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DISCUSSION PAPER NO. 190

Cost and Production in the Newfoundland Fish Products Industry

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RÉSUMÉ

Les auteurs ont utilisé une fonction de coût généralisée à cinq facteurs de Leontief en vue d'établir les rapports entre les coûts et la production dans l'industrie des produits de la pêche à Terre-Neuve au cours de la période 1961-1977. Voici leurs conclusions : 1) l'industrie a réalisé des bénéfices pendant toute la période à l'étude; 2) la productivité globale des facteurs au cours de la période demeure plutôt stable; 3) il existe une appréciable substituabilité entre la main-d'oeuvre et les matières industrielles, entre la main-d'oeuvre et les machines, et peut-être également entre la main-d'oeuvre et l'usine; 4) les auteurs notent une forte relation de complémentarité entre l'énergie et les machines, et peut-être aussi entre la main-d'oeuvre et l'usine; 5) la présence de rendements non homothétiques et croissants d'échelle est manifeste; 6) les tendances temporelles sont conformes à un mode de changement technologique caractérisé par des économies réalisées sur les matières industrielles et par une utilisation de main-d'oeuvre et de capitaux, qui exercent néanmoins en général un effect d'accroissement des coûts; 7) même des hausses appréciables des prix de l'énergie n'auraient que des effets modérés sur la structure des coûts de l'industrie.

ABSTRACT

A five-factor Generalized Leontief cost function is used to infer cost and production relationships in the Newfoundland fish products industry over the period 1961-77. The following conclusions are reached: (1) economic profits have been earned in the industry throughout the period; (2) there is very little trend in total factor productivity over the period; (3) substantial substitutability exists between labour and materials, between labour and machinery, and possibly between labour and energy and between materials and plant; (4) there is a strong complementarily relationship between energy and machinery, and possibly between labour and plant; (5) the presence of non-homothetic and increasing returns to scale is indicated; (6) time trends are consistent with a pattern of technological change which has been materials-saving and labour- and capital-using, but which nevertheless has had, on balance, a modest increasing effect on costs; (7) even substantial increases in energy prices would have only modest effects on the cost structure of the industry.

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1. The Newfoundland fish products industry: a preliminary survey*

The Newfoundland fishery is predominantly a groundfish fishery, and so roughly three-quarters of the output of the industry (by value) is groundfish product (Table 1). While cod has historically been the predominant demersal species landed, fish stock depletion has resulted in a relative decline in the importance of cod and a rise in that of flatfish (flounder, sole, plaice) and of redfish (ocean perch). Outside the groundfishery a minor role is played by herring, salmon, and lobster; in the last two cases, a relatively small catch by weight is offset by high value at the landing stage. More recently, shrimp and squid catches have increased in importance.

A number of processing and preservation techniques are applied to the harvested product. As Table 2 shows, freezing has become the predominant method of processing; after a period of rapid growth, its share of the industry's product has stabilized in the last decade at about a two-thirds proportion. Salting, the traditional method of groundfish preservation, experienced a precipitous decline through the 1960's,** but this appears to have been arrested with the establishment in 1970 of the Canadian Saltfish Corporation with exclusive control over the processing and marketing of Newfoundland saltfish.

As Table 3 shows, the various product-types tend to specialize in different species. The salt product is entirely codfish. Most of the remainder

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*For a general examination of both the harvesting and processing sectors, the reader is referred to Government of Newfoundland and Labrador (1978b) and Munro (1980). A report on a survey of the fresh frozen sector of the industry is contained in Briffett (1979).

**Alexander (1977) has studied the decline of the Newfoundland saltfish trade through the middle part of this century.

Table 1

Value of Seafish Products, Percentage Distribution by Species, Newfoundland, 1968 and 1976

	1968	1976
Groundfish	76.2	76.5
Cod	45.7	30.4
Flounders & soles	14.8	26.9
Redfish	6.3	10.9
Others*	9.4	8.3
Pelagic & estuarial	17.3	14.6
Herring	11.3	9.7
Salmon	5.7	3.5
Others**	0.3	1.4
Molluscs & crustaceans	6.5	8.9
Crabs	-	1.8
Lobsters	6.1	4.1
Others***	0.4	3.0

*Mainly turbot

**Mainly mackerel and caplin

***Mainly shrimp and squid

Source: Statistics Canada, Fisheries Statistics: Newfoundland, Cat. No. 24-202, 1968 and 1976, Table 1

Table 2

Value of Seafish Products, Percentage Distribution by Type, Newfoundland, 1961, 1968 and 1976

	1961	1968	1976
Fresh	13.5	12.8	9.4
Frozen	46.2	52.3	67.9
Bait	3.1	0.3	0.2
Smoked	0.4	*	0.2
Salted	30.2	18.1	9.0
Pickled	2.2	0.9	6.5
Canned	0.3	0.2	0.6
Meal	3.1	10.8	3.4
Oil	0.8	3.6	0.5
Other	0.2	0.3	1.6

* - Included in "other"

Source: Statistics Canada, Fisheries Statistics: Newfoundland, Cat. No. 24-202, 1961, 1968, and 1976, Table 5

Table 3

Value of Seafish Products by Species and Type, in millions of dollars, Newfoundland, 1976

	Groundfish	Pelagic & estuarial	Molluscs & crustaceans
Fresh	5.7	4.3	7.7
Frozen	111.8	8.9	6.1
Bait	-	0.4	-
Salted	16.9	-	-
Pickled	-	12.2	-
Canned	0.4	0.2	-
Meal	5.6	0.8	1.1
Oil	0.6	0.2	-

Source: Statistics Canada, Fisheries Statistics: Newfoundland, Cat. No. 24-202, 1976, Table 5 of the groundfish catch is processed by the fresh frozen sector, which fillets the fish and freezes it in the form of fillet packs of various sizes or large blocks intended for further processing elsewhere. Recently, most cod has been processed in block form, while redfish and flatfish are sold mainly as fillets. The blocked fish is usually of inferior quality, and this is reflected in the price of blocks relative to that of frozen fillets.*

The fillet packs are sold in supermarkets and to restaurants and institutional buyers, depending on size. Blocks are usually sold as intermediate product for further processing in the form of sticks and portions (e.g., prepared fish and chip dinners). It is alleged** that tariff barriers abroad prevent the further processing of the Newfoundland product. In any event, very little additional processing beyond the filleting stage takes place in Newfoundland.***

Recently, the fresh frozen industry has expanded into the processing of non-groundfish species, of which herring, salmon, squid, crab and shrimp are the most important (Table 4). However, the groundfish product remains

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*Setting a Course, p. 234. Government of Newfoundland & Labrador, 1978(b).

**See, for example, Setting a Course, p. 220, and Food Prices Review Board (1975), pp. 18-19.

***Production of $1.1 million in sticks and portions was recorded in 1976, out of a total product of $188 million.

Table 4

Quantity of Fresh Frozen Production by Species, in thousands of pounds, Newfoundland, 1978

Groundfish	169,906
Herring	17,030
Caplin	3,879
Mackerel	3,575
Salmon & Char	702
Other pelagic & estuarial species	20
Squid	46,803
Crustaceans	5,427

Source: Fisheries and Oceans Canada, unpublished data

preeminant, and is likely to remain so for the foreseeable future.*

Sales of fresh seafish have made a modest contribution to the industry (Table 2). These sales consist mainly of unprocessed lobster and salmon, along with some filleted cod, and are apparently mainly exported to New England and Canadian markets.** These fresh seafood sales are basically a merchandising activity, and so are excluded from the analysis in subsequent sections.

The pickled product consists almost entirely of herring, and is marketed predominantly in Europe. Its growth in the 1970's has been at the expense of herring meal, and this is reflected in the reduced share of fish meal over the period (Table 2). At present, meal and oil production are largely a byproduct of groundfish processing, in which the waste or offal goes into meal.

The only species which is extensively canned is crabmeat. Output of this product is small (Table 2).

The dependence of the industry on the export market is illustrated in Tables 5 and 6. Over 70 percent of the industry's output (by value) is exported, mostly to the United States.*** The dominance of

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* Setting a Course, pp. 51-55.

** Setting a Course, p. 233.

*** This should be considered a minimum estimate, as it is possible some Newfoundland product is shipped to other provinces where it is laded for export to foreign markets.

Table 5

Value of Exports of Seafish Products, by Destination, as Percentage of Value of Production, by Commodity Category, Newfoundland, 1977.

	Fish, whole or dressed, fresh or frozen	Fish, fillets or blocks, fresh or frozen	Fish, preserved ex.canned (eg. salted, pickled)	Fish, canned	Molluscs and crustaceans	Total production**
United States	25.9	68.8	11.6	-	30.8	53.6
Europe	12.1	5.8	22.5	0.2	20.3	9.8
Asia*	4.9	-	-	-	27.7	2.6
Caribbean	-	-	40.1	-	-	5.4
Total exports	42.9	74.6	74.3	0.2	79.0	71.4

*Mainly Japan

**Excludes meal, oil, and other seafish products

Note: Exports include only those shipments laded in Newfoundland. Shipments to other provinces may be laded and exported from there.

Source: Statistics Canada, Exports by countries, January to December, 1977 (Cat. No. 66-003), Table 3

Fisheries and Oceans Canada, St. John's, unpublished data

Table 6

Value of Exports of Major Groundfish Products, by Destination, as a Percentage of Value of Production, by Commodity, Newfoundland, 1976.

	Cod, fresh and frozen	Cod, salted	Flatfish	Redfish
United States	69.1	4.5	66.5	73.0
Western Europe	0.1	5.2	0.2	-
Caribbean	-	68.3	-	-
Other	-	4.6	-	-
Total	69.2	82.6	66.7	73.0

Note: Exports include only those shipments laded in Newfoundland. Shipments to other provinces may be laded and exported from there.

Source: G. Munro, Newfoundland Fishing Industry, Table XXVII

Statistics Canada, Fisheries Statistics: Newfoundland, 1976, Table 5 the U.S. market is particularly marked in the case of fillets and blocks. As Table 6 indicates, practically all exports of unsalted groundfish are directed to the United States. The salt product, on the other hand, is sold mainly in the Caribbean area (especially Puerto Rico). However, other foreign markets are more important for molluscs and crustaceans, particularly squid, for which there has recently been heavy Japanese demand. The domestic market is most important for whole or dressed fish (mainly salmon) and for canned fish (mainly crab).

This marketing situation does not provide the industry with a great deal of market power. Briffett (1979), in his survey of the fresh frozen sector of the industry, reports that all firms in his study "considered themselves price takers in the American market".** The position of the industry in the domestic market appears no stronger; "major movements in U.S. wholesale groundfish prices are soon transmitted to Canada, regardless of the supply-demand balance for these products within Canada".* However, in the markets for the pelagic species and squid, apparently price setting is more a matter of bilateral negotiation.**

The structure of the industry is further reflected in the distribution of processing licenses by the provincial government (Table 7). Of the 172 establishments possessing processing facilities, only 52 have freezing equipment. Another 53 act as "feeders" to the freezer plants, landing and filleting the fish and transporting the product on ice to a freezer plant for further processing. In effect, the feeder is a "displaced filleting

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*Food Prices Review Board (1975), p. 19.

**Briffett (1979), p. 10-12.

Table 7

Number of Licensed Fish Processing Establishments, by Region and Type, Newfoundland, March 1979.

	North-East Coast	East Coast	South Coast	West Coast-Strait of Belle Isle	Labrador Coast	Total
Freezer plants	3	30	9	7	3	52
Fresh frozen feeder plants	13	18	7	14	1	53
Fresh frozen packers	1	2	—	1	—	4
Salt dryer plants	4	12	—	2	—	18
Salt feeder plants	10	6	6	20	4	46
Pickling plants	20	24	12	27	2	85
Canneries	3	5	—	—	—	8
Total	30	67	22	48	5	172

Notes: 1. Detail does not sum to the total, because some plants are licensed to perform more than one processing operation.

2. The geographic definitions used in this table are the same as those used in Setting a Course, p. 41

North-East Coast:	Cape Norman - Cape Freels
East Coast:	Cape Freels - Cape St. Mary's
South Coast:	Cape St. Mary's - Burgeo (inclusive)
West Coast - Strait of Belle Isle:	Burgeo (exclusive) to Cape Charles
Labrador:	Cape Charles to Cape Chidley

Source: Government of Newfoundland and Labrador, Department of Fisheries, unpublished data line for the freezer plant".* Many of these feeders are operated using provincial government-owned community-type structures which are leased to the operator, often at a nominal fee.** Usually, they are limited to two or three possible buyers, one of whom takes 90% or more of their product.*** Presumably, this gives the freezer plant considerable monopsony power.

