8,691.0497541	25,762.00000	63,694.00000
VSOFTL	21	1,004.300000	343.5962412	605.20000	1,950.00000
MHARDL	21	23,293.342857	5,049.9325829	9,344.00000	31,993.00000
MSOFTL	21	1,918.114286	819.6713398	868.90000	3,892.00000
VEXVHP	21	0.101854	0.0528594	0.04423	0.19785
MEXVHP	21	0.128690	0.0707258	0.05498	0.24381
VEXVSP	21	0.527556	0.2561565	0.26906	1.13700
MEXVSP	21	0.568640	0.3485402	0.20041	1.37470
CRABL	21	144,285.714286	13,949.6697350	113,600.00000	167,000.00000
CRABBAY	21	66,571.428571	11,730.0529776	45,200.00000	94,100.00000
RPCRAB	21	3.143810	1.7164949	1.20000	6.46000
WPCRAB	21	2.378095	1.3002639	0.86000	4.67000
OTHCRAB	21	77,714.285714	8,619.7033426	59,400.00000	100,200.00000
TIME	21	11.000000	6.2048368	1.00000	21.00000
Y	21	821.484524	440.9090454	349.35000	1,821.70000
POP	21	203.609524	12.5530934	180.75000	222.75000
CPIMPF	21	120.278095	34.5243452	88.67000	201.16000
IIGS	21	137.247619	53.2097788	94.50000	268.80000

TABLE A.2-3. Data for Blue Crab Supply Analysis

Year	(1) VHARDDRG	(1) VHARDSUM	(1) VPC	(1) VXPPOT	(4) I	(1) VSOFTO	(1) MPC	(6) LD
1960	10,545	28,725	1,295	0.052290	0.060	1,059	502	0
1961	9,083	34,893	1,037	0.046549	0.059	1,174	558	0
1962	13,033	40,638	1,004	0.049317	0.059	1,047	718	0
1963	16,525	29,614	1,145	0.059112	0.059	689	589	0
1964	13,135	38,434	1,309	0.071713	0.059	609	616	0
1965	9,434	41,124	1,292	0.077869	0.059	658	748	0
1966	15,244	48,450	1,231	0.062566	0.066	663	805	0
1967	14,978	39,846	1,097	0.052218	0.066	913	843	0
1968	9,873	34,961	1,179	0.114907	0.073	474	779	0
1969	7,695	25,938	1,207	0.106112	0.091	876	843	0
1970	10,559	31,850	1,328	0.060847	0.089	506	1,013	1
1971	10,962	36,845	1,066	0.081305	0.075	322	1,102	1
1972	12,349	36,206	1,110	0.081257	0.075	461	1,002	1
1973	8,881	27,748	1,083	0.109660	0.098	363	913	1
1974	8,083	32,713	1,599	0.108038	0.118	253	1,278	1
1975	4,462	30,336	1,544	0.146126	0.096	349	1,223	1
1976	6,091	19,671	1,581	0.204796	0.089	416	1,326	1
1977	6,124	31,053	1,617	0.187612	0.074	219	1,512	1
1978	6,606	29,448	1,860	0.184330	0.098	274	1,714	1
1979	7,106	32,728	2,075	0.168350	0.116	500	1,766	1
1980	9,406	28,285	--	0.182960	0.183	306	1,762	1

(1) MXPPOT	(1) MTC	(1) MSOFTO	(1) VEXVSP	(1) VSOFTL	(4) Y	(6) SDD	(1) MEXVSP
0.060222	1,926	2,365.0	0.28203	1,553	349.35	0	0.21915
0.058182	2,201	2,341.0	0.26906	1,535	362.90	0	0.22845
0.067030	2,153	3,440.0	0.31766	1,319	383.90	0	0.20041
0.074433	2,040	1,789.0	0.34375	928	402.77	0	0.35609
0.080886	2,091	3,080.0	0.45297	978	437.02	0	0.36268
0.075739	2,500	2,220.0	0.41373	1,078	472.13	0	0.34100
0.076444	2,643	1,560.0	0.36673	1,028	510.40	0	0.38462
0.075636	2,640	1,768.0	0.37302	1,201	544.52	0	0.37952
0.127000	2,772	779.0	0.38714	793	563.17	0	0.46108
0.086871	2,918	1,979.0	0.35590	1,950	630.42	0	0.41448
0.077228	4,941	1,412.0	0.37222	900	885.95	0	0.42432
0.089646	6,326	1,313.0	0.46310	691	742.80	0	0.47778
0.087623	6,300	1,415.0	0.47535	852	801.30	0	0.47746
0.147979	5,775	1,346.0	0.50511	978	903.07	0	0.50561
0.173248	7,626	1,662.0	0.49256	806	983.63	0	0.56562
0.184142	8,082	1,453.0	0.51061	754	1,086.65	0	0.52447
0.244665	8,676	1,266.0	0.72273	761	1,184.35	1	0.72949
0.251960	11,679	1,024.7	0.84400	695	1,303.00	1	1.20110
0.268690	9,623	500.3	1.13700	605	1,458.40	1	1.37470
0.249560	13,517	459.8	0.94000	1,052	1,623.72	1	1.13230
0.263030	8,574	447.2	1.05400	633	1,821.70	1	1.18110

TABLE A.2-3. (contd)

