Employment Prospects in a Commercially Viable Newfoundland Fishery: An Application of 'An Econometric Model of the Newfoundland Groundfishery'

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Abstract An econometric model is utilized to simulate the effects of a policy change in which government financial assistance to a major Canadian marine fishery is withdrawn and the industry is placed on a commercially viable basis. Under near-ideal conditions of marketing and harvesting, harvesting employment would fall drastically, from approximately thirty thousand fishermen under the current regime to approximately six thousand. There would be a concomitant fall in seasonal fish plant employment, and a severe fall in those federal transfer payments (e.g., unemployment insurance) which are currently generated by extensive seasonal employment in both harvesting and processing sectors of the fishery.

The policy analysis consists of simulations with a prototype econometric model which integrates the demand, processing,

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and harvesting sectors of the fishery. The essential components of the 1,000-equation model are described.

Introduction

Important in the cultural and economic life of the Province of Newfoundland and Labrador, the fishery has traditionally provided relatively low income employment for a substantial number of workers, many of them independent small boat ''inshore'' fishermen, and has relied on sizable government assistance. In recent years, there has been much talk of reducing government financial involvement in the fishing industry, an industry that has seen many of its companies become insolvent. In this paper, a large simulation model of the Newfoundland groundfishery is used to investigate the employment prospects of an economically viable fishery. The fishery is here defined as viable when the offshore harvesting and processing sectors take no financial losses and fishermen earn incomes in excess of the poverty line. The results suggest that such employment prospects are very poor indeed.

In the next section we provide, as background, a brief overview of the role of the fishery in the Newfoundland economy and of the present state of that economy. We then discuss the structure of the model, following which we apply the model to determine the economic and employment prospects of the fishery under a variety of conditions. We then test the sensitivity of the model (and, perhaps, of the fishery) to a number of changes in conditions. Finally, we present our conclusions. An appendix contains the model's key equations.

The Fishery and Economic Conditions in Newfoundland

The Newfoundland economy is driven, essentially, by its resource base and by its government and service sectors. There is only a miniscule manufacturing sector separate from that associated with its resource industries. At the height of the fishing season, in July 1985, out of an official labor force of 225,000, Newfoundland had 48,000 workers unemployed, a seasonally adjusted unemployment rate of 21.3%.[1] The Canadian equivalent was 10.5%, a figure itself usually considered to be exceedingly high. These comments provide an important part of the perspective within which the following analysis is to be viewed.

It is important to bear in mind, in this context, that the fishery has traditionally, whether appropriately or not, played the role of employer of last resort. The province's fishery currently provides employment for about 28,000 people in the harvesting sector and about 8,500 in the processing sector.[2] At least 600 communities rely on the fishery almost exclusively as a source of employment[3] and there are about 85 fish processing plants with freezing capacity,[4] the plants often being the only source of non-fishing employment in the community. Fish exports from Newfoundland are largely in the form of frozen fillets and blocks. This paper is concerned only with frozen fish products.

In recent years many of the Newfoundland fishing firms became insolvent and were superceded by Fishery Products International (FPI), a firm owned jointly by the Federal and Newfoundland governments, and the Bank of Nova Scotia. The creditors of the predecessor companies received $75M in federal funds early in 1984 and the new company anticipated—as of October 1984—losses of $25M in 1984 while requesting a further $125M from government "to cover projected operating losses and capital improvements over the next five years."[5] Actual losses in 1984 were $35 million and losses in 1985 were $20 million.[6] The goal of Fishery Products International is to turn a profit and return the company to private interests;[7] the goal of government is to create a viable industry.[8] With profits projected for 1986, FPI is speculating on a possible sale to private interests in 1987 or 1988.[9]

Pursuing the background still further, government subsidies to the Newfoundland fishery in 1981 amounted to about 4.5% of sales when measured in terms of GATT regulations, but total government expenditures in the Newfoundland fishery (including standard administrative expenditures, transfers to individuals—including unemployment insurance benefits—and subsidies to companies) in the same year, for instance, equalled more than $100M, a value nearly equal to that of landings.[10]

Clearly, the Newfoundland fishery is an industry with problems. In their 1980 report on Newfoundland, the Economic Council of Canada recommended "that gear, boat, and other subsidies to the fishery be discontinued,"[11] a drastic remedy with serious implications that the report did not address. Another possibility was mentioned by the chairman of the Royal Commission on the Economic Union and the Development Prospects for Canada who has been quoted as saying that "the inshore fishery in Atlantic Canada has got to go," although Mr. D. S. MacDonald is also supposed to have said that the government would be responsible for finding other jobs for the displaced inshore fishermen.[12] Considering the figures cited at the beginning of this paper, finding such jobs might be difficult.

Mr. M. Kirby, in the 1982 report of his Task Force on Atlantic Fisheries, was more cautious. His first priority was that the "Atlantic fishing industry should be economically viable." His second priority was that fisheries employment "should be maximized subject to the constraint that those employed receive a reasonable income—including fishery-related income transfer payments."[13] While his first priority calls for a viable fishery, the conditions of Kirby's second priority, however, imply that the fishery will continue to be unviable into the foreseeable future. One might argue that Kirby's first two priorities are inherently in conflict.

It is only in MacDonald's statement, if the quotation was correct, that the possible consequences of a "viable" fishery were directly and bluntly drawn.

The remainder of this paper discusses the application of a simulation model of the Newfoundland groundfishery to the analysis of the employment prospects of a viable fishery. The context is provided by the comments earlier in the paper of the state of the Newfoundland economy, the state of the Newfoundland fishery, and the stated objective of the government to render the industry viable.

