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# An Econometric Model of the Market for New England Groundfish

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This paper develops an economic model of the New England groundfish market. A multi-sector, multi-level econometric model is estimated using data from 1970 to 1982. The parameters of the estimated model are used to characterize consumer demand for groundfish and related products. Retail and exvessel demands for fresh and frozen groundfish fillets are found to be highly elastic. Fresh fillets especially show high income elasticity of demand, reflecting their status as a luxury good. Only a very small and statistically weak relationship was found between the prices of imported groundfish and domestic exvessel prices indicating that proposals to assist the domestic industry via tariffs may be ineffectual.

The harvesting, processing, and marketing of fish and fish products has historically played a significant role in the regional economy of New England. While this industry is less important now than in earlier times, it still generates significant income and employment; production of fresh and frozen fish involves over 11,000 seasonal (8,700 equivalent full-time) jobs and accounted for over 600 million dollars in product sales in 1983.

In this paper a market model of one sector of this industry is presented; the market for groundfish and groundfish-based products. Groundfish, such as cod, haddock, ocean perch, flatfish, and related species, constitute the largest share of finfish (by value) caught and processed in New England. Groundfish harvested in New England constitute one of the most important sources of fresh fish for consumers in the United States, and much of the nation's supply of frozen processed fish

The goal of this study is to develop an economic model of the groundfish industry, which includes not only domestic harvests but imported fresh and frozen groundfish as well. This model is estimated to determine the relationships between product prices, landings of fish, imports of groundfish products, and other economic factors relevant to consumer demand for groundfish products (such as income and the prices of competing commodities).

From the estimated model conclusions are drawn as to the nature of consumer demand for these products, as indicated by price and income elasticities for fresh and frozen groundfish, as well as the degree to which various product forms (e.g., fresh fillets, frozen fillets, imported fillets, and processed product) are substitutable for one another. Finally, the model is used to explore the implication for consumers and producers of groundfish products of several policy questions relating to the fishery; namely, restrictions such as tariffs or quotas on imported groundfish, and the impact of variations in groundfish harvests through natural variation or through regulations such as catch quotas.

The next section gives a brief overview of the New England groundfish fishery. Subsequent sections of the paper describe the economic model, the estimation of this model, the interpretation and significance of the results, and some conclusions and policy analyses based on the model.

## **New England Groundfish Fishery: An Overview**

New England fishermen have been harvesting groundfish since the 17th century. Due in part to the enactment of the Fishery Conservation and Management Act of 1976, which established a 200-mile Fishery Conservation Zone and virtually eliminated foreign fishing in the area, recent years have seen a dramatic in-

crease in the number of fishing vessels and fishermen operating in the groundfish fishery. Since 1976 the size of the fleet has more than doubled, from 800 vessels to over 1600 vessels. Accompanying the increase in the size of the fleet since 1976 has been an equally dramatic increase in the total landings of groundfish.

Once landed the bulk of the groundfish harvested are processed into fresh fillets for further distribution to wholesale, retail, and institutional outlets. As fresh fish command a higher price than frozen fillets, only a small share of the domestic landings of cod, haddock, flatfish etc. is frozen.

Besides domestically landed fish, the other source of groundfish products consumed in New England and the rest of the country is foreign imports. Currently about 85 percent of the total domestic supply of all groundfish is accounted for by imports. These are comprised primarily of two product forms: frozen fillets and frozen blocks and slabs. The latter are 10 to 20 pound blocks of frozen groundfish which are cut into individual portions by domestic converters and further processed into fish sticks and fish portions which are sold in restaurants, institutions (schools, hospitals, the military), and in frozen food sections of retail markets. Virtually the entire domestic supply of these fish blocks is imported. Frozen fillets and steaks are also imported for distribution into the same general markets. Historically, little fresh fish has been imported (although such imports have increased in the past two years); such that it comes primarily from Canada and seems to be seasonal in nature. Most imported fresh fish come into the United States in the first quarter of the year.

Figure 1 summarizes the overall market for New England groundfish. As can be seen the market is complex, with many different parties (fishermen, importers, processors and wholesalers, consumers, and institutional purchasers) and many complex interactions between the various parties.

### **An Economic Model of the New England Groundfish Industry**

The econometric model of the market for New England groundfish and related products is specified as a system of sixteen equations. These equations represent the demand for groundfish at the retail and exvessel level, de-

mand for/supply of imported groundfish, and price determination relationships. Four species of fish are treated as an aggregate: cod, haddock, flatfish (plaice, sole, and flounders) and ocean perch (rednsh).

To date, the most comprehensive study of the demand for New England groundfish was the 1977 work by Bockstael.<sup>1</sup> She employed a multi-sector market model based on data from 1964 to 1974 which encompassed retail demand, price determination, and trade in groundfish products as well as exvessel demand. Tsoa, Schrank and Roy also went beyond the exvessel level to consider demand at the wholesale level; however, their model has serious flaws which undermine the usefulness of their results.<sup>2</sup>