Year	(1) MSOFTL	(1) VXPDRG	(1) VEXVHP	(1) MEXVHP	(1) MXPTRT	(1) VHARDPOT	(1) MHARDL
1960	2,788	0.059554	0.050802	0.056893	0.058236	26,949.0	26,875.0
1961	2,692	0.044369	0.044229	0.054980	0.056339	31,605.0	26,646.0
1962	3,892	0.045884	0.046990	0.064014	0.065322	36,855.0	27,650.0
1963	2,109	0.054100	0.055181	0.067972	0.072131	27,471.0	16,904.0
1964	3,499	0.060678	0.065660	0.071368	0.071795	35,580.0	22,517.0
1965	2,695	0.070702	0.073658	0.078611	0.090890	38,864.0	31,993.0
1966	1,885	0.049396	0.057085	0.072927	0.075990	41,063.0	30,373.0
1967	2,187	0.065429	0.053863	0.069950	0.074674	36,079.0	24,589.0
1968	1,002	0.102400	0.109894	0.115903	0.120302	30,976.0	9,344.0
1969	2,251	0.098116	0.094431	0.095724	0.115187	22,929.0	23,014.0
1970	1,579	0.056161	0.056262	0.083698	0.097348	28,120.0	24,935.0
1971	1,530	0.077905	0.077436	0.094765	0.109425	35,250.0	26,075.0
1972	1,575	0.091910	0.080857	0.100588	0.124729	36,012.0	23,482.0
1973	1,515	0.141651	0.110459	0.142535	0.142249	27,718.0	19,539.0
1974	1,821	0.115922	0.104128	0.164389	0.156520	32,713.0	24,661.0
1975	1,655	0.165397	0.144146	0.176228	0.168948	30,226.0	24,264.0
1976	1,475	0.207848	0.197850	0.236078	0.236529	19,670.0	19,430.0
1977	1,164	0.209000	0.181000	0.243330	0.244170	31,004.3	20,159.3
1978	869	0.168350	0.188000	0.243810	0.257520	29,448.3	16,590.1
1979	947	0.215000	0.167000	0.230420	0.238390	32,681.7	24,819.2
1980	1,151	0.215000	0.180000	0.238300	0.262960	28,265.2	25,300.6

(1) MHARDPOT	(1) MHARDTRT	(1) MSOFTTRT	(1) MSOFTPOT	(1) VSOFTPOT	(1) VHARDO	(1) MHARDO
15,446.0	11,222.0	94.0	329	494	1,776.0	207.0
13,854.0	12,597.0	94.0	257	361	3,288.0	195.0
14,883.0	12,573.0	118.0	334	272	3,783.0	194.0
8,481.0	8,321.0	122.0	198	239	2,143.0	102.0
12,061.0	10,362.0	154.0	265	369	2,854.0	94.0
17,592.0	14,254.0	137.0	338	420	2,260.0	147.0
16,188.0	14,051.0	135.0	190	365	7,387.0	134.0
12,834.0	11,634.0	164.0	255	288	3,767.0	121.0
5,003.0	4,264.0	100.0	123	319	3,985.0	77.0
13,053.0	9,813.0	110.0	162	1,074	3,009.0	148.0
14,283.0	10,496.0	64.0	103	394	3,730.0	156.0
15,394.0	10,549.0	61.0	156	369	1,595.0	132.0
13,725.0	9,640.0	53.0	107	391	194.0	117.0
11,476.0	7,944.0	42.0	127	615	30.0	119.0
15,449.0	9,091.0	58.0	101	553	0.0	121.0
15,649.0	8,499.0	48.0	154	405	110.0	116.0
12,918.0	6,425.0	52.0	157	345	1.0	87.0
13,629.7	6,440.7	58.3	81	476	48.7	88.9
12,731.3	3,799.1	82.7	286	331	-0.3(a)	59.7
19,790.2	4,956.6	76.2	411	552	46.3	72.4
21,601.8	3,610.1	90.8	613	327	19.8	88.7

(a) Apparent error in data supplied

TABLE A.2-4. Summary Statistics for Blue Crab Supply Analysis

Variable	N	Mean	Standard Deviation	Minimum Value	Maximum Value
YR	21	70.0000000	6.20483682	60.000000	80.000000
VHARDDRG	21	10,008.2857143	3,267.81369027	4,462.000000	16,525.000000
VHARDSUM	21	33,309.8095238	6,332.39883156	19,671.000000	48,450.000000
VPC	20	1,332.9500000	291.08390453	1,004.000000	2,075.000000
VXPPOT	21	0.1051398	0.05286588	0.046549	0.204796
I	21	0.0839048	0.02945149	0.059000	0.183000
VSOFTO	21	577.6666667	288.23572529	219.000000	1,174.000000
MPC	21	1,029.1428571	400.74159825	502.000000	1,766.000000
LD	21	0.5238095	0.51176632	0.000000	1.000000
MXPPOT	21	0.1342959	0.07756433	0.058182	0.268690
MTC	21	5,476.3333333	3,533.95001851	1,926.000000	13,517.000000
MSOFTO	21	1,600.9523810	790.59126647	447.200000	3,440.000000
VEXVSP	21	0.5275558	0.25615646	0.269055	1.137000
VSOFTL	21	1,004.2857143	343.60444451	605.000000	1,950.000000
Y	21	821.4845238	440.90904536	349.350000	1,821.700000
SDD	21	0.2380952	0.43643578	0.000000	1.000000
MEXVSP	21	0.5686397	0.34854024	0.200411	1.374700
MSOFTL	21	1,918.1428571	819.64060940	869.000000	3,892.000000
VXPDRG	21	0.1102272	0.06209420	0.044369	0.215000
VEXVHP	21	0.1018538	0.05285939	0.044229	0.197850
MEXVHP	21	0.1286897	0.07072584	0.054980	0.243810
MXPTRT	21	0.1352217	0.07166005	0.056339	0.262960
VHARDPOT	21	31,403.7857143	5,205.64244040	19,670.000000	41,063.000000
MHARDL	21	23,293.3428571	5,049.93258287	9,344.000000	31,993.000000
MHARDPOT	21	14,097.2380952	3,502.31479075	5,003.000000	21,601.800000
MHARDTRT	21	9,073.4047619	3,225.23049122	3,610.100000	14,254.000000
MSOFTTRT	21	91.1428571	36.59906517	42.000000	164.000000
MSOFTPOT	21	226.0476190	129.05521151	81.000000	613.000000
VSOFTPOT	21	426.6190476	176.98600967	239.000000	1,074.000000
VHARDO	21	1,906.0238095	2,000.43677103	-0.300000	7,387.000000
MHARDO	21	122.7000000	40.91494837	59.700000	207.000000

