

A Simultaneous Equations Model of the U.S. Market for Canadian Atlantic Cod

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ABSTRACT. Most attempts to model markets for fish products have

concentrated on the demand side of the market. Less work has been done on modelling the supply of fish products. A few simultaneous models exist, but these have incorporated supply considerations at a highly aggregated level, typically without distinguishing among species or product forms. In this paper, we develop a simultaneous equations model of both the supply of and demand for Canadian frozen cod products on the United States market. We model the supply side of the market on the hypothesis of profit-maximization using a multiproduct technology. Our approach is unique in that we explicitly incorporate production decisions into the model and we explicitly model different product types rather than an aggregate "fish product". The model thus permits the estimation of elasticities of demand and supply for specific product types. As a result, we can analyze the process of both demand and supply substitution induced by exogenous changes on the market for cod products.

1. Introduction

Dick Johnston, the founder of IIFET, has made the point (most recently at this morning's plenary session) that the establishment of Exclusive Economic Zones by coastal nations in the late 1970s resulted in major shifts in the structure of production and trade in fish products, as distant water fleets lost access to traditional fishing grounds (Johnston, this volume). While total fish catches rose by only 37 percent from 1977 to 1987, international trade in fish products increased by 73 percent in volume and 198 percent in value. Production of frozen fish products rose by 40 percent over the same period, while international trade in these products increased by 65 percent.¹

This change in the volume and pattern of the trade in fish products has increased

¹Source: Food and Agriculture Organization, *Yearbook of Fisheries Statistics*. Rome: F.A.O., 1987.

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interest in the international markets for these products. This change in focus has been particularly sharp in countries such as Iceland, where fishing is the major industry, and Canada and Norway, where fishing is an important regional industry. Before it was forced to close down major portions of its Atlantic groundfishery in 1992 and 1993, Canada was the world's largest exporter of fish products, although it ranked only sixteenth in the world in landings.

Dick Johnston noted this morning that most attempts to model the fish products market have concentrated on the demand side of the market². Less work has been done on the supply of fish products. A few simultaneous models exist (e.g., Paez, 1981; Crutchfield and Gates, 1983), but these have incorporated supply considerations at a highly aggregated level, typically without distinguishing among species or product forms³.

This emphasis on the demand side in fish market analysis has often been rationalized by the argument (also found frequently in agricultural economics) that supply in such markets is in some sense fixed, at least in the short run, or somehow determined by non-economic (for example, biological or regulatory) forces. If supply is fixed, or determined in a way that economics cannot provide any insights, it behooves economists to focus on the demand side, where economic analysis can make some contribution.

We believe that there are two sets of circumstances in which this rationalization is invalid, and where greater attention to supply considerations is warranted. The first such situation is the case of a multi-species fishery, in which harvesters have a choice of which species to harvest, and in what proportions, and make this choice at least partly on economic grounds (e.g., relative profitability). This situation has recently been successfully modelled by several analysts, most prominently (although by no means exclusively) by Dale Squires (see, for example, Squires 1987, 1988). Because this issue has been handled satisfactorily elsewhere, we shall not be concerned with it in this paper.

The second set of circumstances in which supply considerations become potentially important — and the subject of this paper — occurs when processors have a choice

²See, for example, the studies summarized in Nash and Bell (1969), and in Roy, Tsoa, and Schrank (1991).

³There are two exceptions of which we are aware. Bockstael (1977) develops a simultaneous market model of the New England groundfish industry which distinguishes among three product forms — fresh, frozen, and sticks and portions — but not among species. Schrank, Tsoa, and Roy (1986) present a model of the Newfoundland groundfish industry that distinguishes between two product forms (fillets and blocks) and three species (cod, flatfish, and redfish).

of the product form in which to process a given catch — whether fresh or frozen, of whole or filleted, for example — and make this choice on economic grounds (relative profitability). Under these circumstances, the supply of a particular product type may be highly dependent on, for example, the relative prices of the alternative product forms.

In such cases, there are two problems resulting from an exclusive focus on the demand side of the market. First, only half the market is modelled; one cannot explain trade without explaining supply as well. Second, there is good reason to believe (Roy, Tsoa, and Schrank, 1991) that unless demand and supply relations are estimated simultaneously, the parameter estimates of the demand relation can be seriously biased.

In this paper, we develop a simultaneous equations model of both the supply of and demand for Canadian frozen cod products to the United States market. Our approach is unique in that we explicitly incorporate production decisions into the model and we explicitly model different product types rather than an aggregate "fish product". The model thus permits the estimation of elasticities of demand and supply for specific product types. As a result, we can analyze the process of both demand and supply substitution induced by exogenous changes on the market for cod products.

2. The Atlantic Canada Groundfish Processing Industry

Over 97 percent of Canadian cod landings occur on the Atlantic coast. For this reason, we focus on the Atlantic Coast industry. This industry produces several different product types, ranging from salted cod, fresh and frozen fillets and frozen blocks of several species, to highly processed retail-packaged fish products. Cod made up over 60 percent of the value of Atlantic Coast groundfish landings in 1990. Nearly 33 percent of the value of cod products were in the form of frozen blocks, followed by frozen fillets at 28 percent, salted cod at 18 percent, fresh and frozen whole fish at 12 percent, and fresh fillets at 9 percent (Department of Fisheries and Oceans, 1992).

