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A Review of Regional Economic Models for Alaska Fisheries

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Preface

There are many regional economic models in the literature, and a limited number have been used to investigate the impacts of fishery management policies on communities. However, there is no formal study in the literature that provides a thorough, comparative evaluation of the regional economic models that have been, or can be, used for regional impact analysis for fisheries. In Part I, we describe the Alaska seafood industry, discuss the importance of the industry to the state economy, and indicate the importance of regional economic analysis for the Alaska seafood industry. Next a theoretical overview of regional economic models is provided. Specifically, we discuss major features of each type of regional economic model – economic base model (EB), input-output model (IO), social accounting matrix model (SAM), supplied-determined model, and computable general equilibrium model (CGE). Finally, a comparative discussion of these models is also provided. While Part I focuses on a theoretical review of regional economic models, Part II discusses applications of those regional economic models to fisheries. These include input-output (IO) models, which have been used in many previous studies of regional economic impacts for fisheries, the Fisheries Economic Assessment Model (FEAM), which has been one of the major analytical tools used to examine the impacts of fisheries on the West Coast and in Alaska, and the first regional computable general equilibrium (CGE) model used for fisheries in a U.S. region. In addition, some issues related to specifying such models for Alaska fisheries, data needs and availability for modeling regional economic impacts for Alaska fisheries, and perspectives on regional economic modeling for Alaska fisheries are discussed.

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PART I

Introduction

The Alaska economy is heavily dependent on the seafood industry. Therefore, it is important to be able to estimate the impacts of various fishery management actions on this industry and on the economy as a whole. In 2002, about 5.1 billion pounds of fish and shellfish were harvested in waters off Alaska with an ex-vessel value of about $812 million (National Marine Fisheries Service (NMFS) 2003). In the same year, groundfish accounted for 58% of the ex-vessel value; shellfish, 15%; salmon and halibut, 13% each; and herring 1% (NPFMC 2003). Over the past 5 years, about 23.9 billion pounds of seafood have been harvested in waters off Alaska (NMFS, various years). In 2002, 54%, by weight, of the U.S. commercial fishing harvest came from Alaska (NMFS 2003).

The Alaska seafood industry is an important industry in the state, both in terms of employment and income. Alaska's dominant position in the U.S. seafood industry translates into more than 16% of the state's basic sector employment and more than 47% of private basic sector employment (ahead of oil and gas, mining, forest products, and tourism). Seafood is Alaska's top international export. Fish products represent approximately 40% of Alaska's international exports. Participation and employment in the Alaskan seafood industry has grown in the last decade.

The fishing industry is important to Alaska's residents and communities. Alaskans own about 75% of the total limited entry fishing permits. More than 50% of these Alaskan permit holders reside in rural areas of the state. For many small coastal and river communities, commercial fishing is the major source of income, whether it is direct or indirect. The cities and boroughs of the state receive one-half of the state's fisheries business taxes. Their share of both the FY00 fisheries business and fisheries landing taxes was $19.9

million. For many small communities, this likely represents a significant portion of their tax base (Alaska Department of Fish and Game (ADFG) 2001).

Although the sheer size and importance of this industry to Alaska's regional economy necessitates careful analysis of the effects of fishery policies, federal laws also mandate that such work should be undertaken. Economic analysis of the proposed fishery management policies is required by the Magnuson-Stevens Fishery Conservation and Management Act, National Environmental Policy Act (NEPA), and Executive Order 12866. Economic analysis should include evaluation of regional and community economic impacts of changes in (i) the biological condition of fishery resources, (ii) economic conditions of fishery industries, and (iii) regulations and policies regarding fisheries. To satisfy the requirements of National Standard 8, it is critical to evaluate the regional economic impacts of the proposed fishery management policies. To inform the policymakers and the public of the likely impacts associated with fishery management policies, economists need appropriate economic models to estimate the regional economic impacts attributable to fishery policies.

There are many regional economic models in the literature, and a limited number have been used to investigate the community impacts of fishery management policies. However, there has been no formal study in the literature that provides a thorough comparative evaluation of the regional economic models that have been, or can be, used for regional or community impact analysis for fisheries. In this context, the purpose of this critical review is to:

i) provide a theoretical overview and comparative discussion of the regional economic models,

ii) discuss modeling and data issues in relation to use of these regional economic models for fishery management, and

iii) provide a perspective on regional economic modeling for fisheries in Alaska.

This review consists of two major parts. Part I includes this introduction, a theoretical overview and comparison of regional economic models, and a summary of Part I. Part II includes an overview of the topics to be discussed in Part II, describes regional economic models used to assess the effects of fishery management actions and the issues involved in specifying such models for Alaska fisheries; discusses the data needs and availability for modeling regional economic impacts for Alaska fisheries, and concludes this review and summarizes the major considerations involved in applying regional economic models to Alaska fisheries. Finally, an Appendix details the structure of the Fisheries Economic Assessment Model (FEAM), which has been one of the major analytical tools used to examine the regional economic impacts of fisheries on the West Coast and in Alaska.

Theoretical Overview of Regional Economic Models

Several types of economic impact models have been used to analyze regional economic issues. These include export-base or economic base (EB) models, input-output (IO) models (Miller and Blair 1985), social accounting matrix (SAM) models, and computable general equilibrium (CGE) models. The EB model is the simplest regional economic impact model, followed by the IO model, which has been fundamental to regional economic analysis for the past half century. In an IO model, the effects of changes in exogenous final demand on the economy are calculated using multipliers. The SAM model represents a recent extension of IO analysis (e.g., Adelman and Robinson 1986, Marcouiller et al. 1995). Its genesis is the result of dissatisfaction with both the nature of IO analysis and its limitations in assessing income distribution impacts. However, even the SAM model shares certain other limitations with IO. Specifically, in both types of models, prices are assumed to be fixed and no factor substitution in production or commodity substitution in consumption is allowed. As a result, these models tend to overestimate the impacts.

Regional economists have also used supply-determined IO (SD-IO) models in which final demands for some sectors and gross outputs for the remaining sectors are specified exogenously (Miller and Blair 1985, Chapter 9). SD-IO models were used in situations where the productive capacity of a sector is exogenously reduced. Recently, SAM versions of the SD model, so called supply-determined SAM (SD-SAM) models, have been developed to examine the impact of a change in industry productive capacity on income distribution. Although these SD models are more useful for analyzing the impact of a reduction in productive capacity than the conventional IO and SAM models, they share the same limitations discussed above.

Computable general equilibrium (CGE) models overcome the limitations of these fixed-price models. In CGE models, prices are allowed to vary and substitution effects in production and consumption are allowed. The CGE model also enables analysts to examine the welfare implications of a policy change. Furthermore, the CGE approach is more appropriate than other regional economic model for analyzing the impacts of change in productive capacity of resource-dependent industries.

The following section explains the theoretical framework and elaborates on the strengths and weaknesses of each of these type of models. A comparative discussion of these models is provided at the end of this section.

Economic Base (EB) Models

This subsection draws on Blair (1995). The EB model is based upon the idea that regional economic growth (an increase in income or employment) is attained only by an increase in exports. According to EB theory, the economy is divided into two sectors – a basic sector and a non-basic sector. The basic sector is an export sector, while the non-basic sector includes local industries that serve local demand. In EB theory, export activity is the engine of growth. Export industries generate money that flows into a region. A portion of the income from exports is spent locally by the export workers, which creates local service jobs. In turn, workers serving the local economy spend much of their income locally, thus supporting additional jobs. A portion of the income from these additional jobs is spent locally, generating similar effects. This process continues until the effects disappear.

