An Input-Output Analysis of Maine's Fisheries

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Introduction

Since the passage of the Fisheries Conservation and Management Act of 1976, the New England fishing industry has experienced a substantial revitalization. Maine, perhaps even more than the rest of New England, has rapidly expanded its harvesting and processing sectors. This favorable environment has generated renewed interest in the impact of fisheries on the local economy. In Maine's case, the State has undertaken pier construction and market development activities based in part upon expected, but quantitatively unknown, benefits to the State's economy. This paper presents an input-output model to estimate the impact of fisheries activities on the Maine economy.

Economic activity is a complicated web of interdependent behavior. A change in any part of the economy leads to changes elsewhere. Consequently, estimation of the ultimate total impact of a change in marine harvesting or processing requires measurement of the changes that occur elsewhere in the economy. In other words, the economic importance of the fishing industry depends upon the relationship of fishing to the rest of the economy.

One technique available to obtain these measurements is called input-output analysis[1]. Input-output is basically a massive accounting system which records the sales of each industry to every other industry and to final consumers. With the help of a computer program, this accounting system can be used to trace the connections between all industries in the economy.

In the last decade, regional input-output models have been constructed from census data gathered by the Federal government. These models are now

ABSTRACT—An input-output model of Maine's economy, modified to include nine fisheries sectors, was used to estimate the increases in income induced per dollar of sales for each fisheries sector. Based on these figures, it was estimated that Maine's 1980 landings, valued at $90 million, ultimately generated $240 million in income in Maine.

[1]For a very clear explanation of the mechanics of input-output modelling, the reader is referred to Miernyk (1965). Chapters 2 and 3 of Miernyk thoroughly explain construction and application of input-output models. Chapter 4 on regional models is especially appropriate to the present analysis. Dorfman et al. (1958, chapters 9, 10) is more mathematical, but discusses the underlying assumptions more thoroughly.

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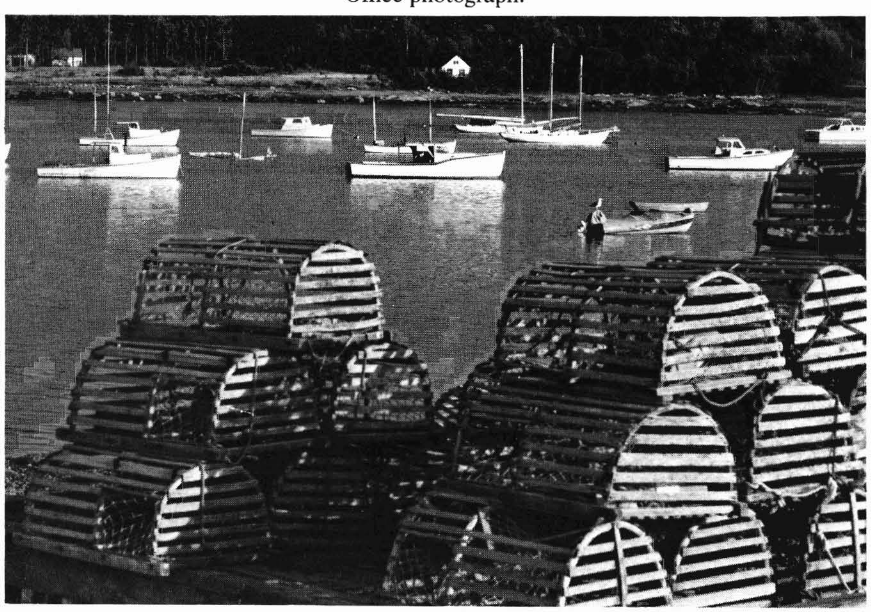
Lobster traps at Round Pond harbor in Maine. State of Maine Development Office photograph.



frequently used to analyze the impact of government policies upon state economies. None of the existing models, however, contain detailed fisheries sectors. Most often, fisheries are included with forestry or agriculture. The present analysis modified one of these aggregated models of Maine's economy to include nine fisheries sectors. The model was further modified to calculate income flows, as well as transactions. This fisheries-oriented model of Maine's economy was then used to estimate income multipliers for each fishing industry.