Most of this product is marketed in the United States. Frozen and fresh products move through different marketing channels into the United States (Mazany *et al.*, 1987). Salt fish products are sold primarily in the Caribbean and Portugal. As there is no U.S. demand to speak of (except for Puerto Rico, and for immigrant groups, primarily in New York), we do not estimate equations for salt cod. The fresh market involves primarily local (Canadian) demand, as well as fish trucked mainly from Nova Scotia to New England markets. Because of the relatively low volumes of international trade in fresh products, we limit our analysis to the frozen

market.

Since each product has its own market niche, an aggregate approach to the modelling of supply is inappropriate. An alternative strategy is to adopt the theoretical framework of a multi-output, multi-input industry. This strategy has been adopted successfully in the modelling of harvesting supply (e.g., Squires, 1987; Squires, 1988; Lipton and Strand 1989), but data limitations have so far impeded its application to the fish processing industry. We have not been able to overcome these data limitations entirely, but we have been able to estimate a model of the market for frozen fish products for several groundfish species (Mazany, Roy, and Schrank, in press). In this paper, we report estimates for a model of the market for frozen cod products.

3. A Model of the Market for Frozen Cod Products

An important characteristic of groundfish processing is the existence of several different end-product forms, which in turn are sold in distinct markets. Thus, groundfish producers must choose whether to process and market their raw material as, for example, fresh fillets, frozen fillets, frozen blocks, or salted fillets. Clearly, then, it is appropriate to view the processing of groundfish as a multiproduct technology.

Such producers can be viewed as possessing a multi-output profit function $\pi(p, w)$, where p is a vector of product prices and w is a vector of factor prices. To be consistent with profit-maximization, this function must be convex, positive linear homogeneous, nondecreasing in p and nonincreasing in w . As well, if the profit function is differentiable, Hotelling's Lemma states that the supply function for the i th product y_i^s can be derived by differentiating the profit function with respect to the price of the i th product p_i . (McFadden, 1978). Thus the supply function can be written in the form

$$y_i^s = \partial\pi/\partial p_i = y_i(p, w). \quad (1)$$

There is one respect in which we do not believe that this model adequately reflects the institutional structure of the Atlantic Canada fish products industry. Producers' decisions are conditioned not only by price levels, but also by a supply of raw material that is irregular, unpredictable and perishable. This would be of no particular consequence from a modelling perspective, if local port markets could be relied upon to establish a market-clearing price promptly. Under such conditions, the effect on supply decisions of fluctuations in landings would be reflected perfectly through the resultant change in the ex vessel price of landings. The level of landings *per se* would have no independent influence on supply.

Port markets in Atlantic Canada do not have this degree of sensitivity to market forces.⁴ In Newfoundland, ex vessel prices in the inshore sector are set through collective bargaining at the beginning of the season. While technically these are minimum prices, in practice deviations from these negotiated levels are infrequent. In Nova Scotia, substantial amounts of inshore groundfish are sold through non-market transactions. When a fisherman lands his catch, the processor buys the whole catch, regardless of whether he needs all species caught or the total poundage caught. The catch is bought at prices that are usually set for the season. In both provinces, the ex vessel price in the offshore sector is an internal transfer price set within vertically integrated firms. A recent study by Gardner Pinfold Consulting Economists (Department of Fisheries and Oceans, 1989) concluded that only about thirty percent of Atlantic groundfish landings by quantity is sold through market transactions.

The implication of this institutional structure is that the ex vessel price of landings is an imperfect indicator of the supply of raw material to fish product processors. The input of raw material into the production process is at least partially quantity-constrained as well as price-constrained. Some processors at some times during the year would be willing to buy more at the posted price than is available at that time. As well, some processors at some times during the year will buy more at the posted price than would be warranted on the basis of myopic profit-maximization, in order to maintain a stable long-run supply relationship with particular fishermen. Consequently, we test the alternative specification that the profits function $\pi(p, w)$ of some processors is constrained by the level of landings q , so that the supply function derived through Hotelling's Lemma is based on the restricted profit function $\pi(p, w, q)$ which includes the level of landings q as a quasi-fixed variable (see Lau, 1976). This specification thus reflects the institutional characteristic that some processors are predominantly quantity-constrained in their input of raw material, some are predominantly price-constrained, and some experience both types of constraints. Our supply functions would then be in the form

$$y_i^s = y_i(q, p, w) \tag{2}$$

We have defined two alternative supply models here. What we will call Model I is a pure price-constrained model, in which producers are constrained entirely by the product and factor prices available to them. Quantity limitations are already reflected in prices, and have no independent influence of supply in this model.

Model II is a pure quantity-constrained model. It is based on the assumption that producers are constrained by the availability of raw material, not by the price of

⁴See, for example, Department of Fisheries and Oceans (1989).

raw material, which is an imperfect indicator of availability because of the existence of port market imperfections. In this model, the ex vessel price does not affect supply decisions in the short run.