A simple EB model is presented below (Blair 1995). The EB theory can be derived from the circular flow model. Income can be expressed as

$$Y = C + (E - M), \qquad \text{Eq. (1)}$$

where Y is total regional income, C is consumption, E is exports, and M is imports. This equation says that income of local residents is equal to consumption (C) plus net monetary inflows (E-M). Consumption consists of two components. One component is independent of level of income. The other component is dependent on local income. The consumption equation is

$$C = A + bY \text{ ,} \qquad \text{Eq. (2)}$$

where A is constant, and b is marginal propensity to consume. Imports are determined by the level of local income as follows:

$$M = iY \text{ ,} \qquad \text{Eq. (3)}$$

where i is the marginal propensity to import.

Substituting Equations (2) and (3) into Equation (1),

$$Y = \frac{1}{1-b+i}\left(A+E\right). \qquad \text{Eq. (4)}$$

Here, $1/(1\text{-}b\text{+}i)$, which is greater than one, is called the EB multiplier. The EB multiplier is calculated as the ratio of total (i.e., basic plus non-basic) activity to basic activity. In practice, estimates of industry employment and/or payroll are generally used as indicators of regional economic activity. Thus, an EB employment multiplier is used to calculate the total number of jobs generated by an increase in export sales sufficient to require the addition of one job in a regional basic industry. The EB multiplier is conceptually similar to the Keynesian multiplier in macroeconomic analysis. The multiplier effect occurs because the initial increase in export income is spent and re-spent, creating additional income. However, some of the additional spending leaks out of the region in the form of monetary outflows. More detailed analysis or discussion of the EB theory is found in North (1955), Tiebout (1956), and Richardson (1973). Excellent critical reviews of theoretical and empirical studies of EB models may also be found in Krikelas (1991) and Krikelas (1992).

The EB model appeals to regional economists because it provides a clear link between the national economy and the regional economy of interest within a standard income determination framework (Richardson 1985). However, the EB theory has many limitations. Some of the important limitations are the following. First, the EB model is a purely demand-side model and gives no attention to the supply side of the economy. For example, labor in-migration or population growth changes the productive capacity of a region, increases output, and leads to economic growth of the region. Also, increases in factor productivity – such as an increase in labor productivity due to education and job training, or an increase in capital productivity due to technological progress – can contribute to economic growth of a region. Second, the theory ignores import substitution as an alternative development strategy. Rather than increasing exports, it may be useful to produce locally what otherwise would have been imported. If products currently being imported are produced locally, which reduces the quantity of imports, the marginal propensity to import in the Equation (4) above will be reduced. This will increase the value of the multiplier for a given amount of exports. Third, a more fundamental criticism concerns the definition of a basic sector. Although balance of trade statistics (accounts of international flows of goods, services, and finances) are available at the national level, there is no authoritative accounting of transboundary (i.e., exports and imports) flows for sub-national regions. Consequently, it is necessary to estimate the contribution of various industries' activities to a region's economic base. This is generally done by either the simple assignment method (in which all manufacturing and resource-based activity is simply defined as basic), or the location quotient method (in which basic industries are defined as those providing a greater proportion of regional employment than that industry does at the national level). Both of these methods can create serious errors in the estimates of the export base, especially if the structure of regional production and consumption is very different than the national average. Also, neither method accounts for the growing prevalence of self-employed activity and the emergence of non-manufacturing exports (e.g., producer services) (Waters et al. 1997). Fourth, a major problem with standard economic base analysis is that it excludes "non-traditional" components of a regional economic base. These "non-traditional" components include transfer and property type income, most of which may be derived from sources outside of a region, and federal government expenditures made in the region (Waters et al. 1997). Finally, it is very difficult to tell how much local non-basic activity was attributable to a particular basic industry since its effects are mixed with impacts caused by other basic industries located in the same region. To separate out the impacts of a particular basic industry in the interdependent economy, economists have turned to IO models.

Input-Output (IO) Models

The following discussion relies on Miller and Blair (1985). In the 1930s, Wassily Leontief developed an IO model of the U.S. to examine the economic interrelationships among its industries, and the IO model has been fundamental to regional economic analysis ever since. In the IO model, changes in final demand, an exogenous variable, are estimated and the effects of these changes on the economy are calculated using multipliers. Since the development of the IO model by Leontief, several studies have used it to analyze agriculture (e.g., Geier and Holland 1991, Leones et al. 1994, Sills et al. 1994), regional economic issues (e.g., Hughes et al. 1991, Holland and Cooke 1992), resource management problems (e.g., Young and Gray 1985, Hamilton and Gardner 1986, Martin et al. 1988; Waters et al. 1994), environmental issues (e.g., Cumberland and Stram 1976, Rose 1983), and marine recreational fisheries (Schorr et al. 1995, Storey and Allen 1993, Herrmann et al. 2001). Application of IO models to investigate the impacts of fishery management policies will be discussed in later in Part II.

Miernyk (1965), Miller and Blair (1985), and Hewings (1985) provide more detail on the IO model. In this review, we will discuss the fundamental features of single-region IO models. See Hewings and Jensen (1986) for a discussion of interregional and multiregional IO models. A survey of IO studies is found in Richardson (1985).

Fundamental Relationships

Suppose that a regional economy is divided into *n* sectors, and that total output of sector *i* and total final demand for sector *i's* product are denoted X_i and Y_i, respectively. Then, the following equations hold:

$$X_i = Z_{i1} + Z_{i2} + \ldots + Z_{ii} + \ldots + Z_{in} + Y_i \qquad i = 1, 2, \ldots, n, \qquad \text{Eq. (5)}$$

where Z_{ij} are monetary values of interindustry sales from sector *i* to sector *j*. The *jth* equation in the above equation system represents the distribution of sector *j's* output. Consider the elements in the ith column on the right-hand side of the equations represented by Equation

(5), [Z_{1i}, Z_{2i}, …, Z_{ii}, …, Z_{ni}]. These elements are sector *i's* purchases of products of the various producing sectors, which are used as inputs in sector *i's* production. These inputs are called intermediate inputs. In the IO framework, a fundamental assumption is that the interindustry flows from *i* to *j* depend entirely and exclusively on the total output of sector *j*. The ratio of the flow of input from *i* to *j* (Z_{ij}) to sector *j's* output (X_j) is called a technical coefficient or input-output coefficient (a_{ij}):

$$a_{ij} = \frac{Z_{ij}}{X_j} \quad \text{or} \quad X_j = \frac{Z_{ij}}{a_{ij}} \quad \text{or} \quad Z_{ij} = a_{ij} X_j . \qquad \text{Eq. (6)}$$

Since these technical coefficients determine fixed proportions of inputs necessary to produce output, the production function in an IO model can be represented as

$$X_j = \min\left(\frac{Z_{1j}}{a_{1j}}, \frac{Z_{2j}}{a_{2j}}, \ \ldots.., \frac{Z_{nj}}{a_{nj}} \right). \qquad \text{Eq. (7)}$$

