Production Costs in Atlantic Fresh Fish Processing

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Abstract Production costs for fresh Atlantic groundfish and scallop processing are examined using direct observation, linear regression analysis, and cost accounting. Assuming that management chooses a production technique where marginal costs are constant over a wide range of production due to management's expectation of predictable and unpredictable variation in product demand and exvessel supply, estimates of marginal cost for nonfish inputs from linear regression results and from cost accounting are compared. Also, regression results for physical yield from fish inputs are compared to estimates from the U.S. Department of Commerce. The similarity in results between these independent forms of estimation supports the maintained hypothesis of constant marginal cost over a wide range of production.

Introduction

Production costs are vital to microeconomic theory. Profit-maximizing management is advised to set production at the rate where marginal revenue equals marginal cost, provided that total revenue covers variable costs. In markets where firms have little control over prices, management thus focuses on the rate of production

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and on minimizing cost. Managers convert theory to practice using cost accounting.

This paper is an investigation of production costs in Atlantic fresh fish processing using direct observation, econometric analysis, and cost accounting. Results from linear regression and cost accounting are compared for product yield and marginal costs of inputs other than fish. (Throughout this paper, marginal cost includes all cost other than the exvessel cost for fish.) Finally, we present evidence of the shape of marginal cost curves for the fresh Atlantic fish processing industry.

The Atlantic Fresh Fish Processing Industry

The U.S. Atlantic fishing industry is composed of three sectors: fishing, processing, and retailing. There is little, if any, vertical integration among the three sectors. The raw material processed is fresh finfish and shellfish, landed locally and imported with different amounts of on-board handling depending on the species. Flounders, ocean perch, lobsters, some scallops, and most whiting are landed whole; cod, haddock, and pollock are landed drawn; some whiting are landed headed and gutted; and most scallops are shucked at sea. Also, drawn cod, haddock, and pollock, whole ocean perch and flounders, and shucked scallops are imported from Canada.

Processing is relatively simple. Fresh fish and shellfish are filleted or shucked (usually by hand), breaded, cooked, and frozen depending on the input and the market demand. Most products do not go through the entire sequence, for example, fresh finfish are generally wholesaled as fresh, raw fillets. Occasionally, for special customers, such as the U.S. Department of Defense, fresh finfish is filleted, frozen into blocks, sawed, breaded, cooked, and frozen into sticks and portions in the same plant. Also, if the exvessel price of fish is low enough to compete with imported frozen blocks, some New England processing plants freeze fillets into blocks. The final and most important step in fresh input processing is wholesale marketing and transportation.

Processing costs depend on the mix and amounts of fixed and variable inputs. Management chooses a range for low average cost production by selecting a set of fixed inputs: the size of plant, amount of machinery, and the number of skilled workers, supervisors, and marketing personnel. For example, increasing the sales force lowers the average cost for large amounts of output by reducing marginal cost and raises the average cost for small amounts by raising fixed costs. Management bases these investment decisions on the expected cost of the various inputs and the expected market for output.

Due to the rapid deterioration of the quality of fresh fish, matching sales to production is crucial. Marketing becomes very expensive beyond the expected range of production because placing "extra" fish takes time, resulting in lower returns, because finding new buyers is costly. Freezing the product in order to extend the marketing period does not solve the problem because prices reflect the difficulty of determining the quality of frozen fish before thawing. Unscrupulous suppliers dumping lower-quality fish on the frozen product market cause buyers to expect lower quality in frozen fish. The price of frozen fish, therefore, is sharply lower than that of fresh fish. This market pattern is similar to lower quality and prices for used cars, since buyers expect that used cars are "lemons" (Ackerlof, 1970).

These considerations indicate a choice between production flexibility, that is, constant marginal cost over a large range of output, or production inflexibility, that is, low marginal cost over a smaller range of output. Flexibility increases minimum average cost above the minimum inflexible cost, because the continuous decision making required for flexibility is expensive. The choice between flexibility and inflexibility depends on the expected accuracy of predictions. If management in a perfectly competitive market expects to produce a specific amount, they choose a technology that minimizes average cost for the expected rate of output. If they are uncertain or expect variation, they choose a more flexible method of production, which maintains low marginal cost at higher rates of production.