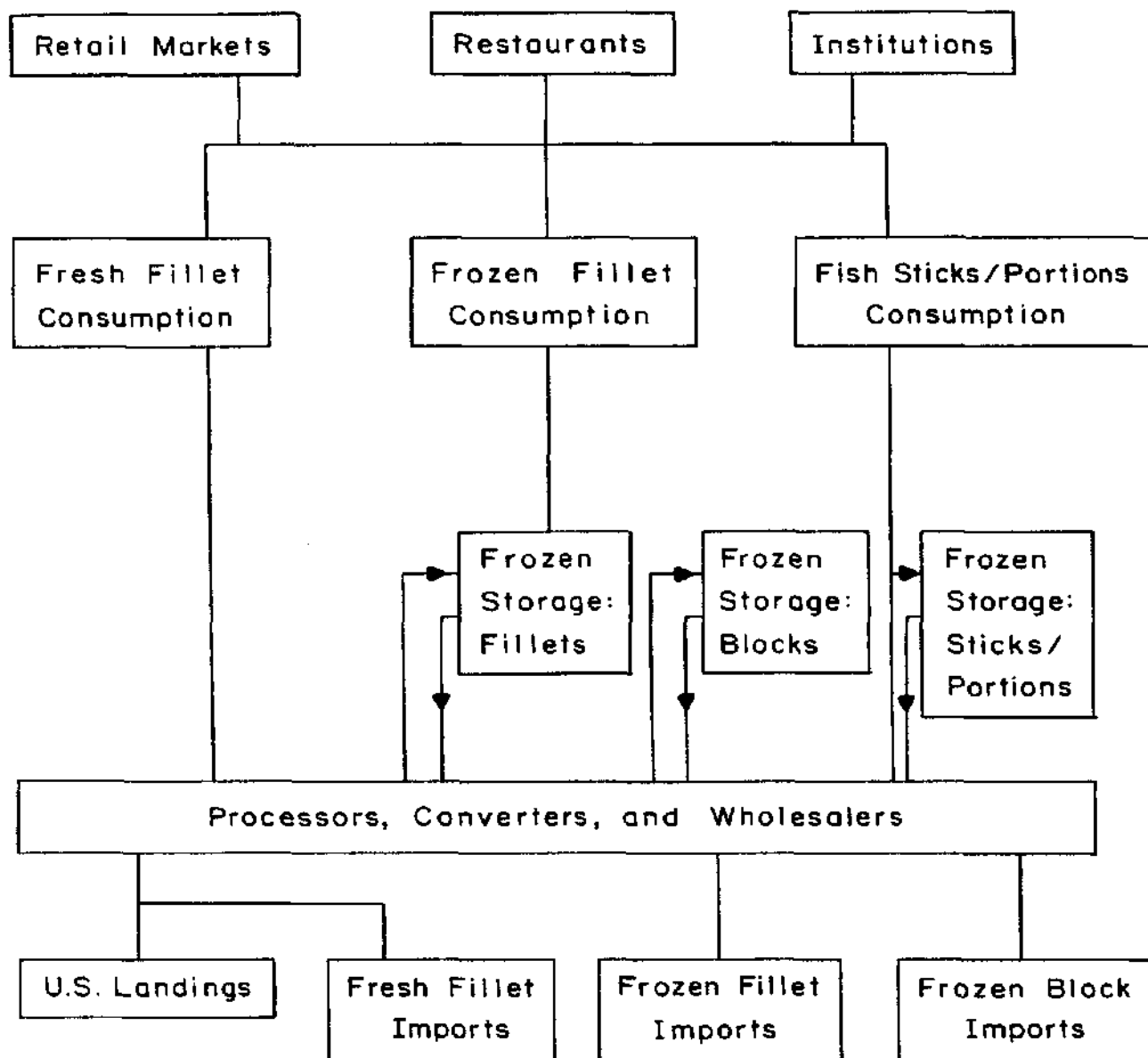
In the eight years since the Bockstael model was published the groundfish industry has undergone some fundamental changes. The most important is the extension of United States jurisdiction to 200 miles. The impact of the new management regime on the industry has been profound. The virtual elimination of foreign harvesting of groundfish and the anticipation of economic profit led to a significant increase in the number of domestic harvesters and a consequent increase in domestic landings. In the years between 1976 and 1982 the groundfish fleet nearly doubled and harvests rose by 90 percent.<sup>3</sup> The intervening years have also seen an increase in the imports of groundfish and groundfish-based products into the United States. Of particular concern to domestic fishermen is the recent increase in the imports of fresh groundfish: the product most directly competitive with domestic groundfish.

The model developed below follows the same general format as that of Bockstael, with

<sup>1</sup> Most studies in the fisheries focus on the harvesting sector. Much of the analytic work has involved estimation of the derived demand for fish at the exvessel (dockside) level. Early examples of this type of analysis as applied to New England groundfish include Bell (1968), Waugh and Miller (1969), Waugh and Norton (1969), Gates and Norton (1974), and Farrell and Lampe (1965). Other, more recent attempts to estimate exvessel and wholesale demand include Gooriesingh (1982) and Tsoa, Schrank and Roy (1982), as well as unpublished studies by Storey and Allen at the University of Massachusetts and Wang (1982). Several other studies have investigated the impact of imported groundfish on the U.S. market (Newton and Houtsma, for example). The same model reported in this paper has been used by the author to address the issue of groundfish imports; see below.

<sup>2</sup> Tsoa, Schrank and Roy use an inventory adjustments model, where the dependent variable is movements of frozen groundfish into and out of cold storage. Since only about 20% of domestic landings are frozen, interpreting then-reported exvessel and wholesale price elasticities as relevant to domestically produced groundfish products is highly misleading.

<sup>3</sup> For details see Crutchfield and Gates (1984).



**Figure 1. Product flows in the New England groundfish industry**

certain differences. Besides covering a different time series, additional equations have been added to differentiate between fresh and frozen groundfish products; the Bockstael model treats imported fillets, whether fresh or frozen, as a single composite commodity. In addition, Bockstael used a complicated distributed lag formulation to explain movements in certain prices for frozen products; a simple one-period lag formulation is used here.

The demand for groundfish products at the retail level is assumed to derive from consumer demand for protein sources. In particular, when considering the demand for fresh and frozen fish products, the demand for these products is considered a function of the price

of the good in question, the prices of substitute fish products, the prices of non-fish protein sources (viz. beef, poultry, and pork), and per-capita income.

The demand for fish and groundfish-based products at the retail level can be categorized in a number of different ways. There are several product forms, including fresh fillets, frozen whole fillets, frozen cooked fillets, and frozen breaded fish sticks and portions. In addition, there are several fish species, including cod, haddock, various types of flatfish, whiting or hake, ocean perch or redfish, and pollock. In some product forms, notably fresh and frozen raw fillets, the species is readily identifiable and the consumer may possess

strong preferences for one species relative to another. On the other hand, frozen processed products such as the cooked fillets and breaded sticks and portions are often sold under the generic classification of "fish"; the species content of the underlying product may not be evident.

Another complicating factor which arises in conjunction with empirical studies of the retail fish market is the multi-dimensional nature of the market. Much of the product movement in groundfish is channelled away from retail supermarkets and specialty markets into institutions such as restaurants, schools, and the armed services. A large percentage of the total consumption of fish portions is consumed in this institutional sector.

Since so much fish product is consumed in the "away from home" market, the usefulness of demand equations based on retail data is problematic. If we can assume that retail and restaurant prices move proportionately, for example, then it can be said that a retail demand equation which uses as an explanatory variable the market retail price can be said to give a reasonably good estimation of total retail demand. A somewhat weaker restriction sufficient to preserve the utility of market-based demand functions is that relative prices between fish and non-fish substitutes (meat, poultry, pork) be the same as in the restaurant trade. (Bockstael 1977). However, problems arise in modelling the retail demand for frozen fish sticks and portions. Adequate retail market price series are not available for these product forms. Since much of this product is consumed "away from home," it can be argued that the appropriate determinant of product substitution is the set of relative product prices faced by the institutions. The wholesale prices for sticks and portions, then, may be reasonable proxies for retail prices in the demand function for these product forms.