A similar structure exists in the saltfish trade. Economic factors have substantially reduced in importance the historic practice of the fisherman splitting and light-salting his catch and drying it in the sun.**** Now, most of the salt product is dried mechanically in a relatively small number (18) of dryer plants, most of which are located on the East Coast. These are supplied both directly and by a larger number of feeders that purchase, split, and salt the fish, and then transport it wet-salted to the dryers. Both types of plants act as agents of the Canadian Saltfish Corporation, on a fee basis. According to Setting a Course, the saltfish sector essentially acts as an overflow from the fresh frozen sector, taking raw material which cannot be processed promptly by the freezer plants or in areas where there is no outlet to frozen fish buyers.*****

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*Setting a Course, p. 243.

**Setting a Course, p. 224.

***Briffett (1979), p. 8.

****Copes (1973), p. 112.

*****Setting a Course, p. 236.

Many of the 172 establishments recorded in Table 7 process fish only as a sideline.* Statistics Canada classifies an establishment into the fish products industry only if it is "primarily engaged" in fish processing. Only 61 establishments are so classified in Newfoundland in the years 1975-77. Since Statistics Canada's Census of Manufactures is our primary data source, most of the establishments recorded in Table 5 are not incorporated into our analysis. We expect, however, more or less complete coverage of the important fresh frozen sector** and substantial coverage of the rest of the industry.

In view of the pivotal role played by the fresh frozen sector of the industry, some additional description of this part of the industry might be worthwhile. The freezer plants can be categorized into integrated and inshore establishments (Table 8). The 12 integrated plants are served by the province's fleet of 80 trawlers, which are generally company-owned. These plants are large,*** remain open all year, and specialize in groundfish production (Table 9). The trawler catches are typically supplemented by purchases from inshore fishermen, especially in the summer months. All the integrated plants are located on the South-East and South Coasts, which are generally ice-free and close to the offshore fishing grounds on the Grand and St. Pierre Banks.

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*The Atlantic Development Board (1969) reported of the 520 fish processing plants in the Atlantic provinces, at least half could be classified as "improved fish houses or stores" (p. 61).

**Our rough calculations indicate that in 1978, at least 98% of fresh frozen groundfish production and 85% (by weight) of other species, would have been produced by Census establishments.

***Plants were classified into 5 size categories, based on the amount of freezer capacity they possessed, for the purposes of Tables 8-10.

Table 8

Number of Processing Establishments with Freezing Equipment, by Type of Operation and Size of Freezing Capacity, Newfoundland, 1978

	Integrated plants	Inshore year-round plants	Inshore seasonal plants	Total
Small	—	2	14	16
Medium - small	—	2	5	7
Medium	—	4	9	13
Medium - large	8	—	6	14
Large	4	—	3	7
Total	12	8	37	57

Source: Fisheries and Oceans Canada, Unpublished Data.

Table 9

Fresh Frozen Production, by Type of Plant and Species, in thousands of pounds, Newfoundland, 1978

	Groundfish	Squid	Other
Large, integrated	48,152	4,832	1,555
Medium - large integrated	61,621	4,814	879
Large, inshore	14,933	8,820	6,000
Medium - large, inshore	17,017	11,897	7,574
Medium inshore year-round	10,681	969	4,290
Medium inshore seasonal	14,989	10,287	5,644
Medium - small	2,106	2,951	1,875
Small	407	2,233	3,188
Total	169,906	46,803	30,643

Source: Fisheries and Oceans Canada, unpublished data

The inshore plants, on the other hand, depend mostly on inshore fishermen for their raw material. As a result, most shut down for a period of time which varies from one to eight months but which generally centres around four or five months in the winter. A small number of inshore plants on the West and South Coasts remain open all year because of the inshore winter fishery there. Because inshore cod landings peak in July and August, the inshore plants diversify their production into non-groundfish species in order to further extend their operating season (Table 9). Moreover, while most inshore plants are fairly small, some are of fairly substantial size (Table 8).

As can be seen from Table 9, the integrated plants dominate fresh frozen groundfish production, accounting for 65% of the sector's output. However, the inshore plants account for 85% (by weight) of fresh frozen production of other species (mainly squid and herring).*

The valuation of the trawler catch is a major problem. Because the trawlers and plants are owned by the same company, extraneous considerations enter into the setting of the transfer price of the raw material. Since trawler crews have traditionally been paid an agreed share of the value of the catch, it is alleged that fish companies have kept the transfer price artifically low.** For whatever reason, it is a generally held belief that

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*The estimate by Setting a Course (p. 222) that the integrated plants account for 50% of fish products, seems to be an overestimate. Our calculations indicate that a 40% figure would be more likely.

**Copes (1973), p. 39.

companies incur losses on their trawler operations and make up the difference on their processing operations.* However, we have been unable to obtain even a ballpark estimate of the degree of this underestimation. The extent to which our cost data is distorted by this arrangement is unknown.

The production figures contained in Table 9 are converted to a per establishment basis in Table 10. As can be seen, there is a considerable diversity in the scale of operations of the plants containing freezer capacity, with the plants in the largest and smallest categories differing in their total fresh frozen production by a factor of 37. Moreover, the top three categories are dominated by three large company groups: Fishery Products Limited, the Lake Group and the H.B. Nickerson-National Sea Products group, which together operate 20 or the 34 plants in these size groups. These three company groups accounted for 75% of fresh frozen groundfish production in 1978, and 64% (by weight) of total fresh frozen production, indicating a considerable degree of concentration in an industry in which there are few barriers to entry other than government licensing restrictions.**

The medium-size plants are typically operated by local firms such as Newfoundland Quick-Freeze, T.J. Hardy, and Ocean Harvesters. None of these companies owns more than two establishments with freezing capacity.***

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*Setting a Course, p. 342.

**At the same time, the estimate by Setting a Course (p. 225) that these companies account for 70 percent of the total annual production of fish products within the province, seems clearly excessive. We expect this figure to be closer to 50 percent.

***However, it is common for these firms to run several feeder plants as well.

Table 10

Average Fresh Frozen Production per Establishment, Groundfish and Total, by Type of Plant, in thousands of pounds, Newfoundland, 1978

	Groundfish	Total
Large, integrated	12,038	13,635
Medium - large, integrated	7,703	8,414
Large, inshore	4,978	9,918
Medium - large, inshore	2,836	6,081
Medium inshore year-round	2,670	3,985
Medium inshore seasonal	1,665	3,436
Medium small	300	990
Small	25	364
Average	2,981	4,340

Source: Fisheries and Oceans Canada, unpublished data

The smaller establishments are local outlets which usually engage in salting and/or pickling operations, and perhaps some merchandising activity as well, in addition to their freezing operations. These establishments rarely rely on their fresh frozen output; indeed, two had no fresh frozen production at all in 1978, despite the existence of freezer capacity in the establishment. Apparently, the common operating practice for these firms is to enter into arrangements with the medium-sized and large firms whereby the latter purchase unprocessed or semi-processed fish supplied on a commission basis.*

These considerations, along with the absence in most ports of more than one plant with freezing capacity**, suggest that the plants possess some degree of monopsony power in the landed fish market. Mensinkai (1969), in his study of fish price fluctuations by port of landing, concludes that "each plant has some degree of control over price".*** This market power is limited by competition from the saltfish trade and by the price at which it becomes profitable for the fishermen to sell to the establishment's closest rival.

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*Setting a Course, p. 227.

**In those few ports (e.g., Dildo) with two freezer plants, there is a clear pattern of specialization by species between the plants -- e.g., one plant processes mainly groundfish and the other mainly other species.

***Mensinkai (1969), p. 38.

Concern has been expressed about the apparent presence of substantial excess capacity in the fresh frozen sector of the industry.* Unfortunately, the appropriate definition of capacity remains unclear. While freezer capacity is generally regarded as the binding constraint in the industry,** the throughput capacity of a given piece of freezer equipment can vary widely with the size of the fillet packs that are being frozen; unfortunately, there is no rule of thumb which is even approximately applicable to all types of equipment. This renders all estimates of freezer capacity somewhat suspect.

However, some insight into the extent of excess capacity can be obtained by examining the seasonal pattern of plate freezer throughput in the industry.*** Table 11 shows that roughly the same level of throughput is maintained through the months of June through September, although in the last month heavy reliance on non-groundfish species is required to maintain this level. Before and after this period, production falls to levels usually less than half of peak production.

In contrast, the seasonal pattern of landings, presented in Table 12, shows a much sharper peak in July and August. A comparison of Tables 11 and 12 then suggests that

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*See Setting a Course, p. 243 ff. That this concern is a long-standing one can be seen from an examination of Mensinkai (1969), pp. 15-28, and Copes (1973), pp. 107-14.

**Setting a Course, p. 248.

***Table 11 refers to plate freezers only; these are by far the dominant method by which fillets and blocks are frozen. While other freezer types do play a minor role in the industry, especially in the processing of non-groundfish species, the plate freezers account for 85% of fresh frozen production by weight.

Table 11

Total Weight (thousands of pounds) of Plate Freezer Product, by Species and Month, and Total Production as Percentage of Peak Utilization (July), Newfoundland, 1978

	Groundfish	Other species	Percentage of peak utilization
January	6,269	964	26
February	10,501	85	41
March	8,059	703	32
April	8,037	3,803	45
May	13,297	4,612	60
June	22,057	4,264	89
July	26,153	3,582	100
August	23,328	7,891	98
September	12,636	14,825	96
October	11,417	7,865	61
November	8,796	1,211	31
December	5,434	170	19

Source: Fisheries and Oceans Canada, unpublished data

Table 12

Landings by Weight (metric tons) and as Percentage of Peak Period Landings, by Month, for Groundfish and Total Seafish, Newfoundland, 1978

	Groundfish		All seafish	
	Weight	Percentage of peak period	Weight	Percentage of peak period
January	8,610	17	10,032	18
February	12,830	26	13,248	24
March	12,188	25	12,652	24
April	12,881	26	23,096	41
May	19,480	39	27,515	49
June	22,010	45	30,800	55
July	49,273	100	55,637	100
August	43,673	89	55,238	99
September	16,819	34	31,691	57
October	19,950	40	36,266	65
November	20,367	42	29,025	52
December	10,134	21	10,916	29

Source: Statistics Canada, Monthly Review of Canadian Fisheries Statistics, (Cat. No. 24-002), Jan.-Dec. 1978, Table 1.

much of the peak landings in July and August are being diverted into other channels, e.g., salt cod. Thus, it may not be unreasonable to assume that the fresh frozen industry is operating close to full capacity in this peak period, and so the percent-of-peak-utilization data in Table 11 can be regarded as a rough indicator of the seasonal variation in capacity utilization. If so, the figures in Table 11 imply that the fresh frozen sector was operating at an average 75 percent of capacity through 1978 as a result of this seasonal fluctuation in utilization. Unless the inshore plants are provided with some means of extending their operating season,* this degree of capacity under-utilization would appear to be inevitable as long as one maintains the present balance between the inshore and offshore fisheries.

A description of the industry would be incomplete without an examination of government involvement therein. Under the Fish Inspection Act, all fish processors in the province must annually obtain a processor's license from the provincial government. While initially licenses were granted subject only to satisfaction of inspection regulations, more recently it must be demonstrated that "any proposed fish processing establishment would not have any significant negative impact on existing facilities in any given community or region".** In other words, the industry is at present a restricted-entry industry.***

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*This is the rationale underlying the planned Primary Landing and Distribution Centre at Harbour Grace, where trawlers would land their catch in the winter months to be trucked to inshore plants now operating on a seasonal basis. See Government of Newfoundland and Labrador (1978a) and (1978c).

**<u>Setting a Course</u>, p. 213. This policy is justified on the basis of efficient capital utilization and minimization of government financial support. We are uncertain to what extent these restrictions are binding in actual practice. Our data indicate that 28 additional licenses were issued in 1977, and 52 in 1978.

***The recent attempt by the Premier of Newfoundland to influence the <u>harvesting</u> policies of the National Sea-Nickerson trawlers through the threat of removal of their <u>processing</u> licenses, adds a new dimension to this authority. (Government press release, December 4, 1979).

The federal government's regulatory involvement in the industry is confined to the enforcement of export regulations once the final product has been processed and prepared for export. However, the province has delegated administration of its Fish Inspection Act to the Federal government to avoid duplication of inspection costs.*

In addition, both levels of government have maintained substantial financial involvement in the industry (Table 13). Up to the late 1960's, the major source of financing for new plant construction was the provincial government's Fisheries Development Authority. In the 1970's, this was supplanted by federal activity through DREE's Regional Development Incentive Act (RDIA) program, and through the jointly-financed Newfoundland and Labrador Development Corporation (NLDC). A provincial role remains in NLDC, the Rural Development Authority (RDA) loan program, and the ARDA III Industrial Incentives grants; these last two programs have been a major source of funding for the smaller plants.**

In addition, groundfish freezer plants received substantial production subsidies from the federal government in 1975-77. Initially set at a level of 15 cents per pound, this figure was later reduced to 8 and finally to 6 cents a pound.