As Johnston (1960) found in his study of a food processing firm, we assume that the uncertainty and expected variation in the annual and seasonal supply of fish and in the prices of fishery products and the sharp increases in marketing and other costs associated with sudden increases in production lead to the choice of flexibility in fresh fish processing. To attain flexibility, fresh fish processing firms choose inputs which are easier to adjust. Consequently, fresh fish processing firms are typically labor intensive, small, family owned, normally operate a single shift, and have extra floor space. Labor is easier to add than capital equipment. It is easier to expand production if the plant has extra floor space and a single shift is the normal operation. Also, family ownership in a small firm allows more rapid decision making, with family members a potential additional source of labor, especially in the area of sales. Furthermore, processing firms operate a low-markup, intermediate trading network among themselves (Mensinkai, 1969; Smith and Peterson, 1977).

As an example, consider the possible responses of a processing company when an unusually large amount of landed fish is available at low prices. Additional labor can be hired or current labor can work overtime, unprocessed fish can be sold to other processing companies, and the family network can be called in to help prepare and market the product. Furthermore, reliable customers may be asked to buy additional quantities during product gluts to ensure their future supply during shortages. These decisions can be quickly made by family-type operations with minimum loss of time.

However, even with production flexibility, there is a range of production beyond low marginal cost where marginal cost rises sharply. The often-heard remark that processing firms will always adjust to the rate of landings is misleading since the range of flexibility of production depends on the *expected* range of landings, prices, and product demand. For example, while working hours can be adjusted quickly, pools of skilled labor, supervisors, and salespeople are fixed in the short run in a port, since long training periods are required to increase the size of these pools. Also, freezer and cooler storage, transportation facilities, and the family network are limited.

Finally, market contacts are costly to develop since perishability of fresh fish intensifies the bargaining process. The processor is forced by the perishability of the product to sell the fish or place it on consignment to new customers, who may be credit risks or unable to sell the product. These sales arrangements are partially the result of forced bargaining due to product perishability and partially the result of the buyers' uncertainty as to the quality of the product. While flexibility is built into the marketing arrangements with regular customers, marketing to new customers is costly, thus setting a limit on production at low marginal cost.

On the other side of the market, the wholesale buyer desires continuity of supply at stable prices. For example, the cost and aggravation to restaurants of changing the menu tie wholesale buyers to unwritten long-term contracts with processing firms, who can guarantee product at relatively stable prices.

To summarize: We assume that fresh fish processing firms build flexibility into the production process, choosing factors which result in constant low marginal cost processing with the range of flexibility limited by the expected range in landings and demand (see Figure 1). Beyond this range of production, we assume that marginal