The Model

The model,[14] as sketched in the flow diagram (Figure 1), has three main sectors: marketing (or demand), processing, and har-

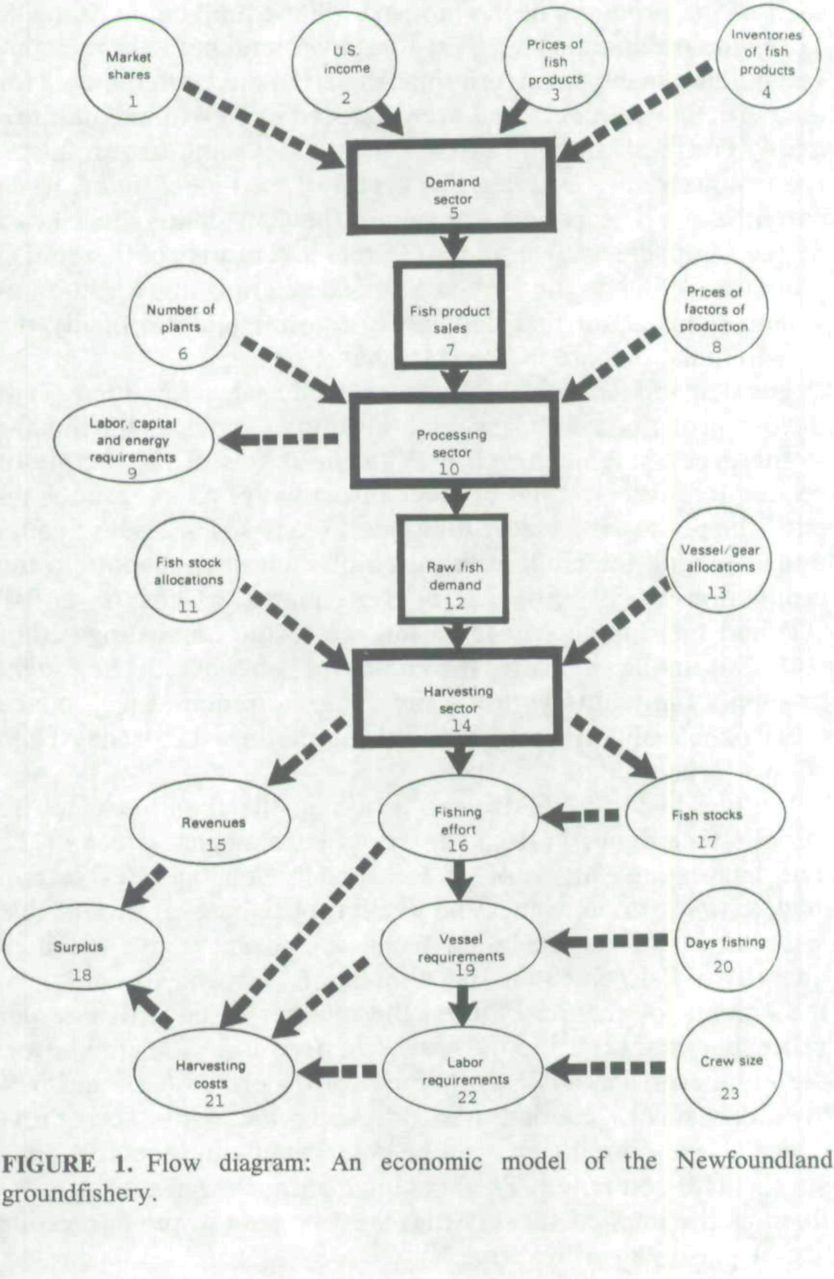

FIGURE 1. Flow diagram: An economic model of the Newfoundland groundfishery.

vesting. The demand submodel consists of an inventory adjustment mechanism that in essence yields a demand function for each of the products of the industry. Since the United States is by far the predominant market for Newfoundland fish, the marketing relationships concern the demand in the United States for the particular products that are produced in Newfoundland: primarily cod, redfish and flatfish frozen blocks and frozen fillets. Exogenous values entering this sector of the model (numbers in parenthesis correspond to boxes on the flow chart) are United States income (2),[15] fish prices (3), and inventories of frozen fish products (4). Once the United States demand is known, the Canadian share (1) of that demand is determined, and finally the Newfoundland share of the Canadian output.

The demand submodel (5) generates the saleable output (7) of the fish processing industry, and this output provides the linkage to the processing sector (10). With the prices of the factors of production (8)[16] and the number of plants (6) as exogenous inputs, the processing sector submodel consists of a series of equations showing the amount required of each of the inputs to the production process (9). One of these inputs, of course, is fish (12) and this input provides a linkage to the harvesting sector (14). This linkage indicates the volume of fish that must be caught to supply the plants with the raw material required to produce the frozen fish products that the marketing sector has been shown to be able to absorb.

We use historical allocators to assign the required catch to various techniques (13) and to specified biological stocks (11). The harvesting subsector of the model then operates in two stages: first, it determines the amount of fishing effort (16) that is required for the specified technique to catch the specified quantity of fish, given the fish population (17); and second, once the amount of required effort, the number of days fishing per vessel per year (20), and the crew size per vessel (23) are known, the number of vessels (19), number of fishermen (22), and harvesting costs (21) are determined. Finally, harvesting sector revenues (15) and total costs can be determined, and the economic surplus (18) computed. The economic surplus, if negative, is defined as the implied subsidy that must be paid to the harvesting sector per dollar of revenue.[17,18]

Before continuing, it might be useful to provide a perspective on the scope of the model. If only one species of fish were involved (e.g., cod), and only one product was produced (e.g., frozen cod fillets), and there was only one biological stock of cod (e.g., northern cod) which was caught with only a single type of gear (e.g., the bottom otter trawl) from a single type of vessel (e.g., the 500-ton stern trawler), then the entire model would consist of about 35 equations. But the Newfoundland groundfishery is more complicated than that. Not only is there cod, but redfish and four species of flatfish. Not only is there northern cod, but there are two other cod stocks, as well as eight redfish stocks and seven stocks of the flatfish species. There are seven gear types, from handlines to trawls, and there are six classes of vessels, from small motor boats of 18′ to trawlers of 150′.[19] In 1981, there were more than 96 species/stock/gear type/vessel class combinations used in the Newfoundland groundfishery. As a result of this diversity of the fishery, the model consists of 1,000 equations. In addition to its econometric aspects, the model provides an accounting and input/output framework for the analysis of the fishery.