In addition to these loan and grant programs, both levels of government have been involved in the actual operation of fish plants (Table 13). In 1955 the

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*<u>Setting a Course</u>, p. 212.

**<u>Setting a Course</u>, pp. 760-61.

Table 13

Federal and Provincial Government Support, Newfoundland Fish Products Industry, 1950-78 (partial list)

Description	Time Period	Federal Expenditure	Provincial Expenditure
Grants and support expenditure			
Valleyfield fish processing plant [a]	1955/56 - 1960/61	$1,084,228	
Community fish handling facilities [a]	1955/56 - 1968/69	4,545,658	
Operating costs: LaScie plant [b]	1962/63 - 1977/78		$1,762,065
Fish Plant Water Systems [a]	1965/66 - 1969/70	7,312,410	524,635
Community fish holding facilities: operating costs [b]	1967/68 - 1974/75		208,263
Fish plants: care and maintenance [b]	1970/71 - 1973/74		99,328
DREE: RDIA Offers [c]	1970/71 - 1978/79	16,637,448	
ARDA III - Industrial Incentives Grants [d]	1974/75 - 1977/78		289,000
Fish handling facilities - capital expenditure (73 facilities constructed) [b]	1974/75 - 1977/78		5,744,292
DREE: Fish Plant Water Systems [e]	1974/75 - 1977/78	5,517,000	613,000

Table 13 (Continued)

Description	Time Period	Federal Expenditure	Provincial Expenditure
Product and Market Development [b]	1974/75 - 1977/78		499,677
Special assistance to community projects [b]	1975/76 - 1977/78		806,695
Canadian Saltfish Corporation [b]	1975/76 - 1977/78		$ 443,659
Frozen groundfish subsidy [f]	1974/75 - 1976/77	$16,020,990	
Fresh fillet subsidy [f]	1974/75 - 1976/77	133,175	
Labrador Services [d]	1976/77 - 1977/78		1,572,649
La Scie plant: capital expenditure [b]	1977/78		232,360
Loans and equity investment			
Fisheries Development Authority: net loans to processing industry [a]	1950/51 - 1968/69		34,247,000
Net direct capital investment in processing plants [a]	1954/55 - 1968/69		11,174,000
Rural Development Authority Loans [d]	1972/73 - 1976/77		482,000
Burgeo fish plant - loans and equity [d]	1975/76 - 1977/78		6,235,000
Newfoundland & Labrador Development Corporation loans and equity [g]	1975/76 - 1978/79		8,922,300

Table 13 (Continued)

Sources: a) Copes (1973), Tables 36-39

b) Province of Newfoundland and Labrador, Public Accounts, various years

c) Regional Economic Expansion, St. John's

d) Setting & Course, Appendix IX

e) Regional Economic Expansion, Annual Report, 1977-78

f) Fisheries and Oceans Canada, St. John's

g) Newfoundland and Labrador Development Corporation, Annual Report, various issues federal government established an experimental saltfish processing facility at Valleyfield. The provincial government ran a plant in LaScie for 15 years, beginning in 1962, during which it poured in over $2 million before selling it to National Sea Products for $450,000.* The Burgeo plant has cost over $6 million in capital investment. The Northern Labrador Services Division manages three small inshore freezer plants in Labrador.

As was mentioned above, the feeder facilities providing fillets to the freezer and salt dryer plants typically operate from structures owned by the provincial government and leased to private operations. As of 1978, 73 such structures had been constructed** at a total capital cost of $5.7 million (Table 13). The rental charges are insufficient to cover even current costs, let alone capital cost. In 1977/78, the Department of Fisheries incurred $150,000 in maintenance and operating expense on these facilities, and recovered only $25,000 in leasing charges, an average $342 per establishment.***

There are as well various expenditures on hard (e.g., water systems) and soft (e.g., product and market development) infrastructure which have been made by both levels of government. These have at times reached substantial levels (Table 13).

It was our original intention to develop an internally consistent time series of these subsidies to the industry. We have been unable to do so, for

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*Setting a Course, p. 757.

**Setting a Course, p. 756.

***Setting a Course, p. 757.

various reasons, although it remains an item high on our list of priorities. However, some of the fruits of our labour are presented in Table 13, where the various programs of government financial support which we have been able to track down are detailed. For each program we provide the amount of federal and provincial expenditure under that program, and the time period over which that expenditure took place. Further expenditures may have been incurred outside that time period, but we have no record of it.

While we draw a distinction between grants and support expenditure, where there is no promise of future return, and loans and equity investment, where there is, this distinction is not a hard and fast one. For some expenditures in the former category, there may be offsetting revenues which we have not been able to isolate. For some programs in the latter category, such as the F.D.A. loans, there has been a substantial rate of default.* In addition, some of the funds ascribed to the provincial government are in reality federal funds "flowing through" the provincial Treasury; we have tried to avoid double-counting when this happens.

We present these statistics only as suggestive of the level of government financial support of the processing sector. Needless to say, we make no claim to completeness. For what it is worth, since 1950 these programs involved an outlay of $120 million, of which half is provincial government

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*Copes (1973), p. 49.

investment in loans and equity. To give this figure some perspective, the industry accounted for $550 million in value added over the period 1958-77*, and for $105 million in gross fixed capital formation over 1955-78.

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*Statistics Canada, Fish Products Industry, various issues.

2. The theory of cost and production

The primary objective of the research on which the main body of this paper is based, is the specification of the production technology of the fish products industry in Newfoundland and Labrador. A knowledge of this technology would enable us to make inferences regarding such matters as the effect of increased energy prices, the repercussions of additional investment incentives, and the feasibility of increased yield through reduced throughput, as suggested in Setting a Course.*

To achieve this purpose, the factor inputs must be specified in some detail, so that the energy and materials inputs are isolated and capital input separated into plant and equipment components. At the same time, it is desirable to place as few *a priori* restrictions as possible on the relationships between these productive inputs, since little is known about the characteristics of these relationships.

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*Setting a Course, p. 347.

**A time trend in the production function would add several additional parameters.

One way in which this can be achieved is through the estimation of a flexible form production function such as the Translog or the generalized quadratic.* An alternative is to make use of the duality relationship explored by Shephard (1953) and Uzawa (1962) to estimate the production parameters indirectly through specification of the cost function. Under certain regularity conditions, the parameters of the production function can be inferred from those of the cost function, and vice versa.** The choice between the two approaches then becomes a matter of convenience.

Estimation of the cost function is facilitated through the use of Shephard's Lemma, which states that for any differentiable cost function $C = C(X,W)$, where C = costs, X = output, and W = a vector of factor prices, which meets weak regularity conditions,

$$\frac{\partial C}{\partial W_i} = F_i \qquad \text{all } i \qquad (1)$$

where F_i is the cost-minimizing input of factor i.***

Shephard's Lemma thus gives us a system of five equations, one for each factor, to estimate the parameters of the cost function. This enormously enhances the degrees of freedom available to estimate the parameters of the cost function, and so of the production function as well.

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* See Fuss et. al. 1978.

** For comprehensive expositions, the reader is referred to McFadden (1978) and Diewert (1974).

*** See McFadden (1978) and Diewert (1974). Shephard's Lemma is based on a maintained hypothesis of cost minimization subject to parametric factor prices. However, in the light of the discussion above (p. 10) on the organization of the market for landed fish, it seems probable that the materials price is not parametric in this industry. Thus, our parameter estimates will reflect (to an unknown extent) the effect of this market imperfection as well as the technological factors in which we are primarily interested.

The functional form which we estimate is an extension of the Generalized Leontief form proposed by Diewert (1971);

$$C = [\sum_{i=1}^{N} \sum_{j=1}^{N} \beta_{ij} \sqrt{W_i W_j}\,] X , \qquad \beta_{ij} \equiv \beta_{ji} \tag{2}$$

Diewert shows that this cost function provides a second-order approximation to any linear-homogeneous cost function. That is to say, for any linear-homogeneous cost function, there is a Generalized Leontief form with exactly the same first- and second-order derivatives at a particular point. At or around this point, then, the Generalized Leontief form will identify (at least approximately) all the first- and second-order derivatives of the cost function (and therefore of the production function).*

This functional form has two limitations for our purposes. First, it is linear-homogeneous in output, which implies constant returns to scale. Second, it assumes an unchanging technology, which is inappropriate in time series analysis. We therefore follow Parks (1971) and Woodland (1975) in generalizing Diewert's equation to the following form:

$$C = [\sum_{i=1}^{N} \sum_{j=1}^{N} \beta_{ij} \sqrt{W_i W_j} + \sum_{i=1}^{N} \beta_{ix} W_i X + \sum_{i=1} \beta_{it} W_i t] X , \qquad \beta_{ij} \equiv \beta_{ji} \tag{3}$$

The hypotheses of constant returns to scale, and of the absence of technological change, can then be subjected to the tests of $\beta_{ix} = 0$, all i, and $\beta_{it} = 0$, all i, respectively.

Application of Shephard's Lemma then gives the following system:

$$F_i = \frac{\partial C}{\partial W_i} \equiv [\sum_{j=1}^{N} \beta_{ij} \sqrt{\frac{W_j}{W_i}} + \beta_{ix} X + \beta_{it} t\,] X , \quad i=1,\ldots,N \tag{4}$$

It is this sytem which we shall estimate.

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*A discussion of the properties of this and other forms of the production function is contained in Fuss et al. (1978).

3. Data Sources

Our primary data source is Statistics Canada's Census of Manufactures, from which we obtained, for the period 1961-1977,* series on man-hours paid, value of fuel and electricity purchased, value of materials purchased, and value of output,** all with respect to the manufacturing activities of establishments in the Newfoundland fish product industry. Non-manufacturing activity, such as retail fish sales and labour engaged in administrative tasks, is excluded from these statistics. In addition, unpublished "experimental data" on the constant-dollar value of mid-year gross capital stock, divided into construction and machinery and equipment, were kindly made available by the Construction Division of Statistics Canada.*** All these series were normalized on a per-establishment basis, with the number of establishments also obtained from the Census of Manufactures.

Our dependence on the census data imposes some limitations on the range of questions to which we can address ourselves. For example, the fact that census covers an annual period makes it impossible for us to analyze the seasonal pattern of production which is such an important characteristic of the industry and which dominates policy discussions regarding optimal use of the industry's capacity.**** We are unable to estimate the extent to which seasonality has affected factor demands and costs.

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* A redefinition of manufacturing activity in 1961 renders earlier data from this source non-comparable with that from this period.

** The last series was computed as the sum of the value of fuel and electricity, value of materials, and value added.

*** A description of the method by which these series were obtained is found in Koumanakos (1979).

**** E.g., Munro (1980), pp. 32-35; Government of Newfoundland and Labrador (1978c), p. 16.

In addition, while the level of aggregation to which our study applies is substantially lower than it is in most studies of this type,* the Newfoundland fish products industry still contains a number of different product-types and species, processed through a number of different preservation techniques (Tables 1-3). Changes in the relative importance of these components may make some of our findings ambiguous in their interpretation. For example, the frozen product has become relatively more important over our sample period (Table 2). In addition, freezing establishments are almost certainly of larger than average size relative to other types of establishments in the industry. A finding that the industry is subject to increasing returns to scale may then be consistent with productivity differences between freezing and other establishments that are unrelated to the scale of these establishments. Unfortunately, there is no way of disentangling these effects in a time series context.

Price data is needed both to fit equation (4) and to deflate the output, energy and materials series. The output deflator is derived from data, reported in Statistics Canada's Fisheries Statistics - Newfoundland, on the quantity and value of fish products by type of product. For each product, an implicit price is calculated, and the prices of all fish products are combined into a "superlative" price index** of fish products. The price index for materials is computed in the same fashion, using data on the quantity and

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*Usually, functions for the entire manufacturing sector of a national economy are estimated. Parks (1971) for Sweden, and Woodland (1975) for Canada, are typical.

**See Diewert (1976) for an exposition of the characteristics of "superlative" indexes.

value of landings by species from Fisheries Statistics - Newfoundland. The price of other material inputs (primarily packing materials) is not incorporated into the index.*

Because no comprehensive data are available on the price of energy sources in the province, we are forced to use national prices derived from data on the quantity and value of various energy sources used by the fish products industry, which are used to compute implicit prices which are in turn combined in a superlative index. Unfortunately, we have reason to believe that this national deflator is not strictly appropriate to Newfoundland, at least with respect to electric power, for which there is fragmentary local evidence.** We suspect that there is less divergence with respect to fuel prices, but we have no hard evidence on the matter.