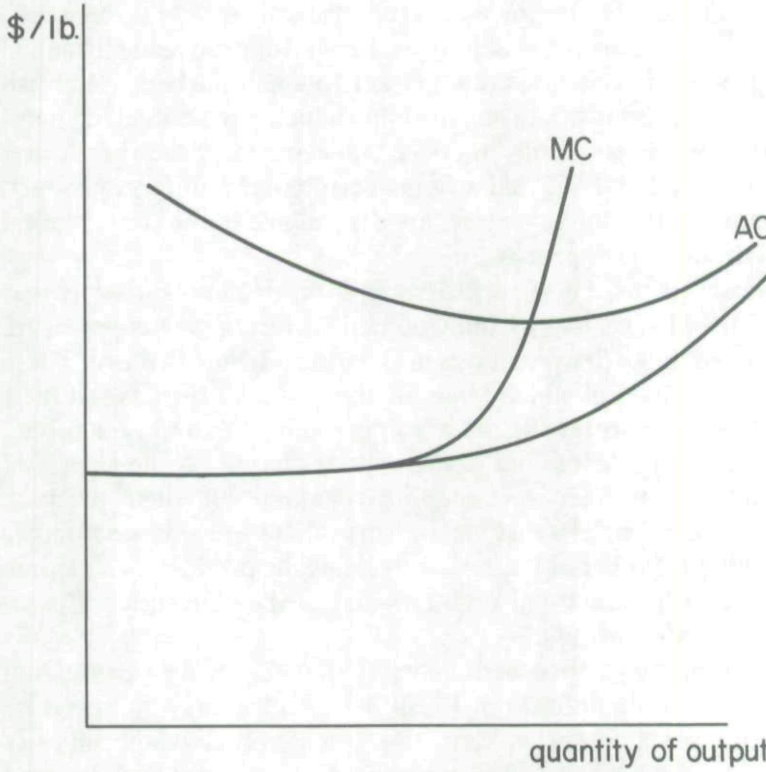

FIGURE 1. Costs as a function of output for the typical firm.

cost of production, excluding fish inputs, rises sharply. The flexibility that management builds into the process means that marginal cost and average variable cost are constant over a wide range of production, leading to relatively constant average cost over the expected range of production. At lower than expected rates of production, average cost is high because fixed cost is averaged over low rates of output. At higher than expected rates of production, average cost is high due to the constraints of limited skilled labor, market contacts, and cooler and transportation space.

Econometric Analysis of Processing Costs

Fresh fish processors are involved in two markets: in the wholesale market as sellers and in the exvessel market as buyers. Attention in this section will focus on the prices in these two markets, wholesale prices and exvessel prices. Fresh fish processing firms sell their product in the wholesale market to supermarkets, retail fish markets, restaurants, and institutions, which derive their demand for processed fresh fish from consumer demand. Since there are a large number of buyers and sellers of a relatively uniform product, we assume that wholesale prices are determined in the conventional competitive market process.

Exvessel prices are in turn derived from demand for processed fresh fish and specifically from wholesale prices. Exvessel prices are determined in the daily auctions in Boston and New Bedford. These auction processes in which large numbers of boat owners sell their landed catch to processing firms is long established and well known in the industry. Buyers bid exvessel prices based on their costs of processing and their assessment of demand for their product, processed fresh fish.[1] Once again, since there are a large number of buyers and sellers of a relatively uniform product, we assume that exvessel prices are also determined in the conventional competitive market process.

The model developed here assumes that the goal of processing firms is profit maximization. Fresh fish plant managers buy their input through a competitive, auction pricing process and sell their output (processed fresh fish) in a competitive market. The individual processing firm is therefore assumed, for purposes of short-run decisions, to regard both the wholesale and exvessel prices as given in their respective markets, and to decide on the physical quantity of fish to purchase and process at the prevailing prices. The individual firms may then be aggregated to determine total market output.

The Model

The purpose of our model is to provide a framework within which exvessel prices, wholesale prices, and processing costs are related, specifically to show that wholesale prices and processing costs determine the exvessel prices processing plants pay for landed fish. The model is a relatively simple aggregate one that is applicable to the short-run processes in which prices are determined. Total quantity of daily landings (X) is assumed exogenous. As discussed later in this section, the data used to estimate the model are short-run prices: daily prices aggregated to monthly observations. The development of a long-run model in which the size of the fishing fleet, the fish catching capacity of the boats, and the processing capacity of plants are treated as variables could be the focus of a subsequent investigation. However, for purposes of this study, these factors are treated as given.

As discussed in the preceding section, the total cost of processing is assumed proportionate to quantity produced.[2] In other words, marginal cost is assumed to be constant over the range of production. In a future study we will analyze processing firms' capacity in relation to the structure of marginal cost and exvessel price determination.

Assuming that firms maximize profits (π_w), the typical firm's profit function is

$$\pi_{w_i} = P_w q_i - P_x X_i - C(q_i) \tag{1}$$

where P_w is the market wholesale price, q_i the amount of processed output by firm i, P_x the market exvessel price, X_i the amount of fish inputs used by firm i, and $C(q_i)$ are costs other than fish inputs for firm i.

Total profits for the industry ($\pi_w = \sum_i \pi_{w_i}$) are thus

$$\pi_w = P_w Q - P_x X - C(Q) \tag{2}$$

where $Q = \sum_i q_i$ and $X = \sum_i x_i$.