A Regional Input-Output Approach

Input-output analysis provides a simple general equilibrium approach to quantitative economic analysis. An increase in the output of one sector increases the demand for output in its supplying industries, and in industries which supply the suppliers, and so on. Intuitively, an input-output model calculates an infinite series of such supplying relationships. For any set of desired net outputs by an economy, the model calculates the total production required of each industry. Hence, it is called a general equilibrium approach.

To obtain general equilibrium answers with a minimum of data requirements, input-output analysis depends upon very strong technological assumptions. Each unit of output (measured in dollars) requires fixed proportions of inputs from every other industry. For example, one dollar's worth of steel might always require five cents of iron ore, three cents of coal, and so on. An economy could satisfy this assumption if the following were all true:

1) There is only one primary input, usually labor.

2) The technology is homogenous of degree one. This implies constant returns to scale along all expansion paths.

3) The technology does not change.

4) Production of each output is separable from production of all other products. This assumption rules out joint products.

If there are two or more primary inputs, the technology must be further restricted to a fixed coefficients production function. The elasticity of technical substitution is zero in this case. Either set of assumptions can only be approximately true in a real economy. These fixed coefficients are estimated from actual transactions in a base year.

In a national input-output model with no foreign sector, all demands are supplied by industries within the national economy. In a regional economy, substantial trading between the region and the rest of the economy will occur. The extent of this trading will determine whether the economic benefit of increased activity remains in the region or flows out to the rest of the economy. These flows in and out of the region must be incorporated into a regional model. For example, in the steel example, a regional model must differentiate between iron ore from within the region and iron ore from the rest of the economy.

This differentiation is based upon actual transactions in the base year. Products are divided into two classes: products which Maine imports on net, and products which Maine exports on net. For products which Maine imports, we assumed the ratio of in-state production to total demand to be constant. That is, out-of-state sources provide a fixed percent of total demand. This assumption is consistent with the fixed coefficients approach of input-output models.

For products which Maine exports on net, all in-state demands are met by in-state production. All changes in demand are absorbed by in-state suppliers. Sales to out-of-state purchasers are exogenous, and do not change as in-state economic activity changes.

For arbitrary changes in fisheries outputs, the input-output model of Maine's economy will estimate the change in output of every Maine industry. These production estimates are often very useful for planning decisions. However, the present analysis is primarily concerned with estimating the total impact of fishing activities upon the economic welfare of Maine citizens. Total output is not a good indicator of economic welfare. A large part of total output in Maine originates outside the State, and so does not generate employment within the State. Also, the percent of total value originating in-state varies from one sector to another. For example, gasoline sales of one dollar generate far less income in Maine than equivalent sales of haircuts. Therefore, we need a better measure of welfare than total sales.

Input-output models can also generate estimates of changes in consumption and income. As a measure of economic welfare, either of these is preferable to estimates of total production. That is not to suggest that income or consumption are perfect measures of welfare. Estimates of changes in income or consumption ignore many important aspects of economic welfare. For example, reductions in leisure, natural resource depletion, and social disamenities are all excluded from the monetary accounting system. While there are techniques which incorporate some of these factors into input-output models, such refinements are beyond the scope of the present work.

The relevant choice here is whether to approximate economic welfare by consumption or by income. Taxes and savings are the major differences between income and consumption. Savings are usually a voluntary alternative to consumption, and therefore must increase individual welfare. Taxes support government activities, and most people would agree that these activities provide at least some benefit to society. Consumption probably understates economic welfare; income may err in the other direction. If we are interested in relative changes, the distinction is not important anyway. Consumption and income increase proportionately in a fixed coefficients input-output model. Economic analyses, and especially those done for economic development purposes, invariably emphasize income, and we have followed that convention.

Income within each industry is measured by value added, which is the difference between gross sales and total purchased inputs. Value added as a measure of state income has a weakness. The percent of the value added which flows to households outside the state is unknown. We have assumed that all value added remains within the State. For labor income (which accounts for

75-80 percent of personal income) this assumption is quite reasonable. For payments to capital and natural resources, however, this assumption is incorrect to some unknown degree.