We expect that the situation in Atlantic Canada would fall somewhere in between these two models, but closer to Model II than Model I. To test this expectation, we also estimate Model III, which is a mixed model in which both the price and quantity of landings have some independent influence on supply decisions. Note that Models I and II are special cases of Model III, so that estimation of Model III enables us to test the first two models statistically. Model III, as it turns out, is also of interest in its own right.

Canadian processors sell their frozen products primarily to wholesalers, retail outlets, and institutions in the U. S. (Mazany *et al.*, 1987). The demand for frozen products at the processor level is thus a derived demand, as the buyers, in turn, sell to other companies or directly to the local consumer. We specify a standard demand function as a function of own-price, the price of alternative products, and income. We also allow habit-persistence in demand by including its lagged value in the demand function (*cf.* Tsoa, Schrank, and Roy 1982). The demand function can then be represented as

$$y_i^d = D[p_i', I, (y_i^d)_{-1}] \quad (3)$$

where y_i^d is demand for the i^{th} product, p_i' is a vector of appropriate prices on the demand side, and I is consumer income.

As a first-order approximation to the true functional forms, we utilize a log-linear specification of the supply and demand functions for estimation of the model.⁵ Homogeneity of degree zero in all prices is imposed on the supply equation and homogeneity of degree zero in prices and income is imposed on the demand equation. Therefore, the regression equation for the supply function of a particular product is in the form:

$$\begin{aligned} \ln y_t^s &= \alpha_s + \beta_s \ln q_t + \sum_j \gamma_{sj} \ln p_{jt} + \sum_k \delta_{sk} \ln w_{kt} + \sum_m \zeta_{sm} D_{mt} + u_t \\ \sum_j \gamma_{sj} + \sum_k \delta_{sk} &\equiv 0 \end{aligned} \quad (4)$$

⁵Since we are not estimating a complete system of cod product markets in this paper, we have only limited opportunity to make use of cross-equation constraints for greater efficiency in estimation. Consequently, we did not use a flexible functional form for the supply function.

where y_t^s = supply of the product in time t ;
 q_t = cod landings in time t ;
 p_{jt} = supply price of the j^{th} product in time t ; $j = 1, \dots, 4$ for frozen fillets, frozen blocks, fresh fillets, and salted product respectively;
 w_{kt} = price of the k^{th} factor of production in time t ; $k = 1, 2$ for labour and fish landings, respectively;⁶
 D_{mt} = monthly dummy variables; $m = 1, \dots, 11$;
 u_t = random error in supply at time t ;

and β_s = elasticity of supply with respect to landings;
 γ_{sj} = elasticity of supply with respect to the j^{th} product price;
 δ_{sk} = elasticity of supply with respect to the price of the k^{th} factor of production; and
 ζ_{sm} = seasonal effect on supply during the m^{th} month (relative to December).

In the pure price-constrained model (Model I), the value of the landings elasticity β_s is set to zero by definition. In the pure quantity-constrained model (Model II), the value of the ex vessel price elasticity δ_{s2} (since for fish landings, $k = 2$) is set equal to zero. These restrictions can be tested using Model III, the mixed model.

Such a specification admits of a rich variety of possibilities with respect to the relationship between the supply of a product, and the associated product and factor prices. The convexity of the underlying profit function requires that the supply of a product be non-decreasing in its own price. The price of other products derived from the same species, however, can affect supply in a positive fashion if the two products are complementary in production, or negatively if they are substitutable in production. An example of the former might be the use of fillet trimmings in blocks or meal; an example of the latter would be the substitution of raw material between fresh and frozen fillets. It is possible that the relationship between two products might exhibit elements of substitutability and complementarity; for example, the supply of blocks may depend on diversion of product from fillets production (substitution), as well as on the use of trimming from fillets production (complementarity). The estimated value of the cross-price elasticity between these two products would depend on the relative strength of these two effects over the

⁶These two factors account for approximately eighty percent of the variable costs of production in the industry. Relatively modest expenditures are incurred for fuel and electricity, packaging materials, operating supplies, and other materials. See, for example, Statistics Canada, *Fish Products Industry*, cat. no. 32-216.

sample period. Conceivably, the net effect could depend on relative prices, quality considerations, and so on.⁷

Factor prices can affect the supply of a particular product in many ways. With a single-product technology, an increase in the price of a factor of production must cause output to fall (at least if the factor is not inferior). With a multi-output technology, there are additional possibilities. For example, if factor intensities differ among product-types, a rise in the price of a factor can cause a reallocation of production from product-types that use that factor intensively, toward other products. The supply of these latter products can increase as a result. For instance, fresh fillets production may be labour-intensive relative to frozen fillets, because of the need for more careful filleting, packing, transporting, etc. If this is the case, a rise in the wage rate could *increase* the supply of frozen fillets.

In summary, then, while the own-price supply elasticity of a product is expected to be positive, the sign of the cross-price elasticities with respect to other products depends on whether the relationship between the two products is one of complementarity (positive) or substitutability (negative). While factor-price elasticities would normally be negative, we cannot exclude the occasional positive elasticity in the case of factors of production what are used relatively less intensively in the supply of the particular product.