APPENDIX A.3

DATA FOR HARD CLAM MODELS

TABLE A.3-1. Data for Hard Clam Supply and Demand Analysis

(6) Year	(2) WPFULTON	(1) QCLNY	(1) QCLVA	(1) TUSCL	(1) TOCL
1960	13.44	3,888.00	1,661.00	14,877	186.0
1961	11.75	4,291.00	1,861.00	14,604	124.0
1962	12.44	4,836.00	1,690.00	13,295	67.0
1963	15.00	5,311.00	2,096.00	14,529	104.0
1964	15.95	5,402.00	2,453.00	14,925	113.0
1965	15.37	5,948.00	2,487.00	15,044	93.0
1966	15.06	6,581.00	1,860.00	15,324	91.0
1967	17.08	7,066.00	1,860.00	16,182	45.0
1968	17.25	6,986.00	1,869.00	15,426	225.0
1969	20.02	7,516.00	1,903.00	16,154	639.0
1970	21.66	7,906.00	1,331.00	16,015	1,747.0
1971	24.66	8,549.00	1,837.00	16,666	2,032.0
1972	29.09	8,500.00	1,338.00	16,153	1,400.3
1973	31.62	7,246.19	1,354.00	14,505	1,457.0
1974	32.57	8,027.80	1,419.00	15,008	805.2
1975	34.50	8,668.00	1,088.36	14,995	1,296.0
1976	37.99	9,028.40	893.30	15,251	5,602.0
1977	43.03	8,530.10	1,020.69	15,443	16,919.2
1978	52.45	7,353.20	497.24	13,295	20,126.0
1979	60.51	5,701.04	619.712	12,058	27,966.0
1980	65.01	4,944.70	753.078	13,370	33,835.0

(4) SEAFP	(2) CHERP	(2) CHOWP	(6) TIME	(1) EXVPNY	(1) EXVPVA	(5) PTL
85.0	8.06	4.11	1	0.61523	0.45515	28
86.9	7.86	4.26	2	0.58098	0.46480	34
90.5	8.54	4.43	3	0.60505	0.48047	66
90.3	9.31	4.65	4	0.67426	0.48282	120
88.2	9.31	4.62	5	0.76564	0.49694	130
90.8	9.89	4.79	6	0.86567	0.53760	121
96.7	10.06	4.94	7	0.87950	0.54301	172
100.0	10.52	4.84	8	1.00340	0.56290	133
101.6	10.47	5.06	9	1.04037	0.56447	119
107.2	10.50	5.20	10	1.08821	0.63058	81
117.8	10.58	5.14	11	1.13547	0.65515	84
130.2	11.02	5.22	12	1.25828	0.76102	96
141.9	11.56	5.47	13	1.55694	0.84454	40
162.8	14.02	5.98	14	1.50562	0.92910	95
187.7	14.48	6.46	15	1.67234	0.93658	92
203.3	15.34	6.89	16	1.64986	0.93903	99
227.3	16.08	8.32	17	2.00711	0.97167	91
251.6	17.00	9.34	18	2.11755	1.29128	88
275.4	18.84	10.42	19	2.40589	1.93871	79
302.3	22.20	12.67	20	3.07610	2.02513	104
330.2	23.68	12.67	21	4.00065	2.26404	146

TABLE A.3-2. Summary Statistics for Hard Clam Supply and Demand Analysis

Variable	N	Mean	Standard Deviation	Minimum Value	Maximum Value
YEAR	21	1,970.0000000	6.2048368	1,960.000000	1,980.000000
WPFULTON	21	27.9261905	16.0259631	11.750000	65.010000
QCLNY	21	6,775.2112381	1572.6687699	3,888.000000	9,028.400000
QCLVA	21	1,518.6371905	560.4578596	497.238000	2,487.000000
TUSCL	21	14,910.4285714	1,140.4828614	12,058.000000	16,666.000000
TOCL	21	5,470.1292857	10,088.0618354	45.000000	33,835.000000
SEAFP	21	155.6047619	79.0889656	85.000000	330.200000
CHERP	21	12.8247619	4.5457140	7.860000	23.680000
CHOWP	21	6.4514286	2.6613348	4.110000	12.670000
TIME	21	11.0000000	6.2048368	1.000000	21.000000
EXVPNY	21	1.4525764	0.8792141	0.580983	4.000647
EXVPVA	21	0.8940484	0.5434317	0.455148	2.264042
PTL	21	98.4761904	33.6476136	28.000000	172.000000

TABLE A.4-1. Data for Soft Clam Demand Analysis

(6) Year	(6) TIME	(4) SEAFP	(2) WSOFTC	(1) TSOCL	(1) SOCLME	(1) SOCLMD	(1) TSURCL	(2) EXVSOPMD	(2) EXVSOPME
1960	1	85.0	6.25	8,579	2,074	5,569	25,071	0.28623	0.39682
1961	2	86.9	5.68	7,363	1,844	4,692	27,502	0.26236	0.43059
1962	3	90.5	5.68	9,396	1,981	6,767	30,854	0.19403	0.45129
1963	4	90.3	5.50	9,754	1,832	6,859	38,586	0.21854	0.42904
1964	5	88.2	5.45	11,030	1,798	8,164	38,144	0.20419	0.45996
1965	6	90.8	5.52	11,308	1,964	7,654	44,088	0.20225	0.49084
1966	7	96.7	5.87	11,919	3,008	7,007	45,113	0.23548	0.46110
1967	8	100.0	6.77	9,823	3,176	5,212	45,054	0.30909	0.46568
1968	9	101.6	7.72	10,368	3,332	5,579	40,552	0.33519	0.41657
1969	10	107.2	8.06	13,481	4,135	7,910	49,575	0.35398	0.42370
1970	11	117.8	8.83	12,906	5,259	6,221	67,318	0.39126	0.47481
1971	12	130.2	10.12	12,652	5,250	5,986	52,535	0.50000	0.51314
1972	13	141.9	16.39	9,078	6,142	1,949	63,471	0.52078	0.60387
1973	14	162.8	20.04	8,627	7,260	668	82,370	0.83383	0.78540
1974	15	187.7	18.41	8,594	5,906	2,099	96,110	0.84755	0.76414
1975	16	203.3	22.20	9,174	6,547	1,246	86,956	0.94222	0.86941
1976	17	227.3	28.33	10,467	7,368	1,751	49,158	1.57053	1.01642
1977	18	251.6	29.33	10,683	7,835	1,758	51,036	1.55575	1.18341
1978	19	275.4	28.97	10,091	6,007	3,284	39,327	1.39129	1.24355
1979	20	302.3	32.43	8,585	5,193	2,859	34,912	1.84260	1.44541
1980	21	330.2	35.62	8,948	5,676	1,957	37,737	2.19162	1.50705