If α is a constant that represents the yield factor, then $q_i = \alpha x_i$ and $Q = \alpha X$. Substituting Q/α for X yields

$$\pi_w = P_w Q - P_x(Q/\alpha) - C(Q) \tag{3}$$

Since firms in a perfectly competitive industry have no control over prices, their only decision is to produce that quantity which maximizes profit. If all firms simultaneously maximize profits, then the first-order condition for a maximum profit for the industry is

$$\partial\pi_w/\partial Q = P_w - P_x/\alpha - C'(Q) = 0 \tag{4}$$

This condition implies establishment of the exvessel price through the auction bid process to satisfy the first-order condition. Rearranging to isolate P_x gives

$$P_x = -\alpha C'(Q) + \alpha P_w \tag{5}$$

Thus exvessel prices are related to marginal cost for inputs other than fish and wholesale prices, both adjusted to exvessel weight through the yield factor α. For a given wholesale price, an increase in marginal cost leads to a lower exvessel price; *ceteris paribus*, an increase in wholesale price results in a higher exvessel price and an increase in the yield factor causes an increase in exvessel price since wholesale price must be greater than marginal processing cost for inputs other than fish.

Equations estimated from this model provide estimates of α, the physical yield of output from landed weight, as the regression coefficient for P_w, and an estimate of the constant marginal cost as the regression constant (intercept) divided by the estimate for α.

Data

Monthly data on exvessel prices and wholesale prices from January 1974 through December 1979, a total of 72 observations, were used separately for each of the four species, cod, ocean perch, scallops, and yellowtail flounder. Average daily exvessel prices weighted by landings for all four species were calculated from reports of landings (in landed weight) and total value of catch, as supplied by National Marine Fisheries Service (NMFS), Northeast Fisheries Center, Woods Hole, Massachusetts (weighout data). All New England ports were used for cod and ocean perch. Since wholesale prices were only available for yellowtail flounder and scallops from New Bedford, we used weighted average prices for New Bedford landings of these species.

Monthly wholesale prices were taken from the *Food Fish Market Review and Outlook*, Table A11, "Wholesale Price, Fish Fillets" at New York City for cod, and Table A22 "Wholesale Price, Frozen Fillets" at Boston for ocean perch. Scallop wholesale prices were from *Shell Fish Market Review and Outlook*, Table A26, "Wholesale Prices for Scallops at New York." Since *Food Fish Market Review and Outlook* does not have wholesale prices for fresh flounder fillets, monthly wholesale prices for yellowtail flounder were estimated by averaging daily prices of fresh yellowtail flounder fillets at the Fulton market using quantities sold in the Fulton market as weights. Both prices and quantities were from *Fishery Market News Report*, "New York Weekly Summary—Selected Species."

Estimated Equations

Equations were estimated using ordinary least squares (OLS) and for cases in which autocorrelation was a problem, generalized least squares (GLS). Results are presented in Table 1.

The fit is quite good for each of the equations with R^2 in excess of 0.8 in every case. The signs are as expected in every case with every estimate significantly different from zero at the 5% level or better. The yield estimated using linear regression for yellowtail flounder and scallops of 0.34 and 0.97 are quite close to the estimated yield from NMFS of 0.35 and 1.00.[3] However, the difference between the linear regression estimates for cod and ocean perch of 0.28 and 0.19 are quite different from the NMFS estimates of 0.38 and 0.28. This comparison is discussed further in the next section.

For these three species (cod, yellowtail, and ocean perch) for which the DW statistic indicated autocorrelation, generalized least