The retail and wholesale demand functions are thus:

- (1)  $C_f = (P_f, P_z, P_s, P_p, P_m, Y, D_1, D_2, D_3)$   
(Retail Fresh Fillets)
- (2)  $C_z = (P_z, P_f, P_s, P_p, P_m, Y, D_1, D_2, D_3)$   
(Retail Frozen Fillets)
- (3)  $C_s = (P_z, P_f, P_z, P_p, P_m, Y, D_1, D_2, D_3)$   
(Whsle Sticks/Portions)

where

$C_f, C_z, C_s$  = total consumption of fresh groundfish fillets, frozen groundfish fillets (cod, had-

dock, ocean perch, and flatfish), and fish sticks/portions, respectively

$P_f, P_z, P_s$  = retail prices of fresh and frozen groundfish and wholesale price index of fish sticks/portions.

$P_m, P_p$  = CPI for meat, CPI for poultry,  
 $Y$  = Per-capita income,

$D_1, D_2, D_3$  = seasonal dummies (spring, summer, fall),

As indicated earlier, domestic landings of groundfish constitute an important segment of the overall market. Domestically landed cod, haddock, flatfish, perch and other groundfish have been historically marketed in the form of fresh fillets. Although the domestically caught share of total supply is only around 15 percent, perishability and other product quality considerations preclude significant marketing of fresh imported fish. Limited supplies and a continuing price differential between fresh and frozen fillets result in most of the domestic harvest being channelled into the fresh market.<sup>4</sup> The demand for domestically caught groundfish will be estimated by two demand functions: demand for fish at the exvessel (dockside) level, and demand for domestic groundfish for freezings. In considering the former, the traditional approach is taken which treats landings as exogenously determined. While this may be defensible in the short run, clearly overall fishing activity and total catch respond to changing prices. In particular, fishermen tend to change their target species in response to changing relative prices and changing profit opportunities (Bockstael and Opaluch 1983). It would therefore be desirable to incorporate in the model some sort of supply relationship for domestic harvests. However, it is unlikely that any useful supply relationship could be realistically estimated, given the lack of information about the underlying biological production relationships in the Atlantic groundfish fishery and the inherent random nature of any living resource stock. For these reasons the exvessel demand function is represented by a price-dependent relationship.<sup>5</sup> The other variables included in the inverse demand function are income, price in-

<sup>4</sup> On average, about 20% of the annual domestic harvest is frozen; primarily ocean perch, hake, whiting and pollock.

<sup>5</sup> Since prices at the exvessel level are characteristically determined by auction at the dockside, where certain quantities of fish are put up for bid, using quantity as the independent relationship is particularly relevant in the New England fisheries.

dexes for meat and poultry, a dummy variable which takes on a value of 1 for the period since the FCMA went into effect, and seasonal dummies.

The demand function for domestic freezings is specified in the usual quantity-dependent form. Since this represents derived demand by processors, other cost variables are included. The wage rate in fish processing is included to reflect processing cost. The amount of imported frozen groundfish is also included, as the demand for domestic sources for freezings will be determined, at least in part, by the total available supplies of frozen product.

The demand functions for domestic fish are:

$$(4) \quad P_e = (L, PI_f, PI_Z, FCMA, P_m, P_p, Y, D_{1s}, D_2, D_a) \quad (\text{Exvessel})$$

$$(5) \quad FZ = (P_e, WR, IF_Z, HF, D_i, D_2, D_a), \quad (\text{Freezings})$$

where

$P_e$  = weighted average exvessel price for groundfish (cod, haddock, ocean perch, flatfish),

$L$  = domestic landings of groundfish,

$FCMA$  = dummy variable, 200-mile limit in effect,

$PI_f, PI_Z$  = The prices of imported fresh groundfish fillets and imported frozen groundfish fillets, respectively,

$FZ$  = domestic freezings of groundfish,

$WR$  = wage rate (\$/hr) in fish processing plants,

$IF_Z$  = imports of frozen groundfish fillets groundfish,

$HF$  = Cold storage holdings of groundfish fillets (inventories),

$P_m, P_p, Y, D_i, D_2, D_3$  = as above.

Imported groundfish account for much of the fillet supply and virtually all of the groundfish fillet supply in the United States. To model this sector of the market, a conventional system of simultaneous supply and demand relationships is specified. Six equations are specified: demand and supply of fresh fillets, frozen fillets, and frozen blocks and slabs. In each equation the quantity imported is specified as a function of its own price. In the case of fillet demand, the import price of the other fillet product (fresh or frozen) is included. Other price variables included in the fillet demand functions are the exvessel price (to account for a substitute product), and the

wholesale fillet price (which reflects the price at which the importer could sell his product.)

Two other variables are included as demand shifters in the demand functions for imported fillets: the amount of fillets in cold storage holdings, and the disappearance rate of fillets. The first is expected to exert an influence on demand for imports; increased supplies of frozen fillets will, *ceteris paribus*, decrease the demand for imported fillets. The disappearance rate is the ratio of total disappearance from storage (changes in holdings plus imports plus freezings) divided by total holdings. This variable is included as a proxy for overall demand; high disappearance rates are indicative of strong final demand, and serve as a signal to importers to increase demand for imports.

The demand function for imported blocks and slabs includes the price of imported frozen fillets, since domestic producers of processed fish sticks, fillets, and portions may either use frozen fillets directly or produce "fillets" which are cut from the frozen blocks. The relative prices of frozen fillets and frozen blocks would then determine, in part, the relative product mix coming into this country.

The supply functions include as an explanatory variable the net supply price of the product. This is defined as the import price in this country less any tariffs. In this formulation, it would appear that exporters pay the tariff. However, as the market tends to equilibrium the actual burden of the tariff will be divided between importer and exporter; the relative share paid by each side dependent on the demand and supply elasticities. Since exporters possess some degree of flexibility over product form; i.e., they may either choose to export fresh fillets, frozen fillets, or frozen blocks, the supply prices of alternative product forms are also included in the supply functions. To serve as a proxy variable for overall groundfish supplies, monthly catches of groundfish by the major North Atlantic fishery nations are present in the supply equations; increases in world landings would tend to increase the willingness of exporters to ship to the U.S. market. Finally, seasonal dummies are added to reflect the seasonal nature of the market. In particular, imports of fresh fillets by the United States tend to be concentrated in the first quarter.