TABLE A.4-2. Summary Statistics for Soft Clam Demand Analysis

Variable	N	Mean	Standard Deviation	Minimum Value	Maximum Value
WSOFTC	21	14.9128571	10.5678182	5.450000	35.620000
TSOCL	21	10,134.6666667	1,619.2841731	7,363.000000	13,481.000000
SOCLME	21	4,456.5238095	2,081.7493273	1,798.000000	7,835.000000
SOCLMD	21	4,532.9047619	2,482.4094526	668.000000	8,164.000000
TSURCL	21	49,784.2380952	19,310.6445540	25,071.000000	96,110.000000
EXVSOPME	21	0.7062939	0.3633288	0.396818	1.507047
EXVSOPMD	21	0.7232743	0.6212256	0.194030	2.191620
SEAFP	21	155.6047619	79.0889656	85.000000	330.200000
YEAR	21	1,970.0000000	6.2048368	1,960.000000	1980.000000
TIME	21	11.0000000	6.2048368	1.000000	21.000000

APPENDIX B

COLLINEARITY DIAGNOSTICS FOR ECONOMIC MODELS OF THE OYSTER, HARD BLUE CRAB, HARD CLAM, AND SOFT CLAM FISHERIES IN THE CHESAPEAKE BAY

APPENDIX B.1

COLLINEARITY DIAGNOSTICS FOR OYSTER MODELS

TABLE B.1-1. Oyster Model Collinearity Diagnostics: First-Stage Equations

Number	Eigenvalue	Condition Index	Variable	Variance Inflation
1	8.525	1.000	INTERCEPT	0.000000
2	0.421396	4.498	TIME	1312.846042
3	0.024666	18.591	C	3.575688
4	0.021119	20.092	Y	330.203694
5	0.003397	50.095	CPIMPF	38.805534
6	0.002242	61.660	POP	1005.504992
7	0.001434	77.101	QBAY	2.278872
8	0.000376214	150.536	QSG	6.957769
9	1.948E-06	2092	IIGS	311.704714

Portion INTERCEPT	Portion TIME	Portion C	Portion Y	Portion CPIMPF	Portion POP	Portion QBAY	Portion QSG	Portion IIGS
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000
0.0000	0.0001	0.0002	0.0004	0.0001	0.0000	0.0017	0.0014	0.0001
0.0000	0.0035	0.0009	0.0008	0.0096	0.0000	0.0264	0.0036	0.0035
0.0000	0.0006	0.0003	0.0000	0.0011	0.0000	0.1531	0.0746	0.0003
0.0003	0.0001	0.0006	0.0137	0.0656	0.0002	0.3969	0.1956	0.0051
0.0001	0.0011	0.3919	0.0054	0.0237	0.0001	0.0611	0.0630	0.0052
0.0003	0.0025	0.0427	0.0354	0.7481	0.0001	0.1748	0.0949	0.0215
0.0001	0.0213	0.1137	0.8035	0.0084	0.0002	0.0294	0.0568	0.4507
0.9992	0.9707	0.4497	0.1408	0.1433	0.9994	0.1564	0.5100	0.5135

TABLE B.1-2. Oyster Model Collinearity Diagnostics: Second-Stage Equations, Retail Price

Number	Eigenvalue	Condition Index	Variable	Variance Inflation
1	6.698	1.000	INTERCEPT	0.000000
2	0.273470	4.949	TIME	662.812859
3	0.022814	17.134	WPOY	47.537426
4	0.002992	47.311	C	1.164063
5	0.002120	56.205	Y	148.028785
6	0.000863622	88.065	CPIMPF	28.937784
7	4.400E-06	1234	POP	445.895710

Portion INTERCEPT	Portion TIME	Portion WPOY	Portion C	Portion Y	Portion CPIMPF	Portion POP
0.0000	0.0000	0.0001	0.0001	0.0000	0.0001	0.0000
0.0000	0.0003	0.0003	0.0027	0.0012	0.0000	0.0000
0.0000	0.0082	0.0232	0.0067	0.0032	0.0144	0.0000
0.0001	0.0002	0.2203	0.3290	0.0008	0.3087	0.0001
0.0007	0.0010	0.1624	0.6500	0.0141	0.2337	0.0005
0.0004	0.0270	0.4533	0.0003	0.9513	0.4429	0.0002
0.9988	0.9633	0.1405	0.0112	0.0293	0.0001	0.9992

TABLE B.1-3. Oyster Model Collinearity Diagnostics: Second-Stage Equations, Wholesale Price

Number	Eigenvalue	Condition Index	Variable	Variance Inflation
1	6.618000	1.000	INTERCEPT	0.000000
2	0.315053	4.583	TIME	33.623580
3	0.042028	12.549	RPOY	164.035324
4	0.020766	17.852	OYEXVP	21.214750
5	0.002173	55.184	QBAY	1.986293
6	0.001351	69.992	QSG	2.937854
7	0.000548	109.894	IIGS	82.963530

Portion INTERCEPT	Portion TIME	Portion RPOY	Portion OYEXVP	Portion QBAY	Portion QSG	Portion IIGS
0.0000	0.0001	0.0000	0.0001	0.0002	0.0002	0.0000
0.0007	0.0065	0.0003	0.0000	0.0041	0.0068	0.0004
0.0004	0.0544	0.0003	0.0296	0.0323	0.0001	0.0022
0.0001	0.0372	0.0006	0.0001	0.1497	0.1891	0.0024
0.5123	0.0503	0.0001	0.0809	0.2411	0.5416	0.1587
0.3703	0.3872	0.0211	0.7552	0.5664	0.0020	0.2541
0.1160	0.4643	0.9776	0.1340	0.0064	0.2602	0.5822