Substituting Equation (6) into Equation (5), and rearranging the terms,

$$\begin{array}{l}
(1-a_{11})X_1 - a_{12}X_2 - \ldots.. - a_{1i}X_i - \ldots.. - a_{1n}X_n = Y_1 \\
-a_{21}X_1 + (1-a_{22})X_2 - \ldots.. - a_{2i}X_i - \ldots.. - a_{2n}X_n = Y_2 \\
. \\
-a_{i1}X_1 - a_{i2}X_2 - \ldots.. + (1-a_{ii})X_i - \ldots.. - a_{in}X_n = Y_i \\
. \\
-a_{n1}X_1 - a_{n2}X_2 - \ldots.. - a_{ni}X_i - \ldots.. + (1-a_{nn})X_n = Y_n.
\end{array} \qquad \text{Eq. (8)}$$

Expressing Equation system (8) in matrix terms,

$$(\mathbf{I}-\mathbf{A})\mathbf{X} = \mathbf{Y}, \qquad \text{Eq. (9)}$$

where **I** is *nxn* identity matrix; **A** is *nxn* input-output coefficient matrix of a_{ij}'s; **X** is a column vector of X_i's; and **Y** is a column vector of Y_i's. Here, **X** is a vector of endogenous variables and **Y** a vector of exogenous variables. If **(I-A)** is non-singular, Equation system (9) can be solved for **X** as

$$\mathbf{X} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{Y}, \qquad \text{Eq. (10)}$$

where $(\mathbf{I}-\mathbf{A})^{-1}$ is often referred to as Leontief inverse. When there is a change in final demand (**Y**), Equation (10) can be used to calculate the total impact on output (**X**) in the different sectors of the economy.

Open Versus Closed Models

The exogenous final demand for a sector's output in Equation (10) consists of household demand, government demand, investment demand, and exports. Although households tend to purchase goods for final consumption, the amount of their purchases is related to their income, which they earn in payment for their labor inputs to production processes. Their labor income depends on the output of each of the production sectors. In most economies, consumer expenditures constitute a major portion of final demand. Thus, one could make the household sector an endogenous sector. This is known as closing the model with respect to households. So the Equation system (5) would now be modified to

$$X_i = Z_{i1} + Z_{i2} + \ldots + Z_{ii} + \ldots + Z_{in} + Z_{i(n+1)} + Y_i^* \qquad i = 1,2, \ldots, (n+1). \qquad \text{Eq. (11)}$$

In Equation (11), $Z_{i(n+1)}$ represents household demand for sector *i's* output and Y_i^* is the remaining final demand for the sector's output. In addition to this modification on each of the equations in Equation system (5), there would be one new equation for the total output of the household sector; that is, the total value of its sales of labor services to the various sectors or total earnings of households. The new equation is

$$X_{n+1} = Z_{(n+1)\,1} + Z_{(n+1)\,2} + \ldots + Z_{(n+1)\,i} + \ldots + Z_{(n+1)\,n} + Z_{(n+1)\,(n+1)} + Y_{(n+1)}^*. \qquad \text{Eq. (12)}$$

Here, $Z_{(n+1)\,i}$ ($i = 1,2, \ldots, n$) represents dollar flows from sector *i* to households; that is, wages and salaries received by households from sector *i*, and $Z_{(n+1)\,(n+1)}$ represents household purchases of labor services. The last term in Equation (12), $Y_{(n+1)}^*$, would include, for example, payments to government employees. Household input-output coefficients are determined in the same manner as any other element in an input-output matrix. The value of sector *j's* purchases of labor services, $Z_{(n+1)\,j}$, divided by the value of total output of sector *j*, X_j, gives the value of household labor services used per dollar's worth of sector *j's* output, that is,

$$a_{(n+1)j} = \frac{Z_{(n+1)j}}{X_j}. \qquad \text{Eq. (13)}$$

For household consumption of output from producing sectors, the value of sector *i's* sales to households, $Z_{i(n+1)}$, is divided by the total output of the household sector, X_{n+1}, yielding household consumption coefficients,

$$a_{i(n+1)} = \frac{Z_{i(n+1)}}{X_{n+1}}. \qquad \text{Eq. (14)}$$

Substituting Equations (6), (13), and (14) into Equations (11) and (12) and rearranging the terms yields

$$\begin{array}{l}
(1-a_{11})X_1 - a_{12}X_2 - \ldots - a_{1i}X_i - \ldots - a_{1n}X_n - a_{1(n+1)}X_{(n+1)} = Y_1^* \\
-a_{21}X_1 + (1-a_{22})X_2 - \ldots - a_{2i}X_i - \ldots - a_{2n}X_n - a_{2(n+1)}X_{(n+1)} = Y_2^* \\
. \\
-a_{i1}X_1 - a_{i2}X_2 - \ldots + (1-a_{ii})X_i - \ldots - a_{in}X_n - a_{i(n+1)}X_{(n+1)} = Y_i^* \\
. \\
-a_{n1}X_1 - a_{n2}X_2 - \ldots - a_{ni}X_i - \ldots + (1-a_{nn})X_n - a_{n(n+1)}X_{(n+1)} = Y_n^* \\
-a_{(n+1)1}X_1 - a_{(n+1)2}X_2 - \ldots - a_{(n+1)i}X_i - \ldots - a_{(n+1)n}X_n + (1-a_{(n+1)(n+1)})X_{(n+1)} = Y_{n+1}^*.
\end{array} \qquad \text{Eq. (15)}$$

Expressing Equation system (15) in matrix terms,

$$\mathbf{(I - A^*)X^* = Y^*}, \qquad \text{Eq. (16)}$$

where **I** is *(n+1)x(n+1)* identity matrix; **A*** is *(n+1)x(n+1)* input-output coefficient matrix; **X*** is a column vector of X_i^*'s; and **Y***is a column vector of Y_i^*'s. Solving Equation system (16) for **X***,

$$\mathbf{X^* = (I - A^*)^{-1}Y^*}. \qquad \text{Eq. (17)}$$

Multipliers

The notion of multipliers rests upon the difference between the initial effect of an exogenous (final demand) change and the total effects of that change. Total effects can be defined in one of two ways – either as the direct and indirect effects (found via elements in the Leontief inverse of an "open" IO model), or as direct, indirect, and induced effects (in the elements of the Leontief inverse of a "closed" IO model). Direct effects represent the impacts of the expenditures and/or production values specified as direct final demand changes. Indirect effects represent the impacts caused by iteration of changes in industries' purchases from other industries in response to the direct final demand changes. Induced effects represent the impacts on all local industries caused by the change in expenditure of household income generated by the direct and indirect effects resulting from direct final demand changes. The multipliers that result from using direct and indirect effects only are known as simple multipliers. When direct, indirect, and induced effects are used, they are called total multipliers. Three of the most frequently used types of multipliers are those that estimate the effects of exogenous changes on outputs of the sectors in the economy, on income earned by households because of the new outputs, and on employment (in physical terms) that is expected to be generated because of the new outputs.