The groundfish import demand equations are:

$$(6) \quad IF_f = (PI_f, PI_Z, HF, PW_2, DF, D_a, D_2, D_3) \quad (\text{Fresh fillets})$$

$$(7) \quad IF_Z = (PI_Z, PI_f, HF, PW_Z, DF, DL, D_2, D_3) \quad (\text{Frozen fillets})$$

$$(8) \quad I_b = (PI_b, HB, P_b, P_s, DB, D_{lf}, D_2, D_3) \quad (\text{Blocks/slabs})$$

The groundfish import supply equations are:

$$(9) \quad IF_f = (PI'_f, PI'_Z, PI'_f, GFICNAF, D_x, D_2, D_3) \quad (\text{Fresh fillets})$$

$$(10) \quad IF_Z = (PI'_Z, PI'_b, PI'_f, GFICNAF, D_{lf}, D_2, D_3) \quad (\text{Frozen fillets})$$

$$(11) \quad I_b = (PI'_b, PI'_f, PI'_Z, GFICNAF, D_x, D_2, D_3) \quad (\text{Blocks/slabs})$$

$IF_f, IF_Z, I_b$  = imports of fresh groundfish fillets, frozen fillets, and blocks,

$PI_f, PI_Z, PI_b$  = prices of imported fresh groundfish fillets, frozen fillets, and blocks,

$PI'_f, PI'_Z, PI'_b$  = import prices of fresh fillets, frozen fillets, and blocks net of import duties,

$PW_Z$  = wholesale price of imported frozen fillets,

$P_b$  = wholesale price of imported frozen blocks/slabs,

$HF, HB$  = holdings of fillets and blocks in the U.S.,

$DF, DB$  = disappearance rates of fillets and blocks,

$P_s, D_1, D_2, D_3$  = as above,

$GFICNAF = ICNAF$  landings of groundfish, a proxy for world supply.

To close the model, it is necessary to specify the price determination relationships for the wholesale and retail markets for fresh and frozen fillets and groundfish blocks. Since the supply of fresh domestic fillets is presumed exogenously determined in the short run, traditional product supply curves are not specified for domestic fillets. Rather, the approach of Bockstael is used, where price markup equations are specified for wholesale and retail prices. (Supply functions, of course, are estimated for imported products.)

In the case of fresh fillets, the determination of retail price is fairly straightforward. A simple markup relationship between the exvessel price and the retail fresh price of groundfish is postulated. Due to the perishability of the product and the premium placed in the market

on fresh fish, the assumption is made that the product moves from original supplier (the exvessel level) through processing, distribution, wholesaling and retailing within the time period used in the analysis (one month). It is presumed that the retail price of fresh fish should exhibit a fairly constant positive relationship to the exvessel price if margins remain stable over time.

The issue of price determination becomes slightly more complex when considering frozen blocks, processed products, and frozen fillets due to the role of inventories. Frozen groundfish fillets and blocks are purchased by importers and other intermediaries for later sale to converters and processors for further processing or distribution. It is assumed that purchasers of foreign and domestic fish products for freezing or further processing will adjust their inventories to accommodate changes in demand or supply conditions. The wholesale price paid by intermediate purchasers of groundfish products will thus be influenced by current and lagged values of inventories and current demand levels.

If holders of fish inventories are unable to adjust their inventories instantaneously to desired levels, then the current wholesale price will depend upon lagged values of the decision variables. One way to model this phenomenon would be to use an inventory adjustment-price expectations model. This approach was taken by Tsoa, Schrank, and Roy (1982) in their study of the groundfish market. Their model, however, does not explicitly consider either the exvessel or the imports market. Rather than use this more complicated approach to price determination, in this study the impact of inventory adjustment is incorporated using simple lagged exogenous and endogenous variables in the price determination equations.

In the model, five price equations are utilized. The first specifies the retail price of fresh fillets as a function of the prices of fresh domestic and imported fillets. The second relates retail frozen fillet price as a function of lagged wholesale frozen fillet prices and lagged imported frozen fillet prices. The third and fourth equations model the wholesale frozen fillet and fish sticks and portions prices as functions of lagged wholesale prices, lagged import prices, holdings, the disappearance rates of fillets and sticks and portions, and world landings. The rationale for the latter is that increases in world landings would lead to lower prices both directly and indirectly as

intermediaries anticipate greater supplies in the future. Similarly, the wholesale price of foreign blocks is presumed to depend on lagged wholesale prices, prices of imports, holdings, world holdings, and seasonal factors.

The price determination relationships are:

$$(12) \quad P_f = (P_e, P_{lf}) \quad (\text{Retail Fresh Fillets})$$

$$(13) \quad P_z = (P_{z-1}, P_{lz}) \quad (\text{Retail Frozen Fillets})$$

$$(14) \quad PW_z = (PW_{f-1}, P_{lz}, HF, DF, GFICNAF, D_1, D_2, D_3) \quad (\text{Whsle Frozen Fillets})$$

$$(15) \quad P_s = (P_{b-1s}, P_{lb}, HSP, DSP, GFICNAF, D_1, D_2, D_3) \quad (\text{Whsle Sticks/Portions})$$

$$(16) \quad P_b = (P_{b-1}, P_{lb}, HB, DB, GFICNAF, D_1, D_2, D_3) \quad (\text{Wholesale Blocks/Slabs})$$

where

$P_f, P_e, P_z, P_b, P_s, P_{lf}$ , and  $P_{lz}$  = as described above

$HF, HB, HSP$  = Cold storage holdings of fillets, blocks, and sticks/portions.

$DF, DB, DSP$  = Disappearance rates of fillets, blocks, and sticks/portions.

$GFICNAF, D_1, D_2, D_3$  = as described above.

A subscript of —1 indicates a lagged variable.

The model of the U.S. groundfish market as presented in this study, then encompasses several market sectors and many different product forms. The model as described above forms a simultaneous system in 16 equations. In the next section of the paper issues relating to the estimation of this multisectoral model are discussed.

### Construction and Estimation of the Model

The market model for the New England groundfish fishery is specified as a set of demand, supply, and price linkage equations defined over the natural logarithms of the endogenous and exogenous variables discussed in the preceding section. To estimate this model, three stage least squares procedures are applied to this system of equations. Simul-

taneous estimation of the entire system in this manner yields superior estimates to OLS and 2SLS alone in models such as this where the error terms are thought to be highly correlated across equations (Theil 1971). The model as estimated consists of 17 exogenous variables, four lagged endogenous variables and 16 endogenous variables.

The data used to estimate the market model were obtained from a variety of sources. The largest single source of data used was a computer database entitled "DB-FISH," which is maintained by the National Marine Fisheries Service. This database contains monthly and annual data on landings, market movements, prices, freezings, and cold storage holdings for all major foodfish and processed products in the United States. These data are based on price surveys, fishermen's trip reports, weigh-out files, and field reports from NMFS and other government personnel. Additional data on New England fisheries were obtained from various researchers at the University of Rhode Island. Import data was obtained from the Bureau of the Census publications on monthly international trade flows. General economic data, such as price indices, per-capita income, and the like were obtained from *Survey of Current Business*.

