Effects of Post-Harvest Treatment Requirements on the Markets for Oysters

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Because of public health concerns, regulators are considering requiring post-harvest treatment of halfshell and shucked oysters by wholesalers and processors. Two recently developed post-harvest treatment technologies may actually reduce the costs of producing shucked oysters, but would increase the costs of halfshell oysters. An interregional model of the wholesale oyster industry is developed to estimate the effects of treatment requirements on prices, output, and employment. If post-harvest treatment is required for all Gulf oysters, price increases are estimated to be less than 20% and, in some cases, prices decrease. Results indicate producer and consumer losses in the halfshell market are partially or more than offset by gains in the shucked market.

Key Words: equilibrium displacement model, oysters, post-harvest treatment, *Vibrio vulnificus*

Regulators of the shellfish industries have been considering whether to require wholesalers and processors of oysters to use post-harvest treatment technologies because of concerns regarding illnesses and deaths due to *Vibrio vulnificus. V. vulnificus* is a bacterium that is naturally present in marine environments and is not associated with environmental contamination [Centers for Disease Control and Prevention (CDC), 2000a]. Although fewer than 100 cases occur each year, the CDC estimates *V. vulnificus* bloodstream infections are fatal about 50% of the time (CDC, 2000b). Most cases are associated with consumption of raw shellfish, particularly Gulf-harvested oysters served raw on the halfshell. However, anecdotal evidence suggests some cases may occur when individuals consume shucked oysters in raw form (see Muth et al., 2000).

In June 1998, the Center for Science in the Public Interest (CSPI) petitioned the U.S. Food and Drug Administration (FDA) to require that all oysters intended for raw consumption be treated using a post-harvest treatment method proven to kill *V. vulnificus* bacteria (CSPI, 1998). In response to the petition, the Interstate Shellfish Sanitation Conference (ISSC) and the FDA are interested in determining the potential economic effects of requiring post-harvest treatment of oysters harvested from the Gulf region of the United States or for the entire United States.[1]

The available post-harvest treatment technologies include cryogenic individual quick freezing (IQF), cool pasteurization, and hydrostatic pressure.[2] The companies currently using these technologies do so because they allow the companies to sell a differentiated (e.g., safer or longer shelf-life) product.

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[1] The FDA regulates seafood plants through its Office of Seafood; however, it has a memorandum of understanding with the Interstate Shellfish Sanitation Conference, an industry organization, to allow the industry to essentially regulate itself.

[2] Shellfish regulators have accepted the scientific data demonstrating the effectiveness of the cryogenic IQF and cool pasteurization processes in reducing *V. vulnificus* to nondetectable levels. Scientific data demonstrating the effectiveness of the hydrostatic pressure process have not yet been submitted.

The cryogenic IQF process, which has been in use for over a decade, is employed by one large plant in Texas and two substantially smaller plants in Florida. For this process, oysters are opened and put on the halfshell, and are then passed through a freezer tunnel that rapidly cools the oysters using liquid CO_2. However, the cryogenic IQF process has not been adapted for shucked oysters.

For the cool pasteurization process, which has been in use since 1997 by one plant in Louisiana, oysters are submerged in a computer-monitored tank of warm water, and then immediately cooled in a tank of cold water. Finally, the hydrostatic pressure process is a new technology, first used commercially in the summer of 1999 by one plant in Louisiana. In this process, oysters are loaded into a water-filled pressure chamber, which is then sealed and pressurized using an electric, 60 horsepower pump.[3] For both the cool pasteurization and hydrostatic pressure processes, oysters intended for the halfshell market are banded prior to treatment, while oysters intended for the shucked market are immediately shucked and put into containers.

The objective of this study is to evaluate the potential economic effects of requiring post-harvest treatment of both raw halfshell and shucked oysters by processors and wholesalers of oysters. To evaluate the economic effects, we developed a simple aggregate deterministic model of the wholesale market for oysters. Data were obtained from the National Marine Fisheries Service, augmented by information provided by industry representatives, to construct a regional baseline scenario of the wholesale oyster market prior to the availability of post-harvest treatment technologies.

For this analysis, we consider potential supply-side effects of treatment (i.e., the costs or potential cost savings and feasibility of treatment at oyster plants for each type of oyster). Potential demand-side effects of treatment are also considered (i.e., consumers' willingness to pay for treated oysters given that the oysters would be "safer" but could potentially have different sensory characteristics compared to untreated oysters). These estimated effects are used in an interregional equilibrium displacement model to predict the effects of treatment requirements on prices, output, and employment in the oyster industry.

[3] The hydrostatic pressure process is so new that when we evaluated it, the company owning the technology had not yet worked out the licensing agreement for other companies to adopt it.

In the scenario presented here, it is assumed that treatment requirements would apply only to the Gulf region. Using the estimated market-level changes from the equilibrium displacement model, changes in producer and consumer surplus are estimated for each product in each region in the United States. Because of uncertainties regarding the demand shift estimates (which are described later), the effects of treatment requirements are estimated both with and without demand shifts.

The remainder of this article is organized as follows. The next section demonstrates graphically the potential economic effects of treatment requirements and the associated equilibrium displacement model. Next, we describe the baseline oyster industry data and the supply and demand curve shift estimates based on the data-collection process. Estimates of the effects of requiring treatment on prices, output, employment, and producer and consumer surplus are then presented. Finally, we discuss the implications of our results for the shellfish regulatory agencies and suggest potential areas for further research.

A Model of the Effects of Post-Harvest Treatment of Oysters

The oyster industry is comprised primarily of three sectors: harvesters, wholesalers/processors, and retailers. Harvesting operations, which can vary from purely "wild" harvesting to highly managed cultivating operations, bring mature oysters from harvest waters to wholesalers/processors. Some harvesters deliver directly to restaurants or other retail outlets, but it is more common for harvesters to sell oysters either to wholesalers or to processors. Wholesalers repack shellstock into sacks, boxes, or bushels and sell them to processors or directly to restaurants or retailers. Processors produce raw shucked oysters; prepared raw halfshell oysters; and smoked, cooked, or canned oysters.

Post-harvest treatment of oysters directly affects wholesalers and processors of oysters (i.e., the wholesale market for oysters) because it changes the wholesale-level costs of producing oysters and impacts the derived demand for oysters. Based on the per unit cost estimates of treatment, which are described in the data section below, treatment requirements will increase the cost of producing halfshell oysters but may increase or decrease the costs of producing shucked oysters, depending on which technology is considered. The requirements would also indirectly affect the harvest-level market