In addition, a wage rate is derived by dividing the value of wages paid by the number of man-hours, both series obtained from the Census of Manufactures. Finally, a user cost of capital measure, similar to that used by Hall and Jorgenson (1967) is computed for both plant and equipment. This series incorporates the effects of interest rates, depreciation, capital gains, corporate tax rates, capital cost and interest payment tax writeoffs, and investment tax credits. Data limitations preclude including the effects of capital subsidies given the industry outside of the corporation taxation system.***

Detailed information on the construction of these data series is presented in the Data Appendix.

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*These account for only twenty percent of materials costs in this industry, over Canada as a whole. The proportion is probably still smaller in Newfoundland, which does not make heavy use of expensive canning processes.

**See Data Appendix, p. 51 below.

***See above, p.13-16.

4. Some preliminary remarks

While it is not the purpose of this paper to present an exhaustive analysis of these data series, certain implications are sufficiently striking to be worth noting here.

First, as Table 14 indicates, the sometimes heavily subsidized fish products industry is remarkably profitable; in fact there is no year, not even the so-called "crisis" years of 1975-76, in which the industry did not earn revenues from its manufacturing activity in excess of the costs, both current and capital, of performing this activity. By costs we mean the value of labour, energy, and material inputs into manufacturing activity, plus the value of capital services used by the industry evaluated at user cost. This result is all the more striking in that these "excess" or economic profits*do not include the value of any subsidies received by the industry over this time period.

This finding of consistent profitability may well be a result of the alleged undervaluation of trawler catches referred to above.** If the "true" shadow price of materials were about twenty percent higher than that reported in the Census of Manufactures, the industry would have been in a break-even position (on average) throughout this period. However, since only about one-third of landings (by value) are caught by offshore trawlers, the true value of the offshore trawler catch would have to be sixty percent higher than that reported to Census in order to obtain this break-even position.

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*This measure is a function of the value of input and output, and so does not depend on our price deflators. It does depend on the accuracy of our quantity and cost of capital series. However, capital's share of costs averaged 6.2% over the period, so even major measurement error here would not change the picture very much.

**See above, pp. 8-9.

Table 14

Economic Profit on Manufacturing Activity, Exclusive of Subsidies, as a Proportion of Value of Output, Newfoundland Fish Products Industry, 1961-77

1961	.149
1962	.165
1963	.123
1964	.170
1965	.210
1966	.149
1967	.246
1968	.230
1969	.162
1970	.159
1971	.185
1972	.203
1973	.240
1974	.141
1975	.050
1976	.065
1977	.147

Source: derived from Statistics Canada data. Profit is defined as value added, less wages paid, less the value of capital services. These latter are evaluated using the user cost of capital series explained in the Data Appendix below (p.53 ff).

Since we have no further evidence to report on the matter, the reader is invited to draw his own conclusions.

A comparison of our findings with those of the Royal Commission to Inquire into the Inshore Fishery of Newfoundland and Labrador would be in order here. The Royal Commission surveyed the financial records of twelve inshore plants, and concluded that in 1979 a net return was received on eight of twelve species listed.*

Our calculations indicate that this resulted, on balance, in a positive net return equal to about 2.5 percent of the net selling value of these twelve species. However, projecting into 1980, the Commission concluded that the 1979 landed prices would have resulted in losses on eight of these species and in an overall financial loss to the plants.**

Unfortunately, the Commission's data are all presented as "bottom-line" net returns on each species; the Report contains no breakdown of cost by category, which would enable us to directly reconcile our methods with theirs. Nevertheless, it does appear that the figures compiled by the Royal Commission are not directly comparable to those reported in Table 14.

The main differences, as we perceive them, are as follows. First, our treatment of capital costs is radically different from that of the Royal Commission. The latter appears to be based mainly on depreciation records and overhead costs.*** This differs from our measurement insofar as it

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*Report, p. 23. Some species, the most important of which appears to be shrimp, were excluded from presentation on grounds of confidentiality.

**Report, pp. 24-26.

***Report, pp. 3-5, 48-50.

ignores the gains received from accelerated depreciation and investment tax credits, and capital gains accruing on existing capital stock. As well, insofar as the depreciation records are based on capital cost allowance schedules, they probably imply too rapid a writeoff of capital costs. On the other hand, the Commission data do not include an estimate of the opportunity cost of the equity invested in the plant. Therefore, it is unclear on *a priori* grounds whether the Royal Commission's allowance for capital cost is an overestimate or underestimate of the user cost of capital.

Second, data limitations precluded our allowing for subsidies to the industry, and also did not permit us to incorporate various overhead charges such as insurance premiums and municipal taxes into our cost calculations. The Royal Commission, on the other hand, did include these factors in their cost estimates. Here, as well, it is difficult, without access to the Commission's worksheets, to be certain about the net effect of these omissions.

Third, our cost figures apply strictly to the manufacturing operations of the industry, and exclude any administrative activity not directly associated with manufacturing. The Royal Commission, on the other hand, made some allocation of administrative and head-office costs to production costs. An examination of Statistics Canada data, however, seems to indicate that this consideration is not a major one.*

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*In 1977, for example, non-manufacturing costs were almost totally offset by non-manufacturing revenues. Additional non-manufacturing wages and salaries accounted for an extra $7 million, as compared with $211 million in shipments.

Fourth, and most important, the Royal Commission's data are based on a sample of inshore plants; any offshore catch is netted out of its calculations. Our study, on the other hand, relates to the entire industry. Therefore, notwithstanding any definitional difference between the two studies, their results are mutually compatible insofar as processing costs in offshore operations are significantly lower than they are in inshore operations.

While any undervaluation in the trawler catch could lead to this result, two additional factors might account for this cost difference. First, as noted above, all integrated operations are year-round, whereas most inshore plants are seasonal, operating six or seven months in the year. This reduces substantially the degree of capacity utilization in the inshore plants, and raises unit capital costs there. Munro (1980) suggests that this degree of seasonality can raise unit output costs as much as 30 percent.* As well, when inshore fish are landed, this usually occurs under glut conditions, when the plant must be operated beyond capacity. This further raises unit costs.

It is also often claimed that the inshore catch contains a higher proportion of small and soft cod. These are more difficult to handle, thereby raising processing costs. Munro's calculations suggest that costs of processing the latter are 40 percent higher than the costs of processing large firm cod. In addition, the latter permit a higher rate of fillet recovery, and can often be sold at a higher unit price, further raising profitability.**

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*Munro (1980), p. 32.

**Munro (1980), p. 34.

In order to obtain a perspective on the rate and pattern of productivity change in the industry, we computed a superlative quantity index of factor inputs* and divided this into our output quantity index in order to obtain an index of total factor productivity. Such an index provides an indicator of the output which is produced by an "equivalent bundle" of factor inputs, in which the productive service of these inputs are evaluated at the value of their marginal products, as reflected in the price of these inputs.** The results are reported in Table 15 and Chart 1. The index proves to be highly volatile, perhaps reflecting to some extent changes in capital utilization over the period.*** There is a positive trend in the series but it is small. Indeed our regression results imply that even this minor increase is due more to the exploitation of economies of scale than to technological change.**** There seems to be no evidence of substantial technological progress in the industry during this period.*****

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*The superlative index used was that appropriate to the Generalized Leontief aggregator function. See Diewert (1976).

**See May and Denny (1979) for an example of the use of this concept. The validity of this procedure requires Hicks-neutral technical change, which is strongly rejected by our statistical tests. We nonetheless believe the picture presented in this index to be broadly accurate.

***At the same time, with capital's share averaging 6.2% of costs in the period, it seems unlikely that even major changes in capital utilization could account for all of the variation in this index.

****See below, p.34-35.

*****Cf. the analysis of technology diffusion contained in Briffett (1979).

Table 15

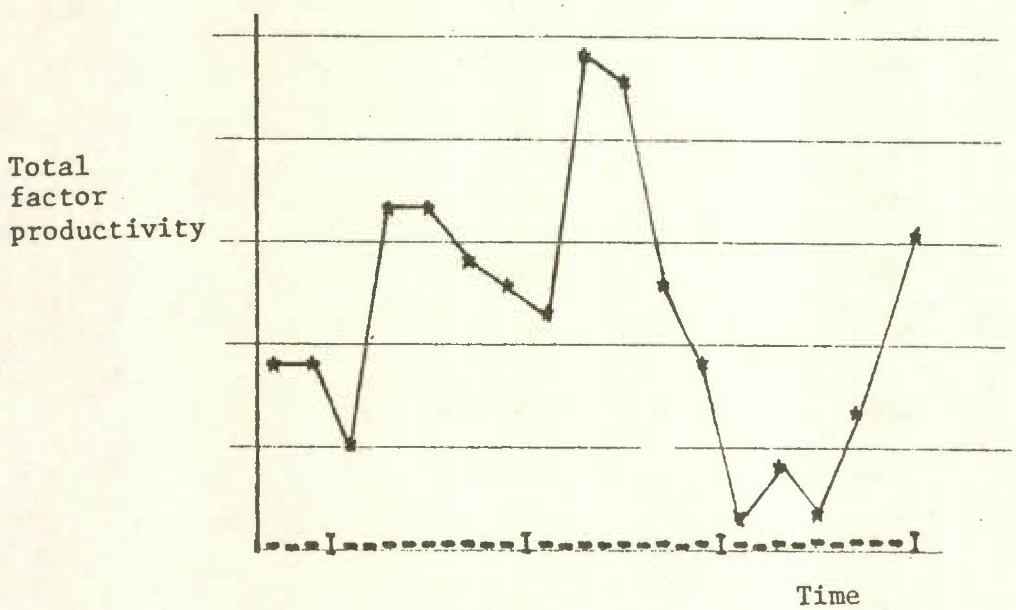
Index of Total Factor Productivity in Manufacturing Activity, Newfoundland Fish Products Industry, 1961-77 (1977 = 100).

1961	91.2
1962	90.7
1963	87.3
1964	98.6
1965	98.2
1966	96.0
1967	94.7
1968	92.9
1969	106.3
1970	104.4
1971	98.1
1972	90.2
1973	82.7
1974	86.4
1975	83.2
1976	88.5
1977	100.0

Source: derived from Statistics Canada data. Total factor productivity is defined as the quotient of a quantity index of output and a quantity index of factor inputs for the industry.

Chart 1

Total Factor Productivity in Manufacturing Activity, Newfoundland Fish Products Industry, 1961-1977.



Source: Table 15

Table 16 presents annual rates of growth in total factor productivity over various periods of time.*

Table 16

Average Annual Rates of Growth, Total Factor Productivity, Newfoundland Fish Products Industry, Various Periods

1961-77	0.5%
1961-69	1.9%
1969-77	-0.8%
1973-77	4.9%

Source: Table 15

*In contrast, May and Denny (1979) estimate annual rate of growth, for the Canadian manufacturing sector, of 0.9% in 1949-76, and 1.08% in 1961-71, but only 0.4% in 1971-76.

5. Empirical results

To each equation in the system (4), we add an error term ε_i reflecting optimization errors by firms in the industry. It seems reasonable to assume that the variance of this error term is proportional to X^2, since increased output is likely to be associated with larger errors. Thus, we divide both sides of (4) by X for purposes of estimation.

Since the ε_i reflect optimization errors, it is likely that they are contemporaneously correlated. Thus, joint estimation of the system (4) is in general more efficient (at least asymptotically) than single-equation estimation.

In addition, output as well as inputs F_i are clearly endogenously determined in the system of which (4) forms a part. Since the supply of materials to the industry is not likely to be perfectly elastic, the price of materials W_m is also specified as endogenous. While an argument can be made that the wage rate W_L is probably exogenous to the industry*, establishments might possess some monopsony power on local labour markets if these are sufficiently isolated and segmented. Thus, we specify the wage rate as endogenous as well.

The prices of energy and of both types of capital, on the other hand, are specified as exogenous. Additional exogenous variables which are assumed to affect the system (4) are the price of output, which influences the industry through the supply function of output; average hourly earnings in the Newfoundland manufacturing sector, which acts on the industry through the

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*The industry employed only 3.6% of the provincial labour force in 1971. In addition, general factor-price equalization considerations (see Copithorne (1977)) suggest that the wage rate in a price-taking manufacturing industry is exogenous.

supply function of labour to the industry; and offshore groundfish catch per day fished, intended as a very rough indicator of fish stocks, the size of which affect the industry through the supply function of material inputs.* While we do not attempt to estimate these additional functions, we incorporate the exogenous variables as instrumental variables in the equations which we do estimate.