We briefly describe each of the econometric components of the model; detailed specifications are relegated to an appendix.

Demand

The econometric component of the demand sector of the model consists of Nerlovian inventory adjustment-price expectations submodels built for the major products of the Newfoundland groundfishery. Each of the submodels includes the following equations:[20]

1. A desired stock function in which inventories desired by suppliers are determined from price expectations;
2. A partial adjustment function for inventories;
3. An equation to determine price expectations;
4. A demand function; and
5. An identity expressing the change in inventory as the difference between the supply of and demand for the fish product during a single period.

It would be inappropriate to estimate a demand function alone, although this is often done in fisheries demand analysis, because of problems of simultaneous-equation bias. To completely avoid such problems would require the development of a supply side for the U.S. fishery. In addition to amounting to an overly-long digression in the development of a Newfoundland model, there are serious potential specification errors to be encountered in modeling the supply side because of inadequate knowledge of the biological relationships underlying the harvesting process. We adopt the Nerlovian model for the joint purposes of avoiding the specification bias that would result from modeling supply and of reducing the simultaneous-equation bias that would result from neglecting supply effects entirely.[21]

Equation (6) in the Appendix is the estimation equation derived from the Nerlovian structure. Although the estimating equation appears superficially to be similar to a conventional demand equation, it is more than that; it is derived from a multi-equation model and each parameter has a structural interpretation. As an example, note in Equation (6) that the coefficient of the lag of the change in inventories has implications for the speed at which price expectations and inventories adjust.

Processing

The objective in developing an econometric processing sector is to specify the production technology of the fish products industry in order to permit inferences to be made regarding the effects of changes in relative prices (such as energy prices and of wages), the repercussions of investment incentives, and the effectiveness in increasing yields from fish inputs by changing the factor mix. To accomplish this purpose, factor inputs must be specified in detail and we define five inputs: labor, materials (primarily fish), energy, and two elements of capital investment: plant on the one hand and equipment on the other. Since little is known about the relationships between these inputs in the fish processing industry, it is desirable that we place few restrictions on the relationships that are to be estimated. The approach taken here[22] is to utilize the duality relationship explored by Shephard (1953) to estimate the production parameters indirectly through the specification of the cost function. Application of Shephard's Lemma to Parks' (1971) and Woodland's (1975) extension of the Generalized Leontief functional form proposed by Diewert (1971) yields a series of equations (represented by Equation (7) in the Appendix) which define the cost-minimizing input of each factor of production.

Harvesting

The core of the harvesting sector of the model lies in production functions for each specific fish stock. The traditional approach in fisheries economics is to specify a constrained Cobb-Douglas function with unit exponents which relates the catch of fish to the fishing effort exerted and the fish population to which that effort is applied. Since catch reduces population, the traditional "Schaefer" model[23] includes a population dynamics equation as well as a production function:

$$Q = kEP \tag{i}$$

$$dP/dt = aP - bP^2 - Q \tag{ii}$$

where Q is catch, E effort, P population, dP/dt the time derivative of population, and k, a, and b are parameters to be estimated.

Three problems which immediately arise concern the measurement of fish populations, the restricted functional form of the production function, and the definition of effort.

Regarding the first problem, the biology profession has developed a series of methods for obtaining population estimates. The quality of these estimates, which are crucial in the setting of catch quotas, is a matter of some dispute.[24] Rather than use the biologists' estimates, economists usually prefer to manipulate the Schaefer model to achieve a single equation which can then be estimated using only catch and effort data. Thus the problem of population is solved; population need not be determined prior to estimation.

Since Equation (i) is a constrained Cobb-Douglas function, a logical solution to the second problem, that of the restricted form of the production function, is to estimate the more general Cobb-Douglas form. This generalization is adopted in the model and Equations (9) and (10) in the Appendix portray the "generalized Schaefer" model.[25] Equation (11) is the nonlinear estimating equation.

The third problem concerns the measurement of effort. In the overview of the model, we indicated that numerous combinations of gear types and vessel classes were used in the Newfoundland groundfishery. If cod of a certain stock are fished by handlining from dories and also by otter trawling from large stern trawlers, then clearly one cannot add the number of days fishing from dories to the number of days fishing from trawlers to obtain a meaningful effort variable. Fifteen men on a multi-million dollar trawler will not have the same average daily catch as two men with handlines in a $15,000 trap boat.

Our approach to this problem is to standardize fishing effort in terms of the average catch per day using a particular technique taken as norm.[26] Using the average daily catch obtained when longlining from intermediate sized longliners (50′ vessels) as norm, we establish the relative productivities by fitting a multiple regression equation of the logarithm of catch per unit effort on a number of binary dummy variables. The dummy variables serve to define the technique, the fish stock, and time (the latter to isolate effects of technical change). Equation (12) in the Appendix is the relationship used to estimate the relative productivities of alternative fishing techniques. Equation (13) shows the calculation for the relative productivity weights which are used to compute an aggregate effort variable (for use in estimating the generalized Schaefer model) as a linear combination of the effort expended using the individual techniques.

We return to our primary problem of estimating the parameters of the production function. Since the Schaefer model involves a population dynamics equation, fish stocks with a biological integrity should determine the data base. The growth pattern of northern cod and Gulf redfish are surely different, so the parameters "*a*" and "*b*" from the population dynamics equation are expected to vary from stock to stock. Since our model relates to a fishery with eighteen distinct stocks, the model should include eighteen pairs of production functions and population dynamics equations. We secure convergence for nine of the eighteen stocks.