Table 1

Estimated Equations, Four Species, January, 1974–December, 1979

Cod	OLS:	$P_x = -0.1503 + 0.2799(P_w)$		
		$(-5.70)^{**}$ $(17.36)^{**}$		
	$N = 72$	$R^2 = 0.8116$	$F = 301.48^{**}$	$DW = 0.874^{**}$
	GLS:	$P_x = -0.1904 + 0.3054(P_w)$		
Yellowtail flounder	OLS:	$P_x = -0.2237 + 0.3370(P_w)$		
		$(-10.04)^{**}$ $(31.62)^{**}$		
	$N = 72$	$R^2 = 0.9346$	$F = 999.81^{**}$	$DW = 1.418^{*}$
	GLS:	$P_x = -0.2400 + 0.3449(P_w)$		
Ocean perch	OLS:	$P_x = -0.0160 + 0.1946(P_w)$		
		$(-2.15)^{*}$ $(22.22)^{**}$		
	$N = 72$	$R^2 = 0.8758$	$F = 493.67^{**}$	$DW = 0.387^{**}$
	GLS:	$P_x = -0.0056 + 0.1839(P_w)$		
Scallops	OLS:	$P_x = -0.2790 + 0.9665(P_w)$		
		$(-7.74)^{**}$ $(71.42)^{**}$		
	$N = 72$	$R^2 = 0.9865$	$F = 5101.12^{**}$	$DW = 1.930$

[a] T statistics are in parentheses below each estimator. N, number of observations; R^2, coefficient of determination; F, F statistic for the equation; DW, Durbin-Watson statistic; P_x, exvessel price per pound; P_w, wholesale price per pound. One asterisk denotes significance at the 5% level; two asterisks denote significance at the 1% level.

squares (GLS) estimation was also used. The GLS procedure that we used was the two-step process advocated by Griliches and Rao.[4] The results from GLS were not appreciably different from OLS. The largest change was an increase in the yield of cod from 0.28 to 0.31. All coefficients from the GLS estimations were significant at the 1% level except for the intercept in the ocean perch equation.

Cost Accounting for Flounder and Cod Processing

As an independent estimate of marginal cost of fish processing, we estimated cost per pound of processed output in the format of income statements for flounders and cod using data from interviews, union contracts, property tax valuations, and statements of condition, filed with the state by all Massachusetts corporations.[5] *Food Fish Market Review and Outlook, Fishery Market News Re-*

port (green sheets), and unpublished data from the National Fishery Statistics Program, NMFS, Washington, D.C. (processed product data), and the Northeast Fisheries Center, NMFS, Woods Hole, Massachusetts (weighout data), were also used. Costs were broken down into cost of fish inputs, other direct costs, and indirect costs. All costs were either estimated for 1979 or adjusted to 1979 prices using the Consumer Price Index (CPI). Low and high estimates of costs with the major difference in exvessel price estimates were computed for each species. Before-tax profits were calculated using average wholesale price for cod and flounder from processed products data from NMFS to establish the "low" estimates of sales. The "high" sales estimates were based on published wholesale prices from *Food Fish Market Review and Outlook* for cod and from the green sheets for yellowtail flounder.

For flounders, our low estimate for direct cost is $1.82 per pound with exvessel price adjusted to fillet weight accounting for $1.33 of the direct cost (see Exhibit 1).[6] Our high estimate of direct cost is $1.92 with exvessel price accounting for $1.42. Thus, direct cost other than for fish inputs is about $0.50 per pound. Roughly 60% of indirect cost, or $0.05 per pound, were for salaries, heat, electricity, telephone, and maintenance expenses; the remainder of direct costs were cost of capital equipment valued at either historic or replacement cost. The low and high estimates for before-tax profits are $0.03 and $0.33 per pound, respectively.

The difference between high and low profit estimates was due to a wide range in the wholesale price data. Published wholesale prices ($2.33 per pound) were considerably higher than the sales prices calculated from the processing plant reports submitted to NMFS ($1.93 per pound). The published wholesale price was the price that Fulton Fish Market dealers charged their customers for yellowtail fillets trucked from New Bedford. The markup for these dealers was probably low because the fillets were sold the same day they arrived, and these dealers were competing with New Bedford firms, which could have sold directly to the same customers. Since the New York prices were collected daily from a number of different wholesale dealers in New York's Fulton market, while the processed products prices were from yearly value reported by

Exhibit 1

Average New Bedford Fish Processing Plant
Estimated Before-Tax Profit from Fresh Flounder Fillets
for the Year Ended December 31, 1979
(dollar per pound fillet weight)