The system (4) was estimated by Iterative Three Stage Least Squares (I3SLS), which is asymptotically equivalent to (but not identical to) maximum-likelihood estimation.** The iterations were subject to the symmetry restriction $\beta_{ij} \equiv \beta_{ji}$, i, j = L, E, M, K_c, K_m.*** The parameter estimates, with associated asymptotic standard errors, are reported in Table 17.

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*This is basically a measure of catch-per-unit-effort, which is universally used by biologists (e.g., Schaefer (1957)) as an index of fish population size. Tsoa et al.(1980) provide evidence that this is a very rough indicator indeed, at least for the Newfoundland offshore groundfishery.

**See Dhyrmes (1973).

***This restriction was subjected to statistical testing, and an F value of 6.99 was obtained on the null hypothesis that the symmetry conditions were satisfied. At 10 and 50 degrees of freedom, this would lead to rejection of the null hypothesis. Possible explanations for this result are (1) the Generalized Leontief is only an approximation to the true functional form, (2) the price variables are measured with error, and (3) the competitive assumption fails to hold for some factors. Despite this result, we maintain these restrictions, since otherwise the parameters have no straightforward economic interpretation.

Table 17

I3SLS Estimates of the Parameters β_{ij} in Equation System (4), With Asymptotic Standard Errors in Parentheses, and Coefficient of determination for Each Equation

j \ i	L	E	M	K_c	K_m
L	0.32295 (2.0372)	0.25258 (0.13004)	1.6114 (0.30432)	-4.0760 (1.5802)	5.2020 (1.3918)
E	0.25258 (0.13004)	0.025625 (0.026202)	$-0.51097\text{x}10^{-2}$ $(0.21878\text{x}10^{-1})$	-0.044236 (0.10889)	-0.40626 (0.08422)
M	1.6114 (0.30432)	$-0.51097\text{x}10^{-2}$ $(0.21878\text{x}10^{-1})$	0.29056 (0.06015)	0.69142 (0.27444)	-0.33973 (0.24178)
K_c	-4.0760 (1.5802)	0.044236 (0.10889)	0.69142 (0.27444)	40.139 (4.6242)	-0.37950 (1.0757)
K_m	5.2020 (1.3918)	-0.40626 (0.082422)	-0.33973 (0.24178)	-0.37950 (1.0757)	45.726 (4.6483)
X	$-0.89600\text{x}10^{-4}$ $(0.30771\text{x}10^{-4})$	$-0.66747\text{x}10^{-6}$ $(0.33746\text{x}10^{-6})$	$-0.39652\text{x}10^{-5}$ $(0.10761\text{x}10^{-5})$	$-0.40748\text{x}10^{-3}$ $(0.12753\text{x}10^{-3})$	$-0.73091\text{x}10^{-3}$ $(0.12638\text{x}10^{-3})$
t	0.22589 (0.05022)	$0.55540\text{x}10^{-3}$ $(0.64479\text{x}10^{-3})$	$-0.74690\text{x}10^{-2}$ $(0.15152\text{x}10^{-2})$	1.4189 (0.18805)	1.0888 (4.6483)
R^2	0.5483	0.7732	0.7919	0.8449	0.9401

Symbols:

- L = labour input, in man-hours
- E = energy input, in hundreds of 1977 dollars
- M = materials input, in hundreds of 1977 dollars
- K_c = construction capital, in 1971 dollars
- K_m = machinery and equipment, in 1971 dollars
- X = output, in hundreds of 1977 dollars
- t = year - 1977

In interpreting these results, the reader should keep in mind that, because of our limited sample, we have not attempted to model any lagged adjustment process in the industry.* This means that the adjustments which we pick up are short-run responses only. It is possible (and indeed likely) that further adjustments to factor inputs take place over a longer period of time, particularly with capital.

We present R^2's for each of the equations as descriptive statistics. We do not present Durbin-Watson statistics, because it is not at all clear how they should be interpreted when the residuals are obtained from simultaneous system estimation, particularly when cross-equation constraints are imposed. However, there is a fair degree of evidence of autocorrelation in most of the equations. Indeed, particularly in the two capital equations, the process appears to be considerably more complex than first-order autoregressive.** Because of this, and because of our small sample size, we make no correction for autocorrelation. This does not affect the consistency of our results, but it does imply that our estimated standard errors and t- and F- values should not be taken too literally. For this and other reasons,*** we shall avoid making categorical statements about the statistical significance of our estimates.

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*An example of such a dynamic model, utilizing a flexible functional form, can be found in Berndt, Fuss, and Waverman (1979).

**When a first-order autoregressive process is estimated, and the equations transformed to eliminate this process, there remains substantial autocorrelation in the transformed residuals.

***The other reasons are: (1) these statistical tests are strictly asymptotic tests, and their validity in small samples is unclear (Zellner and Theil (1962)); (2) while a t- or an F- test applies strictly only to normally distributed random variables, in at least two of our equations, the distribution of the residuals diverges substantially from the normal; (3) it is not clear how many degrees of freedom apply in a system estimation with cross-equation constraints.

The parameter values which we obtain in the estimation process can be used to derive the Allen-Uzawa partial elasticities of substitution between all pairs of factors. Uzawa (1962) showed that these elasticities can be derived from the cost function through the relationship

$$\sigma_{ij} = \frac{CC''_{ij}}{C'_i C'_j} \qquad i,j = L, E, M, K_c, K_m \qquad (5)$$

where C is defined in (3), C'_i is defined in (4), and

$$C''_{ij} = \frac{1}{2} \frac{\beta_{ij} X}{\sqrt{W_i W_j}} \quad , \quad i \neq j$$

$$= -\frac{1}{2} \sum_{k \neq i} \frac{\beta_{ik} X}{W_i \sqrt{W_i W_k}} \quad , \quad i = j \qquad (6)$$

The implied value of the elasticity of substitution at each sample point, then depends on the values of X and the W_i at that point. Unfortunately, for some of these estimates there is a fair degree of variation over the sample.* We do not regard this variation as particularly meaningful; instead, it is probably additional evidence that the β_{ij} parameters are not really constant over the sample, and that the Generalized Leontief form is at best an approximation to the true functional form.

The average values of these elasticities over the sample are presented in Table 18. These values are conditional on those of the exogenous variables in the model. The approximate t-values are contained in parentheses.**

These estimates imply a fair degree of substitutability among factors of production.*** In particular, substantial substitutability is indicated between labour and materials, and between labour and machinery, as reflected in large positive substitution elasticities between these pairs of factors. There is also some suggestion of substitutability between labour and energy and between materials and construction, although the statistical significance

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*Most of the estimates had a standard deviation over the sample of between two and three times its mean value.

**Substitution of (3), (4), and (6) into (5) indicates that the σ_{ij} are non-linear functions of the β_{ij} parameters, so that standard errors cannot readily be computed. However, a standard error can be derived for estimates of σ_{ij} which are conditional on all the variables on the model, including the endogenous variables. The t-values which we present are those based on these estimates, and are intended as approximations to those relevant to the estimates which we present. This is the procedure adopted by Parks (1971) and Woodland (1975).

***A test of the null hypothesis that all the cross-elasticities were zero produced a value of F equal to 13.264, which at 10 and 60 degrees of freedom leads to rejection of the null hypothesis.

Table 18

Estimates of Allen-Uzawa Partial Elasticities of Substitutions, Newfoundland Fish Products Industry Sample Averages, 1961-71, with Approximate t-values in Parentheses

	L	E	M	K_c	K_m
L	-3.2102 (-5.243)				
E	3.4139 (1.9424)	-14.349 (-2.102)			
M	1.0548 (5.2951)	-0.14667 (-0.23356)	-0.44729 (-5.259)		
K_c	-3.2773 (-2.5794)	1.5366 (0.40623)	1.1746 (2.5194)	2.0594 (1.211)	
K_m	2.3491 (3.7376)	-7.9138 (-4.9291)	-0.32382 (-1.4051)	-0.46655 (-0.35279	-3.4153 (-5.219)

Note: Since the matrix of elasticities is symmetric, only the lower triangular portion is presented here.

Source: Derived from parameter estimated in Table 17. Symbols are defined in Table 17.

of these estimates is marginal.

On the other hand, a strong complementarity relationship is indicated in the large negative substitution elasticity between energy and machinery. As well, there is some complementarity indicated between labour and construction, but the statistical significance of the estimate is marginal. The other cross-elasticities do not appear to be significant.

The "own-elasticities" of substitution σ_{ii} are required to be negative in a well-behaved production function. This is not the case with construction, but the positive value is not statistically significant.*

From these substitution elasticities can be derived the own- and cross-price elasticities of demand for each factor of production. These are related by the identity

$$E_{ij} = \frac{\partial \ell n F_i}{\partial \ell n W_j} = M_j \sigma_{ij} \qquad i,j = L, E, M, K_c, K_m \qquad (7)$$

where $M_j \equiv W_j F_j / \Sigma_i W_i F_i$ is the share of factor j in total costs. By Shephard's Lemma, M_j is also the elasticity of the cost function with respect to a change in W_j. The mean values of these elasticities are presented in Table 19. Approximate t-values are included in parentheses.**

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*Unfortunately, the estimated cost function loses concavity as a result; the high negative value of σ_{E,K_m} also induces non-concavity, although this appears to be a problem only in the early period, as after 1970 this elasticity settles down to a more reasonable -4.8 on average. Since there appears to be no statistical procedure available to test for concavity, it is difficult to ascertain how serious this is. Certainly, if the Generalized Leontief form is only an approximation to the true (concave) cost function, concavity is not a foregone conclusion; see Wales (1977) for some interesting simulation results. Nonetheless, the high negative values for σ_{E,K_m} and σ_{L,K_c} should perhaps be treated with some scepticism.

**As with the substitution elasticities, the estimated elasticities are conditional only on the exogenous variables, while the t-values are based on estimates conditional on the endogenous variables as well.

Table 19

Estimates of the Elasticity of Demand for Factor i, with Respect to a Change in the Price of Factor j, and Factor Shares M_j, Newfoundland Fish Products Industry Sample Averages, 1961-77, with Approximate t-values in Parentheses

i \ j	L	E	M	K_c	K_m
L	-0.82107 (-5.243)	0.11227 (1.9424)	0.67342 (5.2951)	-0.059217 (-2.5794)	0.094594 (3.7376)
E	0.87374 (1.9424)	-0.46742 (-2.102)	-0.093718 (-0.23356)	0.028836 (0.40623)	-0.34143 (-4.9291)
M	0.27873 (5.2951)	-0.0048529 (-0.23356)	-0.28184 (-5.259)	0.021048 (2.5194)	-0.013087 (-1.4051)
K_c	-0.83576 (-2.5794)	0.051736 (0.40623)	0.75655 (2.5194)	0.044915 (1.211)	-0.017443 (-0.35279)
K_m	0.59967 (3.7376)	-0.26665 (-4.9291)	-0.20818 (-1.4051)	-0.0079325 (-0.33279)	-0.11690 (-5.219)
M_j	0.26675	0.035177	0.63648	0.019257	0.042338

Source: Derived from Table 18. Symbols are defined in Table 17.

While these elasticities apply only with output and other factor prices unchanged, they provide an indication of the first-round impact on factor inputs of a change in factor prices.

None of our estimated elasticities exceeds unity in absolute value. This is a rather striking result, although perhaps it is not surprising in view of our exclusion of output (and other) reactions and of the short-run nature of our analysis.

Nevertheless our results imply, for example, that an increased wage rate would lead to a significant reduction in employment, as machinery (and to a lesser extent, materials) are substituted for labour. A shift to smaller plants and greater energy use may also be indicated. This suggests that the ability of the Newfoundland Fishermen, Food, and Allied Workers Union (N.F.F.A.W.U.) to raise the wages of plant workers may be quite limited.

Increased energy prices have less of an impact on factor demands, mainly because of the small share of costs accounted for by energy inputs. Nevertheless, a modest reduction in energy use, and in machinery as well, is predicted to occur, along with a relatively minor increase in employment. Thus, a move to the world price of petroleum may well have favourable employment consequences in the industry.

A rise in the price of materials would result in some economizing in the use of these materials, as additional labour is substituted. Indeed, the employment impact of such a price increase would appear to be relatively substantial, since we obtain a labour cross-elasticity of 0.67. Thus, the N.F.F.A.W.U. may have a greater effect on the earnings of plant workers through the price of fish, than through the wage rate.

A change in the rental cost of construction capital has little effect on factor inputs, at least in the context of this short-run analysis. On the other hand, a reduction in the rental cost of machinery would cause some increase in the use of machinery, and an even greater increase in the use of energy, with some reduction in employment. This suggests that capital subsidies would have negative effects on both employment and energy conservation efforts in the industry.