For each of these nine stocks, we now have a nonlinear relationship between effort and catch, with population acting as a constraint on catch, and with dynamics incorporated into the analysis so that world catch in one year affects the population in the next and therefore changes the amount of effort that must be applied to obtain a fixed harvest. As a byproduct of the analysis, we obtain population figures which may be better than those generated by the use of biologists' techniques. While we are careful to avoid making too extravagant a claim, the possibility of econometric techniques generating the best available biological estimates is an exciting one, at least for economists.

Policy Analysis

The problem posed at the start of this paper is to determine the employment implications of a commercially viable Newfoundland fishery. We shall use the model to make this determination under quasi-ideal conditions.

We assume that the Newfoundland groundfishery has reached a state where fish stocks are fully restored, catches are at their maintainable maximum, the catch of all species is of first quality, this quality is maintained throughout the processing and marketing operations, and all the processed fish can be sold. We also assume, as a starting point, that market prices of processed fish, processing and harvesting costs, relative (and absolute) productivities of fishing techniques, and catch allocations by fishing technique remain in our imaginary future the same as they were in 1981, the final year in the period for which the model was built.[27] As with any simulation, alternative assumptions could easily be used but, although 1981 was not a particularly good year, subsequent years have been poor and will hopefully prove to be atypical. The alternative possibility of forecasting future costs, prices, productivity, and allocations would, we believe, simply confuse the basic questions under consideration.

We desire to know the economic state of the fishery under these conditions. An alternative way of viewing the problem is that we are seeking to determine the long-term economic prospect of the industry, as currently structured, under quasi-ideal catch and marketing conditions.

To suggest the power and scope of the model, we have described all of its econometric components. For the particular policy problem under consideration, however, we assume that the entire output of the processing sector can be sold at the assumed price, thus making the demand sector redundant for the purposes of this simulation. In the first stage of the application of the model to this problem, therefore, we bypass the demand submodel and apply the generalized Schaefer analysis to determine the quasi-ideal catch.[28] We then convert three formerly endogenous marketing submodel variables into exogenous variables, and assign them values (essentially in Block 7 of Figure 1) that, when filtered through the processing sector, generate a demand for raw fish equal to the quasi-ideal harvest (Block 12 of Figure 1). The remainder of the application of the model is conventional.

Kirby (1982, p. 119) chooses a 19% gross margin as a target rate, where the gross margin is defined as the value of sales less the cost of sales expressed as a percentage of sales. At this margin, he finds that trawler plants cover their capital costs and obtain reasonable net earnings. In addition, he judges this to be a realistic margin in that it was obtained in 1978, although the gross margin has deteriorated seriously since then. As a benchmark, we define the fishery as being viable when firms that own both the offshore harvesting fleet and the processing plants earn a gross margin sufficient to cover their capital costs[29] and fishermen earn incomes in excess of the poverty line. Table 1 summarizes the results for each of eight simulation experiments.

Run 1 replicates 1981 conditions. The catch of cod, flatfish, and redfish are the actual 1981 figures for the Newfoundland harvest of the eighteen stocks which appear in the model. In this benchmark experiment, the fishery requires approximately 12K fishermen, the processing sector requires about 17M man-hours of labor, and the gross margin is 6.9%.

Table 1

Results of Simulation Experiments

Simulation Experiment	Harvest (thousand metric tons)			Processing Sector Output (hundred million 1977 Canadian dollars)	Labor Input to Processing Sector (million man-hours)	Gross Margin (percentage)	Thousands of Fishermen on Vessels of Tonnage Class j					
	Cod	Flatfish	Redfish				$j=0$	$j=1$	$j=2$	$j=3$	$j=4$	$j=5$
1	238	102	33	2.48	17.1	6.9	8.8	1.4	0.5	0.3	0.2	0.9
2	620	104	204	5.20	35.9	6.9	22.0	3.1	1.3	0.8	0.8	2.0
3	620	104	204	4.86	30.6	18.8	22.0	3.1	1.3	0.8	0.8	2.0
4	620	104	204	4.65	27.6	25.3	22.0	3.1	1.3	0.8	0.8	2.0
5	620	104	204	4.65	27.6	25.3	—	—	—	1.6	0.8	3.5
6	620	104	204	5.20	35.9	22.0	22.0	3.1	1.3	0.8	0.8	0.2
7	620	104	204	5.20	35.9	22.0	—	—	1.3	1.4	0.8	3.4
8	620	104	204	5.20	35.9	4.8	22.0	3.1	1.3	0.8	0.8	2.0

Simulation Experiment	Average Annual Income from Groundfish Harvest Per Fisherman on Vessels of Class j (thousand Canadian dollars)						Simulation Experiment
	$j=0$	$j=1$	$j=2$	$j=3$	$j=4$	$j=5$	
1	3.0	5.8	10.6	24.1	16.0	29.6	1. 1981 conditions
2	3.1	5.8	10.0	22.2	16.3	29.1	2. Run 1 except catch raised to quasi-ideal figure
3	2.4	4.5	7.8	17.3	14.0	24.3	3. Run 2 except price of fish falls by 22%
4	2.1	3.9	6.7	14.8	12.8	21.8	4. Run 2 except price of fish falls by 33%
5	—	—	—	16.3	12.8	22.3	5. Run 4 except inshore catch allocated to offshore
6	3.1	5.8	10.0	22.2	16.3	29.1	6. Run 2 except price of fish rises by 20%
7	—	—	10.0	24.2	16.3	30.0	7. Run 6 except harvest of tonnage classes 0 and 1 allocated to offshore
8	3.1	5.8	10.0	22.2	16.3	29.1	8. Run 2 except fuel costs increased to actual 1981 level

Holding all the conditions of Run 1 constant except that catches increase to the quasi-ideal values discussed above, Run 2 shows that the required number of fishermen rises to 30K, processing plant employment rises to 36M man-hours and the gross margin remains unchanged.[30] If we assume a poverty line income of $12K,[31] and that two-thirds of an inshore fishermen's income arises from groundfish operations, then, for both Run 1 and Run 2, small-boat[32] and small longliner fishermen on average earn far less than the poverty line income. Since vessel performance usually varies considerably even within a particular vessel class (Hilborn, 1985), this does not preclude the viability of some inshore enterprises under the hypothesized conditions. Such viability would be atypical.