A simple output multiplier for sector j is defined as the total value of production in all sectors of the economy that is necessary in order to satisfy a dollar's worth of final demand for sector *j's* output. Formally, the simple output multiplier is the ratio of the direct and indirect effect to the initial effect of the change in final demand. Suppose the elements of the Leontief inverse in Equation (10) are α_{ij}'s. Then the simple output multiplier for sector j is given by

$$O_j = \sum_{i=1}^{n} \alpha_{ij} \ . \qquad \text{Eq. (18)}$$

The total output multiplier, that also captures the induced effects, calculated as

$$O_j^* = \sum_{i=1}^{n+1} \alpha_{ij}^* \ , \qquad \text{Eq. (19)}$$

where α_{ij}* denote the elements in Leontief inverse in Equation (17). The simple income multiplier is given by

$$H_j = \sum_{i=1}^{n} a_{(n+1)i} \alpha_{ij} \ . \qquad \text{Eq. (20)}$$

A simple income multiplier of, say, 0.5 for sector *j* implies that an additional dollar of final demand for sector *j's* output, when all the direct and indirect effects are converted into dollar estimates of income, would generate $0.5 of new household income. The total income multiplier is calculated as

$$H_j^* = \sum_{i=1}^{n+1} a_{(n+1)i} \alpha_{ij}^* = \alpha_{(n+1)j}^* \ . \qquad \text{Eq. (21)}$$

The simple employment multiplier is given by

$$E_j = \sum_{i=1}^{n} w_{(n+1)i}\alpha_{ij} \ , \qquad \text{Eq. (22)}$$

where $w_{(n+1)i}$ is number of employees per dollar's worth of output in sector *i*. A simple employment multiplier for sector *j* of, say, 0.005 implies that a total of 0.005 jobs will be created in the economy due to an increase in final demand of $1 for the output of sector *j*. The total employment multiplier is given by

$$E_j^* = \sum_{i=1}^{n+1} w_{(n+1)i}\alpha_{ij}^* \qquad \text{Eq. (23)}$$

Limitations of Input-Output (IO) Models

Input-output models are very useful for capturing the inter-industry linkages in a regional economy. The models are relatively easy to implement with data from IMPLAN (IMpact analysis for PLANning, Minnesota IMPLAN Group). Though these models remain useful for the analysis of some regional economic issues, the models have some critical limitations. First, the IO model is demand-driven and assumes that the supply of outputs and inputs is unlimited with commodity and factor prices fixed (i.e., the change in demand is always satisfied by increased supply). The result of this assumption is that the model tends to overestimate the effects of policies (Hunter 1989, Miller and Blair 1985). Second, the behaviors of firms and households are not derived from constrained optimization. In the IO model, factor substitution in production and commodity substitution in consumption are not allowed. Instead, the model assumes fixed factor ratios in production and fixed expenditure ratios in consumption. Therefore, IO models are not appropriate for the study of economies facing factor constraints or shifts in relative prices. Third, the technical coefficients or input-output coefficients (a_{ij}) are assumed to be fixed. This assumption is not appropriate in situations where the technical coefficients change due to change in production technology of industries.

Social Accounting Matrix (SAM) Models

The SAM model is an extension of IO analysis that arose due to dissatisfaction with both the nature of IO analysis and its incomplete measure of distributional impacts (Pyatt and Round 1985, Kuening and de Ruijter 1988). During the 1980s, SAMs were used to more fully analyze regional economic development (Eckaus et al. 1981, Cohen 1988, Skountzos 1988), including the effects on income distribution (Adelman and Robinson 1986, Havinga et al. 1987, and Marcouiller et al. 1993). However, because a SAM model has the same basic characteristics and assumptions as an IO model, it cannot overcome the inherent limitations discussed above.

Social Accounting Matrix

A SAM is a matrix of balanced expenditure and income accounts, and provides a tabular snapshot of the economy at one point in time. Constructing a SAM begins with specifying the IO accounts consisting of detailed industry, commodity, factor, and final demand transactions that are balanced to reflect market-level equilibrium, as well as the aggregate income-expenditure equilibrium (Table 1). A SAM also provides information on non-market financial flows by capturing payments of taxes by individuals and businesses, and fund transfers between people or institutions. SAM accounts are an extension of traditional IO accounts. Like IO analysis, a full SAM is a double-entry bookkeeping system capable of tracing monetary flows through debits and credits similar to T-Accounts in basic financial accounting. The column entries represent expenditures or payments made by the economic agents. The row entries represent receipts or income to agents. By accounting definition, total receipts equal total expenditures. For a more detailed discussion of a SAM, see King (1985). The structure of a regional SAM is given in Table 1.

Social Accounting Matrix Models

A standard IO model includes the intersectoral flows of intermediate inputs and so captures one major source of linkages in the economy. However, the IO model ignores the flows from producing sectors to factors of production (value added), and then on to entities such as government and households, and finally back to demand for goods. In a SAM model, these flows can be captured. A SAM model can also examine the distribution of income to various types of institutions and households; that is, the distribution of nominal income between wages and profits and the distribution of wages and profits between various types of households. Discussion of the structure of SAM models below is based on Holland and Wyeth (1993) and Adelman and Robinson (1986).

Table 2 presents an aggregate SAM for the United States in 1982. In the SAM, there are twelve endogenous sectors or accounts and three exogenous sectors or accounts. The twelve endogenous accounts include three industrial sectors (agriculture, agriculture related activity, and other activities), three value-added accounts (labor income, capital income, and indirect business taxes), three institutions (labor, proprietors, and enterprises), and three household types (low, medium, and high income households). The three exogenous accounts are a capital account, government, and the rest of the world.

Dividing each element in a column in the SAM by the sum of the elements in the column results in a matrix of coefficients. Removing the columns and rows for the exogenous accounts from the matrix of coefficients results in the matrix of SAM direct coefficients denoted **S**. Matrix **S** consists of several submatrices. Submatrix **A** is a matrix of technical coefficients indicating the interindustry flows of goods and services. Submatrix **V** is a matrix of value-added coefficients representing how the sectoral income is distributed to each category of value added. Submatrix **Y** is a matrix of value-added distribution coefficients showing how value added is distributed to each of the six institutional subaccounts. Submatrix **C** is a matrix of expenditure coefficients accounting for income spent by each of the six institutional subaccounts on the three industrial commodities. Submatrix **H** is a matrix of institutional and household distribution coefficients. The full matrix **S** of the SAM direct coefficients is

$$S = \begin{bmatrix} A & O & C \\ V & O & O \\ O & Y & H \end{bmatrix}. \qquad \text{Eq. (24)}$$

Then the SAM model can be represented as

$$\begin{bmatrix} X \\ V \\ Y \end{bmatrix} = (I - S)^{-1} \begin{bmatrix} ex \\ ev \\ ey \end{bmatrix}, \qquad \text{Eq. (25)}$$

where

X: vector of sectoral supply (3x1)
V: vector of value added by categories (3x1)
Y: vector of institutional (households') incomes (6x1)
I : identity matrix
ex: vector of exogenous commodity demand (3x1)
ev: vector of exogenous value added (3x1)
ey: vector of exogenous institutional (households') incomes (6x1).