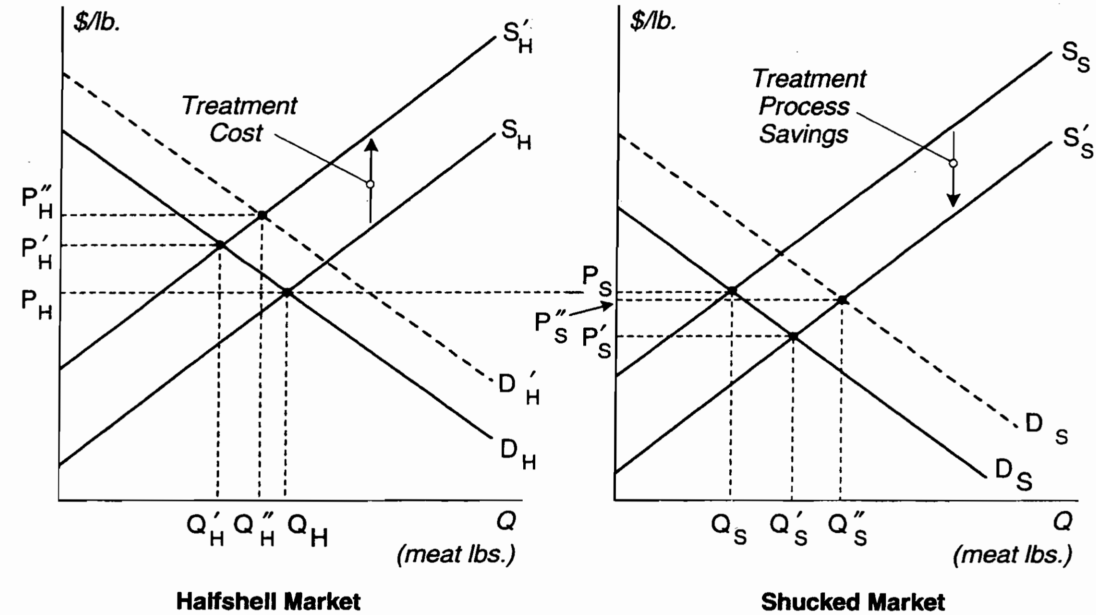

Figure 1. Wholesale market effects of a treatment process that increases the costs of producing halfshell oysters but decreases the costs of producing shucked oysters

for oysters because of changes in the volume of oysters demanded from the wholesale market.

Assuming the wholesale markets for both types of oysters are perfectly competitive, figure 1 illustrates the more likely scenario in which post-harvest treatment increases the costs of producing halfshell oysters but reduces the costs of producing shucked oysters.[4] In the halfshell market, the costs of treatment shift the supply curve upward from S_H to S'_H, and in the shucked market, the cost savings from treatment shift the supply curve downward from S_S to S'_S. Ignoring for the moment potential shifts in the demand for oysters as a result of treatment, the price of halfshell oysters rises relative to the price for untreated oysters from P_H to P'_H, and the price of shucked oysters falls from P_S to P'_S. Correspondingly, the market-clearing quantity of halfshell oysters decreases from Q_H to Q'_H, and the market-clearing quantity of shucked oysters increases from Q_S to Q'_S.

If, however, demand for each type of oyster increases (e.g., due to increased safety and other quality changes), then the price of halfshell oysters increases to P''_H, and the price of shucked oysters may increase or decrease compared to the price of untreated shucked oysters, depending on the relative size of the supply and demand shifts (shown as a decrease to P''_S in figure 1). The market-clearing quantity of halfshell oysters may increase or decrease compared to the market-clearing quantity for untreated oysters depending on the relative sizes of the supply and demand shifts (shown as a decrease to Q''_H in figure 1), and the market-clearing quantity of shucked oysters will increase to Q''_S.

In addition to the shifts in supply and demand due to the direct effects of the treatment process, supply and demand for each product may also shift because of the changes in relative prices of each. In other words, if the price of halfshell oysters rises while the price of shucked oysters falls as a result of treatment requirements, consumers may substitute shucked oysters for halfshell oysters, and producers may shift some production from shucked oysters to halfshell oysters. Similarly, if the price of halfshell or shucked oysters in one region rises relative to the other regions, the derived demand for oysters from that region will decrease while the derived demand for oysters from other regions will increase.

The shellstock market is indirectly affected by treatment because the quantities of shellstock used

[4] We assume the markets for oysters are perfectly competitive because oyster markets in all regions of the country are generally characterized by many small buyers and sellers.

for halfshell and shucked product change. Specifically, if we assume all other inputs, such as labor, water, and energy, are competitively supplied at a constant market price, then decreases in the market quantities of halfshell and shucked oysters correspond to decreases in the market quantity of shellstock. Thus, the price of shellstock decreases along an upward-sloping supply curve for shellstock. However, as the price of shellstock falls, the costs of producing halfshell and shucked oysters decrease, which increases the supply of each product at the wholesale level.

Based on the relationships described above, an interregional equilibrium displacement model was developed of the wholesale halfshell, wholesale shucked, and harvest-level shellstock markets. In developing the model, the following assumptions were made: (*a*) perfectly competitive markets; (*b*) four oyster harvesting and processing regions—Atlantic, Gulf, Northeast, and Pacific—with interregional trade between the Atlantic and Gulf, Atlantic and Northeast, and Gulf and Pacific regions;[5] (*c*) shellstock can be harvested from any region of the country to satisfy processing needs in the other regions; and (*d*) international trade flows of oysters will be unaffected by treatment requirements.

Relative to assumption (*d*), international trade in oysters could potentially be affected by treatment requirements if the requirements meant oysters could not be shipped from or imported into the United States unless treated; however, because international trade of fresh raw halfshell and shucked oysters is a small segment of the industry, and because it is not known how the requirements would apply to traded oysters, this segment is not considered in the model.

For each region, we begin with an equation for the equilibrium conditions in the wholesale halfshell market, wholesale shucked market, and harvest-level shellstock market. For example, in the Gulf region, which makes up nearly two-thirds of the industry volume, wholesale demand and supply for halfshell oysters are equated as follows:

$$(1)\qquad Q_H^D\left(P_H^G, P_H^A, P_H^P, P_S^G, TP_H^G\right) = Q_H^S\left(P_H^G, P_S^G, P_O^G, TC_H^G\right),$$

where, from the left-hand side, Q_H^D is the demand for halfshell oysters, P_H^G is the price of halfshell oysters in the Gulf, P_H^A is the price of halfshell oysters in the Atlantic, P_H^P is the price of halfshell oysters in the Pacific, P_S^G is the price of shucked oysters in the Gulf, and TP_H^G is a demand shifter for consumer preferences toward treatment of Gulf halfshell oysters. On the right-hand side of the equation, Q_H^S is the supply of halfshell oysters, P_O^G is the price of shellstock oysters in the Gulf, and TC_H^G is a supply shifter for the costs of treatment of Gulf halfshell oysters.

We assume halfshell oyster prices in the Gulf are affected by halfshell oyster prices in the Atlantic and Pacific regions and by shucked oyster prices in the Gulf. Thus, halfshell oyster prices in the Gulf are assumed to be unaffected (directly) by shucked oyster prices in the other regions. Note also that this expression assumes prices of other food products (e.g., other shellfish, seafood, protein sources) would not change as a result of changes in oyster prices arising from post-harvest treatment. Because our model uses a single year as the baseline, we assume treatment requirements will not be affected by other demand factors such as income and population. Furthermore, it is assumed that other supply factors, such as wages and energy costs, will not be affected by treatment requirements.

Next, equilibrium in the Gulf shucked oyster market is specified as follows:

$$(2)\qquad Q_S^D\left(P_S^G, P_S^A, P_S^P, P_H^G, TP_S^G\right) = Q_S^S\left(P_S^G, P_H^G, P_O^G, TC_S^G\right),$$

where, from the left-hand side, Q_S^D is the demand for shucked oysters in the Gulf, P_S^G is the price of shucked oysters in the Gulf, P_S^A is the price of shucked oysters in the Atlantic, P_S^P is the price of shucked oysters in the Pacific, P_H^G is the price of halfshell oysters in the Gulf, and TP_S^G is a demand shifter for consumer preferences toward treatment of shucked Gulf oysters. On the right-hand side of the equation, Q_S^S is the supply of shucked oysters in the Gulf, P_O^G is the price of shellstock oysters in the Gulf, and TC_S^G is a supply shifter for the costs of treatment of Gulf shucked oysters. The assumptions of this equilibrium expression are the same as for the halfshell market equilibrium expression (1).