For analytic purposes, it is useful to separate the income generated into three categories:

1) The "direct effect" of income generated in the fishing industry;

2) the "indirect effect" of income generated by sales of goods and services to the fishing industry; and

3) the "induced effects" which arise when personal income generated directly and indirectly is respent.

To provide separate estimates of direct, indirect, and induced income, two closely related input-output models were used. In the first, consumption expenditures in-state were determined exogenously. This is called an open model. In an open model, increased fishing activity generates income within the fishing industry and within supplying industries. These income changes do not affect the level of consumer purchases. In the second or closed model, changes in income do cause changes in consumption. To summarize, direct plus indirect income is estimated by the open model. Direct plus indirect plus induced income is estimated by the closed model. Direct income is known, so indirect income and induced income can be derived by subtraction.

Both the open and the closed models are developed mathematically in the appendix.

The Data

The transactions, total production, and total consumption data for the open model were from the 1963 U.S. Multiregional Input-Output Model and were measured in thousands of 1963 dollars[2]. Trade with the rest of the economy for 1963 was also derived from this source.

The raw data from these national accounts provided 79 industries. These were aggregated to 28 sectors which were roughly consistent with annual data generated by the State of Maine. After 9 fisheries sectors were added, the open input-output model contained 37 industries.

Even with 79 industries, the transaction data collected by Federal agencies was much too aggregated to provide useful information about fisheries. The fisheries sectors were subsumed into two broader industries: 1) Forestry and fisheries and 2) food processing. To provide the detail necessary for policy analysis in fisheries, the fisheries harvesting and processing sectors had to be removed from these two broad categories and reintroduced into the transactions tables as five separate harvesting sectors and four processing sectors. The harvesting sectors were: Clam harvesting; marine worm harvesting; herring and menhaden harvesting; lobster, crab, and scallop harvesting; and groundfish harvesting. For processing, clam and marine worm processing were lumped together. Otherwise, the processing sectors corresponded to the harvesting sectors: Herring and menhaden processing; groundfish processing; and lobster, crab, and scallop processing.

Purchases for the nine fisheries sectors had to be removed from the very aggregate sectors and then reentered as separate sectors. Based upon estimates for 1963[3], fishery purchases were subtracted from the forestry and fisheries sector (yielding a forestry sector) and from the food processing sector (yielding a food, except fish, processing sector)[4]. Then the nine new sets of purchases were added to the transaction data.

The sales of fisheries products were based upon the estimates cited above. All fisheries sales were to final demand, exports, or to other fisheries sectors. Sales to other industrial sectors were assumed to be zero. The data collected could not distinguish between in-state and out-of-state sales to final consumers. Consequently, the following assumptions were used:

1) No in-state consumption of marine bait worms,

2) consumption of 10 percent of the lobster and clam catch in-state, and

3) consumption of 2 percent of herring and groundfish processing output in-state.

To "close" the model, household sector purchases in the base year must be removed from the final demand vector and entered as the purchases of a new 38th industry, called households. Unfortunately, household purchases for 1963 were unavailable. Instead, Maine consumption expenditures were obtained for 1970. The 1970 consumption expenditures were multiplied by the ratio of 1963 total consumption to 1970 total consumption. Note that, as with any other industry, the pattern of purchases of the household sector in any input-output model is assumed to be constant. Likewise, the ratio of total consumption to total income is constant. This consumption data was the only new data required to close the model.

Results

Table 1 lists the income generated within Maine's economy per dollar of the various fish harvesting and processing activities in the State. To help interpret Table 1, consider an example from the herring fishery. Increasing herring landings by $1.00 leads directly and indirectly to an increase in income in Maine of $0.73 ($0.51 in the herring harvesting sector and $0.22 in all others).

[2]Further details on the construction of State input-output tables may be found in Polenske et al. (1972). The use of 1963 technical coefficients for the nonfisheries sectors of the economy was based solely upon the availability of the data. A new table for 1972 is expected shortly and the estimated impact multipliers can be updated to reflect that new data.