Denoting

$$Q = \begin{bmatrix} X \\ V \\ Y \end{bmatrix} \quad \text{and} \quad R = \begin{bmatrix} ex \\ ev \\ ey \end{bmatrix},$$

the SAM model can be represented as

$$Q = (I - S)^{-1} R, \qquad \text{Eq. (26)}$$

where $\mathbf{(I\text{-}S)^{-1}}$ is called the SAM multiplier matrix or matrix of SAM inverse coefficients. Endogenous accounts that pertain to the SAM constructed here in Equation (26) are production sectors, value added, and institutional accounts (which include enterprise and various types of households). Exogenous accounts are specified as government, capital and the rest of the world. Injections to the system include transfers to institutions and to households from government and the rest of the world. In addition, injections occur through demands on production activities generated by government, investment and exports to the rest of the world. Leakages included taxes, savings and imports.

Supply-determined Models

The SD-IO model is a special case of impact analysis in which final demands for some sectors and gross outputs for the remaining sectors are specified exogenously. This model has thus proven useful to regional economists to examine situations in which the productive capacity of a sector is curtailed or eliminated (e.g., Petkovich and Ching 1978, Johnson and Kulshreshtah 1982, and Papadas and Dahl 1999). Recently, SAM versions of the SD model, so called SD-SAM models, have been developed to examine the impact of timber production on income distribution (Marcouiller et al. 1993, Marcouiller et al. 1995), the impacts of European dairy quota (Roberts 1994), or to analyze the effects of public land grazing reductions on urban and rural northern Nevada (Harris et al. 1996). In a study comparing the SD-SAM and CGE models, Seung et al. (1997) examine the effects of exogenous reductions in output levels of livestock, other crops, and hay and pasture sectors. Sectoral final demand changes are increased expenditures in recreation-related sectors from increased wetlands tourism. Their study treats the decrease in the agricultural outputs and the increase in the final demand for the recreation-related sectors as exogenous. Only the SD-SAM model will be discussed below because the SD-IO model shares a very similar structure. Miller and Blair (1985; Chapter 9) provide a detailed explanation of the SD-IO model. Discussion of the structure of SD-SAM model below is based on Seung et al. (1997).

Suppose there are *n* production sectors, a value-added account, and a household account in the economy. Suppose further that the first *k* sectors' outputs are supply-determined. In the SD-SAM model, the first *k* sectors' outputs are treated as exogenous variables and the final demand variables for the first *k* sectors (ex_1, ex_2, …, ex_k) are treated as endogenous variables. Moving the exogenous variables to the right hand side and the endogenous variables to the left hand side in the equation system represented by Equation (25) or Equation (26), and expressing the equations in matrix form, the SD-SAM model can be represented by (Miller and Blair 1985, Marcouiller et al. 1995):

$$Z \quad = \quad B^{-1}W \ , \qquad \text{Eq. (27)}$$

where Z is a column vector, whose elements are

$$Z \quad = \quad \lfloor ex_1, ex_2, \ldots, ex_k, X_{(k+1)}, X_{(k+2)}, \ldots, X_n, \ldots, V, Y \rfloor ;$$

$$B \quad = \quad \begin{bmatrix} -1 & 0 \cdots & 0 & -S_{1(k+1)} & -S_{1(k+2)} & \cdots -S_{1n} & -S_{1v} & -S_{1y} \\ 0 & -1 \cdots & 0 & -S_{2(k+1)} & -S_{2(k+2)} & \cdots -S_{2n} & -S_{2v} & -S_{2y} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 \cdots & -1 & -S_{k(k+1)} & -S_{k(k+2)} & \cdots -S_{kn} & -S_{kv} & -S_{ky} \\ 0 & 0 \cdots & 0 & (1-S_{(k+1)(k+1)}) & -S_{(k+1)(k+2)} & \cdots -S_{(k+1)n} & -S_{(k+1)v} & -S_{(k+1)y} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 \cdots & 0 & -S_{y(k+1)} & -S_{y(k+2)} & \cdots -S_{yn} & -S_{yv} & (1-S_{yy}) \end{bmatrix} ; \text{ and}$$

$$W = \begin{bmatrix} -(1-S_{11})X_1 & + & S_{12}X_2 & + \cdots\cdots + & S_{1k}X_k & \\ S_{21}X_1 & - & (1-S_{22})X_2 & + \cdots\cdots + & S_{2k}X_k & \\ \vdots & & \vdots & & \vdots & \\ S_{k1}X_1 & + & S_{k2}X_2 & + \cdots\cdots & -(1-S_{kk})X_k & \\ S_{(k+1)1}X_1 & + & S_{(k+1)2}X_2 & + \cdots\cdots + & S_{(k+1)k}X_k & + ex_{(k+1)} \\ \vdots & & \vdots & & \vdots & \vdots \\ S_{n1}X_1 & + & S_{n2}X_2 & + \cdots\cdots + & S_{nk}X_k & + ex_n \\ S_{v1}X_1 & + & S_{v2}X_2 & + \cdots\cdots + & S_{vk}X_k & + ev \\ S_{y1}X_1 & + & S_{y2}X_2 & + \cdots\cdots + & S_{yk}X_k & + ey \end{bmatrix}.$$

Here S_{ij}'s are the elements of matrix **S**; X_1, X_2, …, and X_k are exogenous variables, which denote the output levels of the supply-determined sectors; ex_{k+1}, ex_{k+2}, …, ex_n, ev, and ey are exogenous final demand variables; and ex_1,ex_2,…, ex_k, X_{k+1}, X_{k+2}, …, X_n, V, and Y are endogenous variables.

These SD models are very useful for investigating the impacts of reduced production capacity for resource-dependent economic sectors. However, they have the same limitations that a fixed-price model faces (i.e., fixity of prices, no factor substitution in production and no commodity substitution in consumption). In addition, the SD models employ more restrictive assumptions than the conventional IO or SAM models. By making the supply-determined sectors' outputs exogenous, the final demands for the same sectors are "forced" to be endogenous.

Computable General Equilibrium (CGE) Models

Computable general equilibrium (CGE) models are based on the Walrasian general equilibrium structure (Walras 1954) formalized by Kenneth Arrow, Gerard Debreu, and others in the 1950s. The models explicitly incorporate supply constraints, identify prices and quantities separately, and have smooth, twice differentiable production and preference functions. Thus, substitution effects in production and in consumption are allowed in CGE models. Factor and commodity markets attain their equilibrium through the adjustment of relative prices.

Computable general equilibrium (CGE) models have been used for dealing with the issues of efficiency, distortionary, and distributional effects of national tax policies and international trade policies. Many CGE tax models are based on Harberger's (1959, 1962, 1966) analysis of corporate and capital income taxes in the United States. The theoretical foundation of most models dealing with the impacts attributable to change in trade policies is the trade theory formulated by Heckscher and Ohlin. Some examples of the national-level CGE models include Robinson et al. (1990), Hertel and Tsigas (1988), and Shoven and Whalley (1984). A survey of CGE models of tax and trade policies is available in Shoven and Whalley (1984).

The primary drawback in regional CGE analysis has traditionally been a lack of regional data. However, the development of the IMPLAN database (Alward et al. 1989) and more recent developments of regional SAMs have spurred both interest in, and development of, regional CGE models. For example, Harrigan and McGregor (1988) used a two-region model of Malaysia to analyze the effects of change in world demand for commodities produced in Malaysia. The authors simulated the effects under (i) a neoclassical closure, in which labor markets clear continuously, and (ii) a Keynesian closure, which assumes rigid nominal wages. Morgan et al. (1989) used a six-region model of the United States to study the impacts of unilateral and multilateral removal of regional (state and local) and Federal taxes. Kraybill et al. (1992) used a two-region model of the United States to examine regional impacts of the Federal budget deficit and international trade imbalances. The results of their analysis show that Federal fiscal policies have important implications for the pattern of income distribution across regions. Seung et al. (2000) developed a dynamic CGE model for a rural county in Nevada, in which the economic impacts of reallocating water from irrigated agriculture to recreational use in a rural county in Nevada are examined. Seung and Kraybill (2001) employed a dynamic CGE model to investigate the effects of infrastructure investment for Ohio. For fisheries, Houston et al. (1997) developed a regional CGE model to evaluate the impacts associated with reduced marine harvests for a coastal Oregon region.