Finally, because the demand for shellstock is derived from the demand for halfshell and shucked oysters, equilibrium in the shellstock market is determined based on the quantity demanded from each of these markets:

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[5] We assumed oysters are shipped between these regions but not between the Northeast and the Gulf or between the Northeast and the Pacific based on information provided by multiple industry representatives. Because fresh oysters are highly perishable, they are usually shipped only between adjacent regions.

$$(3) \qquad Q_O^G\left(P_O^G\right) = Q_H^G + Q_S^G,$$

where Q_O^G is the quantity of shellstock oysters, Q_H^G is the quantity of halfshell oysters, and Q_S^G is the quantity of shucked oysters. The equilibrium price in the shellstock market is determined based on the supply function for shellstock oysters.

This set of equilibrium conditions was developed for each of the four regions included in the analysis. By totally differentiating the equilibrium conditions in the halfshell and shucked oyster markets and expressing each in elasticity form, a set of five equations was obtained for each region, describing the following:

- price changes in the wholesale halfshell market,
- price changes in the wholesale shucked market,
- quantity changes in the wholesale halfshell market,
- quantity changes in the wholesale shucked market, and
- price changes in the shellstock harvest market.

The change in the quantity of shellstock oysters was then obtained by adding the quantity changes in the halfshell and shucked markets because, as noted above, the shellstock market is assumed to adjust completely to changes in the halfshell and shucked markets.

The complete model, with 20 equations and 20 unknowns (five equations for each of the four markets), is provided in appendix table A1. The model was programmed in Microsoft Excel to obtain the matrix solutions to the model under alternative scenarios. The percentage shifts in the supply and demand for oysters resulting from treatment are used as inputs into the model. Plausible estimates of the elasticities needed to parameterize the model were developed based on estimates in Cheng and Capps (1988) and Anderson et al. (1996), and on descriptions of industry practices (see appendix table A2 for a complete listing of elasticities). These estimates allow us to provide indications, but not precise estimates, of the magnitude of responses to post-harvest treatment.

Based on Cheng and Capps' (1988) estimate for shucked oysters consumed at home, the own-price elasticity of demand for Gulf shucked oysters at the wholesale level is assumed to be −1.10. The demand for Gulf halfshell oysters is expected to be less elastic than the demand for shucked oysters, but no empirical estimates of the own-price elasticity of demand are available; thus, a value of −0.55 is assumed, which is half the value for shucked oysters. The own-price elasticities of demand for halfshell and shucked oysters in each region were then based on these estimates. To make this adjustment, we calculated how much higher the price in percentage terms was in other regions and increased the elasticity estimates by that proportion.[6]

The within-region cross-price elasticity of demand between halfshell and shucked oysters in all regions is assumed to be 0.30, based on Cheng and Capps' (1988) estimate of the cross-price elasticity of demand for oysters and poultry. No empirical estimates of the cross-price elasticities of demand across regions are available, but these values are expected to be very inelastic. For trade between the Gulf and other regions, a value of 0.20 is assumed for the cross-price elasticities of demand for halfshell oysters in different regions, and a more elastic value of 0.40 for the cross-price elasticities of demand for shucked oysters due to the greater transportability of shucked oysters. For trade between the Atlantic and Northeast regions, which are not affected by the *V. vulnificus* threat, these values are assumed to be 50% higher.

On the supply side, a very inelastic supply for shellstock oysters of 0.1 is assumed, because the quantity of shellstock is primarily environmentally influenced. Although oyster harvesters may exert more effort to harvest oysters when prices are higher, the total quantity harvested will not be affected substantially in the short run. Because no supply elasticity estimates are available for halfshell and shucked oysters at the wholesale level, it is assumed these values are 1.0.

Even though harvest volumes may be largely fixed, supply is more elastic at the processing level when processors have a choice of the product form in which to process a given catch (see Roy, Mazany, and Schrank, 1994). However, because some processors have established markets for one product or another, we believe there are limits to the amount of substitutability between halfshell and shucked oysters. Thus, a low value is assumed for the cross-price elasticity of supply between shucked and halfshell oysters (−0.30). Finally, the cross-price elasticities of supply between the shellstock and halfshell markets and between the shellstock and shucked markets are based on Anderson et al.'s (1996) conjecture that approximately half of the value of shellstock price changes is reflected in wholesale market supply adjustments.

[6] A reviewer noted this assumption implies oysters from all regions are homogeneous products. However, the attributes of oysters vary across regions. Although this method of adjusting elasticities is not precise, it provides a method for adjusting them in the right direction.

Table 1. Baseline Wholesale Oyster Industry Data, 1997

Description	U.S. Total	Region: Atlantic	Gulf[a]	Northeast	Pacific
Halfshell Price (output):					
Per meat-weight pound ($)	6.64	7.70	5.55	9.56	7.94
Per oyster ($)[b]	0.18	0.20	0.14	0.24	0.37
Shucked Price (output):					
Per meat-weight pound ($)	4.42	5.13	4.44	5.31	3.97
Per oyster ($)[b]	0.14	0.13	0.11	0.14	0.19
Shellstock Price (input):					
Per meat-weight pound ($)	2.57	3.41	2.13	3.61	2.74
Per oyster ($)[b]	0.07	0.09	0.05	0.09	0.13
Halfshell Volume (output):					
Meat-weight pounds (millions)	17.8	1.8	11.1	2.4	2.5
No. of oysters (millions)[b]	652.7	69.8	436.7	93.7	52.5
Shucked Volume (output):					
Meat-weight pounds (millions)	29.3	5.3	13.9	0.3	9.8
No. of oysters (millions)[b]	975.7	209.4	545.8	10.4	210.1
Shellstock Volume (input):					
Meat-weight pounds (millions)	47.0	7.1	25.0	2.6	12.3
No. of oysters (millions)[b]	1,628.4	279.1	982.5	104.1	262.7
Halfshell Revenue ($ millions)	117.7	13.7	61.7	22.8	19.5
Shucked Revenue ($ millions)	129.5	27.4	61.7	1.4	38.9
Shellstock Cost ($ millions)	120.8	24.2	53.3	9.6	33.6
Number of Plants:[c]					
Shucker/packer	392	112	161	79	40
In-shell	1,121	232	173	446	270
Number of FTE Workers[d]	1,953	398	1,098	42	416

[a] Gulf halfshell and shellstock volumes do not include the 10% of the market estimated to be processed by cryogenic individual quick freezing (IQF).

[b] We assumed a yield of seven pounds of meat per 275 oysters, except in the Pacific where we assumed 150 oysters because Pacific oysters are larger than the Eastern oysters harvested in the other regions.

[c] The number of plants listed is the number of shellfish shippers and shuckers/packers on the Interstate Shellfish Shippers List, and is an upper bound on the number of oyster plants. Because inland plants are not included above, U.S. totals shown here are less than U.S. totals appearing on the Shippers List.

[d] FTE = full-time equivalent. The number of FTE workers was estimated assuming 14,000 meat pounds per shucker and 105,000 pounds per worker handling in-shell oysters.

Baseline Data, Supply Shifts, and Demand Shifts

The data used to estimate the economic effects of treatment requirements include the 1997 baseline industry data and the proportionate supply and demand shift estimates for the treatment technologies. Table 1 provides the baseline industry data used in the model. Although the data are included in the model in meat-weight equivalents, the corresponding estimated numbers and prices of individual oysters are also listed in table 1.

Two primary reasons explain the use of 1997 industry data as the baseline in the model. First, it is the most recent year for which complete data are available for the industry. Second, with the exception of the cryogenic IQF process, post-harvest treated oysters were not yet widely available; thus, the 1997 data are mostly unaffected by changes in the marketplace resulting from the availability of post-harvest treatment technologies.