The landings elasticity for each product should be positive, and indeed close to unity. However, departures from unity would occur if marginal changes in landings are directed disproportionately to particular products. This might occur, for example, if limitations in freezing capacity force peak catches to be directed toward fresh or salted production. Under these circumstances, a particularly high level of landings would be associated with a relatively low proportion of these landings being directed to the capacity-constrained frozen products, and so the landings elasticities of these products would be less than unity. Departures from a unit landings elasticity could also occur if the product yield on peak-load catches differs from the average yield, perhaps because of quality differentials. For example, if high landings are associated with a predominance of small, soft-fleshed fish, proportionately smaller amounts of these landings could be directed into usable product, and landings elasticities would tend to fall below unity as well.

The regression equation for the demand function of a particular product is in the form:

⁷In a somewhat similar fashion, Gordon, Hannesson, and Bibb (1993) use a translog system to examine the allocation of Norwegian cod among frozen, salted and dried products. However, they do not integrate their model with either a cost function or a demand function.

$$\ln y_t^d = \alpha_d + \beta_d \ln y_{t-1} + \sum_j \gamma_{dj} \ln p'_{jt} + \delta_d \ln I_{t-1} + \sum_m \zeta_{dm} D_{mt} + v_t \quad (5)$$

$$\sum_j \gamma_{dj} + \delta_d \equiv 0$$

where y_t^d = demand for the product in time t ;
 y_{t-1} = consumption of the product in time $t-1$;
 p'_{0t} = price of the product in time t ;
 p'_{jt} = price of the j^{th} substitute product, for $j = 1, \dots, m-1$;
 p'_{mt} = Consumer Price Index for all items in time t ;
 I_{t-1} = disposable income in period $t-1$;
 v_t = random error in demand at time t ;

and β_d = coefficient of habit-persistence;
 γ_{dj} = elasticity of demand with respect to the j^{th} product price;
 δ_d = income elasticity of demand; and
 ζ_{dm} = seasonal effect on demand during the m^{th} month (relative to December).

Because monthly data are used to estimate the model, we assume a one period lag in the response of demand to changes in income (cf. Tsoa, Schrank and Roy, 1982). We expect the coefficient of habit-persistence β_d to be positive, and higher the greater the degree of habit-persistence. The own-price elasticity should be more negative, and cross-price elasticities should be more positive, the greater the degree of demand substitutability. Income elasticity should be positive if cod is a normal good.

4. Data Sources

The focus of this study is the substitution possibilities which exist on both the demand side (substitution between Canadian product and that obtained from alternative suppliers) and the supply side (substitution by producers of one cod product for another), and the extent to which this process of substitution is sensitive to changes in relative prices. Consequently, we assume that prices on the Canada-U.S. market for cod products adjust so that producer supply is equated to final demand within the time period in question (one month). While this is not an unrealistic assumption in the fresh fish market, where the products must be sold quickly, it is not always appropriate for the frozen market, where inventories rather

than prices may account for at least some of the adjustment.

Unfortunately, there are serious data problems with inventories of fish products. First, it is not possible to distinguish among inventories of fish products from different countries, as would be necessary if products originating from different countries are not close substitutes for one another. Secondly, both Canadian processors and U.S. buyers hold inventories of Canadian-source products. This complicates the modelling process even further. Because of these data difficulties, we impose the market-clearing assumption as a first approximation. Moreover, we consider the modelling of inventory accumulation of fish products to be sufficiently challenging (see Tsoa, Schrank and Roy, 1982; Wessells and Wilen, 1993) as to be worthy of study unencumbered by consideration of other issues.

Consumption data on cod products are not available for either Canada or the United States. We take Canadian production to be equal to consumption of the Canadian product. Since demand for the Canadian product is dominated by the U.S. market, the product prices and income data which are used to estimate the equation system (4)-(5) are those appropriate to the U.S. market.

Monthly Canadian production data are available for frozen cod fillets and cod blocks,⁸ but not for fresh and salted products. For the latter products, it would be necessary either to use an annual time series, or to estimate an import or export function rather than a supply function. The disadvantage of the first alternative is that at most sixteen observations on the price data are available. The disadvantage of the second is that the U.S. import function must be specified as a semi-reduced form incorporating both Canadian supply and U.S. final demand, as well as inventory accumulation in both Canada and the United States. Such a specification detracts from the stability, and adds to the complexity of the estimated form. Preliminary examination of each of these alternatives has not been discouraging. However, this paper reports results only for the frozen products; these account for 65 percent of the production of cod products in Atlantic Canada.

As discussed in Section 2 above, Atlantic coast production of cod products is allocated by producers into five distinct market forms: frozen fillets, frozen blocks, salt cod, fresh fillets, and fresh and frozen whole fish. Production of whole fish is constrained by non-market considerations; out-of-province sales are prohibited by the provincial government in Newfoundland and strongly discouraged in Nova Scotia. Preliminary estimates indicated that the U.S. import price of Canadian whole fish was not a significant factor in the allocation of product among product

⁸Department of Fisheries and Oceans, *Canadian Fisheries: Product and Stocks, Monthly Freezings*, various issues.

types. Consequently, we choose to concentrate on producer substitution among the remaining products: fresh fillets, frozen fillets, frozen blocks, and salt cod.