TABLE B.1-4. Oyster Model Collinearity Diagnostics: Second-Stage Equations, Ex-Vessel Price

Number	Eigenvalue	Condition Index	Variable	Variance Inflation
1	4.748	1.000	INTERCEPT	0.000000
2	0.223843	4.606	TIME	13.071576
3	0.022010	14.688	RP	166.069446
4	0.005326	29.860	WP	115.384306
5	0.000421566	106.131	QBAY	1.513112

Portion INTERCEPT	Portion TIME	Portion RPOY	Portion WPOY	Portion QBAY
0.0003	0.0007	0.0000	0.0000	0.0004
0.0069	0.0242	0.0003	0.0002	0.0168
0.0014	0.3741	0.0042	0.0138	0.0500
0.7350	0.0889	0.0089	0.0011	0.6996
0.2563	0.5121	0.9866	0.9849	0.2332

APPENDIX B.2

COLLINEARITY DIAGNOSTICS FOR HARD BLUE CRAB MODELS

TABLE B.2-1. Hard Blue Crab Model Collinearity Diagnostics: First-Stage Equations (Virginia)

Number	Eigenvalue	Condition Index	Variable	Variance Inflation
1	8.488	1.000	INTERCEPT	0.000000
2	0.465285	4.271	CRABL	8.593331
3	0.023648	18.946	Y	362.946926
4	0.015993	23.038	CPIMPF	33.451926
5	0.003838	47.032	POP	797.358108
6	0.001649	71.751	CRABBAY	24.376787
7	0.0008137	102.137	IIGS	156.090599
8	0.000287339	171.877	VHARDL	12.748021
9	2.538E-06	1829	TIME	1291.681819

Portion INTERCEPT	Portion CRABL	Portion Y	Portion CPIMPF	Portion POP	Portion CRABBAY	Portion IIGS	Portion VHARDL	Portion TIME
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
0.0000	0.0001	0.0003	0.0001	0.0000	0.0004	0.0001	0.0010	0.0001
0.0000	0.0009	0.0008	0.0106	0.0000	0.0001	0.0073	0.0052	0.0042
0.0001	0.0000	0.0028	0.0016	0.0001	0.0109	0.0003	0.0356	0.0000
0.0000	0.0973	0.0000	0.0273	0.0000	0.0464	0.0016	0.2963	0.0008
0.0001	0.0007	0.0260	0.8946	0.0000	0.0181	0.0713	0.0161	0.0014
0.0000	0.4005	0.0771	0.0079	0.0000	0.4681	0.1792	0.2036	0.0011
0.0009	0.4275	0.8080	0.0024	0.0002	0.4012	0.6894	0.2552	0.0371
0.9988	0.0730	0.0851	0.0554	0.9996	0.0548	0.0508	0.1868	0.9553

TABLE B.2-2. Hard Blue Crab Model Collinearity Diagnostics: First-Stage Equations (Maryland)

Number	Eigenvalue	Condition Index	Variable	Variance Inflation
1	8.508	1.000	INTERCEPT	0.000000
2	0.435475	4.420	CRABL	8.398695
3	0.026879	17.791	Y	359.581478
4	0.020547	20.349	CPIMPF	33.294233
5	0.006192	37.341	POP	814.311465
6	0.001712	70.496	CRABBAY	7.619983
7	0.001116	87.314	IIGS	155.839586
8	0.000319233	163.251	MHARDL	4.383617
9	2.486E-06	1850	TIME	1316.772897

Portion INTERCEPT	Portion CRABL	Portion Y	Portion CPIMPF	Portion POP	Portion CRABBAY	Portion IIGS	Portion MHARDL	Portion TIME
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000
0.0000	0.0002	0.0003	0.0001	0.0000	0.0014	0.0002	0.0027	0.0001
0.0000	0.0000	0.0015	0.0005	0.0000	0.0001	0.0024	0.1253	0.0007
0.0000	0.0003	0.0001	0.0144	0.0000	0.0066	0.0059	0.0766	0.0038
0.0001	0.0060	0.0037	0.0017	0.0000	0.3318	0.0000	0.4065	0.0000
0.0001	0.0461	0.0274	0.8709	0.0000	0.0573	0.0462	0.0049	0.0008
0.0001	0.5699	0.0101	0.0596	0.0001	0.4366	0.1218	0.0413	0.0001
0.0008	0.3025	0.8698	0.0014	0.0002	0.0406	0.7747	0.1393	0.0378
0.9989	0.0750	0.0870	0.0513	0.9996	0.1256	0.0488	0.2033	0.9566

TABLE B.2-3. Hard Blue Crab Model Collinearity Diagnostics: Second-Stage Equations, Retail Price

Number	Eigenvalue	Condition Index	Variable	Variance Inflation
1	6.634	1.000	INTERCEPT	0.000000
2	0.331078	4.476	WPCRAB	31.884366
3	0.017700	19.360	CRABL	2.257643
4	0.012728	22.830	Y	128.342692
5	0.003440	43.912	CPIMPF	31.238556
6	0.000872336	87.207	POP	755.453301
7	2.629E-06	1589	TIME	1295.347087

Portion INTERCEPT	Portion WPCRAB	Portion CRABL	Portion Y	Portion CPIMPF	Portion POP	Portion TIME
0.0000	0.0001	0.0001	0.0000	0.0001	0.0000	0.0000
0.0000	0.0035	0.0026	0.0007	0.0000	0.0000	0.0001
0.0000	0.0521	0.0106	0.0291	0.0304	0.0000	0.0015
0.0000	0.2414	0.0109	0.0004	0.0045	0.0000	0.0068
0.0001	0.1817	0.5239	0.0102	0.2120	0.0001	0.0003
0.0008	0.2219	0.4335	0.7307	0.7512	0.0004	0.0075
0.9991	0.2993	0.0185	0.2288	0.0018	0.9996	0.9839