Many of the variables used in this study were derived from other variables. For example, the absolute tariffs, expressed in cents per pound, were converted to tariff rates to be usable in a simulation analysis in a log-linear model. Disappearance rates are denned as the sum of first of the month cold storage holdings, plus freezings, imports, and domestic landings, less end of month storage holdings, divided by end of month holdings. Since monthly consumption of fish products are not reported, the consumption values for fish fillets and sticks and portions are defined as landings plus imports less net changes in holdings. Import prices were derived by dividing the reported value of imports inclusive of tariff and transportation cost to the United States by the reported quantity. Monthly data from 1970 to 1982 were used in the estimation of the model.

The estimation results are reported in table 1. Along with the estimated parameters of the various demand, supply, and price determination equations, the t-ratios are also reported. While t-statistics are not strictly valid as measures of statistical precision of parameter estimates in simultaneous equations models,



**Table 1. Regression Results**

Weighted mean square error for system = 1.084950 with 1922 degrees of freedom. Weighted R-square for system = 0.8034. This is the R-square that corresponds to the approximate F test on all non-intercept parameters in the system.

Equation 1: Retail Demand for Fresh groundfish Fillets

Dependent Variable:  $C_t$ : Consumption of Fresh groundfish Fillets

Variable	Parameter Estimate	T Ratio	Variable Label
Intercept	7.913189	5.9177	
$P_r$	-4.666434	-6.5275	Retail Price — Fresh Fillets
$P_z$	3.941464	3.1278	Retail Price — Frozen Fillets
$P_g$	-0.561590	-1.5247	Whsle Price Index — Sticks/Portions
$P_m$	-0.933144	-2.1368	CPI: Meat
$P_P$	2.097267	4.1620	CPI: Poultry
$Y$	2.996532	2.8780	Per Capita Income
$D_1$	0.180430	2.8189	Dummy Variable: Spring
$D_2$	0.079540	1.0510	Dummy Variable: Summer
$D_3$	-0.099264	-1.1354	Dummy Variable: Fall

Equation 2: Retail Demand for Frozen groundfish Fillets

Dependent Variable:  $C_z$ : Consumption of Frozen groundfish Fillets

Variable	Parameter Estimate	T Ratio	Variable Label
Intercept	9.971436	9.6730	
$P_z$	-1.112016	-1.1513	Retail Price — Frozen Fillets
$P_r$	0.897868	1.6757	Retail Price — Fresh Fillets
$P_s$	0.335767	1.2063	Whsle Price Index — Sticks /Portions
$P_m$	0.068819	0.2144	CPI: Meat
$P_p$	-0.138468	-0.3775	CPI: Poultry
$Y$	-0.480648	-0.6284	Per Capita Income
$D_1$	0.156457	2.7185	Dummy Variable: Spring
$D_2$	0.116461	1.7887	Dummy Variable: Summer
$D_3$	0.147776	2.0173	Dummy Variable: Fall

Equation 3: Wholesale Demand for Fish Sticks and Portions

Dependent Variable:  $C_a$ : Consumption of Fish Sticks and Portions

Variable	Parameter Estimate	T Ratio	Variable Label
Intercept	7.283168	8.9650	
$P_s$	-0.100275	-0.4420	Whsle Price Index — Sticks/Portions
$P_r$	0.018715	0.0434	Retail Price — Fresh Fillets
$P_z$	0.106130	0.1358	Retail Price — Frozen Fillets
$P_m$	-0.132169	-0.5160	CPI: Meat
$P_p$	0.471344	1.6026	CPI: Poultry
$Y$	0.288565	0.4714	Per Capita Income
$D_1$	0.070129	1.8079	Dummy Variable: Spring
$D_2$	-0.105868	-2.3102	Dummy Variable: Summer
$D_3$	0.007990288	0.1499	Dummy Variable: Fall

Equation 4: Exvessel Demand for Domestic Groundfish Fillets

Dependent Variable:  $P_e$ : Exvessel Price of Domestic Groundfish

Variable	Parameter Estimate	T Ratio	Variable Label
Intercept	0.735148	1.1873	
$L$	-0.363590	-7.7625	U.S. Domestic Groundfish Landings
$Y$	1.653082	3.5324	Per Capita Income
$P_m$	-0.055814	-0.3347	CPI: Meat
FCMA	-0.014092	-0.3947	Dummy Variable for 200-mile limit
$P_p$	0.507804	2.8327	CPI: Poultry
$Pl_f$	0.141447	0.8094	Fresh Fillet Import Price
$Pl_2$	0.094824	0.7327	Frozen Fillet Import Price
$D_1$	-0.021962	-0.5295	Dummy Variable: Spring
$D_2$	-0.034164	-0.9606	Dummy Variable: Summer
$D_3$	-0.142104	1.7982	Dummy Variable: Fall

## Equation 5: Demand for Domestic Fillets for Freezing

Dependent Variable: FZ: Freezings of Domestic Groundfish Fillets

Variable	Parameter Estimate	T Ratio	Variable Label
Intercept	12.747239	3.6948	
$P_e$	-2.049196	-5.7418	Weighted Average Exvessel Price
WR	0.970700	1.6458	Wage Rate in Fish Processing (\$/hr)
$IF_z$	0.550604	1.8298	Frozen Fillet Imports
HF	-0.569838	-2.8162	Frozen Fillet Holdings
$D_1$	-0.359758	-1.8038	Dummy Variable: Spring
$D_2$	0.131578	0.5644	Dummy Variable: Summer
$D_3$	0.059843	0.2743	Dummy Variable: Fall

## Equation 6: Fresh Fillet Import Demand Dependent

Variable:  $IF_r$ : Imports of Fresh Fillets

Variable	Parameter Estimate	T Ratio	Variable Label
Intercept	6.841358	7.1472	
$PI_f$	-1.234504	-3.8511	Import Price Fresh Fillets
$PI_z$	0.025000	2.6701	Import Price Frozen Fillets
HF	0.272718	2.9768	Frozen Fillet Holdings
$P_f$	-0.805160	-1.9958	Fresh Fillet Retail Price
DF	0.526392	3.9868	Frozen Fillet Disappearance Rates
Y	0.244477	0.5214	Per Capita Income
$P_e$	0.401117	2.6772	Weighted Average Exvessel Price
$D_1$	0.460385	4.3296	Dummy Variable: Spring
$D_2$	0.065368	0.6311	Dummy Variable: Summer
$D_3$	-0.000816749	-0.0087	Dummy Variable: Fall