Except for salt cod, these fish products are sold predominantly in the United States. It is therefore reasonable to use as the producer price for these products the U.S. wholesale price, converted into Canadian dollars at the prevailing exchange rate. Monthly data are available for the period 1972-87 for U.S. wholesale prices of frozen boneless cod fillets and of cod blocks.⁹ Because a continuous series on wholesale prices of fresh fillet products is not available, we use the U.S. import price for fresh cod fillets as a supply price for this product.¹⁰ Since salt cod is sold on a variety of markets, we use the Canadian export price for this product.¹¹ For input prices we use the ex vessel price of cod,¹² and average hourly earnings in the fish processing industry for the Atlantic region.¹³ Monthly Canadian landings data for Atlantic cod are also available.¹⁴

In the demand equations, we use for own-prices the same U.S. wholesale prices as were used in the supply equations. The prices for the substitute goods used in the demand function for Canadian frozen cod fillets were the U.S. import prices for fresh cod fillets and for frozen cod fillets imported from Iceland and Denmark respectively. The substitute prices used in the demand for Canadian cod blocks were the U.S. import prices of cod blocks imported from Iceland and Denmark respectively.¹⁵ Earlier work (Tsoa, Roy and Schrank, 1991) has satisfied us that markets for different species are fairly segmented, and that little inter-species

⁹We use the U.S. wholesale price of Canadian 5 lb pack (boneless), imported cod blocks, frozen flatfish fillets, and imported flatfish blocks respectively, all obtained from *Food Fish Situation and Outlook* and the *Boston Blue Sheet*. The boneless fillet series begins in June of 1972, while the others begin in January of the same year.

¹⁰The U.S. import price is derived implicitly as value divided by volume, both figures from unpublished data provided by the U.S. Department of Commerce.

¹¹The Canadian export price is derived implicitly as value divided by volume, both figures from Department of Fisheries and Oceans, *Canadian Fisheries: Exports* and *Canadian Fisheries: International Trade*, various issues.

¹²Ex vessel price was calculated as landings by value divided by landings by volume for the Atlantic Region, both figures obtained from Department of Fisheries and Oceans, *Canadian Fisheries: Landings by Month*.

¹³Statistics Canada, *Employment, Earnings, and Hours* (cat. no. 72-002).

¹⁴Department of Fisheries and Oceans, *Canadian Fisheries: Landings by Month*, various issues.

¹⁵All import prices are derived implicitly as value divided by volume, both figures from unpublished data provided by the U.S. Department of Commerce.

substitution takes place in response to changes in relative prices. Similarly, both institutional information and estimation results seem to confirm that cod fillets and blocks are marketed in distinct, non-intersecting channels, and that only limited market substitution occurs on the demand side between these market forms.

5. Results of Estimation

Demand and supply functions based on equations (4) and (5) are jointly estimated for both frozen cod fillets and cod blocks as an incomplete system, using Three Stage Least Squares. The variables specified as endogenous are Canadian production of the two products, market prices of the two products, ex vessel price of cod, and Atlantic Canada cod landings. This last variable is treated as endogenous on the grounds that it is partially determined by the demand of processors of the two products for raw material. However, because our focus is on the market for the final products, we do not close the system by estimating demand and supply functions for landed cod.

Monthly data for the period 1972-87 are used to estimate these equations. Estimated coefficients for the supply equations, with associated *t*-values, are presented in Table 1 below. The coefficients for the demand equations are presented in Table 2. Alternative estimates using the pure price-constrained model (Model I), the pure quantity-constrained model (Model II), and the mixed model (Model III) are presented in all cases.

The supply equation results can be summarized as follows:

- The landings coefficient, where this variable is utilized, is never statistically different from unity.¹⁶ In one model (Model III), the fillets coefficient is below unity and the blocks coefficient is above unity by roughly equivalent amounts. This result is compatible with the interpretation that marginal landings in glut situations are allocated disproportionately to blocks, perhaps because of quality considerations.
- Although sensitive to model specification, own-price elasticities are usually significant and always greater than unity, with frozen fillets more supply-

¹⁶We experimented with Almon lags on landings in an attempt to discover a lagged pattern of adjustment of capacity to changes in landings. The most common pattern observed was a strong dependence on landings in the months between one and two years previous to the current month. This result is consistent with an investment lag in which pressure of landings on capacity results in the installation of additional capacity with a one to two year lag. No significant shorter-term lagged pattern was found.

elastic than blocks. This result suggests that there are more opportunities for product substitution in the former case than in the latter, and these additional opportunities lead to a greater sensitivity to changing profitability among product forms when relative prices change.