Overview of a Generic Computable General Equilibrium (CGE) Model

For expositional clarity, the discussion of a generic CGE model is limited to static, single-region models. For an excellent survey of regional CGE models including multiregional CGE models, see Partridge and Rickman (1998).

Production -- Most of CGE models employ a two-level production function. In the first level, a value-added function is used to determine the components of the value added:

$$VA_i = VA_i \ (L_i, K_i; \Omega_i), \qquad \text{Eq. (28)}$$

where VA_i denotes a quasi-concave value-added function, L_i and K_i are labor and capital employed in sector *i*, and Ω_i is a vector of parameters. Cobb-Douglas (CD) or Constant Elasticity of Substitution (CES) value-added functions are used in most CGE models because they are convenient forms in terms of (i) consistency with the theoretical restrictions and (ii) analytical tractability (Shoven and Whalley 1992). In a CD function, it is implicitly assumed that the elasticity of substitution between factors of production is unity. CES functions, a generalization of CD, allow this value to vary but specify the same elasticity of substitution between factors of production. Some regional CGE models using CES functions allow for differing elasticities of substitution by employing "nested" functional forms. Alternatively, flexible functional forms (FFF) are used in some cases (e.g., Despotakis and Fisher 1988). FFF allow for not only differing elasticities of substitution but also complementarity, between inputs (Partridge and Rickman 1998). In the second level, intermediate inputs are combined in fixed ratios:

$$X_i = \min\left[\frac{VA_i}{a_{vi}}, \frac{X_{1i}}{a_{1i}}, \frac{X_{2i}}{a_{2i}}, \ldots, \frac{X_{ni}}{a_{ni}}\right], \qquad \text{Eq. (29)}$$

where X_i is the output level in sector *i*, a_{vi} is the share of the value-added in one unit of output, X_{ji} is sector *i's* use of intermediate good *j*, and a_{ji} is an input-output coefficient that represents the amount of the *jth* good needed to produce one unit of the *ith* product. The structure of production in a typical regional CGE model is depicted in Figure 1.

Factor Demand -- Factor demands are derived from the firm's profit maximization problem. Assuming that sector *i* uses labor and capital as primary factors of production, and that the production technology is represented by a CD function, those demand functions are given by

$$L_i = \frac{\alpha_i (PV_i) X_i}{W_i} \text{ (labor demand function)} \qquad \text{Eq. (30)}$$

and

$$K_i = \frac{\kappa_i (PV_i) X_i}{R_i} \text{ (capital demand function),} \qquad \text{Eq. (31)}$$

where α_i and κ_i are share parameters for labor and capital, respectively; W_i and R_i are the wage rate and the return to capital in sector *i*, respectively; and PV_i is the net price of a unit of value-added in sector *i*. Since it is generally assumed in CGE models that the quantities of factors have their limits, substitution effects are allowed if the relative prices of factors change.

Consumption -- Household preferences in regional CGE models are often represented by a Stone-Geary (Stone 1954), CD, or CES utility function. Consumer demand is derived from utility maximization subject to a budget constraint. Many CGE modelers use the demand functions based on a CES utility function or other more flexible demand functions to allow for substitution effects. Suppose that the preferences of different types of households are represented by a CES utility function, and that each type of household consumes both locally produced goods and imported goods. Then, the demand function of household type *h* for each good is given by

$$Q_{ih} = \frac{\beta_{ih}\,(HEXP_h)}{PQ_i^{\gamma_h} \sum_j \beta_{jh}\, PQ_j^{(1-\gamma_h)}}, \qquad \text{Eq. (32)}$$

where Q_{ih} is quantity of good *i* consumed by household type *h*; β_{ih} is the share parameter for good *i* and household *h*; $HEXP_h$ is household *h's* total expenditure on goods; PQ_j is price of good *j*, a composite of locally produced and imported versions; and γ_h is household *h's* elasticity of substitution for goods. Some regional CGE models use the linear expenditure system (LES), which is based on a Stone-Geary utility function (Stone 1954), because of its desirable properties of adding-up, homogeneity, symmetry, and negativity, although substitution effects are ignored in this system (Deaton and Muellbauer 1980). The structure of consumption in a typical regional CGE model is depicted in Figure 2.

Factor Mobility -- Regional CGE models often employ various assumptions about factor mobility. For example, Hoffmann et al. (1996) and Waters et al. (1997) specified three different model variants for intersectoral and inter-regional factor mobility. In the first model, both labor and capital are assumed to be mobile between sectors, but neither labor nor capital is mobile between regions. Therefore, the total stock of each factor of production in the regional economy is fixed at its base-year level. As a result, both wage rate and return to capital are endogenously determined, and differentials in wage rate and return to capital exist across regions. The assumption seems plausible if the period of analysis is relatively short. In the second model, labor is perfectly mobile between regions and the total capital stock is fixed at its base-year level and immobile between regions. The wage rate is fixed in nominal terms and is equalized between regions, but the return to capital is endogenously determined. In the third model, both labor and capital are perfectly mobile between regions. Results from this model variant depict long-run effects. In this model variant, in- or out-migration of labor and capital occur such that both the wage rate and the return to capital are fixed at their base-year levels, and are equalized between regions. This model version is analogous to a fixed-price, IO-type constant multiplier model. The first and third models are specified as extreme cases for inter-regional factor mobility and the second model as an intermediate case.

Jones and Whalley (1989) discuss when the assumption of perfect mobility or immobility of labor across regions may be inappropriate. If labor is assumed to be perfectly mobile, it is difficult to identify the magnitude of policy effects on region(s) of interest. This is because this assumption implies that all the regions, with wage rates equalized across all the regions, constitute a single homogeneous region. If labor is assumed to be completely immobile, the policy effect is easily identified, but the model ignores efficiency issues arising from inter-regional movement of labor. Therefore, in some regional CGE models, it is assumed that labor is *partially* mobile between regions. For partial mobility of labor, the following type of labor migration function is often used in regional CGE models:

$$LMIG_k = LSTK_k \left[\left(\frac{WAVG_k}{WROW_k} \right)^{LME_k} - 1 \right], \qquad \text{Eq. (33)}$$

where $LMIG_k$ denotes the net in-migration of labor type *k*; $LSTK_k$ is the aggregate stock of labor type *k* in base year; $WAVG_k$ and $WROW_k$ are the average wage rates of labor type *k* in the study region and in the rest of the world, respectively; and LME_k is the labor migration elasticity for labor type *k*. This equation specifies that the net in-migration of labor is dependent on the relative wage rates.