TABLE B.2-4. Hard Blue Crab Model Collinearity Diagnostics: Second-Stage Equations, Wholesale Price (Virginia)

Number	Eigenvalue	Condition Index	Variable	Variance Inflation
1	5.609	1.000	INTERCEPT	0.000000
2	0.342767	4.045	RPCRAB	56.716412
3	0.026666	14.503	VEXVHP	17.917329
4	0.014557	19.629	CRABBAY	2.527223
5	0.004403	35.692	IIGS	17.406769
6	0.002555	46.851	TIME	9.443386

Portion INTERCEPT	Portion RPCRAB	Portion VEXVHP	Portion CRABBAY	Portion IIGS	Portion TIME
0.0003	0.0001	0.0003	0.0003	0.0002	0.0007
0.0055	0.0014	0.0031	0.0147	0.0002	0.0082
0.0115	0.0015	0.1475	0.0145	0.0007	0.5286
0.0682	0.0144	0.1272	0.0086	0.2667	0.1997
0.9145	0.0048	0.4042	0.8820	0.0479	0.0041
0.0001	0.9778	0.3175	0.0799	0.6844	0.2587

TABLE B.2-5. Hard Blue Crab Model Collinearity Diagnostics: Second-Stage Equations, Wholesale Price (Maryland)

Number	Eigenvalue	Condition Index	Variable	Variance Inflation
1	5.608	1.000	INTERCEPT	0.000000
2	0.352621	3.988	RPCRAB	73.247546
3	0.022737	15.705	MEXVHP	39.043632
4	0.010195	23.453	CRABBAY	2.302693
5	0.004490	35.339	IIGS	16.995319
6	0.002049	52.320	TIME	9.340156

Portion INTERCEPT	Portion RPCRAB	Portion MEXVHP	Portion CRABBAY	Portion IIGS	Portion TIME
0.0003	0.0001	0.0002	0.0003	0.0002	0.0007
0.0067	0.0009	0.0018	0.0156	0.0002	0.0075
0.0043	0.0059	0.0345	0.0118	0.0277	0.7691
0.3556	0.0000	0.0662	0.1138	0.3231	0.0041
0.6257	0.0001	0.3297	0.7874	0.3089	0.0318
0.0074	0.9930	0.5676	0.0711	0.3398	0.1867

TABLE B.2-6. Hard Blue Crab Model Collinearity Diagnostics: Second-Stage Equations, Ex-Vessel Price (Virginia)

Number	Eigenvalue	Condition Index	Variable	Variance Inflation
1	4.608	1.000	INTERCEPT	0.000000
2	0.365536	3.550	RPCRAB	51.694434
3	0.018001	15.999	WPCRAB	68.293613
4	0.007083	25.504	VHARDL	2.229708
5	0.001839	50.059	TIME	10.982957

Portion INTERCEPT	Portion RPCRAB	Portion WPCRAB	Portion VHARDL	Portion TIME
0.0005	0.0002	0.0001	0.0007	0.0009
0.0056	0.0014	0.0011	0.0199	0.0070
0.0565	0.0310	0.0202	0.0537	0.7100
0.7111	0.1024	0.0000	0.6894	0.1852
0.2264	0.8650	0.9785	0.2364	0.0968

TABLE B.2-7. Hard Blue Crab Model Collinearity Diagnostics: Second-Stage Equations, Ex-Vessel Price (Maryland)

Number	Eigenvalue	Condition Index	Variable	Variance Inflation
1	4.637	1.000	INTERCEPT	0.000000
2	0.327986	3.760	RPCRAB	49.864691
3	0.019522	15.412	WPCRAB	58.023959
4	0.013658	18.425	MHARDL	1.180164
5	0.002135	46.602	TIME	10.113344

Portion INTERCEPT	Portion RPCRAB	Portion WPCRAB	Portion MHARDL	Portion TIME
0.0011	0.0002	0.0002	0.0015	0.0010
0.0177	0.0017	0.0015	0.0447	0.0088
0.4375	0.0120	0.0117	0.4233	0.3973
0.4986	0.0550	0.0181	0.4779	0.5540

APPENDIX B.3

COLLINEARITY DIAGNOSTICS FOR HARD CLAM MODELS

TABLE B.3-1. Hard Clam Model Collinearity Diagnostics: First-Stage Equations

Number	Eigenvalue	Condition Index	Variable	Variance Inflation
1	6.782	1.000	INTERCEPT	0.000000
2	1.062	2.527	SEAFP	141.498219
3	0.131405	7.184	TUSCL	10.923572
4	0.013394	22.502	WPFULTONL	324.101874
5	0.008975	27.488	CLNY	73.622455
6	0.002198	55.540	TOCL	22.125003
7	0.000683707	99.593	CLVA	7.504492
8	0.000170884	199.211	TIME	229.866388

Portion INTERCEPT	Portion SEAFP	Portion TUSCL	Portion WPFULTONL	Portion CLNY	Portion TOCL	Portion CLVA	Portion TIME
0.0000	0.0000	0.0000	0.0000	0.0000	0.0003	0.0002	0.0000
0.0001	0.0001	0.0000	0.0000	0.0000	0.0158	0.0034	0.0000
0.0002	0.0002	0.0000	0.0001	0.0005	0.0731	0.0383	0.0015
0.0003	0.0145	0.0022	0.0155	0.0120	0.3993	0.0309	0.0006
0.0381	0.0149	0.0041	0.0009	0.0000	0.0028	0.4829	0.0272
0.0393	0.2855	0.0327	0.0457	0.0224	0.0023	0.4218	0.0133
0.8157	0.0106	0.2337	0.0955	0.0156	0.0134	0.0193	0.1736
0.1063	0.6743	0.7272	0.8423	0.9494	0.4930	0.0031	0.7838

TABLE B.3-2. Hard Clam Model Collinearity Diagnostics: Second-Stage Equations, Wholesale Price