			Low	*High*
Average sales price per pound for all flounders computed from processed products[1]			$1.928	
Weighted average yellowtail wholesale price per pound, N.Y.C.[2]				$2.334
Less direct costs per pound:				
Cost of fillets	*Low*	*High*		
Exvessel price, flounders at N.B.[3]	$0.477			
Exvessel price, yellowtail, N.E. ports[4]		$0.510		
Unloading cost[5]	0.050	0.050		
	$0.527	$0.560		
Cost of fillets (at 0.36 yield)			1.464	1.556
Direct labor[6]			0.221	0.221
Packaging (from interviews)			0.048	0.048
Transportation to New York (from interviews)			0.048	0.048
Water (from interviews)			0.016	0.016
Carrying cost on accounts receivable[7]			0.021	0.025
Carrying cost on inventory[8]			0.003	0.003
Total direct costs per pound			$1.821	$1.917
Contribution margin (sales-direct costs)			$0.107	$0.417
Less indirect costs per pound[9]			0.078	0.084
Estimated before-tax profit			$0.029/lb	$0.333/lb

[1] Weighted average annual price of fresh Atlantic flounder products reported by New Bedford processing plants to NMFS in 1979.

[2] Weighted annual average of daily wholesale prices for New Bedford yellowtail fillets at the Fulton Fish Market in New York City as reported in *New York Market News* (Green Sheet), NMFS, 1979.

[3] "New Bedford Landings—1979," from Statistics and Market News Office, NMFS, New Bedford, Massachusetts: weighted average exvessel price for sanddabs, blackback, dabs, sole, fluke, and yellowtail sold at the New Bedford daily auction.

[4] Weighted average exvessel price for yellowtail flounder for major New England ports from Northeast Fisheries Center, NMFS, Woods Hole, Massachusetts.

[5] Estimates for unloading, packaging, transportation, and water from 1981 interviews adjusted to 1979 using the CPI.

processing plants, the New York price estimates are probably more accurate.

The direct cost estimates for cod production are similar to those for yellowtail flounder except for different exvessel prices between the species, transportation, direct labor, and carrying charges (see Exhibit 2).[7] Transportation to New York is not considered as a cost for the low estimate for cod since we assumed that most cod was sold locally. Transportation was considered as a cost in the high estimate of profits which uses the New York City wholesale price as an estimate of revenue. Direct labor cost is lower for cod than for yellowtail flounder because of the ease of filleting the larger size of cod. Also, carrying cost on inventory was lower for cod than yellowtail because of the lower wholesale price.

Our low estimate of direct costs for cod is $1.30 per pound of which exvessel price was $0.89 in fillet weight. Our high estimate of direct costs is $1.46 with exvessel price accounting for $1.00. Direct cost excluding fish inputs was thus $0.41 per pound with $0.05 added for transportation to New York. Roughly 70% of indirect cost ($0.07 per pound) were for salaries, heat, electricity, and telephone with the remainder the cost for capital equipment.

As was true for flounder, the major cause of the difference between low estimate of before-tax profit ($0.02 per pound) and our high estimate ($0.26 per pound) was the difference in the estimates of wholesale prices. The published New York City price was $0.40 higher than the price reported by the processing plants to NMFS.

(*Exhibit notes continued*)

[6] Estimated from the contract covering 1979 between Seafood Workers Union and New Bedford processing firms.

[7] Calculated using wholesale prices of $1.93 and $2.33 and 1979 average prime rate of 13% as follows: $P_{wh} \times 13\%$ annual interest rate × 30-day average collection period ÷ 365 days = $0.021/lb and $0.025/lb.

[8] Calculated using $115,000 inventory balance from Exhibit 5, "Average New Bedford Fish Processing Plant Pro Forma Balance Sheet for 1979," in Georgianna and Dirlam (1982, p. 54), as follows: $115,000 inventory × 13% interest rate × 0.40 allocation of inventory balance to flounder ÷ 2,013,000 lb average yearly flounder production for the plants used.

[9] Indirect costs include clerical, sales, supervisory, and maintenance salaries, heat, insurance, interest on long-term debt, electricity, telephone, nonincome taxes, maintenance costs, and depreciation. Low estimate uses historic cost depreciation; high estimate uses replacement costs.