The majority of the data were obtained from the U.S. National Marine Fisheries Service (Koplin, 1999), the U.S. Department of Commerce [(USDC), 1997], and the FDA (2000). These data were augmented with information provided by several individuals within the industry [USDC/National Oceanic and Atmospheric Administration (NOAA), 1999].[7] However, because cryogenic IQF oysters, which comprise approximately 10% of the volume of oysters in the Gulf, are marketed differently from and to a different clientele than fresh oysters, this volume was excluded from the baseline data (see Muth et al., 2000).

Costs of Treating Oysters (Supply Shifts)

To obtain estimates of the per unit costs of treating oysters—used as a proxy for the shift in supply of oysters if treatment were required—we interviewed representatives of the three companies currently supplying treated oysters: Hillman Shrimp and Oyster Company, Dickinson, Texas; AmeriPure Oyster Companies, Inc., Kenner, Louisiana; and Motivatit Seafoods, Inc., Houma, Louisiana. These companies are large relative to average size plants in the industry, and have all voluntarily developed and adopted post-harvest treatment technologies in order to market differentiated products or because post-harvest treatment reduces production costs.

Hillman Shrimp and Oyster Company currently uses the cryogenic IQF process in one plant and plans to install treatment equipment in a second plant (Hillman, 1999). The cryogenic IQF process allows the company to market oysters to cruise lines, casinos, and other establishments requiring oysters that can be stored for long periods of time and that are already prepared on the halfshell.

AmeriPure Oyster Companies developed the cool pasteurization process for marketing safer oysters, particularly to restaurants and establishments such as Red Lobster and Marriott (Schegan and Fahey, 1999). Motivatit Seafoods, Inc., the third oyster supplier interviewed, developed the hydrostatic pressure process, primarily because the company was seeking a less costly method for shucking oysters (Voisin, 1999).

The owners of these three companies were asked to provide information for two or more typical plant sizes based on a typical operating schedule. Using the data furnished by the company owners, we then adjusted their estimates to a consistent operating schedule (2,500 hours per year), aggregated individual capital equipment items and operating and maintenance items, and annualized plant expansion and capital equipment costs. The resulting cost estimates include the following:

- annualized plant expansion costs for the space required to house the treatment equipment;
- annualized capital equipment and installation costs;
- annual operating and maintenance costs (e.g., labor, energy, water, replacement parts, and oyster bands for halfshell product); and
- per unit royalties charged by the owners of the technologies for the cool pasteurization and hydrostatic pressure processes.

Table 2 lists the per unit treatment costs for medium-size (or average-size) processes for each treatment technology. The estimates provided are based on $10 per hour wage rates (including benefits), and also on $15 per hour wage rates (including benefits) to reflect higher wage rates in the Northeast region.[8] While estimates on a per meat pound are used in the model, estimates on a per oyster basis are also given in table 2 for comparison. Although all three treatment technologies increase the costs of producing halfshell oysters, two of the technologies actually reduce the costs of producing shucked oysters by up to 3¢ per oyster. These cost savings for shucked oysters arise because the technologies increase weight yields per oyster, reduce the required amount of shucking labor, or both.

It may appear puzzling that oyster facilities have not yet adopted technologies which could reduce their costs of production. However, because these technologies are so new, they have not yet diffused throughout the industry. Furthermore, the scientific data to demonstrate the effectiveness of the hydrostatic pressure process have not yet been submitted to shellfish regulators. Compared to the cool pasteurization and hydrostatic pressure treatment processes, the treatment costs for IQF halfshell product are very large, primarily because the oysters must be shucked and prepared on the halfshell prior to treatment and because the oysters must be kept frozen once they are treated.

Willingness to Pay for Treated Oysters (Demand Shifts)

To obtain estimates of the changes in willingness to pay for treated oysters—used here as a proxy for the shift in demand for oysters if treatment were required—we conducted taste tests of treated oysters in New Orleans, interviewed 20 restaurant managers

[7] See Muth et al. (2000) for a complete description of the data collection and adjustment process.

[8] These wage rate estimates were provided by industry representatives in each of the modeled regions.

Table 2. Per Unit Treatment Cost Estimates (medium or average size processes)

Treatment Process	Halfshell Wage Rates		Shucked Wage Rates	
	$10/Hour	$15/Hour	$10/Hour	$15/Hour
	<------------------- dollars ($) ------------------->			
Cryogenic IQF:				
Cost per oyster	0.139	0.177	NA[a]	NA[a]
Cost per meat-weight pound[b]	5.461	6.954	—	—
Cool Pasteurization:				
Cost per oyster	0.035	0.043	−0.001	0.002
Cost per meat-weight pound[b]	1.375	1.689	−0.039	0.079
Hydrostatic Pressure:				
Cost per oyster	0.033	0.036	−0.029	−0.028
Cost per meat-weight pound[b]	1.296	1.414	−1.139	−1.100

[a] The cryogenic individual quick freezing (IQF) process has not been adopted for use on shucked oysters.

[b] Cost per pound of meat was calculated based on the assumption that 275 oysters yield seven pounds of meat. In the Pacific, where a different species of oyster is harvested, the cost per oyster would be higher than these estimates, but the number of oysters per pound would be lower; consequently, the per pound estimates would be similar.

throughout the United States, and interviewed representatives from plants that currently market treated oysters about their sales experiences. Each of these data-collection processes is discussed more fully below.

Acceptance of treated oysters by individual consumers depends on whether the individual is concerned about safety and whether sensory changes are perceived as a result of treatment. In comparison, acceptance of treated oysters by restaurant managers is based on their perception of the derived demand for treated oysters by consumers, but also on their concerns about potential liability from serving oysters.

In addition to sensory and safety considerations, offering treated oysters may be more feasible for retail establishments if the treatment eliminates the need to have an oyster shucker on staff. In particular, oysters treated by the hydrostatic pressure process are opened by the process, but are kept shut with a band. Oysters treated by the cryogenic IQF process are sold frozen on the halfshell. In either case, treated halfshell oysters can be served without an experienced shucker on staff. Ultimately, acceptance of treated oysters by both restaurant managers and grocery stores is reflected in the sales experiences of the companies that market treated oysters.

The blind taste tests of raw halfshell oysters were conducted in August 1999, in New Orleans.[9] Nineteen participants, all of whom were frequent consumers of oysters, evaluated untreated oysters and oysters treated by each of the three treatment methods. Because treated oysters currently retail in the range of $1 to $2 per dozen more than untreated oysters, the participants were asked how treatment combined with a price increase in this range would affect their consumption of oysters, assuming only treated oysters were available on the market. Participants' responses, which were similar across treatments, indicated they would reduce the frequency with which they consume oysters by one-third to one-half. Responses were essentially the same at either a $1 or a $2 price increase. These reactions may be due to one or more of the following factors: (*a*) the increased price for treated oysters; (*b*) changes in the sensory characteristics of treated oysters; and (*c*) the perception that treated oysters are no longer a raw, live product.

The results of our taste test are consistent with the findings of a survey conducted with approximately 1,000 individuals in the mid-Atlantic and Southeastern states (Lin and Milon, 1995). This survey found that frequent oyster consumers (comparable to the taste test participants in our survey) were less willing to pay a price premium for safer oysters than infrequent consumers. However, based on results reported by Lin and Milon, their survey respondents overall were willing to pay 18% to 20% more for safer oysters without regard to potential changes in the sensory characteristics of the oysters.

In addition, a survey of approximately 1,000 Florida residents found 70% of respondents would be willing to pay up to double the untreated oyster price for oysters treated by a depuration process

[9] A more complete description of the taste tests is available in Muth et al. (2000).