Under conditions of the first two runs, the gross margin is an entirely inadequate 6.9%. Several options may be available to increase the margin: product price can increase relative to costs; processing costs can be reduced by rationalizing plant operations; or harvesting costs can be reduced by lowering the price of fish paid[33] to inshore fishermen (thereby also lowering the harvest revenue basis of trawlermen's share payments).[34] The first of these options is discussed in the next section. The second option has been the subject of considerable political controversy in Newfoundland over the last several years (and will continue to be given the five year management plan of Fishery Products International Ltd.), but the analysis is beyond the current capabilities of the model. In the remainder of this section, therefore, we consider the effects of reducing the price of harvested fish.

In Run 3, the price of fish falls by 22% to generate a gross margin of 19%, the value suggested by Kirby. With the drop in the relative price of fish, substitution occurs in the processing sector (presumably wastage increases), and labor input to the processing sector falls to 31M man-hours. Fishermen's income falls but medium-longliner (tonnage class 2) fishermen remain at about the poverty line. It is apparent, however, that with the large expansion of the fishery, 19% is far too small a margin for full recovery of capital costs. The required margin is 25%. In Run 4, this margin is obtained by further cutting fish prices to two-thirds of their original level. Processing sector labor falls further to 28M man-hours and fishermen in medium-sized longliners—as well as those in the smaller inshore vessels—have earnings on average below the poverty line.

Since a viable fishery requires fishermen to earn more than the poverty line and in Run 4 inshore fishermen on average earn less that this amount, in Run 5 we reallocate the inshore catch to the offshore sector. The gross margin remains at 25%, all classes of fishermen earn incomes in excess of the poverty line, processing sector labor requirements remain at 28M man-hours, but the number of fishermen required to harvest the optimal catch falls to 6K.[35] As a rough approximation, this figure can be taken to represent the long term prospects for employment in Newfoundland's fish harvesting sector in the absence of major technological progress. Any such progress would likely only further reduce the number of fishermen.

Sensitivity Analysis

With any simulation exercise, the question arises of the degree to which the results are robust with respect to particular assumptions. If the model solutions are highly unstable when parameter or variable values are altered, then the usefulness of the model is placed in serious doubt. The obtaining of "reasonable" solutions under the altered conditions suggests, at least, that there is no *prima facie* case against the model and the results of the simulation might be interesting as reflecting upon the world which is being modelled. In this section, we briefly discuss the effects of, first, a relative increase in the price of fish products and, second, an increase in the price of marine fuel.

In Run 6, the conditions of Run 2 are replicated except that the price of fish products is increased by 20%. With output held constant, revenues rise, and the gross margin rises from 6.9% in Run 2 to 22%. Only a 3% reduction in the price of fish is required for the fish companies to cover their capital costs. Since harvesting conditions have not been changed, 30K fishermen are still required but 25K of these are on small boats and small longliners and are earning well less than poverty line incomes. Reallocating the harvests of vessels in tonnage classes zero and one to the offshore in Run 7, the number of fishermen falls to 7K. Amortizing the increased number of offshore vessels, however, would require an increase in gross margin to 27.5%, and the price of fish would have to fall by 12%. All remaining fishermen would earn incomes in excess of the poverty line.

The method of projecting costs to 1981 that is discussed in Schrank, Tsoa, and Roy (1984, p. 7.4) generates a fuel cost that is one and one-third times its value for 1978, while the actual increase in the industry selling price of refinery products during that period was nearly two and one-third. In Run 8, we return to the conditions of Run 2 except that fuel costs of vessels are suitably adjusted upwards.[36] We would expect this change to adversely effect the offshore sector relative to the inshore sector. With the increase in the operating costs of the trawlers, the gross margin falls, from 6.9% in Run 2 to 4.8% in Run 8. The price of raw fish must fall in Run 8 by more than was necessary in Run 2 for the processing/trawler companies to break even, but the increased reduction is modest, the effect on the number of fishermen earning less than the poverty line is nil, and the detailed results, therefore, are not presented here.

In summary, the sensitivity analyses show the model to be robust and, to the degree that it adequately reflects conditions in the real world, the analyses provide interesting results concerning reactions of the fishery to changes in prices and fuel costs. A relative increase in the price of fish products to costs of 20%, as appeared in the sensitivity analysis, is substantial and would depend on the vagaries of the international marketplace. Such an increase would go a long way towards rendering the fish companies viable but it would not improve the situation of the fishermen. Switching harvests to tonnage classes of vessels where fishermen earn incomes greater than the poverty line would reduce the number of fishermen dramatically, by more than three-quarters. An increase in the cost of marine fuel of nearly three-quarters has only a minor effect on the fishery. While the increased cost clearly impinges more strongly on the offshore than on the inshore fleets,[37] the differential impact is not so great that the rank ordering of the cost-effectiveness of vessels in alternative tonnage classes is changed.

Conclusions

We have discussed a large econometric model of the Newfoundland groundfishery and have applied the model to investigate the implications for fishermen's employment of policy changes that would reduce government financial support for the fishery in favor of a ''commercially viable,'' self-sufficient, fishery.

The results are dramatic. We have assumed that the Newfoundland fishery increases its harvests of cod and redfish far beyond its historical experience, and that no marketing problems arise in selling the output of the processing sector. We further assumed that prices paid to fishermen for their catch were adjusted downward to permit the owners of processing plants and the offshore fleet to financially break even. Finally we assumed a reallocation of harvest by fishing technique so that surviving fishermen would earn a ''reasonable'' income from fishing. The resulting scenario would see the inshore harvesting sector eliminated; a total of only six thousand fishermen would remain in the industry.