- This interpretation of the own-price supply elasticities is confirmed by an examination of the cross-price elasticities. In the case of frozen fillets, the cross-price elasticities are always negative, almost always significant, and almost always numerically greater than unity, indicating considerable substitution in production in response to changes in relative prices. With cod blocks, in contrast, the cross-price elasticities, while usually negative, are usually numerically smaller than unity and almost never significant. There is weak evidence of a complementarity relationship with salt cod. These results suggest that the allocation between blocks and fillets of all kinds is determined predominantly by quality considerations, and is only weakly influenced by relative price considerations. Thus, a change in the price of a cod fillet product has a relatively small impact on the production of cod blocks because the relatively low-quality block product is not highly substitutable with the higher-quality fillet product. On the other hand, the allocation of fillets among fresh, frozen and salt categories appears to be highly sensitive to price considerations. We believe that this may reflect how landed cod is sorted for production. A certain proportion goes to frozen production regardless of prices because of contractual obligations and the importance of maintaining frozen retail markets (Mazany *et al.*, 1987). The rest is allocated on an expected-profit basis. Good quality fish is usually allocated to either fillet (frozen or fresh) or salt production, while lower quality fish is allocated to block production. This limited degree of inter-product substitutability is similar to that found by Gordon *et al.* (1993) for Norway.
- Contrary to *a priori* expectations, the factor price elasticities are both positive in the pure price-constrained Model I, possibly indicating specification error. In Models II and III, the wage rate elasticity is the correct sign, and is significant in the blocks equations. The ex vessel price coefficient is negative in the blocks equation but significantly positive in the fillets equation (in the mixed Model III). This last result is unexpected, and difficult to justify in theory. We believe that ex vessel price is acting as a quality indicator for the raw material. High-quality cod is sold at a high ex vessel price, and is directed predominantly to fillets production. Low-quality cod is sold at a low price, and is directed to block production. This accounts for the fact that ex vessel price appears with different sign in the two equations.

In terms of goodness of fit, statistical significance, and consistency with theory, Model I (the pure price-constrained model) is inferior to the other two models. This result suggests that the institutional structure of the industry is such that landings have an influence on supply decisions that is independent of price considerations. Since the wage rate and, to a lesser extent, ex vessel price are correlated with the level of landings, it appears that these variables are acting as proxies for landings in Model I.

There is less basis to choose between Models II and III, particularly with respect to the blocks market, where ex vessel price makes little contribution to the estimation results. This variable *does* play an important role in the frozen fillets equation, although the strong *positive* effect this variable has on the production of frozen fillets is difficult (although not impossible) to reconcile with the theoretical model. The significance of the positive coefficient, and the substantial impact that inclusion of this variable has on goodness of fit, suggests that port markets for Atlantic cod are at least partially segmented, probably in accordance with quality considerations, and that utilizing landings as a global indicator of raw material supply oversimplifies a complex relationship between processors and harvesters.

The estimated demand equations are less sensitive to model specification, particularly with respect to comparisons between Models II and III. This is because the differences in model specification relate to inclusion of variables in the supply equation only. The demand equation results can be summarized as follows:

- Habit persistence in the demand for both frozen cod fillets and cod blocks is such that as a first-order approximation it can be said that the required adjustment to a change in demand takes place at a rate of fifty percent per month. This result suggests that virtually all of the adjustment takes place within half a year.
- The demand for both products is price elastic,¹⁷ with the demand for Canadian blocks more elastic than that for Canadian frozen fillets. This suggests that price substitutability is greater for the former product.
- This interpretation of the own-price demand elasticities is confirmed by an examination of the cross-price demand elasticities for the two products. While all cross-price elasticities are positive, as expected, those for the demand for frozen Canadian fillets are less than one and not significantly

¹⁷This result is not incompatible with the common finding (for example, Tsoa, Schrank and Roy, 1982) that the demand for cod products in the United States market is price-inelastic, since the model presented in this paper estimates the demand for cod products from a single national supplier. This demand is presumably more elastic than that for cod products from all suppliers.

different from zero except with respect to the price of frozen Icelandic fillets. By contrast, those for the demand for Canadian blocks are greater than unity and statistically significant. This result suggests that the markets for cod fillets of various types tend toward segmentation, and do not interact strongly with one another. The markets for cod blocks, on the other hand, act more like a standard commodities market, and price changes in one market have a significant impact on the others.

- The demand for both products is strongly income-elastic. This result is consistent with previous work we have done (for example, Tsoa, Schrank, and Roy, 1982; Schrank, Tsoa, Roy and Skoda, 1990).
- There are strong seasonal patterns in demand, stronger than those that affect supply. Once more, this is consistent with previous work (Tsoa, Schrank, and Roy, 1982; Mazany, 1986; Schrank, Tsoa, Roy and Skoda, 1990).

The estimated model clearly demonstrates that fish processors respond to economic incentives in the allocation of raw materials to distinct product-types. In most (although not all) cases examined, changes in relative prices induce substantial reallocations of product from one category to another.