Table 3. Proportionate Demand Shift Estimates Resulting from Post-Harvest Treatment

	Demand Shift Estimates (%)[a]	
Treatment Process	Halfshell	Shucked
Cryogenic IQF	33	NA[b]
Cool Pasteurization	15	15
Hydrostatic Pressure	20	10

[a] These percentages were calculated based on data provided by the companies that currently sell post-harvest treated oysters.

[b] The individual quick freezing (IQF) process has not been adopted for use on shucked oysters.

that reduces the number of pathogenic organisms (Degner and Petrone, 1994).

In the fall of 1999, a survey of 20 restaurant managers was conducted in San Antonio, New Orleans, Gulfport, New York, Chicago, Seattle, and various cities in Florida. Separate surveys were developed for restaurants that currently serve cooked oysters only, serve raw untreated oysters, and serve treated oysters. Three of the six restaurants currently serving cooked oysters indicated they are at least somewhat likely to serve raw treated oysters, but the other three were either somewhat unlikely or unlikely to do so. Six of the seven restaurants currently serving raw untreated oysters reported they expect that treatment would have no effect on sales if only treated oysters were available and treated oysters retailed for $1 more per dozen. Finally, six of the seven restaurants currently serving either cool pasteurized or cryogenic IQF oysters responded that their patrons do not seem to have noticed a difference in the oysters served.

When we questioned representatives of the companies currently marketing treated oysters, they claimed they are able to obtain a higher price for treated oysters compared to untreated oysters. Based on their responses, we calculated an approximate percentage increase in willingness to pay at the wholesale level for halfshell and shucked oysters for each treatment process. These percentages, which are provided in table 3, indicate a price increase of 10% to 33% for treated oysters. However, we were only partially able to independently verify these stated increases.

Overall, most evidence on the potential effects of post-harvest treatment on demand for oysters suggests demand will be unaffected or may potentially increase relative to untreated oysters. Because of the uncertainties in estimating the potential increase in demand for oysters, our model is estimated below both with and without the demand shifts.

Model Results

Regulators of the shellfish industries could institute post-harvest treatment requirements for oysters in a number of ways. For example, they could require treatment of all oysters harvested in all regions of the United States, all oysters harvested in the Gulf, or only Gulf-harvested oysters intended for the raw halfshell market. For the purposes of this analysis, the results of the model are presented based on the assumption that the requirements would apply to the Gulf region for both halfshell and shucked oysters.

Because insufficient information is available on the characteristics of oyster plants to model the process of technology adoption, separate results are estimated assuming, in one case, that all producers adopt the cool pasteurization process and, in a second case, that all producers adopt the hydrostatic pressure process. As explained previously, we believe cryogenic IQF oysters are in a different market from fresh oysters, and therefore treatment requirements would not essentially affect the market for cryogenic IQF oysters. Consequently, we exclude the portion of the Gulf oyster volume available in the form of cryogenic IQF product and do not present separate results assuming additional adoption of this process.

Table 4 presents the predicted effects of requiring post-harvest treatment of Gulf oysters for both the cool pasteurization and hydrostatic pressure processes assuming no shift in demand for oysters as a result of treatment. The differences between these two treatments arise primarily because the hydrostatic pressure process results in greater cost savings for shucked oysters compared to the cool pasteurization process and a reduction rather than an increase in the required number of plant workers.

First, assuming all producers adopt the cool pasteurization process, the wholesale price of halfshell oysters is predicted to increase by 18.8% in the Gulf compared to 3% or less for the other regions. Prices of shucked oysters are predicted to increase by 5.6% even though the per unit processing costs decrease because consumers will shift some consumption from halfshell to shucked product. In the Gulf, the equilibrium quantity of halfshell oysters is estimated to decrease by 7.5%, while the quantity of shucked oysters is estimated to increase by 1%.

The net effect in the Gulf of changes in these two markets is a reduction in the equilibrium quantity of shellstock oysters by 2.8%. In comparison, the quantities of all products increase in the other regions as

Table 4. Predicted Effects of Requiring Post-Harvest Treatment of Gulf Oysters with Only Supply Shifts Included in the Model (1997 baseline)

	Percentage Changes by Region			
Treatment Process	Atlantic	Gulf	Northeast	Pacific
Cool Pasteurization Process				
▸ **Wholesale Prices:**				
Halfshell (output)	3.0	18.8	0.7	2.7
Shucked (output)	2.0	5.6	0.7	1.7
Shellstock (input)	0.1	-0.3	0.0	0.1
▸ **Quantities:**				
Halfshell (output)	2.3	-7.5	0.5	2.2
Shucked (output)	1.0	1.0	0.5	0.9
Shellstock (input)	1.3	-2.8	0.5	1.1
▸ **Plant Employment**	1.1	28.1	0.5	0.9
Hydrostatic Pressure Process				
▸ **Wholesale Prices:**				
Halfshell (output)	0.8	11.7	0.0	0.8
Shucked (output)	-1.6	-9.4	-0.4	-1.5
Shellstock (input)	-0.1	0.3	0.0	-0.1
▸ **Quantities:**				
Halfshell (output)	1.3	-9.0	0.1	1.3
Shucked (output)	-1.8	12.6	-0.4	-1.7
Shellstock (input)	-1.0	3.0	0.1	-1.1
▸ **Plant Employment**	-1.6	-28.1	-0.1	-1.5

consumers substitute oysters from other regions for Gulf oysters. Overall, employment at Gulf plants is predicted to increase by 28.1% due to the increase in workers required to run the treatment process and the increase in shucked oyster volumes (shucked oysters require more workers relative to halfshell oysters).

Because the hydrostatic pressure process substantially lowers the per unit processing costs for shucked oysters, adoption of this process in the Gulf region results in a greater reduction in the quantity of halfshell oysters (9%) and a greater increase in the quantity of shucked oysters (12.6%) than the cool pasteurization process. The net effect of these changes is an increase in the quantity of shellstock oysters at the harvest level of 3%. In other regions, the quantity of halfshell oysters increases slightly as the quantity of shucked oysters decreases as a result of substitution of product between regions.

In the Gulf, the price of halfshell oysters is predicted to increase by 11.7%, and the price of shucked oysters is predicted to decrease by 9.4% as producers shift production to shucked oysters. Because of the increased demand for shellstock oysters, the price of shellstock oysters is predicted to increase by 0.3%. In other regions, the prices of halfshell oysters are predicted to be unchanged or increase slightly, while the prices of shucked and shellstock oysters decrease slightly.

Finally, although the cool pasteurization process is predicted to increase plant employment, the hydrostatic pressure process is predicted to decrease plant employment in the Gulf region by 28.1%, primarily due to a reduction in shucking labor.

The economic effects of treatment requirements were also estimated assuming that not only will the costs of production change but also that the demand for treated oysters will increase relative to untreated oysters. The percentage increases in willingness to pay for oysters, as reported by the companies currently treating oysters, are used as a proxy for the proportionate shift in demand for treated oysters (see table 3). Table 5 presents the predicted effects of requiring post-harvest treatment of Gulf oysters with both supply and demand shifts included in the model.

In this case, increases are predicted in the prices and quantities of both halfshell and shucked oysters for both treatments. In the Gulf, prices are estimated to increase by 30.2% to 34.7% for halfshell oysters, and by 2.1% to 18.8% for shucked oysters. Quantities are predicted to increase by 3.9% to 5.6% for halfshell oysters, and by 8.9% to 18% for shucked oysters.