Under the unlikely assumption that there would be no rationalization of the fish processing sector of the industry, the tremendously increased harvest would result in an increase of about 10M man-hours of fish plant employment. While this increase in employment would ease the shock of the reduction in the number of fishermen, it would fall far short of fully compensating for it.[38] It is highly unlikely, however, that an industry moving towards economic self-sufficiency would not dramatically increase productivity (and therefore limit employment) in the processing, as well as the harvesting, sector. As well, the reallocation from inshore to offshore harvesting would likely result in a reallocation of processing jobs from seasonal inshore employment to year-round offshore employment. It is possible that processing employment would actually fall as a result. In other words, the estimate of 28 million man-hours of labor required by the processing sector in Runs four and five may be far too high.

A further implication of the virtually total shift from inshore to offshore operations is that there would be a massive drop in unemployment insurance payments to both inshore fishermen and fish plant workers who will no longer be employed for enough weeks in the year to qualify for unemployment insurance.

The policy analysis made by government in its desire to render the industry financially self-sufficient will be made in the context of the overall Newfoundland economic situation, a situation that offers little hope of alternative employment, at least in the short term.

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Notes

1. See the Government of Newfoundland and Labrador's *Labour Force Flashsheet* published August 9, 1985.

2. See Tables K-7 and N-3 in Government of Newfoundland and Labrador, *Historical Statistics of Newfoundland and Labrador*, V. II(IV), January 1985.

3. Kirby (1982), p. 70.

4. Schrank, Tsoa, and Roy (1984), p. 3.1.

5. *Financial Post* (October 27, 1984), p. 6.

6. St. John's *Evening Telegram* (May 28, 1986), p. 1.

7. *Globe and Mail* (November 19, 1984), p. B3.

8. One of the terms of reference of the Kirby Task Force on Atlantic Fisheries was to determine "how to achieve and maintain a viable Atlantic fishing industry." Kirby (1982), p. 363.

9. St. John's *Evening Telegram* (May 29, 1986), p. 3.

10. To be more precise, government expenditures in 1980/81 were $125M, a figure which was 112% of the value of groundfish landings, 79% of the value of seafish landings and 31% of the value of fish products. Schrank, Skoda, Roy, and Tsoa (1987), Tables A.1 and VII.

11. Economic Council of Canada (1980), p. 101.

12. St. John's *Evening Telegram* (July 3, 1984), p. 1.

13. Kirby (1982), p. vii.

14. The model is discussed in far greater detail in Schrank, Tsoa, and Roy (1984).

15. On the flow chart, circles represent exogenous inputs to the model, ovals represent outputs of the model, bold squares represent further outputs which provide key linkages between the sectors of the model which are themselves represented by bold rectangles.

16. In this context: labor, energy, fish, and capital.

17. The "surplus" is the difference between revenues and costs, divided by revenues. Thus, a "negative surplus" of $1.00 for harvests using a specific technology implies a subsidy of $1.00 for every dollar of fish harvested with that technology. The subsidy might be paid for by government or the operation might be cross-subsidized from other company operations. See Schrank, Tsoa, and Roy (1980) for further details and examples.

18. We have specified a fishery that is demand driven; it is at least equally possible that the Newfoundland fishery is supply driven. In this case, either fishing effort (16) or catch (13) can be considered as exogenous input and the model can be run in reverse.

19. Economic Council of Canada (1980), pp. 84–85.

20. References to the literature and further details of the demand analysis appear in Tsoa, Schrank, and Roy (1982, 1986).

21. Supply effects have been introduced into single-equation fisheries demand models, as in Bell's classic paper (Bell, 1968), but only in an *ad hoc* way. The Nerlovian model rationalizes the introduction of supply effects such as inventory terms.

22. This approach to the estimation of a production technology for the Newfoundland fish products industry is discussed at length in Roy, Schrank, and Tsoa (1981).

23. For a discussion of the Schaefer model, see Munro (1980), Chapter 2.

24. The headline "4X Haddock Overestimated" from the *Atlantic Fisherman* (April 26, 1985), p. 26, reflects an all too common problem.

25. We restrict the choice of functional form to the general Cobb-Douglas because more flexible functional forms such as the translog would, with population unknown, raise horrendous estimation problems. The generalized Schaefer model is discussed in detail in Tsoa, Schrank, and Roy (1985).

26. Discussions of this approach appear in Schrank, Tsoa and Roy (1980) and in Roy, Schrank, and Tsoa (1982).

27. The assumption of exogenous prices of processed fish implies that Newfoundland is a price taker. With the enormous increase in cod

production anticipated in the policy analysis, this assumption may be untenable; Newfoundland would play a major role in the United States market. Price would probably fall as a result of the increased output. This would require firms to lower the price of raw fish even more than is shown in the simulations, thus reinforcing our conclusions.

28. We define the optimal (or "quasi-ideal") catch on a species basis (i.e. the optimal catch for cod, flatfish, and redfish). We obtain the maximum sustainable yield for the nine stocks for which we have generalized Schaefer estimates and we assume that these maximum sustainable yields are the appropriate total allowable catches for all stocks. To illustrate the computation for cod, we find a maximum sustainable yield for northern cod (NAFO divisions 2J3KL) to be 548,857 metric tons and for 3Ps cod to be 71,287 (see Schrank, Tsoa, and Roy, 1984, p. 9.83). The sum of these two figures, 620,144, is taken as the optimal catch for all three cod stocks: 2J3KL, 3Ps, and 3Pn4RS. In 1981, the two cod stocks for which we have estimated generalized Schaefer models accounted for 74.3% of the cod catch of all three stocks. The maximum sustainable yield for the three flatfish stocks for which we have estimated Schaefer models is 80,042 and these stocks represent 83.7% of the non-turbot flatfish catch of 1981. Since turbot is caught in substantial quantities and the time series for this species is too short to permit Schaefer estimation, we add the 1981 actual turbot catch (2GHJ3KL) to the maximum sustainable yield to obtain an 'optimal' flatfish catch of 104,216 metric tons. Similarly, for redfish, we use the 204,568 metric ton maximum sustainable yield obtained from the estimation of generalized Schaefer models for four stocks as the optimal catch for all eight redfish stocks. In 1981, the four Schaefer stocks accounted for 55.1% of the total redfish catch. We are underestimating the ideal optimal catches.