Imports -- In most CGE models, imports are determined by an import demand function. This function is derived from cost-minimization by economic agents subject to a CES trade aggregation function (which indicates preferences for domestic goods versus imported goods). The difference between the prices of the domestic version and the imported version of each good determines imports. CGE models frequently employ the "Armington assumption" that products produced in different regions are different from each other in quality (Armington 1969).

Thus, import demand is determined in two stages. In the first stage, utility is maximized subject to a budget constraint – yielding demand by commodity type. In the second stage, quantities of the imported version and domestic version of a commodity are determined by cost-minimization subject to the overall level of the commodity demanded by stage one. Specifically, the optimization problem of commodity users is to minimize

$$(PQ_i)Q_i = (PD_i)D_i + (PM_i)M_i \qquad \text{Eq. (34)}$$

subject to

$$Q_i = A_i^C[\delta_i M_i^{-\rho_i} + (1-\delta_i)D_i^{-\rho_i}]^{\frac{1}{\rho_i}}, \qquad \text{Eq. (35)}$$

where PQ_i is the price of the composite good *i*, Q_i is its quantity, PM_i is the price of the imported good *i*, PD_i is the price of the locally produced good *i*, M_i and D_i are quantities of imported and locally produced good *i*, respectively, A_i^c and δ_i are constants, and $\nu_i = 1/(1+\rho_i)$

is the elasticity of substitution between imports and locally produced goods. This yields import demand function for good *i*:

$$M_i = \left(\frac{PD_i}{PM_i}\right)^{\upsilon_i} \left(\frac{\delta_i}{1-\delta_i}\right)^{\upsilon_i} D_i \,. \qquad \text{Eq. (36)}$$

Thus, imports of good i depend on the ratio of the domestic price of the good (PD_i) and the price of imported good i (PM_i).

Exports -- Exports of a good are determined by revenue-maximizing behavior of firms, given the profit-maximizing production level for the good. Therefore, exports depend on the ratio of the domestic price of the good (PD_i) and the export price of the good (PE_i), which is assumed to be exogenously given in most regional CGE models. Producers allocate their products according to a constant elasticity of transformation (CET) function between domestically supplied goods (D_i) and exported goods (E_i).

Thus, export supply is determined in two stages. In the first stage, producers choose optimal quantities of goods through profit maximization. In the second stage, given the optimal quantities of the (tradable) goods obtained in the first stage, they maximize their revenue by selling their products to domestic market and foreign markets. Specifically, the optimization problem of producers in the second stage is to maximize

$$(PX_i)X_i = (PD_i)D_i + (PE_i)E_i \qquad \text{Eq. (37)}$$

subject to

$$X_i = A_i^T \left[\gamma_i E_i^{\varphi_i} + (1-\gamma_i) D_i^{\varphi_i}\right]^{\frac{1}{\varphi_i}}, \qquad \text{Eq. (38)}$$

where X_i is output of good *i*, A_i^T is shift parameter, γ_I is share parameter, and $\lambda_i = 1/(\varphi_i-1)$ is the elasticity of transformation between exports and domestically consumed version. This yields export supply function for good *i*

$$E_i = \left(\frac{PE_i}{PD_i}\right)^{\lambda_i}\left(\frac{1-\gamma_i}{\gamma_i}\right)^{\lambda_i} D_i . \qquad \text{Eq. (39)}$$

Market Equilibrium and Budget Constraints -- By definition, commodity markets and factor markets clear in equilibrium. In CGE models, market equilibrium conditions are expressed with explicit prices and quantities. Household budget constraints, budget constraints of various levels of governments, and the balance of payments constraint must be satisfied in equilibrium. Also, Walras' Law implies that in equilibrium, the sum of savings from all sources must be equal to gross private investment. Computable General Equilibrium models are calibrated so that all these conditions are met in the benchmark equilibrium.

Parameter Calibration

The parameter calibration discussed here is based on Kraybill (1993). Implementing a CGE model requires data on model parameters. In most CGE studies, a procedure called "calibration" is used to determine the parameter values (Mansur and Whalley 1984). This procedure can be illustrated as follows. Suppose that a regional CGE system is expressed compactly as a set of model equations:

$$f(x, y; \theta, \pi) = 0, \qquad \text{Eq. (40)}$$

where x is a vector of exogenous variables; y is a vector of endogenous variables; θ is a vector of parameters given by previous econometric studies (e.g., elasticities); and π is a vector of parameters (e.g., share and shift parameters) solved for with x,y, and θ given. Here, vectors x and y are calculated from the benchmark data set. Calibration consists of solving the above equations for θ and π. Because calibration in a CGE model usually involves only a single observation of model variables, the unknown parameters cannot be solved for deterministically. Some parameters (θ) such as elasticities of substitution and elasticities of transformation must be specified on the basis of econometric research. The remaining parameters (π) such as share parameters are then determined by solving the model equations with the base-year observations for model variables (x and y) and the exogenous parameters (θ) substituted in. Once the values of θ are calculated, the system of equations can be solved given x, θ, and π to replicate the benchmark values of the endogenous variables (y).

Comparing Fixed-price Models with Flexible-price Models

In this subsection, fixed-price models such as IO or SAM models are compared with flexible-price models (CGE models). The discussion in this subsection relies on Kraybill (1993). There are three simplifying assumptions in the original Leontief IO model. The first assumption is that demand equations for final goods are dropped. The second assumption is that supply equations for primary inputs are dropped. The third assumption is that relationships among all variables are linear.

The first assumption implies that factor income from production activity does not have any effect on final demand. This assumption suppresses demand shifts that may arise from households' spending their factor income. This assumption is relaxed in most "closed"

IO models by adding to the transactions matrix one more column and one more row for household accounts. The first and the second assumptions together imply that the basic Leontief IO model ignores the important economic concepts of scarcity and efficiency. Under the second assumption, the supply constraints on primary factors of production are either non-existent or non-binding. Therefore, the opportunity costs of resource usage do not change as the output level changes. By imposing supply constraints, results in CGE models are drastically different from those obtained in IO models (Harrigan et al. 1991). In IO models, relative prices play no role in allocating resources efficiently. This is contrary to neoclassical economic theory. Economic interaction, which is most essential to the neoclassical theory of resource allocation, is not allowed in the basic IO model, where supply constraints and relative prices are suppressed. The second assumption is relaxed in the supply-side (or supply-determined) IO model with factor supply constraints. However, both closed IO and supply-side IO models have a serious limitation of the basic IO model that relative price effects and substitution effects in production and consumption are ignored. The third assumption implies constant returns to scale. Under this assumption, the IO model uses simple linear functions, rather than the nonlinear functional forms of neoclassical theory. Thus, shifts in the use of factors and commodities can not be decomposed to identify quantity changes separately from price changes. Under this assumption, relative price-induced substitutions in production and consumption are unidentifiable.

The CGE model is characterized by a fuller general equilibrium than either the basic IO or its linear extensions since in the CGE model all three of the IO assumptions are relaxed. The first assumption is relaxed because CGE models use demand functions whose arguments are income and relative prices. The second assumption is relaxed by imposing supply constraints on primary factors of production in the CGE model. The third assumption is relaxed because nonlinear functional forms are used in CGE models. Because fixed-price models assume that there are no resource constraints and no fixed period of adjustment in factor markets, these models may be more useful in calculating long-term effects of policies for relatively small regions where factors of production seem to be perfectly mobile. Compared with fixed-price models, CGE models are able to show both short-term (2-5 years) and long-term effects depending on how the models are specified. In a study by Seung et al. (1997), a fixed-price model (SDSAM model) and a CGE model are empirically compared. In their study, the authors estimated the impact of transferring water from irrigated agriculture to outdoor recreation. Model results show that compared with the CGE model, the SDSAM model overestimates the policy impacts, and estimates production decreases in sectors where production might not change or may in fact increase.