Exhibit 2

Boston Fish Processing Plant Estimated Before-Tax Profit from Fresh Cod Fillets for the Year Ended December 31, 1979 (dollar per pound fillet weight)

			Low	*High*
Cod sales price per pound computed from processor's reports[1]			$1.413	
Weighted average wholesale price per pound, N.Y.C.[2]				$1.816
Less direct costs per pound:				
Cost of fillets	*Low*	*High*		
Exvessel price of cod, N.E. average[3]	$0.340			
Exvessel price of cod, Boston[4]		$0.380		
Average of unloading and freight cost[5]	0.050	0.050		
	$0.390	$0.430		
Cost of fillets (at 0.38 yield)			1.026	1.132
Direct labor[6]			0.193	0.193
Water and sewer (from interviews)			0.002	0.002
Packaging			0.048	0.048
Transportation[7]			0.000	0.048
Carrying cost on accounts receivable[8]			0.015	0.019
Carrying cost on inventory[9]			0.016	0.016
Total direct costs per pound			$1.300	$1.458
Contribution margin (sales − direct costs)			$0.113	$0.358
Less indirect costs[10]			0.092	0.100
Estimated before-tax profit			$0.021/lb	$0.258/lb

[1] Weighted average annual price of fresh Atlantic cod products reported by Boston processing plants to NMFS in 1979.

[2] Table A11, "Exvessel, Wholesale, and Retail Prices of Cod, Monthly," *Food Fish Market Review and Outlook*.

[3] Weighted average exvessel price for major New England ports in 1979 from Northeast Fisheries Center, NMFS, Woods Hole, Massachusetts.

[4] Weighted average exvessel price for Boston in 1979 from Northeast Fisheries Center, NMFS, Woods Hole, Massachusetts.

[5] Estimates for unloading, water and sewer, and packaging from 1981 interviews adjusted for 1979 using the CPI.

[6] Direct labor costs were calculated based on an average pay rate, including fringe benefits, FICA, and FUTA payment of $15.60 per hour in 1982, for fish processing workers from Joe Lake, Business Agent, Seafood Workers' Union and Frank Byrnes, owner of F.M. Byrnes, a fish processing firm on the Boston fish pier. We estimated that one fish cutter and one full-time equivalent floorman, skinner, trimmer, and wrapper process 125 lb of fillets per hour. Based on an average pay increase of 9% a year from 1979 to 1982, the direct labor

Compared to the weighted average profit margin for processed food for 1979 of 3% (*Business Week*, March 17, 1980), the range in profit margins for both flounder and cod from 1.5 to 14% for the low and high price estimates is quite high. However, fish processing is much riskier than most other food processing businesses.

Results and Conclusions

Table 2 presents a comparison of estimates of physical yield and marginal cost from our linear regressions with yield estimates from NMFS and direct costs from cost accounting estimates. The yields for all species from linear regression estimates are lower than NMFS estimates but are quite close especially for yellowtail flounder (0.34 from regression and 0.35 from NMFS) and scallops (0.97 from regression analysis and 1.00 from NMFS). A possible explanation for the low regression estimate for ocean perch yield is our use of wholesale price for frozen fillets as a proxy for wholesale price of fresh U.S. fillets, which was unavailable. The independent variable used here, therefore, is subject to variable measurement error since the difference between prices for fresh and frozen fillets depends on market conditions, while the dependent variable is not. Under such circumstances the estimated coefficient will be less than the true coefficient (Johnston, 1972). The underestimate for cod yield is not as easily explained since the wholesale price is that for fresh fillets at New York City.

(*Exhibit notes continued*)

costs per pound of cod in 1979 were as follows: 2 workers × \$12.05/hr ÷ 125 lb fillets processed per hour = \$0.193.

[7] At the low wholesale price, local sales were assumed resulting in no transportation expense. Transportation expense to New York City was estimated as in Exhibit 1 for cod sold at the N.Y.C. wholesale price.

[8] Calculated using wholesale prices of \$1.413/lb and \$1.816/lb × 13% interest rate × 30-day average collection period ÷ 365 days = \$0.015/lb and \$0.019/lb.