Some policy implications of these results will be considered in a subsequent section.

We now consider the non-price terms reported in Table 17. Each of the output terms are negative, and most are significant. This result indicates the presence of increasing returns to scale in the industry. A joint test of the hypothesis that the output terms are zero produced a highly significant F-statistic of 32.314, which at 5 and 60 degrees of freedom indicates a decisive rejection of the hypothesis of constant returns to scale.

From these parameter values we derive estimates of the output-elasticities of demand for each factor of production, and thus of the cost function, through the relationships

$$E_{ix} = 1 - \frac{X^2}{F_i} \beta_{ix} \quad , \quad i = L, E, M, K_c, K_m$$

$$E_{cx} = 1 - X^2 \sum_j \frac{M_j}{F_j} \beta_{jx} \qquad (8)$$

where E_{ix} is the output-elasticity of demand for factor i, and E_{cx} is the output-elasticity of the cost function. The mean values of these estimates across the sample, along with approximate standard errors, are presented in Table 20. These estimates are conditional on the values of the exogenous variables.

These estimates imply considerable variation in the response of factor demands to changes in output. Indeed, the hypothesis that these output-elasticities are equal (homothetic technology) can be tested and the resultant

Table 20

Estimates of Output Elasticities of Demand for Factors of Production and of the Cost Function, Newfoundland Fish Products Industry, Sample Averages, 1961-77, with Approximate Standard Errors in Parentheses

E_{LX}	0.60657 (0.13512)
E_{EX}	0.26587 (0.37117)
E_{MX}	0.80096 (0.05413)
E_{K_cX}	0.17307 (0.25881)
E_{K_mX}	-0.06048 (0.16246)
E_{CX}	0.68152 (0.04990)

Source: derived from parameter estimates in Table 17. Symbols are defined in Table 17.

F-statistic has a value of 21.096, which, at 4 and 60 degrees of freedom seem to indicate rather decisive rejection of the null hypothesis.

Particularly low values are found in the two capital elasticities, neither of which is significantly different from zero. This is consistent with the existence of substantial excess capacity in the industry through our sample period. In all, these results suggest that significant cost savings can be obtained through increasing output per establishment. For example, a 20 percent increase in output is predicted to cause average costs to fall by 6½ percent.

Time trends are introduced into each equation in order to pick up the effects of technological change, although they could be reflecting any other time-systematic factor which is not otherwise incorporated into our model (e.g., aggregation bias, measurement error).* All time trends (except that in the energy equation) appear to be strongly significant. The hypothesis that all time coefficients are zero produces an F-value of 22.882, which at 5 and 60 degrees of freedom indicates rejection of the null hypothesis.

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*An attempt was made to extract the effect of technological change from the analysis by computing a superlative quantity index of factor inputs and using it in place of output on the left-hand side of the regressions. This procedure is valid only under the maintained hypothesis of Hicks-neutral technological change. However, the time trends remained significant in the regressions, and this result is consistent with the presence of non-neutral technological change. The use of the input index in the place of the output index did not materially alter the parameter estimates.

The results are consistent with a pattern of technological change which is on balance material-saving and labour- and capital-using. If this interpretation is correct, then the cost savings resulting from the reduced input of raw materials has been insufficient to offset the additional labour and capital costs required to implement the new technology. The average effect of this process on the average cost function, as measured by the relationship

$$\frac{\partial C/X}{\partial t} = \sum_i W_i \frac{\partial F_i/X}{\partial t} \qquad (9)$$

is a modest (and marginally significant) 0.23094 per annum (t-statistic = 2.948), which is 0.5 percent of the sample average of C/X. Thus, this process has had, on balance a modest increasing effect on costs. This suggests that the increase in total factor productivity over the sample noted above (Table 15) is due entirely to the economies of scale resulting from a higher output per establishment.

6. An alternative specification CES

Because flexible functional forms such as the Generalized Leontief are not parsimonious in the use of parameters, and because our sample size is extremely small, we attempted to estimate a simpler form of the production function, the CES form.* This differs from the Generalized Leontief form in that a constant elasticity of substitution is imposed on all pairs of factors. Thus, the production function is in the form

$$X = A \left[\sum_i (\delta_i e^{\lambda_i t} F_i)^{-\rho} \right]^{-s/\rho} \qquad (10)$$

where $\Sigma \delta_i \equiv 1$, λ_i is the rate of factor i-augmenting technical change, ρ is a parameter related to the elasticity of substitution, and the function is homogeneous of degree s.

A form which is linear in parameters can be obtained through the marginal productivity equations

$$\frac{\partial X}{\partial F_i} = \frac{W_i}{p} \qquad i = L, E, M, K_c, K_m \qquad (11)$$

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*See Fuss et al. (1978), esp. pp. 237-44.

where p is the price of output. Taking logs and rearranging gives us

$$\ell n\, F_i = \beta_{io} + \beta_x\, \ell nX - \beta_w\, \ell n\, (W_i/p) + \beta_{it}t \qquad (12)$$

$$i = L, E, M, K_c, K_m$$

where β_w is the elasticity of substitution and β_x is related to the scale parameter s through the expression

$$\beta_x \equiv \frac{1 + \rho/s}{1 + \rho} \qquad (13)$$

This system was estimated with I3SLS. First, the restriction that the coefficients of ℓnX and $\ell n\, W_i/p$ are the same in all equations, as required by the CES specification, was tested and rejected with the F-statistic equal to 10.399. If we nonetheless retain the CES specification as a maintained hypothesis, we obtain the results reported in Table 21. Asymptotic standard errors are presented in parentheses.

The elasticity of substitution, β_w, is extremely low at 0.14. The implied scale parameter s has value 0.618, which is also quite low; the hypothesis of constant returns to scale ($\beta_x = s = 1$) is strongly rejected. The time trends, on the other hand, seem too large to be reflecting a process of technological change.

It is our view then that the CES form is a serious misspecification of production relationships in this industry, and that an adequate specification requires a greater degree of flexibility, such as that obtained in the previous section.

Table 21

Parameter Estimates, C.E.S. Production Function, Newfoundland Fish Products Industry, with Symptotic Standard Errors in Parentheses

β_x	0.66954 (0.04814)
β_w	0.13567 (0.01823)
β_{Lt}	0.023142 (0.0038203)
β_{Et}	0.059796 (0.0063967)
β_{Mt}	-0.007505 (0.0025309)
$\beta_{K_c t}$	0.065015 (0.0066976)
$\beta_{K_m t}$	0.062424 (0.0046529)

7. Some policy implications

The provincial government's plant licensing policy is governed by the objective of preventing excessive "proliferation" of processing establishments and consequent inefficient utilization of capital investment.* The presumption underlying this objective is that free entry results in an excessive number of plants which are too small or are producing at too low a rate of capacity utilization.

This presumption is consistent with our finding of a substantial degree of increasing returns to scale over the sample period, which suggests that an increase in the output of the average establishment would lead to a significant reduction in average costs.** On the other hand, this hypothesis must be reconciled with the apparent price-taking behaviour of the industry at the establishment level***, and with the finding of persistent and substantial excess profits throughout this period (Table 14).

One explanation consistent with our findings and with other evidence regarding the industry****, is the existence of substantial monopsony power in the landed fish market, and perhaps the labour market as well.

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*Setting a Course, p. 213.

**See above, p. 34.

***See above, p. 5 .

****See above, p. 10 .

A Chamberlinian situation of monopsonistic competition would then result, in which the average cost curve rises before increasing returns to scale are exhausted, as a result of the less-than-perfectly elastic supply of landed fish input to the establishment. This is illustrated in Figure 1, in which the average cost curves ac_i, defined for a given set of factor prices, shift upward with increased output because of the higher demand (and therefore higher price W_F) for landed fish. This would trace out a "true" average cost curve AC which flattens out and then turns up while increasing returns to scale (as reflected in a downward-sloping ac curve) are still being experienced.

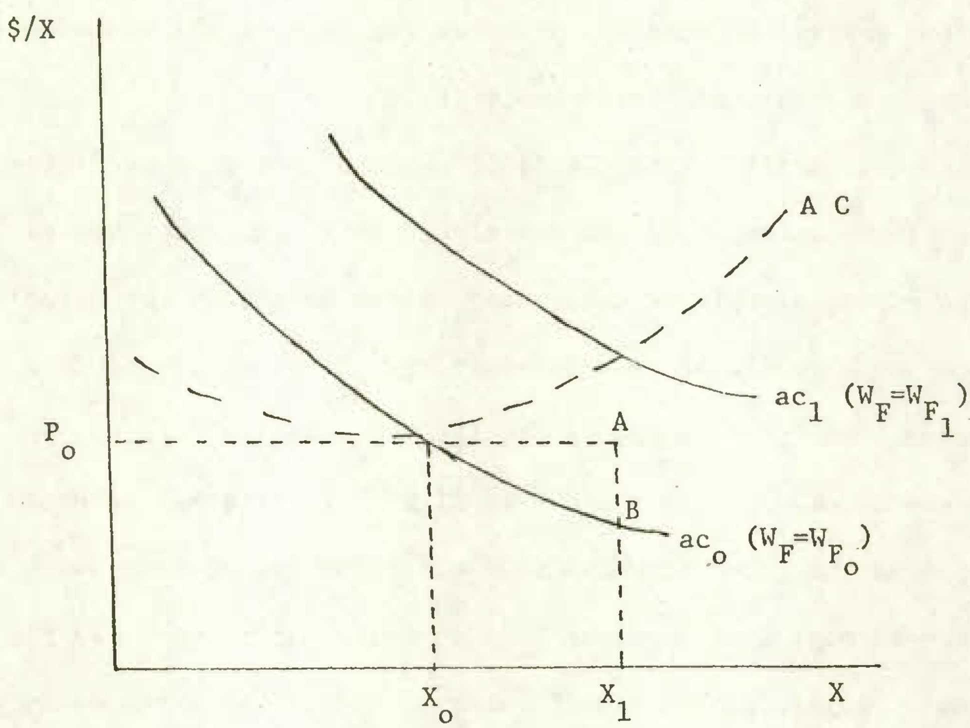

Figure 1

Under these conditions, free entry, along with price-taking in the product market, would result in a long-run equilibrium at which p = min AC, that is, at output X_o. This level of output would not fully utilize the capacity of the establishment, as reflected in the downward slope of the ac curve at this point.

The purpose of restricted entry is to permit a fuller utilization of capacity, by enabling a fewer number of firms to produce more than in the free entry equilibrium. However, it is obvious from Figure 1 that since profits are maximized at X_o, a firm cannot increase output beyond X_o without suffering losses unless the AC curve is shifted downward, presumably through a reduction in W_F. This reduction could take place only through the exercise of a greater degree of monopsony power on the part of the individual establishments, as a result of restricted entry.

The characteristics of the final outcome cannot be predicted without knowledge of the extent to which restricted entry increases the market power of the processing establishments. Suppose the output of the establishment rises to X_1 as a result of restricted entry. If the increase in monopsony power is weak, so that the downward shift in AC is small (i.e., the new AC curve passes between points A and B in Figure 1), primary fishermen would obtain some of the gains from the more efficient use of processing capacity, in the form of higher fish prices (the ac curve shifts up). In the limit, if the new AC curve passes through point A, all of the gains would accrue to primary fishermen. On the other hand, if the increase in monopsony power is sufficiently great, the new AC curve can pass below point B, in which case primary fishermen would be worse off as a result of lower fish prices.

The case for restricted entry is then not unambiguous. Greater economies in capacity utilization would no doubt occur, but at the cost of additional inefficiencies resulting from greater monopsony power in the market for landed fish.* On balance, we are not convinced that restricted entry is in the public interest. Our judgment is influenced heavily by our estimates of the level of economic profit earned in the industry (Table 14), which seem to indicate that restricted entry has had the effect, whether intended or not, of conferring substantial and unwarranted protection to the profit position of the industry. In short, the case for restricted entry in the processing sector has not, in our view, been proved.

We now consider an analysis by the Research and Productivity Council,** indicating the possibility of substantial gains in groundfish production through an increase in the product yield of landed roundfish. This increase would be achieved through reducing "throughput" in the processing operation (i.e., the materials-labour ratio) from 450 to 300 lbs. of roundfish per manhour. According to the study, this reduced throughput would increase yield by 30-35 percent, at the cost of a 10 percent fall in labour productivity.

Our analysis has found a substantial degree of substitutability between labour and materials; the Allen-Uzawa partial elasticity of substitution between the two is around unity (Table 18). This suggests that greater use of labour may be able to produce less wastage in the filleting of groundfish, for example. Therefore, it appears that a yield-productivity tradeoff such as proposed by the Research and Productivity Council is, broadly speaking, technically feasible.