Data constraints limited our analysis to the production of frozen fillet and block products, although the estimated cross-elasticities suggest a pattern of substitution between these products and the fresh and salted fillet products as well. Ideally, we would like to estimate an equation system, modelling production in all product categories. However, monthly production data are not available for fresh and salt fish products. An alternative specification is to use U.S. imports rather than Canadian production as the dependent variable. U.S. import data are available on a monthly basis for a variety of groundfish products.¹⁸ However, this solution does change the character of the problem somewhat because, as noted above, we are no longer estimating a supply function, but rather an import function. The import function in turn must be specified (at least theoretically) as a semi-reduced form incorporating supply, domestic final demand, and inventory accumulation. The estimation is thus further removed from the more fundamental determinants of technology and consumer preferences. As well, additional estimation problems are introduced, since import prices must be defined implicitly as value divided by volume. The specification implies that the volume of imports appears in the import function both on the left-hand side and also implicitly on the right-hand side in the

¹⁸This approach would not be appropriate for Canadian salt cod, the markets for which are more widely distributed than those for fresh fillets. Canadian export data could be used, but export data are believed to be inferior to import data. See Georgianna and Dirlam (1983), and Schrank, Tsoa and Roy (1987).

derivation of the import price. This formulation could lead to spurious correlation that would bias the results.

6. Conclusion

One basic conclusion arises from this work. We have examined an industry which is rife with market imperfections at the harvesting, processing, and marketing levels. The common-property characteristic of the basic resource is well known. A substantial proportion of the raw material is provided to processors through non-market mechanisms. Finally, a substantial degree of market segmentation takes place in the market for the final product.

Despite these institutional characteristics, it is clear from the evidence provided in this paper that market prices play an important role in allocating the raw material among competing product forms, and in allocating demand among similar products. In a fundamental way, prices *do* matter, even in these highly imperfect markets. An attempt to model the fish product industry without paying close and detailed attention to price determination must tell only part of the story.

At the same time, it is clear that a conventional modelling exercise such as that presented in this paper tells only part of the story as well. The representation of port markets as partly quantity-constrained and partly price-constrained, while yielding interesting and useful implications, is somewhat *ad hoc* and lacks clear theoretical justification. Nor does it seem correct to represent cod as a homogenous raw material, equally suitable for all products. Unfortunately, a fully satisfactory treatment of both problems involves severe data requirements.

Table 1
Regression coefficients and *t*-values,
supply functions (equation 4)

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	Frozen Fillets			Frozen Blocks		
	Model I	Model II	Model III	Model I	Model II	Model III
Constant	28.06 (5.77)	7.79 (1.52)	8.37 (1.95)	22.96 (4.39)	-0.45 (-0.12)	0.16 (0.04)
Landings	—	1.03 (8.26)	0.93 (8.52)	—	1.06 (11.00)	1.06 (10.56)
Price of frozen fillets	3.08 (1.49)	5.80 (3.32)	4.12 (2.47)	-1.08 (-0.48)	-0.79 (-0.62)	-0.26 (-0.18)
Price of blocks	-1.06 (-1.47)	-2.58 (-3.32)	-2.36 (-3.71)	2.54 (3.19)	1.40 (2.56)	1.26 (2.21)
Price of fresh fillets	-2.48 (-2.14)	-2.37 (-2.43)	-1.58 (-1.75)	-1.66 (-1.33)	-0.28 (-0.38)	-0.53 (-0.66)
Price of salt cod	-2.50 (-7.42)	-0.84 (-2.20)	-1.22 (-3.66)	-1.16 (3.12)	0.29 (1.04)	0.33 (1.12)
Wage rate	1.07 (5.50)	-0.01 (-0.04)	-0.13 (-0.61)	0.76 (3.47)	-0.62 (-3.22)	-0.60 (-3.07)
Ex vessel price	1.90 (4.17)	—	1.17 (3.00)	0.60 (1.17)	—	-0.20 (-0.56)
January dummy	0.02 (0.11)	-0.00 (-0.01)	0.15 (0.97)	-0.14 (-0.61)	0.03 (0.24)	0.01 (0.05)
February dummy	0.47 (2.21)	-0.07 (-0.42)	0.15 (0.89)	0.56 (2.34)	0.24 (1.75)	0.21 (1.31)
March dummy	0.43 (1.98)	-0.17 (0.95)	0.04 (0.26)	0.25 (1.02)	-0.14 (0.97)	-0.18 (-1.10)
April dummy	0.22 (1.06)	-0.28 (-1.60)	-0.13 (-0.80)	0.23 (0.97)	-0.13 (-1.60)	-0.16 (-1.04)
May dummy	0.37 (1.64)	-0.46 (-2.26)	-0.31 (-1.70)	0.52 (2.08)	-0.22 (-2.26)	-0.24 (-1.38)

Note: Coefficients printed in **bold** are significant at the five percent level.