Number	Eigenvalue	Condition Index	Variable	Variance Inflation
1	5.651	1.000	INTERCEPT	0.000000
2	0.315607	4.231	EXVPNY	55.657480
3	0.023941	15.364	SEAFP	55.424330
4	0.007806	26.906	TUSCL	4.429926
5	0.001210	68.351	WPFULTONL	176.222565
6	0.000477029	108.840	TIME	22.807411

Portion INTERCEPT	Portion EXVPNY	Portion SEAFP	Portion TUSCL	Portion WPF[illegible]	[illegible]on
0.0000	0.0001	0.0001	0.0000	0.00[illegible]	0.[illegible]3
0.0011	0.0018	0.0006	0.0016	0.0003	0.0013
0.0019	0.0329	0.0012	0.0004	0.0026	0.2638
0.0037	0.2287	0.2148	0.0084	0.0027	0.0238
0.0915	0.2820	0.7833	0.08[illegible]3	0.4629	0.0594
0.9018	0.4544	0.0000	0.9013	0.5315	0.6514

TABLE B.3-3. Hard Clam Model Collinearity Diagnostics: Second-Stage Equations, New York Ex-Vessel Price

Number	Eigenvalue	Condition Index	Variable	Variance Inflation
1	4.232	1.000	INTERCEPT	0.000000
2	0.689567	2.477	WPFULTON	88.648166
3	0.068857	7.840	CLNY	15.318238
4	0.008309	22.570	TOCL	14.347103
5	0.000850154	70.558	TIME	96.869478

Portion INTERCEPT	Portion WPFULTON	Portion CLNY	Portion TOCL	Portion TIME
0.0002	0.0001	0.0002	0.0016	0.0001
0.0012	0.0001	0.0008	0.0491	0.0000
0.0342	0.0005	0.0006	0.0770	0.0147
0.0198	0.1510	0.1414	0.8568	0.0000
0.9446	0.8482	0.8569	0.0155	0.9852

TABLE B.3-4. Hard Clam Model Collinearity Diagnostics: Second-Stage Equations, Virginia Ex-Vessel Price

Number	Eigenvalue	Condition Index	Variable	Variance Inflation
1	4.936	1.000	INTERCEPT	0.000000
2	0.930571	2.303	WPFULTON	70.004391
3	0.114381	6.569	CLVA	4.956511
4	0.010238	21.957	TOCL	16.691837
5	0.006955	26.639	EXVPNY	33.812294
6	0.002309	46.237	TIME	16.764838

Portion INTERCEPT	Portion WPFULTON	Portion CLVA	Portion TOCL	Portion EXVPNY	Portion TIME
0.0003	0.0001	0.0006	0.0011	0.0003	0.0005
0.0012	0.0001	0.0100	0.0204	0.0002	0.0001
0.0004	0.0010	0.0403	0.1483	0.0006	0.0462
0.3906	0.0311	0.5330	0.0143	0.0211	0.1968
0.0223	0.0008	0.0083	0.5352	0.7353	0.4524
0.5852	0.9668	0.4079	0.2807	0.2425	0.3041

APPENDIX B.4

COLLINEARITY DIAGNOSTICS FOR SOFT CLAM MODELS

TABLE B.4-1. Soft Clam Model Collinearity Diagnostics: First-Stage Equations

Number	Eigenvalue	Condition Index	Variable	Variance Inflation
1	7.039	1.000	INTERCEPT	0.000000
2	0.740040	3.084	SEAFP	139.777064
3	0.169762	6.439	WSOFTC	72.511787
4	0.028466	15.726	TSOCL	30.407519
5	0.014505	22.030	TIME	52.584813
6	0.006526	32.843	SOCLME	72.227687
7	0.000823638	92.449	TSURCL	3.335318
8	0.000464015	123.169	SOCLMD	93.324906

Portion INTERCEPT	Portion SEAFP	Portion WSOFTC	Portion TSOCL	Portion TIME	Portion SOCLME	Portion TSURCL	Portion SOCLMD
0.0001	0.0000	0.0001	0.0000	0.0001	0.0000	0.0006	0.0000
0.0003	0.0001	0.0011	0.0001	0.0004	0.0001	0.0003	0.0016
0.0000	0.0009	0.0036	0.0000	0.0001	0.0015	0.1033	0.0019
0.0091	0.0021	0.0132	0.0033	0.0116	0.0270	0.3134	0.0000
0.1303	0.0001	0.0001	0.0000	0.0763	0.0154	0.2079	0.0133
0.1117	0.0189	0.2361	0.0017	0.1444	0.0267	0.0516	0.0142
0.7031	0.8214	0.4802	0.0939	0.7481	0.0028	0.3194	0.0256
0.0455	0.1564	0.2656	0.9010	0.0191	0.9264	0.0035	0.9434

TABLE B.4-2. Soft Clam Model Collinearity Diagnostics: Second-Stage Equations, Wholesale Price

Number	Eigenvalue	Condition Index	Variable	Variance Inflation
1	6.487	1.000	INTERCEPT	0.000000
2	0.462055	3.747	WSOFTC	43.161366
3	0.028588	15.063	SEAFP	186.229951
4	0.012383	22.888	TSOCL	1.467881
5	0.006339	31.990	EXVSOPME	91.899589
6	0.003220	44.880	EXVSOPMD	34.738568
7	0.000753459	92.786	TIME	15.200970

Portion INTERCEPT	Portion WSOFTC	Portion SEAFP	Portion TSOCL	Portion EXVSOPME	Portion EXVSOPMD	Portion TIME
0.0002	0.0002	0.0000	0.0003	0.0001	0.0002	0.0003
0.0055	0.0016	0.0000	0.0131	0.0001	0.0051	0.0002
0.0306	0.0010	0.0003	0.0102	0.0101	0.0094	0.3295
0.0615	0.1086	0.0015	0.2731	0.0018	0.4407	0.0236
0.2872	0.4761	0.0013	0.6178	0.0024	0.0840	0.1669
0.5587	0.3243	0.0282	0.0804	0.2863	0.4312	0.0084
0.0563	0.0881	0.9666	0.0050	0.6993	0.0293	0.4711