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*It is possible that this dilemma may be resolved by the establishment of the N.F.F.A.W.U. as bargaining agent for both inshore and offshore fishermen, as well as for the plant workers. However, the N.F.F.A.W.U. did not begin to play a significant role in the harvesting sector until 1975.

**Research and Productivity Council (1977). Cited in Setting a Course, pp. 246-9.

However, the Council appears to be taking an overly optimistic view of this tradeoff; at least, this is the case if our aggregate results can be applied to the frozen groundfish sector. Table 19 shows that a rise in the price of materials would have, in proportional terms, double the impact on labour input that it would have on materials input; thus, a 10 percent fall in labour productivity would be accompanied by only a 5 percent rise in roundfish yields, not the 30-35 percent suggested by the Council study. A fall in the wage rate would have similar effects. At the elasticity values reported in Table 19, a one-third increase in yield could be obtained through either a quadrupling in the price of materials, or a reduction in the wage rate to a quarter of its current level; neither alternative seems feasible under current arrangements, or particularly desirable.

A further implication of our results is that there is a high degree of substitutability between labour, and machinery and equipment. Both the federal and provincial governments have channelled a great deal of support into the industry for purposes of expansion, modernization, and the establishment of new facilities.* One of the declared purposes of this support is the creation of additional employment opportunities in the industry.** However, to the extent that this support is provided in the form of capital grants for machinery and equipment (as opposed to construction), our results suggest that such grants will induce substitution for labour and so might actually reduce employment. If employment creation is the objective,

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*See pp.13-16 above. The over $16 million in offers made by DREE to firms in the Newfoundland fish products industry in the period 1971-79, accounted for about 22% of gross fixed capital formation in the industry in that period.

**While this may not be the only objective, it appears to be the predominant one. See, for example, Atlantic Provinces Economic Council (1976), esp. p.168.

any subsidies provided should presumably be labour subsidies. This point has been made before,* but does not appear to have received the attention it deserves in policy circles.

Finally, we inquire about the effect on the industry of higher energy prices, a matter of current concern. We note from Table 19 that energy accounts for 3.5 percent of total production costs. Thus, even substantial increases in energy prices will have only modest effects on the cost structure of the industry. We would expect substantial increases in employment, and some reduction in investment requirements, based on the analysis in Table 19. We conclude that a move to world prices should not endanger the viability of the industry.

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*See Woodward (1974a), (1974b), and (1975).

Data Appendix

Data from the Census of Manufactures, as reported in Fish Products Industry (Statistics Canada Cat. No. 32-216) provide series on the value of output and of non-capital inputs, and on man-hours paid in the industry by province. Constant dollar values of capital stock in the industry, for both structures and machinery and equipment, can also be obtained from Statistics Canada.*

Prices are required by our production study for two purposes. First, deflators are needed to convert the current dollar data provided by the Census of Manufactures into quantity indexes. Second, input prices enter directly into the factor demand equations to be estimated.

We thus require a price index for the output of the industry, and also price indexes for material inputs and energy inputs respectively. We also require a cost of capital series for each type of capital. An implicit wage rate can be obtained directly from the Census of Manufactures.

The next section contains a brief discussion of the theory of index numbers and describes the procedures which we adopt in calculating these. The second section presents and evaluates price indexes we have computed for the output and inputs of the industry as described above. Section three describes the rationale on which our cost of capital estimates are based. The price data computed for the regression study is presented at the end of this Appendix, in Table A3.

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* Koumanakos (1979).

1. Theory of Index Numbers

The purpose of an index number is somehow to summarize a vector (of prices or quantities) as a scalar. The index number problem, as classically conceived, is how to do this without losing information meaningful to the problem at hand. As it happens, the economic theory of aggregation has been concerned with similar questions. Recently, the relationship between the two has been substantially clarified.*

Ideally, an index number should retrieve the exact value of some aggregate of prices or quantities, and it should do this without requiring an exact knowledge of the function defining this aggregate. (If this function is known, after all, an index number is not needed.)

Unfortunately, no index will exactly retrieve the value of an aggregate for all possible forms of the aggregation relationship.** Of course, we often do not know the form of the aggregation relationship in which we are interested. This suggests assuming a form which is expected to closely approximate the true but unknown aggregation relationship. Obvious candidates include those forms which can provide a second-order approximation to an arbitrary twice-differential function, such as the Translog, the generalized Leontief, and the generalized quadratic. Index numbers which are exact for such forms (Diewert calls these "superlative" index numbers) are in a sense "second-order approximations" to the true index number.

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*See Diewert (1976) for what is both a useful survey and a major contribution.

**There is an exception to this statement. A Divisia index, in its pure form, exactly retrieves the value of any aggregate, no matter what the functional form. However, the Divisia index is a line integral, and requires, in a sense, an infinite amount of information. In practice, the Divisia index must be approximated by observations at discrete points.

As it happens, there are an infinite number of such superlative index numbers. We selected three for further examination: the Tornqvist approximation to the Divisia index, which is exact for the Translog form; an index exact for the generalized Leontief form, hereafter known as the generalized Leontief index; and Irving Fisher's "ideal" index, which is exact for the generalized quadratic form.*

A decision had to be made as to whether one base year would be selected for the entire time period, or whether bases would be selected for several overlapping subperiods and the resultant subseries chained together (in the limit, for example, we would have a chain of (T-1) 2-period indexes). If the index number is exact, the two procedures produce the same result. If, as seems likely, the "superlative" index number used is only an approximation to the true exact index number, the two procedures diverge. In this case, the chaining procedure would be recommended, since it is likely that as prices and quantities deviate from the base year values, the approximation gets progressively worse.

In the end, it was decided to chain, for two reasons. First, the product price series produced several cases of new products introduced, and old products deleted, in the course of the time series, so some chaining would have been required in any event. A similar situation occurs in the energy price series, in which progressively more disaggregated information becomes available over time.

However, the price series for fish landings is consistent throughout the sample period, and would not have to be chained. As an experiment, we computed a series for each of our three "superlative" indexes, using 1977 as a base. We then compared these series with comparable indexes composed of two-year series chained together.

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* See Diewert (1976)

We found the 1977-base price indexes tended to diverge from one another (although not uniformly) over time, as the series became more distant from the base period. Thus the Leontief index deviated as much as 3%, and the Tornqvist index as much as 4.6%, from the Fisher "ideal" index. This is consistent with the conjecture expressed above that as prices and quantities deviate from their base year values, the approximation becomes progressively worse.

On the other hand, the 2-year chains tracked one another quite closely; the Leontief index never diverged more than 0.3%, and the Tornqvist index never more than 0.5%, from the Fisher ideal index. This suggests, although it does not prove, that the two-year chains approximate the "true" function quite closely.

Two-year chain indexes were also computed for the price of fish products, and of energy inputs, with similar results. In the case of fish products the Leontief index never diverges more than 0.7%, and the Tornqvist index never more than 1.1%, from the Fisher index. The Fisher energy index never diverges more than 0.1% from the others.

This suggests that the choice among alternative "superlative" indexes is not critical when the base is continually shifted through the use of two-year chains. However, the use of the Fisher "ideal" index commends itself, for the following reasons.*

First, when a series is deflated by a Fisher price index, the resultant constant dollar series is a Fisher quantity index. No other superlative index possesses this property.

Second, the resultant Fisher quantity index is consistent with revealed preference theory, in the sense that if A is revealed preferred to B, the value of the quantity index corresponding to A exceeds that corresponding

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* See Diewert(1976)

to B. Thus, even when the Fisher index is not "exact", it will at least move in the direction predicted by revealed preference theory.

Third, the generalized quadratic function, for which the Fisher index is exact, includes as special cases the polar extremes of perfect and zero substitutability (linear and Leontief aggregator functions respectively). It appears plausible that the three aggregates of concern here approximate one of these; e.g., different energy sources are likely to be close substitutes.

Because of these considerations, the superlative price indexes used in this study are all Fisher ideal chain indexes, based on links of two years duration.

2. Construction of Price Indexes

(A) Price of Fish Products, Newfoundland, 1961-77

The raw data for the index was obtained from Fisheries Statistics - Newfoundland, Statistics Canada Cat. No. 24-202, except for 1977 which was obtained from unpublished data held by Fisheries and Oceans Canada. These sources report the quantity and value of fish products, by type of product. Prices were obtained by dividing the value of a product-type by the quantity. These data usually refer to sales in the case of a fresh or salt product and to production in other cases. Some products of minor importance (e.g., seal oil) are omitted; in addition, sales of fresh round or dressed finfish and fresh molluscs and crustaceans in shell are omitted, as these are considered to be a merchandising activity by Statistics Canada and so are excluded from the value of manufacturing output of the industry in the Census of Manufactures.

Unfortunately, not all of the product that remains after these deletions appear to be included in the Census universe. There are indications of significant undercoverage in the Census: only 61 establishments are recorded in the years 1975-1977 while 172 establishments were licensed by the provincial government to engage in fish processing in mid 1979.* While most of these were licensed fairly recently, we have records of at least 82 licensed establishments in the summer of 1976. Some of this discrepancy might be accounted for by establishments whose main activity is something other than fish processing (e.g. retail or wholesale trade). In addition, the minimal processing which occurs when, for example, an inshore fisherman dry-salts his catch is also excluded from the Census data.

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* See above, p.7

The value of fish products as reported by Fisheries Statistics exceeds the value of gross output of the fish products industry by about 20% in 1975-76, even when fresh round and in shell are deducted from the former. This could be due to (a) product not flowing through the Census universe, or (b) the value as reported by Fisheries Statistics including merchandising or transportation costs excluded from the establishment-based Census data. Either could be a source of distortion.

(B) Price of landed fish, Newfoundland, 1961-77

A breakdown of materials by value and quantity is available for the Fish Products Industry for Canada as a whole.** This is not of much use for our purposes, since both the weights and the implicit prices can be expected to vary substantially in response to local conditions.

Raw fish account for 80% of the cost of materials (probably more in Newfoundland which does not use canning extensively).** An index of landed fish prices can be computed using data on the quantity and value of landings by species from Fisheries Statistics-Newfoundland. (Statistics Canada Cat. No. 24-202). This is available for the period 1961-76. Comparable data are obtained for 1977 from Fisheries and Oceans Canada, Canadian Fisheries - Primary Sector Activities.

A price index so calculated has the same comparability problems as does the output price index discussed in (A) above. It is not clear to what extent these landings flow through the processing sector.* In addition, trawler landings are believed to be undervalued, although it is not known by how much.*** Finally, the price of non-fish materials is ignored in these calculations.

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*For most of our period, the value of landings as reported in Fisheries Statistics exceeds the cost of materials to the fish products industry as reported in the Census of Manufactures. However, in 1976 and 1977 landings equalled about 80% of materials costs.

**Statistics Canada, Fish Products Industry, various issues (e.g. Table 5, 1977)

***See above, pp. 8-9

(C) Price of Energy Inputs, Fish Products Industry, Canada, 1961-77

This data was obtained from Census of Manufactures, Fish Products Industry, Statistics Canada Cat. No. 32-216. Prices were obtained by dividing the value of an energy input by the quantity used. Energy inputs are categorized into gasoline, fuel oil, and electricity (plus some minor sources ignored here) to 1972. Fuel oil is disaggregated further beginning in 1973. Data is not available by province.

As a check on the implicit prices of the various petroleum products, we compared these with Statistics Canada's Industry Selling Price indexes for these commodities. They are reasonably comparable, although the I.S.P. series are really too short for us to draw any firm conclusions.

It is not clear whether this price index based on Canadian data can be successfully applied to Newfoundland. No evidence exists as to whether the Canadian proportions used are typical of Newfoundland, at least in this period. For what it is worth, in the early 1950's, the Newfoundland industry spent a substantially below-average proportion of its energy expenditure on electricity, but this proportion rose to the Canadian average in 1956-57. We have no provincial data after 1957.

Moreover, it is not clear to what extent the national price indexes are appropriate to Newfoundland. No evidence on this point exists for fuel prices. Statistics Canada does compile a Selling Price Index for commercial sales of electricity by province, beginning in 1971, and the Newfoundland index deviated substantially from the national index. However, neither index approximated the implicit price calculated for the fish products industry, for the years of 1975-77. In short, it is not clear which of these indexes is most appropriate.

As an experiment, we chained the Newfoundland electricity S.P.I. for the period 1971-77 to the implicit price of electricity calculated from the Census of Manufactures for the earlier period, and recomputed our three superlative indexes. We found an increase in the extent to which the three indexes deviate from one another, throughout the period (1972-77) in which the I.S.P. is effective. In 1975 the deviations exceed 10%. This suggests that the price-quantity combinations on which these indexes are computed are inconsistent with cost-minimization.