[9] Calculated using inventory balance of \$407,000 from Exhibit 9, "Average Boston Fish Processing Plant Pro Forma Balance Sheet for 1979," in Georgianna and Dirlam (1982, p. 61), as follows: \$407,000 inventory × 13% interest rate × 0.35 allocation of inventory to cod ÷ 1,141,000 lb average yearly cod production per plant = \$0.016/lb.

[10] Indirect costs include clerical, sales, supervisory, and maintenance salaries, nonincome taxes, insurance, electricity, telephone, heat, interest expense on long-term debt, rent, and depreciation. Low estimate is based on rent and historic cost depreciation; replacement cost depreciation was used for high estimate.

Table 2
Comparison of Estimates for Yield and Marginal Cost

	Yield from Regressions		Yield from NMFS	Marginal Cost from Regressions		Marginal Cost from Cost Accounting
	OLS	GLS		OLS	GLS	
Yellowtail	0.34	0.34	0.35	0.66	0.70	0.50[a]
Cod	0.28	0.31	0.38	0.54	0.62	0.46[b]
Ocean perch	0.19	0.18	0.28	0.08	0.03	
Scallops	0.97	—	1.00	0.29	—	

[a] Direct cost from Exhibit 1 exclusive of exvessel price; note that unloading cost is converted to fillet weight using 0.35 as yield factor.
[b] Direct cost from Exhibit 2, including transportation to New York but exclusive of exvessel price; note that unloading is converted to fillet weight using 0.38 as yield factor.

The estimates of marginal cost from regression analysis are higher than the direct cost estimates for both cod and yellowtail flounder. For cod, estimated marginal cost from regression was $0.54 per pound compared to $0.46 per pound from cost accounting. The difference for flounder was higher, $0.66 per pound from regression analysis compared to the direct cost estimates of $0.50 per pound. However, direct cost is a very conservative estimate of marginal cost; some indirect costs, such as part of telephone, electricity, heat, and clerical salaries, should probably be included as marginal costs. This amounts to $0.05 to $0.07 per pound. Part of before-tax profit should probably also be included as marginal cost. Most of the equity used in the fresh fish processing industry is used to buy fish inputs, which obviously increase with production. Also, before-tax profit includes a premium for risk which is due mainly to the perishability of the product and the unexpected variation in supply of fish inputs and demand for output. The total amount of risk would therefore increase with output, making risk premium a marginal cost. However, there is no guidance from the literature or from our experience to estimate the proportion of normal profit that varies with output.

The importance of these findings is that econometric results are rarely compared to cost accounting. We believe that the results from these different methods of analysis for fresh fish processing are remarkably consistent for both yield and marginal cost. Unfortunately, there are no generally accepted tests for comparison.

This consistency of results tends to support the maintained assumptions relating to the structure of the processing industry, profit maximization, and the constancy of marginal cost in fish processing, an industry with large expected and unexpected variation in both supply and demand.

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Notes

1. In New Bedford, a group of six to eight processing firms, which have unloading facilities, buy at the auction. They sell some exvessel fish to secondary dealers who do not have off-loading facilities. However, the total exvessel demand is the sum of both primary and secondary dealers' demands.

2. See Johnston (1960, pp. 87–92).

3. The estimates of yield were from Dennis Main, Port Agent, NMFS, New Bedford, Massachusetts, and Don Fitzgibbon, National Fisheries Statistics Program, NMFS, Washington, D.C., and are widely used throughout the industry.

4. Griliches and Rao (1969). See also the discussion in Johnston (1972, pp. 259–65). Specifically, the method used was Durbin's first step of estimating from the equation

$$Y_t = \alpha(1 - \rho) + \rho Y_{t-1} + \beta X_t - \beta\rho X_{t-1} + E_t$$

and using the estimated ρ in the Prais-Winsten estimator in the second step.

5. Income statements were prepared by Bonita Daly, CPA Staff Accountant with J. G. Hodgson & Company Inc., New Bedford, Massachusetts. For more detail, see Georgianna and Dirlam (1982).

6. For more information on these estimates, see Exhibits 1 through 5 in Georgianna and Dirlam (1982).

7. For more information on these estimates, see Exhibits 6 through 10 in Georgianna and Dirlam (1982).

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