[3]The estimation of input requirements per dollar of sales for fisheries sectors was based upon interviews conducted with industry and government personnel in 1979. Details of this estimation are contained in J. Wilson, T. Duchesneau, H. Briggs, B. Burlingame, K. Rollins, and D. Williams, The economic impact of fisheries in the State of Maine. *In* C. J. Walton (editor), Fisheries management and development: Completion report to the State Planning Office for the period October 1, 1978 to September 30, 1979, Volume IV, Element E. Transactions were estimated by multiplying input requirements per dollar times 1963 fishery sales reported in Lyles (1965).

[4]In some instances the subtraction of fisheries sectors created negative transactions in forestry and food sectors. These transactions were assumed to be zero.

Table 1.—In-state income multipliers for nine fishing industries.

Industry	Direct	Indirect	Induced	Total
Harvesting sector				
Clam	0.57	0.20	0.77	1.54
Worm	0.72	0.10	0.83	1.65
Herring and menhaden	0.51	0.22	0 74	1 47
Lobster, crab, and scallop	0.35	0.34	0.69	1.38
Groundfish	0.29	0.37	0.66	1.32
Processing sector				
Clam and worm	0.24	0.58	0.83	1.65
Groundfish	0.14	0.53	0.66	1.33
Herring and menhaden	0.28	0.31	0.59	1.18
Lobster, crab, and scallop	0.17	0.42	0.58	1.17

Table 2.—Estimated in-state income from nine fishing industries, 1980.

Industry	Gross output	Estimated income
Harvesting sector		
Groundfish	$19,697,000	$26,000,040
Herring and menhaden	6,427,000	9,447,690
Lobster, crab, and scallop	52,670,000	72,684,600
Clams	8,554,000	13,173,160
Worms	2,499,000	4,123,350
Processing sector[1]		
Groundfish	$18,021,000	$23,968,000
Herring and menhaden	56,509,000	66,681,000
Lobster, crab, and scallop	70,872,000	82,920,000
Clam and worm	17,507,000	28,886,000

[1]All processing figures are preliminary estimates based on 1980 reported landings and the proportion of landings to processed value in 1963. Direct, indirect, and induced income are included in estimated income.

Table 3.—Estimated in-state income of processing sectors, excluding fish purchases, 1980.

Processing sector	Gross output	Estimated income
Groundfish	$18,021,000	$ 9,731,340
Herring and menhaden	56,509,000	58,204,270
Lobster, crab and scallop	70,872,000	34,018,560
Clam and worm	17,507,000	11,240,480

This $0.73 of income is responsible, as it is in turn spent on consumption items, for an additional $0.74 of income—the induced income effect[5]. Consequently, the total impact upon income per dollar of herring landings is $1.47.

The income generated per dollar of sales was higher for fisheries than for virtually any other sector in the State. For example, the total income multiplier for wood and paper products, the State's most important industry, is .98. The higher ratio of income to sales for fisheries is explained by two factors. First, many fisheries are relatively more labor intensive, generating greater direct value added. Second, fisheries seem to purchase relatively more of their inputs in-state as compared with other industries. For example, boat building services are a major input which is produced in-state.

The total impact of any one fishery on the Maine economy for 1980 is estimated by multiplying gross output in 1980 times the total income multiplier. These calculations are presented in Table 2.

However, estimating the aggregate impact of all nine fisheries sectors is a bit more complicated than simply adding the columns in Table 2. To the extent that fisheries sectors buy from each other, either directly or indirectly, simply adding the columns in Table 2 would lead to inadvertent double counting. For the five harvesting sectors, this double counting is relatively minor—consisting mostly of bait purchases. Therefore, adding the separate figures for the five harvesting sectors will not be substantially in error. The $90 million in landings for 1980 generated approximately $125 million in income.

The processing sectors purchase their primary input—fish—directly from the harvesting sector. Therefore, estimated income for processing sectors includes income generated by increased purchases of fish. Adding the harvesting income estimates to the estimates for the processing sector will double count income attributable to harvesting. Table 3 presents the estimated impacts of the processing sector exclusive of fish purchases. Processing generated an estimated net addition to income of $113 million in 1980, only slightly less than the income generated in harvesting. Adding the processing sector impacts to the harvesting sector impacts provided an estimated total income of $239 million.