TABLE B.4-3. Soft Clam Model Collinearity Diagnostics: Second-Stage Equations, Ex-Vessel Price (Maine)

Number	Eigenvalue	Condition Index	Variable	Variance Inflation
1	5.471	1.000	INTERCEPT	0.000000
2	0.411383	3.647	WSOFTC	55.500621
3	0.082733	8.132	SOCLME	7.946302
4	0.018246	17.315	TSURCL	3.164421
5	0.013392	20.212	EXVSOPMD	47.563233
6	0.003561	39.195	TIME	13.412714

Portion INTERCEPT	Portion WSOFTC	Portion SOCLME	Portion TSURCL	Portion EXVSOPMD	Portion TIME
0.0032	0.0002	0.0007	0.0011	0.0003	0.0006
0.0603	0.0021	0.0005	0.0277	0.0065	0.0009
0.7967	0.0001	0.0366	0.0845	0.0047	0.0082
0.1016	0.0043	0.6568	0.7514	0.0322	0.0021
0.0232	0.0344	0.1524	0.0803	0.0250	0.9817
0.0151	0.9589	0.1529	0.0549	0.9313	0.0066

TABLE B.4-4. Soft Clam Model Collinearity Diagnostics: Second-Stage Equations, Ex-Vessel Price (Maryland)

Number	Eigenvalue	Condition Index	Variable	Variance Inflation
1	5.153	1.000	INTERCEPT	0.000000
2	0.664636	2.785	WSOFTC	101.485638
3	0.150537	5.851	SOCLMD	9.149146
4	0.024113	14.619	TSURCL	3.784629
5	0.005433	30.799	EXVSOPME	43.488558
6	0.001790	53.653	TIME	18.528988

Portion INTERCEPT	Portion WSOFTC	Portion SOCLME	Portion TSURCL	Portion EXVSOPMD	Portion TIME
0.0003	0.0001	0.0006	0.0011	0.0002	0.0004
0.0010	0.0010	0.0206	0.0006	0.0005	0.0016
0.0000	0.0011	0.0213	0.1514	0.0039	0.0002
0.1035	0.0033	0.0932	0.0036	0.0115	0.2815
0.7083	0.0001	0.2044	0.7166	0.2346	0.3039
0.1869	0.9945	0.6599	0.1266	0.7494	0.4123

DISTRIBUTION

NUREG/CR-4002
PNL-5226
RE

No. of
Copies

15 M. Masnik
Office of Nuclear Reactor
Regulation - TMIPO
U.S. Nuclear Regulatory Commission
Bethesda, Maryland 20814

B. Snyder
Office of Nuclear Reactor
Regulation - TMIPO
U.S. Nuclear Regulatory Commission
Bethesda, Maryland 20814

U.S. Nuclear Regulatory Commission
Division of Technical Information
and Document Control
7920 Norfolk Avenue
Bethesda, Maryland 20014

O. Capps. Jr.
Department of Agricultural
Economics
V.P.I. and S.U.
Blacksburg, Virginia 24060

L. Shabman
Department of Agricultural
Economics
V.P.I. and S.U.
Blacksburg, Virginia 24060

46 Pacific Northwest Laboratory

RC Adams
L. Brown (30)
JW Currie
RM Fleischman
RJ Moe
LA Nieves (2)
MJ Scott
KL Imhoff
JJ Tawil
Publishing Coordination (2)
Technical Information (MH) (5)

NRC FORM 335
(2-84)
NRCM 1102,
3201, 3202

U.S. NUCLEAR REGULATORY COMMISSION

BIBLIOGRAPHIC DATA SHEET

SEE INSTRUCTIONS ON THE REVERSE

1. REPORT NUMBER (Assigned by TIDC, add Vol. No., if any)
NUREG/CR-4002
PNL-5226

2. TITLE AND SUBTITLE
Development and Application of Econometric Demand and Supply Models for Selected Chesapeake Bay Seafood Products

3. LEAVE BLANK

4. DATE REPORT COMPLETED

MONTH	YEAR
September	1984

5. AUTHOR(S)
L. A. Nieves, R. J. Moe

6. DATE REPORT ISSUED

MONTH	YEAR
December	1984

7. PERFORMING ORGANIZATION NAME AND MAILING ADDRESS (Include Zip Code)
Pacific Northwest Laboratory
P. O. Box 999
Richland, WA 99352

8. PROJECT/TASK/WORK UNIT NUMBER

9. FIN OR GRANT NUMBER
B2366

10. SPONSORING ORGANIZATION NAME AND MAILING ADDRESS (Include Zip Code)
TMI Program Office
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

11a. TYPE OF REPORT
Topical

b. PERIOD COVERED (Inclusive dates)

12. SUPPLEMENTARY NOTES

13. ABSTRACT (200 words or less)

Five models were developed to forecast future Chesapeake seafood product prices, harvest quantities, and resulting income. Annual econometric models are documented for oysters, hard and soft blue crabs, and hard and soft clams. To the degree that data permit, these models represent demand and supply at the retail, wholesale, and harvest levels. The resulting models have broad applications in environmental policy issues and regulatory analyses for the Chesapeake Bay.

14. DOCUMENT ANALYSIS - a. KEYWORDS/DESCRIPTORS

Chesapeake Bay	supply models
crabs	demand models
oysters	seafood markets
econometric analysis	
clams	

b. IDENTIFIERS/OPEN-ENDED TERMS

15. AVAILABILITY STATEMENT
Unlimited

16. SECURITY CLASSIFICATION
(This page)
Unclassified
(This report)
Unclassified

17. NUMBER OF PAGES

18. PRICE

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555

NUREG/CR-4002

DEVELOPMENT AND APPLICATION OF ECONOMETRIC DEMAND AND SUPPLY MODELS
FOR SELECTED CHESAPEAKE BAY SEAFOOD PRODUCTS

DECEMBER 1984