## Equation 7: Frozen Fillet Import Demand

Dependent Variable:  $IF_z$ : Imports of Frozen Fillets

Variable	Parameter Estimate	T Ratio	Variable Label
Intercept	6.652490	11.8546	
$PI_z$	-0.546000	-2.3412	Import Price Frozen Fillets
$PI_f$	0.264300	3.9421	Import Price Fresh Fillets
HF	0.265711	5.8131	Frozen Fillet Holdings
$PW_z$	0.246199	2.4104	Frozen Fillet Retail Price
DF	0.543375	7.6140	Frozen Fillet Disappearance Rates
$P_e$	0.238491	3.7105	Weighted Average Exvessel Price
Y	0.146231	4.1221	Per Capita Income
$D_1$	0.148897	2.5917	Dummy Variable: Spring
$D_2$	0.421059	7.3722	Dummy Variable: Summer
$D_3$	0.421888	7.8002	Dummy Variable: Fall

## Equation 8: Block Import Demand

Dependent Variable:  $I_b$ : Imports of Frozen Blocks/Slabs

Variable	Parameter Estimate	T Ratio	Variable Label
Intercept	5.466287	7.0723	
$PI_b$	-0.996132	-2.3561	Block Import Price
HB	0.177789	3.2936	Block Holdings
$P_s$	0.118068	1.0626	Whsle Price Index — Sticks/Portions
$P_b$	1.714113	4.3903	Block Wholesale Price
DB	0.022535	1.2185	Block Disappearance Rate
Y	-0.243152	-0.5707	Per Capita Income
$D_1$	0.129256	1.8233	Dummy Variable: Spring
$D_2$	0.179237	2.4711	Dummy Variable: Summer
$D_3$	0.078106	1.1209	Dummy Variable: Fall

## Equation 9: Fresh Fillet Import Supply

Dependent Variable:  $IF_f$ : Imports of Fresh Fillets

Variable	Parameter Estimate	T Ratio	Variable Label
Intercept	2.383599	3.9430	
$PI'_f$	0.370120	1.8203	Tariff Adj. Fresh Fillet Imp. Price
$PI'_z$	-0.090241	-2.9678	Tariff Adj. Frozen Fillet Imp. Price
$PI'_b$	-0.050943	-2.6701	Tariff Adj. Block Import Price
GFICNAF	0.203954	3.8186	ICNAF Landings
$D_1$	0.501167	5.2250	Dummy Variable: Spring
$D_2$	-0.010177	-0.1026	Dummy Variable: Summer
$D_3$	-0.039215	-0.4129	Dummy Variable: Fall

## Equation 10: Frozen Fillet Import Supply

Dependent Variable:  $IF_z$ : Imports of Frozen Fillets

Variable	Parameter Estimate	T Ratio	Variable Label
Intercept	10.239218	21.5483	
$PI'_z$	0.162713	2.2837	Tariff Adj. Frozen Fillet Imp. Price
$PI'_f$	-0.069440	-2.4139	Tariff Adj. Fresh Fillet Imp. Price
$PI'_b$	-0.058240	-2.7012	Tariff Adj. Block Import Price
GFICNAF	-0.046605	-1.6610	ICNAF Landings
$D_1$	0.171081	2.9568	Dummy Variable: Spring
$D_2$	0.361881	6.0766	Dummy Variable: Summer
$D_3$	0.381853	6.6475	Dummy Variable: Fall

## Equation 11: Block Import Supply

Dependent Variable:  $I_b$ : Imports of Blocks/Slabs

Variable	Parameter Estimate	T Ratio	Variable Label
Intercept	7.070326	8.2410	
$PI'_b$	0.759629	6.4346	Tariff Adj. Block Import Price
$PI'_z$	-0.203217	-3.2232	Tariff Adj. Frozen Fillet Imp. Price
$PI'_f$	-0.174495	1.2513	Tariff Adj. Fresh Fillet Imp. Price
GFICNAF	0.141365	2.7424	ICNAF Landings
$D_1$	0.240523	3.3321	Dummy Variable: Spring
$D_2$	0.291651	3.8366	Dummy Variable: Summer
$D_3$	0.192452	2.7008	Dummy Variable: Fall

## Equation 12: Price Determination: Fresh Fillet Retail Price

Dependent Variable:  $P_f$ : Retail Price of Fresh Groundfish Fillets

Variable	Parameter Estimate	T Ratio	Variable Label
Intercept	3.386898	28.4232	
$P_e$	0.571774	13.0785	Weighted Average Exvessel Price
$PI_f$	0.242142	9.2416	Fresh Fillet Import Price

## Equation 13: Price Determination: Frozen Fillet Retail Price

Dependent Variable:  $P_z$ : Retail Price of Froz. Groundfish Fillets

Variable	Parameter Estimate	T Ratio	Variable Label
Intercept	1.308132	9.6296	
$P_{z-1}$	0.365828	5.9505	Ret. Froz. Fillet Price Lag 1 Month
$P_{iz}$	0.477909	9.5782	Frozen Fillet Import Price

Equation 14: Price Determination: Frozen Fillet Wholesale Price  
Dependent Variable:  $PW_z$ : Wholesale Price of Frozen Fillets

Variable	Parameter Estimate	T Ratio	Variable Label
Intercept	0.886670	2.4843	
$FW_{t-1}$	0.708396	12.7511	Whsle Froz. Fillet Price Laq 1 Month
HF	-0.070555	-2.9854	Frozen Fillet Holdings
DF	-0.053343	-1.5121	Frozen Fillet Disappearance Rate
GFICNAF	0.00977897	0.6207	ICNAF Landings
$Pl_z$	0.235684	4.7980	Frozen Fillet Import Price
$D_1$	-0.010238	-0.6597	Dummy Variable: Spring
$D_2$	-0.014940	-0.9436	Dummy Variable: Summer
$D_3$	0.015959	1.2513	Dummy Variable: Fall

Equation 15: Price Determination: Whsle Price of Sticks and Portions  
Dependent Variable:  $P_s$ : Whsle Price Index of Fish Sticks/Portions

Variable	Parameter Estimate	T Ratio	Variable Label
Intercept	-4.199884	-3.4952	
$P_{s-1}$	0.078632	0.2951	Whsle Price Sticks/Port. Laq 1 Month
HSP	0.667558	7.8493	Sticks/Portions Holdings
DSP	0.392065	6.5028	Sticks /Portions Disappearance Rate
GFICNAF	-0.094300	-2.4139	ICNAF Landings
$D_1$	0.058407	1.6228	Dummy Variable: Spring
$D_2$	0.129939	3.2232	Dummy Variable: Summer
$D_3$	0.014396	0.4135	Dummy Variable: Fall
$Pl_b$	0.898164	4.6660	Block Import Price

Equation 16: Price Determination: Whsle Price of Groundfish Block  
Dependent Variable:  $P_b$ : Wholesale Price of Blocks and Slabs

Variable	Parameter Estimate	T Ratio	Variable Label
Intercept	0.859634	2.8099	
$P_{b-1}$	0.155009	2.4206	Whsle Block Price Lagged 1 Month
$Pl_b$	0.705825	11.3021	Block Import Price
HB	-0.066193	-3.8543	Block Holdings
DB	0.026663	4.4519	Block Disappearance Rate
GFICNAF	0.025180	1.5232	ICNAF
$D_1$	0.032045	1.8914	Dummy Variable: Spring
$D_2$	0.032647	1.7271	Dummy Variable: Summer
$D_3$	0.039686	2.4468	Dummy Variable: Fall

they can be used in a general way as indices of the reliability of the estimated coefficients.