The input-output model also provided detailed information on how various nonfishing industries within the State are affected by fishing activities. Such information may be useful for economic planning activities by the State[6]. The detailed data has obvious political interest as well. Those industries which may gain directly or indirectly from increased fishing activity have an interest in policies which promote the fishing industry.

Tables 4 and 5 present the estimated impact upon selected Maine industries from a $100,000 increase in harvesting or processing activities. These estimates are based upon the open model, and include only indirect effects. Therefore, these industries directly or indirectly supply fishing industries. The numbers in Tables 4 and 5 are rounded to the nearest thousand dollars. The tables include all industries which receive $1,000 or more of income per $100,000 of harvesting or processing activity.

Tables 4 and 5 contain no major surprises. Most of the entries reflect the pattern of direct purchases by fishing industries. The groundfish, herring, and lobster fisheries are major purchasers of boats (included in motor vehicles), nets (fabrics), and gear. The very labor intensive clam and worm digging industries have much less indirect input. The figures for the processing sectors are

[5]Because consumption is a constant percent of income, and because the consumption pattern is fixed, estimated induced income in an input-output model is necessarily a constant proportion of direct and indirect income. However, that that proportion was almost exactly one in this analysis was strictly an empirical accident.

[6]It has been suggested that data on income earned by out-of-state industries might also be useful for planning purposes. Industries which supply fishing activities directly or indirectly could be encouraged to locate here. Perhaps due to our very aggregated definition of industries, this input-output model did not provide very useful information. The major out-of-state purchases were in electrical and mechanical machinery, petroleum, and chemicals. Maine would obviously like to attract some of these industries, but purchases by fishermen and processors will not be a significant factor.

Table 4.—Income generated in selected Maine industries per $100,000 of fishing activity. (In thousands of dollars.)

	Harvesting sector				
Nonfishing industry	Groundfish	Herring and menhaden	Lobster, crab, scallop	Clam	Worm
Livestock	$2	$2	—	—	—
Wood and paper products	1	1	2	1	1
Maintenance and construction	1	—	1	—	—
Fabrics and misc. textiles	9	7	1	—	—
Engines and machinery	1	1	1	1	—
Motor vehicles	3	4	3	8	6
Transportation and warehousing	5	1	4	—	—
Wholesale and retail trade	3	2	2	1	1
Finance and insurance	9	3	8	3	—
Miscellaneous retail	1	1	5	4	—
Electrical manufacturers	1	1	1	—	—

Table 5.—Income generated in selected Maine industries per $100,000 of fish processing. (In thousands of dollars.)

	Processing sector			
Nonfishing industry	Groundfish	Herring and menhaden	Lobster, crab, scallop	Clam and worm
Livestock	1	1	—	—
Wood and paper products	3	2	2	2
Maintenance and construction	2	1	—	—
Food and kindred products	—	2	—	—
Fabrics and misc. textiles	5	1	1	—
Metal products	—	1	—	—
Engines and machinery	2	1	1	—
Motor vehicles	2	1	2	5
Transportation and warehousing	4	5	4	1
Utilities	1	3	—	—
Wholesale and retail trade	4	1	2	1
Finance and insurance	6	2	5	2
Miscellaneous retail	3	3	4	3

harder to interpret, but generally seem to reflect purchases by both processors and fishermen.

The large indirect income earned by the finance and insurance and the transportation and warehousing sectors is perhaps the only surprise in Tables 4 and 5. Fishermen who operate boats do spend a large portion of their income on interest and insurance. The relatively large income earned by the transportation and warehousing sector is harder to explain. Maine's remote location perhaps explains the importance of this sector.

We estimate that fisheries-related income accounted for 2.8 percent of Maine's 1980 total personal income of $8.6 billion. These figures emphasize the importance of fisheries activities to Maine's economy. We suspect these estimates have a conservative bias, because a number of smaller fisheries (sea moss, elvers, anadromous species, periwinkles, and sea urchins) are excluded. The analysis is also limited to fisheries per se, and does not include other marine activities such as shipping and recreation.

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Appendix: Construction of the Model

Although the two input-output models are conceptually quite different, mathematical application involves essentially identical calculations. The following discussion describes the open model in detail, and then outlines the necessary modifications to "close" the model.