Table 5. Predicted Effects of Requiring Post-Harvest Treatment of Gulf Oysters with Supply and Demand Shifts Included in the Model (1997 baseline)

	Percentage Changes by Region			
Treatment Process	Atlantic	Gulf	Northeast	Pacific
COOL PASTEURIZATION PROCESS				
▸ **Wholesale Prices:**				
Halfshell (output)	6.2	34.7	1.6	5.7
Shucked (output)	5.5	18.8	1.9	4.9
Shellstock (input)	0.4	0.7	0.1	0.3
▸ **Quantities:**				
Halfshell (output)	4.3	3.9	0.9	4.0
Shucked (output)	3.5	8.9	1.3	3.0
Shellstock (input)	3.7	6.7	1.0	3.2
▸ **Plant Employment**	3.5	39.8	1.1	3.1
HYDROSTATIC PRESSURE PROCESS				
▸ **Wholesale Prices:**				
Halfshell (output)	4.2	30.2	0.9	3.9
Shucked (output)	1.7	2.1	0.7	1.4
Shellstock (input)	0.1	1.3	0.1	0.1
▸ **Quantities:**				
Halfshell (output)	3.6	5.6	0.6	3.5
Shucked (output)	0.4	18.0	0.4	0.2
Shellstock (input)	1.2	12.5	0.6	0.9
▸ **Plant Employment**	0.5	-20.3	0.5	0.4

As a result of increases in halfshell and shucked oyster quantities, the quantity and price of harvest-level shellstock oysters increase as well. However, increases in shellstock harvests of the magnitude predicted by the model may not be feasible given current practices for harvesting oysters and the current stock of oysters.

Using the predicted price and quantity changes from the model, changes in producer and consumer surplus resulting from post-harvest treatment requirements were estimated, assuming consumers are indifferent between treated and untreated oysters. These estimates assume treatment affects only the costs of producing but not the demand for oysters, because the latter results are more tenuous and because the predicted increases in oyster harvests are likely infeasible. Table 6 presents the estimated changes in producer and consumer surplus for both the cool pasteurization and hydrostatic pressure processes. In estimating these surplus changes, linear demand and supply curves and parallel supply curve shifts were assumed.

For the cool pasteurization process, producer surplus is estimated to decrease by approximately $4 million in the Gulf halfshell oyster market because of the higher costs of processing halfshell oysters, but is estimated to increase by approximately $2.3 million in the Gulf shucked oyster market because of the lower costs of processing.[10] However, as a result of interregional trade, producer surplus in the other regions is estimated to increase in both markets but by smaller absolute amounts. Consumer surplus in the Gulf halfshell market is predicted to decrease by nearly $9.6 million, while consumer surplus in the Gulf shucked market is estimated to decrease by nearly $1.5 million. In this case, consumer surplus in most of the other regions is predicted to decrease slightly in both the halfshell and shucked oyster markets.

In the halfshell oyster market, the measures of producer and consumer surplus for the hydrostatic pressure process are similar to those for the cool pasteurization process because the costs of treating halfshell oysters are similar. However, the processing cost savings for shucked oysters are much larger; thus, the measures of producer and consumer surplus are substantially larger and in some cases opposite in sign. In particular, for the hydrostatic

[10] To place the surplus changes discussed in this section in context, the benefits of eliminating the 20 or so deaths that occur each year because of *V. vulnificus* in oysters would be approximately $120 million, assuming a value of a statistical life of $6 million (U.S. EPA, 1997). Including the benefits of eliminating the morbidity due to *V. vulnificus* would increase this figure even more.

Table 6. Estimated Changes in Producer and Consumer Surplus Resulting from Post-Harvest Treatment of Gulf Oysters with Only Supply Shifts Included in the Model (1997 baseline, $000s)

		Region			
Treatment Process	U.S. Total	Atlantic	Gulf	Northeast	Pacific
COOL PASTEURIZATION PROCESS					
▸ **Producer Surplus:**					
Halfshell (output)	-3,179.2	316.5	-4,025.4	103.3	426.4
Shucked (output)	2,949.1	284.9	2,319.8	6.7	337.7
▸ **Consumer Surplus:**					
Halfshell (output)	-9,604.0	-3.3	-9,577.8	-23.6	0.8
Shucked (output)	-1,841.0	-162.3	-1,467.3	-2.4	-208.9
▸ **Net Surplus Change**	-11,675.1	435.7	-12,750.7	83.9	556.0
HYDROSTATIC PRESSURE PROCESS					
▸ **Producer Surplus:**					
Halfshell (output)	-5,569.2	176.8	-6,024.5	25.5	253.1
Shucked (output)	8,419.0	-478.7	9,543.2	-5.8	-639.7
▸ **Consumer Surplus:**					
Halfshell (output)	-8,157.0	61.6	-8,317.9	14.6	84.7
Shucked (output)	6,839.3	21.8	6,791.2	0.7	25.6
▸ **Net Surplus Change**	1,532.2	-218.5	1,992.0	35.0	-276.3

pressure process, producer and consumer surplus losses in the Gulf halfshell oyster market are estimated at approximately $6 million and $8.3 million, respectively, but producer surplus in the Gulf shucked oyster market is estimated to increase by over $9.5 million, and consumer surplus is estimated to increase by nearly $6.8 million.

Based on these surplus calculations for the hydrostatic pressure process, adoption of this process could actually lead to a small net positive welfare gain of approximately $2 million. Specifically, the results in table 6 suggest that mandating the hydrostatic process would raise social welfare even if it did not reduce oyster consumption-related illness. This finding raises the prospect of a "free-lunch" solution, which justifiably warrants suspicion in the view of most economists. Why, if the technology shift raises welfare, does the market not adopt it in the first place?

To address this question, we must return to the point made earlier: the hydrostatic process is entirely new and producers have not yet had sufficient opportunity to adopt it. This analysis suggests, in the fullness of time, producers might find it in their interest to adopt the technology without any requirements by regulators. However, we also caution that the cost estimates (including cost savings) used in this analysis are preliminary estimates. If the actual costs of the technologies are higher (and the cost savings are lower), the net surplus measures could be negative. In this case, the social costs of the requirement would need to be weighed against the benefits of illness reduction to determine net benefits of the requirement.

Conclusions

Based on the results of this research, the per unit costs of post-harvest treatment of Gulf-harvested oysters are generally small and in some cases negative, and the demand for treated oysters either will be unaffected or may potentially increase relative to the demand for untreated oysters. These estimates are similar for the cool pasteurization and hydrostatic pressure treatment processes, except that the hydrostatic pressure process appears to result in greater processing cost savings relative to the cool pasteurization process. In comparison, the cryogenic IQF process is substantially different from the other two processes; therefore, this technology was not included as an option in the economic model.

The estimated supply and demand curve shifts were incorporated into an interregional equilibrium displacement model of the oyster industry. Based on the results of the model with supply shifts included, and assuming treatment requirements for only Gulf-harvested oysters, price increases of 19% or less are predicted and, in some cases, price decreases in the Gulf region. In other regions, prices are predicted to change by 3% or less.

If demand shifts are also included in the model, the predicted price and quantity effects are much greater. However, these findings are more tenuous and the required increase in harvest volumes is likely infeasible.

For both treatment methods, the results predict producer and consumer surplus losses in the Gulf halfshell oyster market, and producer and consumer surplus gains in the Gulf shucked oyster market. Further, although consumer surplus gains more than offset producer surplus losses for the hydrostatic pressure process, this is not the case for the cool pasteurization process. Surplus changes in the other regions, which arise from interregional trade with the Gulf, are minimal.

The results of this study are useful for the regulatory agencies responsible for making decisions regarding regulation of the oyster industry. However, although this study provides industrywide predictions of the effects of treatment requirements, it does not address the effects of treatment requirements on individual plants. While the aggregate economic model shows somewhat moderate effects of treatment requirements, the effects on individual plants may differ from the aggregate model predictions. In particular, individual plants may shut down either because the revenue of the plant is not sufficient to cover its production costs plus the costs of treatment, or because it is technically infeasible for the plant to install treatment equipment.