. . . (Cont' d)

Table 1
Regression coefficients and *t*-values,
supply functions (equation 4)
(continued)

	Frozen Fillets			Frozen Blocks		
	Model I	Model II	Model III	Model I	Model II	Model III
June dummy	0.46 (2.06)	-0.58 (2.58)	-0.46 (2.31)	0.85 (3.43)	-0.16 (-2.58)	-0.18 (-0.97)
July dummy	0.54 (2.57)	-0.95 (3.87)	-0.76 (3.44)	1.10 4.65)	-0.35 (-3.87)	-0.37 (-1.81)
August dummy	0.24 (1.15)	-1.12 (4.66)	-0.96 (-4.45)	0.73 (3.11)	-0.60 (-4.66)	-0.63 (-3.12)
September dummy	-0.26 (-1.22)	-0.97 (4.60)	-0.94 (-5.15)	0.19 (0.76)	-0.57 (-4.60)	-0.57 (-3.35)
October dummy	-0.48 (-2.39)	-0.85 (4.63)	-0.86 (-5.47)	-0.23 (-1.04)	-0.66 (-4.63)	-0.66 (-4.44)
November dummy	-0.42 (-2.15)	-0.41 (2.50)	-0.40 (2.76)	-0.32 (-1.44)	-0.28 (2.50)	-0.29 (-2.10)
R ²	0.60	0.66	0.74	0.62	0.81	0.81

Note: Coefficients printed in **bold** are significant at the five percent level.

Table 2
Regression coefficients and *t*-values,
demand functions (equation 5)

	Frozen Fillets			Frozen Blocks		
	Model I	Model II	Model III	Model I	Model II	Model III
Constant	-4.92 (-1.45)	-11.84 (-3.40)	-10.39 (-2.97)	-0.38 (-0.19)	-4.43 (-2.16)	-3.80 (-1.81)
Consumption lagged	0.38 (6.68)	0.51 (8.42)	0.52 (8.46)	0.43 (8.08)	0.49 (9.10)	0.49 (9.04)
Price of frozen fillets	-2.09 (-3.10)	-2.02 (-2.92)	-1.89 (-2.75)	—	—	—
Price of fresh fillets	0.40 (0.67)	0.82 (1.38)	0.71 (1.19)	—	—	—
Price of Icelandic fillets	0.47 (1.92)	0.63 (2.22)	0.65 (2.37)	—	—	—
Price of Danish fillets	0.44 (1.87)	0.41 (1.50)	0.27 (1.03)	—	—	—
Price of blocks	—	—	—	-3.69 (-3.97)	-3.13 (-3.33)	-3.16 (-3.37)
Price of Icelandic blocks	—	—	—	1.74 (3.52)	1.55 (3.13)	1.51 (3.07)
Price of Danish blocks	—	—	—	1.57 (2.78)	1.88 (5.34)	1.52 (2.71)
Consumer Price Index	-1.02 (-2.55)	-2.18 (-4.93)	-1.91 (-4.32)	-0.98 (-2.38)	-1.75 (-4.21)	-1.64 (-3.85)
Disposable Income	1.80 (4.98)	2.34 (6.13)	2.17 (5.60)	1.36 (3.81)	1.87 (5.34)	1.77 (4.87)
January dummy	-0.36 (-2.34)	-0.40 (-2.61)	-0.40 (-2.59)	-0.45 (-2.69)	-0.44 (-2.65)	-0.45 (-2.67)

Note: Coefficients printed in **bold** are significant at the five percent level.

. . . (Cont' d)

Table 2
Regression coefficients and *t*-values,
demand functions (equation 5)
(continued)

	Frozen Fillets			Frozen Blocks		
	Model I	Model II	Model III	Model I	Model II	Model III
February dummy	0.35 (2.36)	0.36 (2.41)	0.37 (2.45)	0.58 (3.50)	0.59 (4.54)	0.58 (3.54)
March dummy	0.24 (1.57)	0.18 (1.19)	0.18 (1.12)	-0.14 (-0.79)	-0.17 (-0.96)	-0.17 (-0.99)
April dummy	0.07 (0.43)	-0.08 (-0.01)	-0.02 (-0.10)	0.02 (0.09)	-0.00 (-0.03)	-0.01 (-0.05)
May dummy	0.49 (3.04)	0.45 (2.80)	0.43 (2.69)	0.48 (2.78)	0.45 (2.63)	0.44 (2.59)
June dummy	0.39 (2.31)	0.32 (1.88)	0.30 (1.77)	0.67 (3.77)	0.61 (3.46)	0.61 (3.41)
July dummy	0.28 (1.66)	0.20 (1.21)	0.19 (1.11)	0.70 (3.81)	0.64 (3.51)	0.63 (3.44)
August dummy	-0.04 (-0.23)	-0.10 (-0.61)	-0.12 (-0.72)	0.09 (0.49)	-0.03 (-0.16)	0.02 (0.11)
September dummy	-0.16 (-0.97)	-0.18 (-1.13)	-0.20 (-1.24)	-0.17 (-0.95)	-0.21 (-1.18)	-0.22 (-1.22)
October dummy	-0.32 (-2.07)	-0.32 (-2.08)	-0.33 (-2.17)	-0.34 (-2.05)	-0.37 (-2.20)	-0.37 (-2.22)
November dummy	-0.40 (-2.67)	-0.39 (-2.65)	-0.39 (2.66)	-0.31 (-1.93)	-0.32 (-1.96)	-0.32 (-1.96)
R ²	0.73	0.75	0.74	0.70	0.72	0.72

Note: Coefficients printed in **bold** are significant at the five percent level.

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