In summary, although serious doubts exist as to the usefulness of the composite index as a price series for the Newfoundland industry, no superior alternative seems available.

3. The User Cost of Capital

The price of capital which we use in this study is based on a user cost concept which expresses the opportunity cost of acquiring and using capital for a specific period of time. It is, in other words, the implicit rental paid by the firm for the use of a unit of capital over a specified period. The measures which we develop for the industry are similar to those presented in Hall and Jorgenson (1967).

Suppose an investment good is acquired at time t, at a price q(t). (We assume (for reasons of tractability) that the investment good depreciates physically at a constant percentage rate δ). The firm obtains a return from this acquisition, in four parts. First, it receives (more or less immediately) an investment tax credit $k\ q(t)$ $(0 \leq k < 1)$ which it may deduct from its income tax liability.

Second, it may deduct from its taxable profits an amount $(1-k)\ q(t)\ D\ (s-t)$ of capital cost allowance in the year $s \geq t$; $D\ (s-t)$ is the schedule based on which capital cost may be deducted, where s-t is the age of the capital asset.

Third, if the firm borrows to finance the acquisition of the capital asset, any interest payments on the loan may be deducted from taxable income. Typically, of course, a firm does not finance all of its capital acquisition through borrowing; some proportion must come from the firm's equity. Let $(1-k)\ q(t)\ I\ (s-t)$ be the amount of interest payments deductible at time s. The function $I\ (s-t)$ represents the proportion of the original cash outlay on which there remains debt outstanding at time s. The derivation of this function is explained below.

Finally, the capital asset provides a productive return $c(s)\ e^{-\delta\ (s-t)}$ in year s, where c(s) is the value of a unit of production services provided by a capital asset. Since the asset depreciates physically at rate δ, the flow of productive services from the asset declines correspondingly.

The firm invests until the present discounted value of the future return to holding a capital asset equals the cost of acquiring the asset. If the rate of discount is r, and the rate of corporate taxation is u, this requires that:

$$q(t) = \int_t^\infty e^{-r(s-t)} [(1-u)c(s)e^{-\delta(s-t)} + u(1-k)q(t)I(s-t)$$

$$+ u(1-k)q(t)D(s-t)]ds + kq(t) \quad \text{(A1)}$$

where we allow for the fact that a proportion u of the productive return c(s) is taxed, but that the same proportion of interest payments and capital cost allowance is returned to the firm because of their deductibility from taxable income.

If both sides of (A1) are differentiated and a number of tedious substitutions are made, one obtains:

$$\bar{c}(t) = \frac{q(t)(r + \delta - \lambda)(1-k)(1 - ux - uy)}{1-u} \quad \text{(A2)}$$

where $\lambda = \frac{\dot{q}(t)}{q(t)}$ = the percentage rate of change in the price of the capital good, $x = \int_t^\infty e^{-r(s-t)}D(s-t)ds$ is the present value of capital cost allowance per dollar capital cost, and $y = \int_t^\infty e^{-r(s-t)}I(s-t)ds$ is the present value of interest deductions per dollar capital cost. This is the rental value or user cost of capital which we use in our regression equations.

To obtain values of x and y, we must specify functional forms for D(s-t) and I(s-t). Of the two, the latter is conceptually more problematic, since funds may not be borrowed (or retained) specifically to acquire a particular asset. For a firm that depends totally on loan capital, however, it is clear that $I(s-t) = e^{-\delta(s-t)}$ and so $y = \frac{1}{r+\delta}$. It is more reasonable, however, to assume that a certain proportion $\upsilon < 1$ of the firm's capital is financed through debt, and so we obtain $y = \frac{\upsilon}{r+\delta}$.

We must make more elaborate specifications for D(s-t). Normally, a capital asset is placed in a certain asset class for tax purposes and a constant proportion δ_T of the value of the assets in that class is deductible each year. Thus,

$$D(s-t) = \delta_T e^{-\delta_T(s-t)} \qquad \text{(A3)}$$

and so

$$x = \frac{\delta_T}{r + \delta_T} \qquad \text{(A4)}$$

In the Newfoundland food products industry, structures would normally fall in class 6 (which includes frame and steel buildings, as well as wooden breakwaters and wharfs), for which $\delta_T = 0.1$. Machinery and equipment would fall in class 8(which includes tangible property acquired for manufacturing and processing), for which $\delta_T = 0.2$.

However, we must also take account of various forms of accelerated depreciation which have been enacted in our sample period. We have made the following adjustments:

(1) Class 29. Since May 8, 1972, machinery and equipment used for the purposes of manufacturing or processing may be written off in equal installments over two years. Thus,

$$D(s-t) = 0.5, \qquad 0 \leq s - t \leq 2 \qquad \text{(A5)}$$

(2) Section 13(10), Income Tax Act. Machinery and equipment acquired between December 4, 1970 and March 31, 1972 may be valued at 115% of actual cost for capital cost purposes. Thus,

$$D(s-t) = 1.15\delta_T e^{-\delta_T(s-t)} \qquad \text{(A6)}$$

$$= 0.23e^{-.2(s-t)}$$

(3) Class 21. Machinery and equipment acquired between December 6, 1963 and March 31, 1967 for use in a new manufacturing or processing business in a regional development designated area, may be written off in equal installments over two years. Thus, equation (A5) applies to this asset class

(4) Class 19. Machinery and equipment acquired between June 14, 1963 and December 31, 1966, by a firm with a required degree of Canadian ownership, may be written off in equal installments over two years as well. Equation (A5) applies.

(5) Class 20. Structures built between December 6, 1963 and March 31, 1967, in a regional development designated area, may be written off in equal installments over five years, Thus,

$$D(s-t) - 0.2, \quad 0 \leq s - t \leq 5 \quad \text{(A7)}$$

(6) Section 1009, Income Tax Regulations. Incremental investments made between June 21, 1961 and March 3, 1964 may be written off in the first year at a 50% increased rate.

These allowances substantially increase the present value of the capital cost allowances obtained from the acquisition of a capital asset. Table A1 illustrates what these present values would be at an interest rate of 10%. Table A2 presents the actual historical series of these present values for both structures and equipment.* The substantial changes in these present values over time reflect changing interest rates as well as tax changes.

Equation (A2) was used to calculate measures of the user cost of capital for the Newfoundland fish products industry, for both structures and equipment. The following data sources were used:

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*When a particular depreciation rule applies to only part of a year, the values of the two applicable present values are linearly interpolated according to the number of days they were in force.

Price of investment goods q: implicit deflators for construction, and for machinery and equipment, Newfoundland fish products industry, as obtained from Statistics Canada. However, these are based on national data (Koumanakos, 1979). The deflators are set at $q = 1.0$ for 1971.

Rate of discount r: McLeod-Young-Weir index of 10 Industrial bonds, annual average. It is possible that the risk class of firms from which this sample is drawn differs from that typical of the Newfoundland fish products industry, so that this index may underestimate the true discount rate. However, see the discussion below regarding the derivation of υ.

Rate of physical depreciation δ: ratios of capital consumption allowances to net mid-year stocks, for structures and for machinery and equipment, Newfoundland fish products industry, as obtained from Statistics Canada. Again, these are based on national data regarding useful lives.

Rate of price increase λ ($=\dot{q}/q$). The instantaneous rate of change $\dot{q}$ in the deflators q were obtained by fitting (by least squares) a quadratic form (in time) through five consecutive points, and differentiating the quadratic at the middle point to obtain an estimate of $\dot{q}$ at that point. Five points were used to reduce the sensitivity of the estimate to deviations in the true time path of $q(t)$ from the quadratic form. This was done for both construction and machinery and equipment.

Investment Tax Credit Rate k: statutory rate applicable to capital investments in Newfoundland. Mid-year changes were linearly interpolated.

Rate of corporate income tax u: statutory rate, federal plus provincial, applicable to manufacturing and processing profits earned in Newfoundland. Mid-year changes were linearly interpolated. No allowance is made for small-business tax concessions.

Proportion of investment financed through debt υ. We base these estimates on financial information regarding the proportion of the total return to all capital (debt plus equity) which is applicable to debt. This financial information was obtained from the Department of National Revenue's Taxation Statistics for 1961-64, and from Statistics Canada's Corporation Financial Statistics (Cat. No. 61-207) for 1965-71 and 1973-76. A value for 1972 was derived as the average of that for 1971 and 1973, and a value for 1977 as the average value prevailing in 1974-76. Since financial statistics are not defined on an establishment basis, the data are applicable to the fish products industry in Canada as a whole.

Return to debt capital is taken as equal to the value of interest paid reported in the income-expenses accounts of the industry. However, net profit is inadequate as a measure of the return to equity because of its high volatility from year to year, and because it does not include the value of accrued capital gains on the firms' assets.

To obtain a measure of the return to equity, we took the book value of the equity position of the firms in the industry, as reported on their balance sheets, deducted from this the net book value of depreciable assets, and added Statistics Canada's estimate of the current market value of mid-year net capital stocks in the industry. We took this to be a measure of the current market value of equity in the industry, on the assumption that the book value of current and non-depreciable assets and liabilities is a reasonable approximation of current market value. We than multiplied this estimate of the value of equity by the discount rate r, to obtain an estimate of the equilibrium return to equity in the industry. On this we based an estimate of υ, the ratio of return to debt capital, to return to all capital (debt and equity). This showed minor variations from year to year, but averaged 0.38 over the sample.

As a check on this procedure, we compared the estimate of the return to equity so derived with the sum of after-tax profits and accrued capital gains on depreciable assets, the latter having been estimated from Statistics Canada data on capital stocks. These two measures averaged almost precisely the same, at about $12 million per annum, over the period 1961-71.

In 1973, however, the machinery and equipment deflator began to acclerate sharply, and the implied rise in accrued capital gains to the industry which would result from this was not matched by a comparable increase in the equilibrium return to equity in our calculations. Some possible explanations (not mutually exclusive) for this non-correspondence are: (1) accelerated inflation has caused distortions in capital markets, so that these markets no longer accurately capitalize the value of capital gains into the market value of equity; (2) as a result of the 1971 tax reform, unrealized capital gains are being discounted by investors to allow for future tax liability on realization; (3) our assumption on the accuracy of book value as a measure of the true value of non-depreciable assets and liabilities is less justifiable in an inflationary environment. In any event, our estimate of υ for the period 1973-76 is 0.33, which is somewhat lower than in the entire sample.

Table A-1

Present Value of Capital Cost Allowances per Dollar Capital Cost, under Various Provisions of the Income Tax Act and at a 10 Per Cent Rate of Interest

Class	Normal	S.1009	S.13(10)
6	0.5	0.522	___
8	0.66	0.694	0.766
20	0.787	0.820	___
19, 21, and 29	0.906	0.934	___

Table A-2

Estimated Present Value of Capital Cost Allowance, per Dollar Capital Cost, for Both Structures and Equipment, Newfoundland Fish Products Industry, 1961-77

	Structures	Equipment
1961	0.654	0.794
1962	0.665	0.805
1963	0.680	0.893
1964	0.882	0.954
1965	0.870	0.945
1966	0.854	0.938
1967	0.655	0.792
1968	0.559	0.717
1969	0.532	0.694
1970	0.521	0.693
1971	0.546	0.707
1972	0.546	0.845
1973	0.541	0.920
1974	0.495	0.905
1975	0.481	0.899
1976	0.488	0.902
1977	0.508	0.909

Table A-3

Output and Input Price Indexes, Fish Products Industry, Newfoundland and Labrador, 1961-77

	Price of fish products (1977=100)	Price of fish landings (1977=100)	Price of energy imputs (1977=100)	User cost of construction capital	User cost of machinery and equipment
1961	26.0	24.0	40.8	0.057	0.058
1962	27.4	25.6	41.5	0.053	0.051
1963	28.9	27.7	41.4	0.044	0.042
1964	29.6	31.0	40.3	0.025	0.044
1965	32.3	32.6	38.6	0.023	0.065
1966	33.6	34.6	39.4	0.035	0.094
1967	31.7	36.2	38.7	0.055	0.118
1968	30.5	31.9	38.4	0.062	0.119
1969	32.7	32.9	38.1	0.070	0.123
1970	38.4	39.8	38.9	0.069	0.136
1971	46.6	45.0	38.3	0.056	0.119
1972	56.0	53.0	45.4	0.031	0.071
1973	76.4	68.0	52.1	0.010	0.023
1974	75.9	75.4	60.9	0.035	0.034
1975	78.4	76.7	62.3	0.060	0.067
1976	89.2	82.7	83.8	0.093	0.093
1977	100.0	100.0	100.0	0.079	0.104

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