The oyster industry is characterized by many small operations which may not have the financial resources or possess the technical knowledge to install and maintain treatment equipment. One possible solution to this problem is the construction and operation of central treatment facilities. However, the use of central treatment facilities would require a high degree of coordination and accountability, especially given the highly perishable nature of halfshell and shucked oysters.

To address issues related to the individual plant effects of treatment requirements, development of an individual plant-level model of the industry would be useful. To develop such a model, information would be needed on the characteristics and number of plants of different types in the oyster industry. Using these data, a supply curve for the industry could then be constructed which more accurately reflects heterogeneous industry supply conditions. Similarly, the costs of treatment could also be more accurately assigned based on plant characteristics, rather than assuming the average-size plant costs.

Furthermore, an assessment could be made to determine whether the demand effects of post-harvest treatment differ by plant because they serve different types of clientele (e.g., retail, wholesale, and dockside sales). Using the estimated price and output changes from the model, it could then be predicted whether plants may close in response to treatment requirements, and the similarities in characteristics of the plants that close could be identified.

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Table A1. Complete Set of Elasticity Equations Describing the Effects of Post-Harvest Treatment for Oysters Across Regions

Gulf Region:

- $$\left(\varepsilon^D_{H,G} - \varepsilon^S_H\right)\mathrm{dln}\left(P^G_H\right) + \left(\varepsilon^D_{H\text{-}S} - \varepsilon^S_{H\text{-}S}\right)\mathrm{dln}\left(P^G_S\right) - \varepsilon^S_{H\text{-}O}\mathrm{dln}\left(P^G_O\right) + \varepsilon^D_{H,G\text{-}A}\mathrm{dln}\left(P^A_H\right) + \varepsilon^D_{H,G\text{-}P}\mathrm{dln}\left(P^P_H\right) = -\mathrm{dln}\left(TP_{H,G}\right) + \mathrm{dln}\left(TC_{H,G}\right)$$
- $$\left(\varepsilon^D_{S,G} - \varepsilon^S_S\right)\mathrm{dln}\left(P^G_S\right) + \left(\varepsilon^D_{S\text{-}H} - \varepsilon^S_{S\text{-}H}\right)\mathrm{dln}\left(P^G_H\right) - \varepsilon^S_{S\text{-}O}\mathrm{dln}\left(P^G_O\right) + \varepsilon^D_{S,G\text{-}A}\mathrm{dln}\left(P^A_S\right) + \varepsilon^D_{S,G\text{-}P}\mathrm{dln}\left(P^P_S\right) = -\mathrm{dln}\left(TP_{S,G}\right) + \mathrm{dln}\left(TC_{S,G}\right)$$
- $$\varepsilon^D_{H,G}\mathrm{dln}\left(P^G_H\right) + \varepsilon^D_{H\text{-}S}\mathrm{dln}\left(P^G_S\right) + \varepsilon^D_{H,G\text{-}A}\mathrm{dln}\left(P^A_H\right) + \varepsilon^D_{H,G\text{-}P}\mathrm{dln}\left(P^P_H\right) - \mathrm{dln}\left(Q^G_H\right) = TP_{H,G}$$
- $$\varepsilon^D_{S,G}\mathrm{dln}\left(P^G_S\right) + \varepsilon^D_{S\text{-}H}\mathrm{dln}\left(P^G_H\right) + \varepsilon^D_{S,G\text{-}A}\mathrm{dln}\left(P^A_S\right) + \varepsilon^D_{S,G\text{-}P}\mathrm{dln}\left(P^P_S\right) - \mathrm{dln}\left(Q^G_S\right) = -\mathrm{dln}\left(TP_{S,G}\right)$$
- $$\varepsilon^S_O\left(\frac{Q^G_S}{Q^G_O}\right)\mathrm{dln}\left(Q^G_S\right) + \varepsilon^S_O\left(\frac{Q^G_H}{Q^G_O}\right)\mathrm{dln}\left(Q^G_H\right) - \mathrm{dln}\left(P^G_O\right) = 0$$

Atlantic Region:

- $$\left(\varepsilon^D_{H,A} - \varepsilon^S_H\right)\mathrm{dln}\left(P^A_H\right) + \left(\varepsilon^D_{H\text{-}S} - \varepsilon^S_{H\text{-}S}\right)\mathrm{dln}\left(P^A_S\right) - \varepsilon^S_{H\text{-}O}\mathrm{dln}\left(P^A_O\right) + \varepsilon^D_{H,A\text{-}G}\mathrm{dln}\left(P^G_H\right) + \varepsilon^D_{H,A\text{-}N}\mathrm{dln}\left(P^N_H\right) = 0$$
- $$\left(\varepsilon^D_{S,A} - \varepsilon^S_S\right)\mathrm{dln}\left(P^A_S\right) + \left(\varepsilon^D_{S\text{-}H} - \varepsilon^S_{S\text{-}H}\right)\mathrm{dln}\left(P^A_H\right) - \varepsilon^S_{S\text{-}O}\mathrm{dln}\left(P^A_O\right) + \varepsilon^D_{S,A\text{-}G}\mathrm{dln}\left(P^G_S\right) + \varepsilon^D_{S,A\text{-}N}\mathrm{dln}\left(P^N_S\right) = 0$$
- $$\varepsilon^D_{H,A}\mathrm{dln}\left(P^A_H\right) + \varepsilon^D_{H\text{-}S}\mathrm{dln}\left(P^A_S\right) + \varepsilon^D_{H,A\text{-}G}\mathrm{dln}\left(P^G_H\right) + \varepsilon^D_{H,A\text{-}N}\mathrm{dln}\left(P^N_H\right) - \mathrm{dln}\left(Q^A_H\right) = 0$$
- $$\varepsilon^D_{S,A}\mathrm{dln}\left(P^A_S\right) + \varepsilon^D_{S\text{-}H}\mathrm{dln}\left(P^A_H\right) + \varepsilon^D_{S,A\text{-}G}\mathrm{dln}\left(P^G_S\right) + \varepsilon^D_{S,A\text{-}N}\mathrm{dln}\left(P^N_S\right) - \mathrm{dln}\left(Q^A_S\right) = 0$$
- $$\varepsilon^S_O\left(\frac{Q^A_S}{Q^A_O}\right)\mathrm{dln}\left(Q^A_S\right) + \varepsilon^S_O\left(\frac{Q^A_H}{Q^A_O}\right)\mathrm{dln}\left(Q^A_H\right) - \mathrm{dln}\left(P^A_O\right) = 0$$

(continued . . .)