## Estimation Results

In interpreting the results, it is useful to compare how the estimated coefficients compare with a priori expectations as to their magnitude and sign. Clearly, we would expect that the own-price coefficients for the supply functions be positive and for the demand functions to be negative; economic theory predicts that demand curves slope downward and supply curves slope upward. It is reassuring to note that in all instances the estimated own-price coefficients for the demand and supply func-

tions have the "correct" signs, although the statistical significance of the own price coefficients in the import supply functions is low.

To give some comparison with previous studies, table 2 presents selected coefficients from the estimated model with corresponding parameter estimates from Bockstael and Tsoa, Schrank and Roy. The results obtained here correspond fairly well with those of Bockstael in sign and magnitude. The elasticities reported by Tsoa, Schrank and Roy are not directly comparable with those obtained here owing to the different natures of the models. Their "wholesale frozen/whole sale fillet demand elasticities," however, are close to the frozen fillet import demand elasticities of this

**Table 2. Comparison of Results**

	Current	Bocks tael	Tsoa, Schrank, Roy
1. Exvessel Price Flexibility	-0.36	-0.67	
2. Fresh Fillet Retail Demand Elasticity	-4.66	-6.21	—
3. Frozen Fillet Retail Demand Elasticity	-1.11	-3.71	—
4. Fish Sticks/Portions Demand Elasticity	-0.10 <sup>1</sup>	-0.50 <sup>1</sup>	—
5. Frozen Fillet Import Demand Elasticity	-0.54	-0.07	-0.40 to -0.61 <sup>2</sup>
6. Frozen Block Import Demand Elasticity	-0.99	-0.06 <sup>1</sup>	-2.89 <sup>2</sup>
7. Frozen Fillet Import Supply Elasticity	0.16	0.69	—
8. FrozenBlock Import Demand Elasticity	0.75	0.60	—

<sup>1</sup> Not significant at 95 percent confidence level.

<sup>2</sup> Reported as "wholesale demand price elasticity," derived from demands for frozen inventories.

model. (The comparison derives from the fact that most frozen fillets are imported.) The exvessel price flexibility of about  $-0.4$  is in accordance with most studies going back to Farrell and Lampe, which report price-elastic exvessel demand.

The signs of the cross-price and cross-quantity coefficients depend on the nature of the relationships between species and product forms (*viz.* complementarity or substitutability). In the three retail demand functions gross substitutability prevails; only the cross-price elasticity between fish sticks and portions and fresh fillets is negative, and this estimate is not statistically significant. A relatively weak substitutability seems to prevail; the cross-price elasticities are all less than one.

Another interesting result appears in the estimated exvessel demand equations. Imported groundfish fillets, either fresh or frozen, exhibit some degree of substitutability with domestically landed groundfish. The cross-price effects between domestic exvessel demand and import prices are positive, indicating that an increase in the price of imported fish will, other things being equal, lead to an increase in demand for, and the prices of, domestic groundfish. However, the cross-effects are not very large; an estimated elasticity of .09 for fresh fillet imports and .14 for frozen fillet imports. Nor are they statistically significant, as indicated by the t-ratios.

The estimated price determination equations yield results which, for the most part, conform with a priori expectations. The coefficient on lagged price is positive and significant in all cases. The coefficients on block or fillet holdings are negative; indicating that large inventories would tend to decrease the price offered by intermediaries for domestic or imported frozen fish. It will be recalled that

intermediary behavior was thought to reflect a desire to maintain inventories at an appropriate level. This seems to be borne out by the estimated coefficients on disappearance rates; in all equations the coefficient on the disappearance rates was positive. This would indicate that as demand increases and stocks are depleted intermediaries tend to offer a higher price for frozen fish in order to maintain or rebuild holdings.<sup>6</sup> World landings of groundfish, as reflected by reported ICNAF landings also seem to have a depressing effect on the wholesale price of groundfish; all coefficients on ICNAF landings are positive and significant. Again, this is consistent with the hypothesis that anticipation of future increases in supply would tend to decrease the price intermediaries would offer for frozen groundfish products.

Turning now to the imports market, it appears that the supplies of all forms of groundfish are quite inelastic. The estimated supply elasticities of fresh fillets, frozen fillets, and blocks are 0.37, 0.16, and 0.75, respectively. These results tend to confirm the hypothesis that import supplies coming into the United States are not very sensitive to price; that exporters are liable to take whatever they can get for their supplies.

The demand for imported fresh groundfish fillets is more price-elastic than the demand for frozen groundfish. The demand for frozen groundfish blocks is price inelastic, but, as with fillets, the absolute value of the demand elasticity was larger than that on the supply side.

<sup>6</sup> Of the three equations with negative coefficients, only that of flatfish is statistically significant at a 95% level; the others cannot be considered to be negative at any reasonable level of confidence despite the negative estimated coefficient.

## Analysis and Interpretation

An econometric model of this sort can be used to analyze several public policy issues relating to the fishery. Many economic analyses of commercial fisheries focus on "the tragedy of the commons"; the economic cost of open access, non-regulated fisheries and the contrast with the optimal levels of exploitation.<sup>7</sup> These types of issues cannot be directly addressed by an econometric model of the type considered here without an integrated bio-economic modelling strategy which incorporates biological production processes (although information on consumers' surpluses can be extracted from the estimated demand functions). It can be reasonably assumed, however, that the New England groundfish fishery is likely to remain open-access for the foreseeable future (at least as opposed to some sort of limited entry program). If one takes as given the current structure of the fishery an economic model of the type developed here can still be used to analyze several interesting issues.