29. Our results will therefore be overoptimistic since firms would require a larger gross margin if they were to make a profit. Our assumptions are therefore extremely conservative but by making them we avoid the contentious issue of deciding what would be a "reasonable" level of profits.

30. The scale economies reported in Schrank, Tsoa, and Roy (1984), while appropriate for the sample period, are too great to be continued for substantial increases in production beyond those encountered during the sample period. As an approximation, we treat the scale economy variables as constants set at their 1981 values. One result is that the gross margin becomes invariant to output, assuming that prices remain unchanged.

31. This is one of the figures cited by Kirby (1982), p. 66.

32. Inshore vessels include motorboats and trapboats (tonnage class 0, less than ten tons, motorboats of 18′–22′ and trapboats of 22′–39′), small longliners (tonnage class 1, ten to twenty-five tons, 35′–45′) and medium-sized longliners (tonnage class 2, twenty-five to fifty tons, 55′). Offshore vessels are large longliners (tonnage class 3, fifty to one hundred-fifty tons, 65′), medium-sized wetfish trawlers (tonnage class 4, one hundred-fifty to four hundred-fifty tons, <145′) and large wetfish trawlers (tonnage class 5, five hundred to one thousand tons, >145′). The details of vessels in these tonnage classes, as well as their cost structures and the assumption concerning the share of fishermen's income generated by groundfish operations, are discussed in Schrank, Tsoa, and Roy (1980).

33. It may seem politically unfeasible to cut the price of fish but there exist potential methods of accomplishing much the same purpose. Plans are currently underway to require that all fish sold to processing plants will have been bled, gutted, washed and iced on board the harvesting vessel. Obviously the gross output of a vessel will decline substantially when fish must be bled and gutted, rather than landed "round", as heretofore. If the price of fish rises (ostensibly to compensate the fishermen for the better quality fish), but by less proportionately than the catch falls, then in effect the price of fish will have dropped. Our assumption of a drop in the price of fish is therefore not as unreasonable as it may at first seem.

34. Inshore fishermen are assumed to be paid on a share of gross revenue basis while trawlermen are paid on a share basis plus a per diem rate for sea time.

35. Reallocating the inshore catch to the offshore sector substantially increases the required number of offshore vessels and the gross margin of 25% is no longer adequate. A further reduction in the price of fish to 49% of its original value is necessary to restore viability. Although fishermen's earnings would obviously fall, none would fall to below the poverty line.

36. Substitution effects of the change in relative prices are ignored. In addition, since energy costs in the processing sector are small (about 3% of total processing sector costs), the effect on the processing sector of the increase in the price of fuel is also ignored.

37. The total cost of vessel operations increases by less than 1% for small boats (tonnage class zero) and by 8.6% for large trawlers (tonnage class five) as a result of the rise in fuel prices.

38. If fish plant workers are assumed to work fifty hours per week

for a fifteen week season, the increase in employment would be 13K workers while the drop in the number of fishermen would be closer to 24K.

39. This model, together with the implications of the stochastic terms, is discussed in greater detail in Tsoa, Schrank, and Roy (1985), pp. 44–50. Support for relatively simple models that omit biological detail (such as age structure) is offered in a recent paper by Ludwig and Walters (1985).

40. Equation (12) assumes a linear relationship between Q and E. In Roy, Tsoa, and Schrank (1986) we have shown that this assumption does not bias the estimate of α obtained from Equation (11) when the results of Equation (12) are used in the computation of the aggregate effort variable.

41. This estimator is biased, but the bias is known and can be corrected for. See Schrank, Tsoa, and Roy (1984), pp. 5.47–5.52.

42. Revenues and costs of the harvesting sector are discussed in greater detail in Chapter 7 of Schrank, Tsoa, and Roy (1984).

Appendix

Equations Referred to in the Text

Demand Sector

$$S_t^* = \alpha_0 + \alpha_1 P_t^e P_{t+1}^e \tag{1}$$

$$S_t = S_{t-1} + \lambda_1(S_t^* - S_{t-1}) \tag{2}$$

$$P_{t+1}^e = P_t^e + \lambda_2(P_t - P_t^e) + \sum_i \delta_i D_{it} \tag{3}$$

$$Q_t^d = \beta_0 + \beta_1 P_t + \beta_2 P_t^0 + \beta_3 Y_{t-1} + \beta_4 Q_{t-1}^d \tag{4}$$

$$S_t - S_{t-1} \equiv Q_t + M_t - Q_t^d \tag{5}$$

where:

D	represents monthly binary variables;
M	represents United States imports;
P	represents price;
P^e	represents expected price;
P^0	represents the price of substitute products;
Q	represents United States production;
Q^d	represents United States demand;
S	represents inventories held in the United States;
S^*	represents desired inventories;
Y	represents United States personal income;

and the subscript t associated with a stock variable represents the stock at the end of period t, and t associated with a flow variable has the usual interpretation of identifying the period over which the flow occurs.

$$\begin{aligned} Q_t + M_t = {} & \beta_0 + \beta_1 P_t + (2 - \lambda_1 - \lambda_2)(S_{t-1} - S_{t-2}) \\ & - (1 - \lambda_1)(1 - \lambda_2)(S_{t-2} - S_{t-3}) + \lambda_1 \lambda_2 \alpha_1 (P_t - P_{t-1}) \\ & + \beta_2 P_t^0 + \beta_3 Y_{t-1} + \beta_3 Q_{t-1}^d + \sum_i \theta_i D_{it} \end{aligned} \tag{6}$$

where $\theta_i = \lambda_1 \alpha_1 (\delta_i - \delta_{i-1})$

Processing Sector

$$F_i = \frac{\partial C}{\partial W_i} \equiv \left[\sum_{j=1}^{N} \beta_{ij} \left(\frac{W_j}{W_i} \right) + \beta_{ix} X + \beta_{it} t \right] X \tag{7}$$

where: C represents cost;
F_i represents the required input of factor i;
t represents time;
W_i represents the unit price of factor i; and
X represents output.

$$GMRG = \left(\sum_{i=1}^{M} P_i X_i - \sum_{j=1}^{N} F_j W_j \right) \bigg/ \sum_{i=1}^{M} P_i X_i \tag{8}$$

where: i refers to the ith product;
j refers to the jth non-capital factor; and
$GMRG$ represents gross margin.