The solution of an input-output model requires data on purchases in some base year by each industry and by final consumers. This data is then manipulated algebraically to construct a linear relationship between final demands and total production of each industry. Based upon this relationship, estimates can be made of income generated by changes in levels of economic activity in various industries. In the present application a 37-industry model of the Maine economy was used. To solve such an input-output model, the following data is required for any single year[7]:

$[TR]$: a 37 × 37 transactions matrix (one row and one column for each industry). An element $\{tr_{i,j}\}$ represents sales from the ith industry (located anywhere in the United States) to the jth Maine industry.

$\underline{TP}$: a 37-element vector of total production of each industry in Maine. An element $\{tp_i\}$ represents the output of the ith Maine industry.

$\underline{FD}$: a 37-element vector of final demands for the output of each industry. Each element $\{fd_i\}$ is the sum of personal consumption expenditures, State and local government purchases, Federal government purchases, gross private investment, net inventory change, foreign exports, and residual accounting elements (including service industry residuals, scrap and secondary transfers out) by Maine's consumers, businesses, and governments.

$\underline{TC}$: a 37-element vector of total intermediate and final consumption in Maine (whether purchased in or out of the State). An element $\{tc_i\}$ represents total Maine purchases from the ith industry.

From this data, we may derive the following:

$\underline{W}$: a 37-element vector of intermediate purchases by Maine businesses. Intermediate purchases include all goods and services used up in the productive process. Intermediate purchases do not include investment purchases, which are included in final demand. An element $\{w_i\}$ may be calculated as

$$w_i = \sum_{j=1}^{37} tr_{i,j}. \quad (1)$$

Alternatively, intermediate demand may be derived from the relation among total consumption, final demand, and intermediate demand:

$$tc_i = fd_i + w_i. \quad (2)$$

Now derive a matrix $[A]$ whose typical element $\{a_{i,j}\}$ is calculated:

$$a_{i,j} = tr_{i,j}/tp_j. \quad (3)$$

An element $\{a_{i,j}\}$ represents the direct requirements of inputs from industry i per dollar of output of industry j. $[A]$ is called a "technical coefficients matrix." We can then represent $\underline{W}$ as

$$\underline{W} = [A]\ \underline{TP}. \quad (4)$$

We can also derive a vector of value added coefficients, $\underline{V}$. Value added is the difference between value of output and cost of purchased materials. According to the accounting convention used, value added is the sum of all forms of income. An element $\{v_i\}$ is the percent of the value of total product which becomes income in the ith industry:

$$v_i = 1 - \sum_{i=1}^{37} a_{j,i}. \quad (5)$$

In a national input-output model, the next step would be to apply the accounting identity that total consumption equals total production for each product. This identity is not true in a regional model. Rather, there may be extensive net purchases from out-of-state firms, or substantial net sales to out-of-state buyers. Consequently, we must introduce vectors of net "exports" or net "imports" exchanged with the rest of the United States:

$\underline{M}$, a 37-element vector of net imports from other States. An element $\{m_i\}$ represents net purchases of the ith product by Maine consumers and businesses from out-of-state firms. For the base year, $\{m_i\}$ is calculated as:

$$\text{if } tc_i > tp_i, \text{ then } m_i = tc_i - tp_i, \text{ otherwise, } m_i = 0. \quad (6)$$

$\underline{X}$, a 37-element vector of net exports of products to consumers and firms in other States. For the base year, an element $\{x_i\}$ is calculated:

$$\text{if } tp_i > tc_i, \text{ then } x_i = tp_i - tc_i, \text{ otherwise } x_i = 0. \quad (7)$$