Table A1. Continued

Northeast Region:

- $\left(\varepsilon_{H,N}^{D}-\varepsilon_{H}^{S}\right)\mathrm{dln}\left(P_{H}^{N}\right)+\left(\varepsilon_{H\text{-}S}^{D}-\varepsilon_{H\text{-}S}^{S}\right)\mathrm{dln}\left(P_{S}^{N}\right)-\varepsilon_{H\text{-}O}^{S}\mathrm{dln}\left(P_{O}^{N}\right)+\varepsilon_{H,N\text{-}A}^{D}\mathrm{dln}\left(P_{H}^{A}\right)=0$
- $\left(\varepsilon_{S,N}^{D}-\varepsilon_{S}^{S}\right)\mathrm{dln}\left(P_{S}^{N}\right)+\left(\varepsilon_{S\text{-}H}^{D}-\varepsilon_{S\text{-}H}^{S}\right)\mathrm{dln}\left(P_{H}^{N}\right)-\varepsilon_{S\text{-}O}^{S}\mathrm{dln}\left(P_{O}^{N}\right)+\varepsilon_{S,N\text{-}A}^{D}\mathrm{dln}\left(P_{S}^{A}\right)=0$
- $\varepsilon_{H,N}^{D}\mathrm{dln}\left(P_{H}^{N}\right)+\varepsilon_{H\text{-}S}^{D}\mathrm{dln}\left(P_{S}^{N}\right)+\varepsilon_{H,N\text{-}A}^{D}\mathrm{dln}\left(P_{H}^{A}\right)-\mathrm{dln}\left(Q_{H}^{N}\right)=0$
- $\varepsilon_{S,N}^{D}\mathrm{dln}\left(P_{S}^{N}\right)+\varepsilon_{S\text{-}H}^{D}\mathrm{dln}\left(P_{H}^{N}\right)+\varepsilon_{S,N\text{-}A}^{D}\mathrm{dln}\left(P_{S}^{A}\right)-\mathrm{dln}\left(Q_{S}^{N}\right)=0$
- $\varepsilon_{O}^{S}\left(\dfrac{Q_{S}^{N}}{Q_{O}^{N}}\right)\mathrm{dln}\left(Q_{S}^{N}\right)+\varepsilon_{O}^{S}\left(\dfrac{Q_{H}^{N}}{Q_{O}^{N}}\right)\mathrm{dln}\left(Q_{H}^{N}\right)-\mathrm{dln}\left(P_{O}^{N}\right)=0$

Pacific Region:

- $\left(\varepsilon_{H,P}^{D}-\varepsilon_{H}^{S}\right)\mathrm{dln}\left(P_{H}^{P}\right)+\left(\varepsilon_{H\text{-}S}^{D}-\varepsilon_{H\text{-}S}^{S}\right)\mathrm{dln}\left(P_{S}^{P}\right)-\varepsilon_{H\text{-}O}^{S}\mathrm{dln}\left(P_{O}^{P}\right)+\varepsilon_{H,P\text{-}G}^{D}\mathrm{dln}\left(P_{H}^{G}\right)=0$
- $\left(\varepsilon_{S,P}^{D}-\varepsilon_{S}^{S}\right)\mathrm{dln}\left(P_{S}^{P}\right)+\left(\varepsilon_{S\text{-}H}^{D}-\varepsilon_{S\text{-}H}^{S}\right)\mathrm{dln}\left(P_{H}^{P}\right)-\varepsilon_{S\text{-}O}^{S}\mathrm{dln}\left(P_{O}^{P}\right)+\varepsilon_{S,P\text{-}G}^{D}\mathrm{dln}\left(P_{S}^{G}\right)=0$
- $\varepsilon_{H,P}^{D}\mathrm{dln}\left(P_{H}^{P}\right)+\varepsilon_{H\text{-}S}^{D}\mathrm{dln}\left(P_{S}^{P}\right)+\varepsilon_{H,P\text{-}G}^{D}\mathrm{dln}\left(P_{H}^{G}\right)-\mathrm{dln}\left(Q_{H}^{P}\right)=0$
- $\varepsilon_{S,P}^{D}\mathrm{dln}\left(P_{S}^{P}\right)+\varepsilon_{S\text{-}H}^{D}\mathrm{dln}\left(P_{H}^{P}\right)+\varepsilon_{S,P\text{-}G}^{D}\mathrm{dln}\left(P_{S}^{G}\right)-\mathrm{dln}\left(Q_{S}^{P}\right)=0$
- $\varepsilon_{O}^{S}\left(\dfrac{Q_{S}^{P}}{Q_{O}^{P}}\right)\mathrm{dln}\left(Q_{S}^{P}\right)+\varepsilon_{O}^{S}\left(\dfrac{Q_{H}^{P}}{Q_{O}^{P}}\right)\mathrm{dln}\left(Q_{H}^{P}\right)-\mathrm{dln}\left(P_{O}^{P}\right)=0$

Notes: In the above equations, superscripts *S* and *D* denote supply and demand, respectively; subscripts *S*, *H*, and *O* denote shucked oysters, halfshell oysters, and shellstock oysters, respectively; superscripts and subscripts *G*, *A*, *N*, and *P* denote Gulf, Atlantic, Northeast, and Pacific regions, respectively; *TP* and *TC* denote treatment preferences on the demand side and treatment costs on the supply side. We assume the Gulf is linked to the Pacific and Atlantic regions, the Atlantic is linked to the Gulf and Northeast regions, the Northeast is linked to the Atlantic region, and the Pacific is linked to the Gulf region.

Table A2. Oyster Demand and Supply Elasticity Estimates Used in the Economic Impacts Model

Elasticity		Assigned Value
Within-Region Own-Price Elasticities of Demand:		
▸ Halfshell	$\left(\varepsilon_{H,G}^{D}\right)$	−0.55
	$\left(\varepsilon_{H,A}^{D}\right)$	−0.77
	$\left(\varepsilon_{H,N}^{D}\right)$	−0.94
	$\left(\varepsilon_{H,P}^{D}\right)$	−0.77

(continued . . .)

Table A2. Continued

Elasticity		Assigned Value
Within-Region Own-Price Elasticities of Demand (continued):		
▸ Shucked	$\left(\varepsilon^{D}_{S,G}\right)$	-1.10
	$\left(\varepsilon^{D}_{S,A}\right)$	-1.26
	$\left(\varepsilon^{D}_{S,N}\right)$	-1.32
	$\left(\varepsilon^{D}_{S,P}\right)$	-1.26
Within-Region Cross-Price Elasticities of Demand:		
▸ Halfshell-Shucked	$\left(\varepsilon^{D}_{H\text{-}S}\right)$	0.30
▸ Shucked-Halfshell	$\left(\varepsilon^{D}_{S\text{-}H}\right)$	0.30
Interregional Cross-Price Elasticities of Demand:		
▸ Halfshell	$\left(\varepsilon^{D}_{H,G\text{-}A},\ \varepsilon^{D}_{H,A\text{-}G},\ \varepsilon^{D}_{H,G\text{-}P},\ \varepsilon^{D}_{H,P\text{-}G}\right)$	0.20
	$\left(\varepsilon^{D}_{H,A\text{-}N},\ \varepsilon^{D}_{H,N\text{-}A}\right)$	0.30
▸ Shucked	$\left(\varepsilon^{D}_{S,G\text{-}A},\ \varepsilon^{D}_{S,A\text{-}G},\ \varepsilon^{D}_{S,G\text{-}P},\ \varepsilon^{D}_{S,P\text{-}G}\right)$	0.40
	$\left(\varepsilon^{D}_{S,A\text{-}N},\ \varepsilon^{D}_{S,N\text{-}A}\right)$	0.60
Within-Region Own-Price Elasticities of Supply:		
▸ Halfshell	$\left(\varepsilon^{S}_{H}\right)$	1.00
▸ Shucked	$\left(\varepsilon^{S}_{S}\right)$	1.00
▸ Shellstock	$\left(\varepsilon^{S}_{O}\right)$	0.10
Within-Region Cross-Price Elasticities of Supply:		
▸ Halfshell-Shucked	$\left(\varepsilon^{S}_{H\text{-}S}\right)$	-0.30
▸ Shucked-Halfshell	$\left(\varepsilon^{S}_{S\text{-}H}\right)$	-0.30
▸ Halfshell-Shellstock	$\left(\varepsilon^{S}_{H\text{-}O}\right)$	-0.50
▸ Shucked-Shellstock	$\left(\varepsilon^{S}_{S\text{-}O}\right)$	-0.50