There is currently much interest within the industry in expanding the market for New England groundfish through more intensive marketing of fresh fish and by enhancing the quality of the domestic catch. The demand elasticities derived from the model confirm the characterization of the market for fresh fish as a seasonal one, with fresh fish considered a "luxury good." As such, efforts to increase shelf life and preserve the freshness of the product should prove beneficial to domestic marketers of groundfish. As shown in table 3, the demand for fresh groundfish is quite income and price elastic. Frozen products (fillets and sticks/portions) are much less price elastic with income elasticities not significantly different from zero. The cross price elasticities between fish products and other protein sources (meat and poultry) are much lower for frozen products than for fresh. Indeed, the prices of alternative protein sources seem to have very little effect on the demand for frozen fish products. These differences between fresh and frozen products reflect the division of the market between imported (primarily frozen) and domestic (primarily fresh) sources. Fresh fish consumption, it will be recalled, tends to be seasonal, and much

Table 3. Estimated Price and Income Elasticities

	Retail Fresh Fillets	Retail Frozen Fillets	Wholesale Sticks/ Portions
Fresh Fillets	-4.66	0.89	0.10
Frozen Fillets	3.91	-1.11	0.18
Sticks	0.50	0.34	-0.10
Income	2.99	-0.48	0.28
CPI: Meat	-0.93	0.06	-0.13
CPI: Poultry	2.10	-0.13	-0.47

Note: Own-price elasticities emphasized.

fresh product is consumed in what has been termed the "white linen napkin" restaurant trade. Frozen fish, however, tends to be marketed in the form of pre-cooked, convenience foods at the supermarkets and in lower quality, "fast-food" restaurants and institutions. In an open access fishery such as this one the standard paradigm is that the industry will tend towards an equilibrium where the marginal vessel earns zero profits. Of vital importance to the industry is the degree to which changes in landings influence the prices and revenues received by fishermen; for the marginal vessel the difference of one or two cents per pound over a season can make a substantial difference between profit and loss. The importance of even small variations in exvessel price for the New England groundfish fleet cannot be overstated; industry performance in the past few years has declined relative to the post-1977 expansion due to the 200-mile limit. A recent study by Crutchfield and Gates shows that in several major New England ports, for instance, real economic profits (after accounting for the opportunity costs of labor) have declined for the average vessel in recent years, and may indeed be negative for some vessels.

Solving for the reduced form of the model the exvessel price flexibility is obtained; the estimated value is about  $-0.4$ .<sup>8</sup> This corresponds to an exvessel demand elasticity of about  $-2.5$ , under certain assumptions. Exogenous changes in landings, due to either the inherent stochastic nature of the resource or through some quota regulation will change both revenue and price but in the opposite direction. A good season will, other things being equal, decrease the price but increase

<sup>7</sup> For example see the study by Gates and Norton (1974) on the yellowtail flounder fishery.

<sup>8</sup> The reduced form is used due to presence in the exvessel demand equation of endogenous variables (import fillet prices).

total fleet revenue. Conversely, decreased harvests will drive up the price, but not so much as to increase revenues. This conclusion has relevance in the context of optimal regulation referred to above. Although reduction of effort levels will decrease harvests and incomes in the short run, future increases in catch as stocks recover will increase total revenue to the fleet over current levels.

The most controversial issue in the New England groundfish fishery at present is the effect that imports have on domestic harvesters. Part of the blame for the problems of the domestic groundfish fishery has been attributed to the presence in the U.S. of large numbers of imported groundfish. The importance of imported groundfish to the overall market has already been noted. A study just concluded by the International Trade Commission found that imports do inflict damage on domestic producers (USITC 1984). The contention is that imported fish are harmful to the U.S. domestic groundfish fishery by depressing prices at critical times and by acting as a barrier to increased domestic production of frozen fish products (particularly blocks and slabs). Much has also been said about the fact that the Canadian groundfish industry receives financial assistance in a variety of forms (see Corey and Dirlam (1982) and Kirby (1982) for additional background.)

The model of the groundfish market discussed in this paper can be used to assess impact of trade policies aimed at reducing the flow of imported groundfish into this country. In a related study, Crutchfield (1985a) used this model to estimate the impact of levying countervailing duties on imported groundfish products. To do this, a simulation procedure was executed which applied the average values of the exogenous variables and several hypothetical tariff rates to the reduced form coefficients. The tariff rate was varied from 0 percent to a value equal to 50% of the import price. The expected effect of the imposition of such a tariff was to increase the exvessel price by about 20%. If the tariff rate was calculated at the estimated rate by which Canadian exports are subsidized (about 20%—see Corey and Dirlam 1982) the estimated increase in the U.S. exvessel price was only about 7 percent in the short run.

The reason for this apparent lack of impact may be found in the structure of the market. Up until recently, most imported groundfish came in as either frozen fillets or frozen

blocks. On the other hand, most domestic landings are marketed fresh except during periods of peak supply when the relative price advantage of fresh fish diminishes. As noted, the fresh and frozen products tend to move through different markets, and do not directly compete with each other. Given that the bulk of imported fish is used to make processed products, it can be said that the competitive link between domestic and imported fish is rather tenuous.

Although domestic producers would not seem to gain much from a tariff, consumers of imported groundfish products would clearly be worse off than before; the tariff would raise prices of frozen groundfish products at the retail level by a significant amount. In a welfare economics sense as defined by the compensation criteria, society would be worse off if such tariffs were imposed due to the losses in consumer surplus by consumers of frozen fish. If it is deemed desirable in some way to assist the domestic fishermen through trade restrictions then a direct quota on imports would seem more effective than a tariff (although in the long run any benefits from protection in the form of increased exvessel prices would probably be dissipated by additional entry into the fishery).

The situation may be changing, however. The last year or so has seen a fairly sharp rise in the importation of fresh groundfish from Canada. Such product is a more direct competitor of domestic fish than frozen fillets or frozen fish blocks. Since these developments are not fully reflected in the data used in this study, it may be the case that the current impact of imported fresh fish on the domestic market may be greater than the results reported here may indicate.

## Summary of Results

The primary goal of this study has been to provide an economic model of the New England groundfish fishery which could be used to explore policy options relating to fishery management and generate information about consumer demand for groundfish which could be useful in future studies on the marketing and distribution of groundfish products.

The model as developed provides generally significant estimates of the interrelationships between domestic landings, foreign imports, intermediary behavior, and consumer prefer-

ences in determining prices and consumption of fish products. Disaggregating the model between fresh and frozen and product forms yields further insight into the degree to which the various types of fish products are substitutes in consumption and production. It is found that fresh fish are, generally speaking, more of a luxury good than frozen products, and consumption of fresh tends to be more price sensitive than consumption of frozen fillets and processed products.

Significant interdependence between domestic landings and exvessel prices was found, which illustrates the susceptibility of the domestic fishery to exogenous changes in either economic or biological conditions. Finally, the issue of imported groundfish and its relationship to domestic prices was addressed. It was found that no strong impact could be expected on the domestic exvessel price of groundfish if tariffs were increased on imported fish.

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