Let us now define a diagonal matrix $[Q]$. A diagonal element, $\{q_{i,i}\}$, of this matrix is defined:

$$q_{i,i} = m_i/tp_i. \quad (8)$$

Consequently:

$$\underline{M} = [Q]\underline{TP}. \quad (9)$$

Now, total production can be related to final demand and exports by algebraic manipulation of the preceding definitions:

$$\underline{TP} + \underline{M} = \underline{TC} + \underline{X}; \quad (10)$$
$$\underline{TP} + \underline{M} = \underline{FD} + \underline{W} + \underline{X}; \quad (11)$$
$$\underline{TP} + [Q]\underline{TP} = \underline{FD} + \underline{W} + \underline{X}; \quad (12)$$
$$\underline{TP} + [Q]\underline{TP} = \underline{FD} + [A]\underline{TP} + \underline{X}; \quad (13)$$
$$\underline{TP} + [Q]\underline{TP} - [A]\underline{TP} = \underline{FD} + \underline{X}; \quad (14)$$
$$([I] + [Q] - [A])\underline{TP} = \underline{FD} + \underline{X}; \quad (15)$$
$$\underline{TP} = ([I] + [Q] - [A])^{-1}(\underline{FD} + \underline{X}). \quad (16)$$

Finally, the vector of generated incomes, $\underline{Y}$, may be calculated. An element $\{y_i\}$ represents the income generated in the ith industry:

$$\underline{Y} = \underline{V}'\ [I]\ \underline{TP}. \quad (17)$$

Additionally, total State income, y^*, may be calculated

$$y^* = \underline{V}'\underline{TP}. \quad (18)$$

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[7]The notational conventions used throughout are: Vectors are underlined; matrices are indicated by brackets [ ]; elements of matrices are denoted by small, subscripted letters; scalars are indicated by small, asterisked letters; and the identity matrix is represented as $[I]$.

To close the model of the Maine economy, consumption demand must be removed from the final demand vector and made to depend endogenously upon the income generated within the model. To accomplish this, a 38th industry, the "household sector," is added to the transactions table, to the production vector, and to the consumption vector. The new column added to the transactions table measures the purchases of the household sector from each other sector. The new element in the total production vector equals total income. The new row in the transactions matrix represents the payments of all sectors to the household sector for services rendered in the process of production. This includes both labor and capital earnings. Because income is measured as value added in this model, the payments to the household sector by the jth industry $\{tr_{38,j}\}$ may be computed as:

$$tr_{38,j} = v_j \cdot tp_j. \qquad (19)$$

The new element in the total consumption vector equals zero, because households are assumed not to purchase directly from other households.

After the construction of the household sector and its inclusion as a new industry in the transactions matrix, the solution for the closed model is exactly analogous to the open (no household sector) model.

Because an input-output model is linear, it is not necessary to resolve the system for every conceivable change in production. Rather, the ratio of change in income to change in total production in any sector is a constant "multiplier" which may be applied to any hypothetical change in production. These multipliers are extremely useful policy tools, and are the most important product of this analysis.

To compute these multipliers, both versions of the model were solved for base year (1963) final demands. To estimate the separate impact of each sector, (e.g., groundfish harvesting) the total value of output of each sector was inflated by \$100,000. The model was then solved again to find a new total output vector consistent with this \$100,000 increase. The increase in each element in the new total output vector measured the increase in gross output from each industry necessary to support the hypothesized \$100,000 increase in output. The sum of these changes constitutes an estimate of the total impact (per \$100,000) of groundfish harvesting (for example) on the gross output of industries within the State. This was done for each of the nine fishery sectors using both the "closed" and "open" models.

When combined with the information on value added in each industry, these estimates of change in the gross value of output can be translated into estimates of expected changes in income—direct, indirect, and induced. Direct income per dollar for any industry is simply v_i, the value added per dollar of output. The indirect plus direct income impact per dollar is computed as the ratio of the change in total State income to the change in gross output, as estimated in the open model. Subtraction of the direct effect yields the indirect effect alone. Finally, the change in direct plus indirect plus induced income per dollar of sales is estimated within the closed model. Again, the induced effect can be calculated by subtraction.

To summarize mathematically, let us introduce the notational convention that a subscript "o" refers to the open model and the subscript "c" refers to the closed model. The multipliers for each of the nine fisheries sectors are calculated:

$$\text{direct income multiplier} = v_i \qquad (20)$$

$$\text{indirect income multiplier} = (\Delta y^*/\Delta tp_i)_o - v_i \qquad (21)$$

$$\text{induced income multiplier} = (\Delta y^*/\Delta tp_i)_c - (\Delta y^*/\Delta tp_i)_o - v_i. \qquad (22)$$