Harvesting Sector

$$Q_t = e^k E^\alpha P^\beta \tag{9}$$

$$P_t - P_{t-1} = aP_{t-1} - bP_{t-1}^2 - Q_t \tag{10}$$

where: E represents effort;
P represents fish population; and
Q represents catch.[39]

$$Q_t = e^k E_t^\alpha \left[(1 + a) \left(\frac{Q_{t-1}}{e_k E_{t-1}^\alpha} \right)^{1/\beta} - b \left(\frac{Q_{t-1}}{e_k E_{t-1}^\alpha} \right)^{2/\beta} - Q_{t-1} \right]^\beta \qquad (11)$$

$$\begin{aligned} \ln (Q/E)_{ijkrmt} = {} & \alpha + \sum_i \sum_j \delta_{ij} G_i V_j + \sum_k \beta_k K_k \\ & + \sum_r \gamma_r R_r + \sum_m \eta_m M_m + \sum_t \xi_t Y_t \\ & + \sum_k \sum_i \sum_j \lambda_{kij} K_k G_i V_j + \sum_j \sum_p \phi_{jp} V_j P_p \end{aligned} \qquad (12)$$

where:

$(Q/E)_{ijkrmt}$ = Catch (in metric tons) of groundfish per day fishing for vessels of the ith gear type and jth tonnage class in the rth NAFO division, mth month of the tth year when the main (or target) species is the kth;
G_i = Dummy variable representing the ith gear type;
V_j = Dummy variable representing the jth vessel tonnage class;
R_r = Dummy variable representing the rth NAFO division;
K_k = Dummy variable representing the kth main species;
M_m = Dummy variable representing the mth month;
Y_t = Dummy variable representing the tth year;
P_p = Dummy variable representing years p and after;

and there is a stochastic term which is not shown here.[40]

The relative productivity weight for the ij gear type/vessel class combination for the kth species for the pth range of years with respect to an alternative gear type/vessel class combination is the θ defined in Equation (13):[41]

$$\frac{(Q/E)_{ijkp}}{(Q/E)_{uvkp}} = \frac{e^{\delta_{ij} + \lambda_{kij} + \phi_{jp}}}{e^{\delta_{uv} + \lambda_{kuv} + \phi_{vp}}} = e^{\theta}_{ijuvkp} \qquad (13)$$

Revenue of the harvesting sector is obtained from Equations (14) and (15) below.[42]

$$R.ijkl = Q.ijkl \times PQ.ijkl \qquad (14)$$

where: $Q.ijkl$ represents the catch of species k from stock l using gear type j from vessels of class i;
$PQ.ijkl$ represents the associated unit price of catch $Q.ijkl$; and
$R.ijkl$ represents the total landed value of catch $Q.ijkl$

Total revenue of a vessel class then equals:

$$R.j = \sum_i \sum_k \sum_l R.ijkl \tag{15}$$

The harvesting sector costs section of the model is a complicated collection of identities resting upon exogenous unit costs and manpower and vessel requirements which are themselves determined higher in the recursive ordering of the model. Here we summarize some of the major components of this part of the model.

$$TGC.ijk = GCU.ijk \times V.ijk \tag{16}$$

$$THC.ijk = HCU.ijk \times V.ijk \tag{17}$$

$$SCSH.ijk = SCRP.ijk \times R.ijk \tag{18}$$

$$SCSH.j = \sum_i \sum_k SCSH.ijk/MT.j \tag{19}$$

$$TPPP.j = SCSH.j + PDCR.j \times DAS.j \tag{20}$$

$$TFNC.ijk = FNCC.ijk \times V.ijk \tag{21}$$

$$TOC.ijk = \frac{FUEL.ijk + MANT.ijk + DTH.ijk}{DAS.ijk} \times DF.ijk \times V.ijk \tag{22}$$

$$TC.j = TPPP.j + \sum_i \sum_k [TFNC.ijk + TOC.ijk + THC.ijk + TGC.ijk] \tag{23}$$

where the subscript: i represents a gear type;
j represents a vessel class; and
k represents a species of fish.

and where:

DAS represents annual days at sea;
DF represents annual days fishing;
$FNCC$ represents annual fixed non-capital cost per vessel;
$FUEL$ represents annual fuel cost per vessel;

GCU	represents unit annual cost of gear cost;
HCU	represents unit annual cost of hull and engine;
MANT	represents annual maintenance cost per vessel;
MT	represents the total number of shipper and crew;
OTH	represents annual miscellaneous operating costs per vessel;
PDCR	represents per diem crew payments for time at sea;
SCRP	represents skipper plus crew percentage share of the catch;
SCSH	represents skipper plus crew share of the catch;
TC	represents total cost;
TFNC	represents total fixed non-capital cost;
TGC	represents total gear cost;
THC	represents total hull and engine cost;
TOC	represents total operating cost;
TPPP	represents total payment per person per year; and
V	represents the number of vessels.

The surplus of the harvesting sector is:

$$S = \left(\sum_j R.j - \sum_j TC.j\right)/\sum_j R.j \qquad (24)$$

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