Computable General Equilibrium models have conceptual (theoretical) advantages over IO or fixed-price models. However, CGE models are subject to some problems. Although availability and reliability of data are constraining factors for all types of regional economic models, this problem is exacerbated in regional CGE modeling due to the more demanding data requirements. In particular, there is an insufficient basis in the literature from which to specify the necessary parameter (elasticity) values for the non-linear functions in regional CGE models. In addition, CGE models also necessarily specify fewer sectors than IO models because of computational complexity associated with solving large systems of nonlinear equations. In some applications, this higher level of aggregation may have deleterious effects on impact estimates. Table 3 presents and compares the characteristics of each of the regional economic models. Koh et al. (1993) provides both analytical and empirical comparisons of a fixed-price model with a CGE model for the State of Oklahoma.

Summary

We provided an overview of the Alaska seafood industry, discussed the importance of the industry to the state economy, and indicated the importance of regional economic analysis for the Alaska seafood industry. We also provided a theoretical overview of regional economic models. The EB model is the simplest regional economic impact model, followed by the IO model, which has been fundamental to regional economic analysis for the past half century. The IO model has frequently been used in regional economic analyses mainly because it is relatively easy to implement and it is able to capture inter-industry linkages within a region. An IO model that is extended to provide more complete measures of income distribution impacts across institutions is referred to as a SAM model. More recently, SD-IO and SD-SAM models have been used for a special case of impact analysis in which the productive capacity of a sector is curtailed or eliminated. Although these fixed-price models are useful for some situations, the models share some significant limitations: none of them allow for price changes or substitution in production or consumption. As a result, these models tend to overestimate impacts on regional economies. CGE models overcome these limitations of the fixed-price models by allowing for endogenous prices and substitution effects in production and in consumption. However, CGE models are subject to their own problems, such as insufficient information about elasticities and other parameter values used in the models.

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Table 1. -- Structure of a Regional Social Accounting Matrix (SAM).

	Industry	**Commodity**	**Labor**	**Capital**	**Household**	**Government**	**Savings-Investment**	**ROW**
Industry		Gross Output (Make Matrix)						
Commodity	Intermediate Input Use (Use Matrix)				Household Purchase	Government Purchase	Investment	Exports
Labor	Labor Factor Income							
Capital	Capital Factor Income							
Household			Resident Labor Income	Resident Capital Income		Transfer to Household		
Government	Indirect Business Tax			Corporate tax & Property tax	Personal Income Tax	Transfer to Government		
Savings-Investment				Depreciation & Retained Earnings	Household Savings	Government Savings		
ROW		Imports	Labor Income Leakage	Capital Income Leakage			- (External Savings)	

Note: 1. ROW denotes rest of the world

Table 2. -- Aggregate SAM for the United States in 1982.

	ACTIVITIES			VALUE ADDED			INSTITUTIONS						EXOGENOUS			TOTAL
Account	Agricul ture	Agr.-related	Other	Labor income	Capital income	Indirect taxes	Labor	Propri-etors	Enter-prises	Low-inc. HH	Med-inc. HH	High-inc. HH	Capital account	Gov't	Rest of the world (ROW)	
ACTIVITIES	-------------- A ---------------						-------------------------------- C ----------------------------------									
Agriculture	49.91	93.81	9.81	0	0	0	0	0	0	5.26	8.45	6.71	-0.22	8.28	19.41	201.42
Agr-related	70.63	1119.77	442.84	0	0	0	0	0	0	388.57	691.97	633.89	40.55	451.88	97.33	3937.43
Other	7.97	452.87	644.77	0	0	0	0	0	0	44.89	102.2	102.95	374.53	190.32	231.68	2152.18
VALUE ADDED	-------------- V --------------															
Labor income	18.79	1314.26	531.18	0	0	0	0	0	0	0	0	0	0	0	0	1864.23
Capital income	45.13	701.08	200.05	0	0	0	0	0	0	0	0	0	0	0	0	946.26
Indirect taxes	3.64	217.21	37.92	0	0	0	0	0	0	0	0	0	0	0	0	258.77
INSTITUTIONS				-------------- Y ----------------			--------------------------------- H ------------------------------------									
Labor	0	0	0	1612.91	0	0	0	0	0	0	0	0	0	0	0	1612.91
Proprietors	0	0	0	0	111.51	0	0	0	0	0	0	0	0	0	0	111.51
Enterprises	0	0	0	0	834.77	0	0	0	0	0	0	0	0	53.25	0	888.02
Low-inc. HH	0	0	0	0	0	0	145.4	9.72	80.61	0	0	0	0	205.12	-0.18	440.67
Med-inc. HH	0	0	0	0	0	0	742.07	33.92	133.37	0	0	0	0	107.9	-0.51	1016.75
High-inc. HH	0	0	0	0	0	0	725.44	67.87	225.32	0	0	0	0	49.71	-0.48	1067.86
EXOGENOUS																
Capital account	0	0	0	0	0	0	0	0	388.05	-18.76	56.86	97.4	0	-115.24	6.55	414.86
Gov't	0	0	0	251.31	0	258.76	0	0	60.66	20.71	156.47	226.9	0	179.51	-24.42	1129.90
ROW	5.35	38.42	285.63	0	0	0	0	0	0	0	0	0	0	0	0	329.40
TOTAL	201.42	3937.42	2152.2	1864.22	946.28	258.76	1612.91	111.51	888.01	440.67	1015.95	1067.85	414.86	1130.7	329.38	

Source: Table 1 in Adelman and Robinson (1986) and Table 1 in Holland and Wyeth (1993)
Note: Row totals may not equal column totals due to rounding errors.

Table 3. -- Characteristics of Regional Economic Models.

	EB	IO	SAM	Supply-determined Models	CGE
Equilibrium conditions	Aggregate regional expenditure = aggregate regional income ($)	Value added expenditure = value added receipts ($) Industry expenditure = industry receipts ($) Household expenditure = household receipts ($)	Value added expenditure = value added receipts ($) Industry expenditure = industry receipts ($) Household expenditure = household receipts ($) Institutional expenditure = institutional receipts ($)	The equilibrium conditions for SDIO are the same as those given for IO model in the third column. The equilibrium conditions for SDSAM are the same as those given for SAM model in the fourth column.	Goods supplied = goods produced (quantity) Factors supplied = factors demanded (quantity) Household expenditure = household receipts ($) Government expenditure = government receipts ($) Savings = investment ($) ROW leakages = ROW injections ($)
Producer behavior	Fixed coefficients Substitution effects are not allowed	Intermediate and primary input demands are determined by Leontief function Substitution effects are not allowed	Intermediate and primary input demands are determined by Leontief function Substitution effects are not allowed	Intermediate and primary input demands are determined by Leontief function Substitution effects are not allowed	Intermediate demand is determined by Leontief function Primary input demand is determined via optimization Substitution effects are allowed

Table 3. -- (Continued).

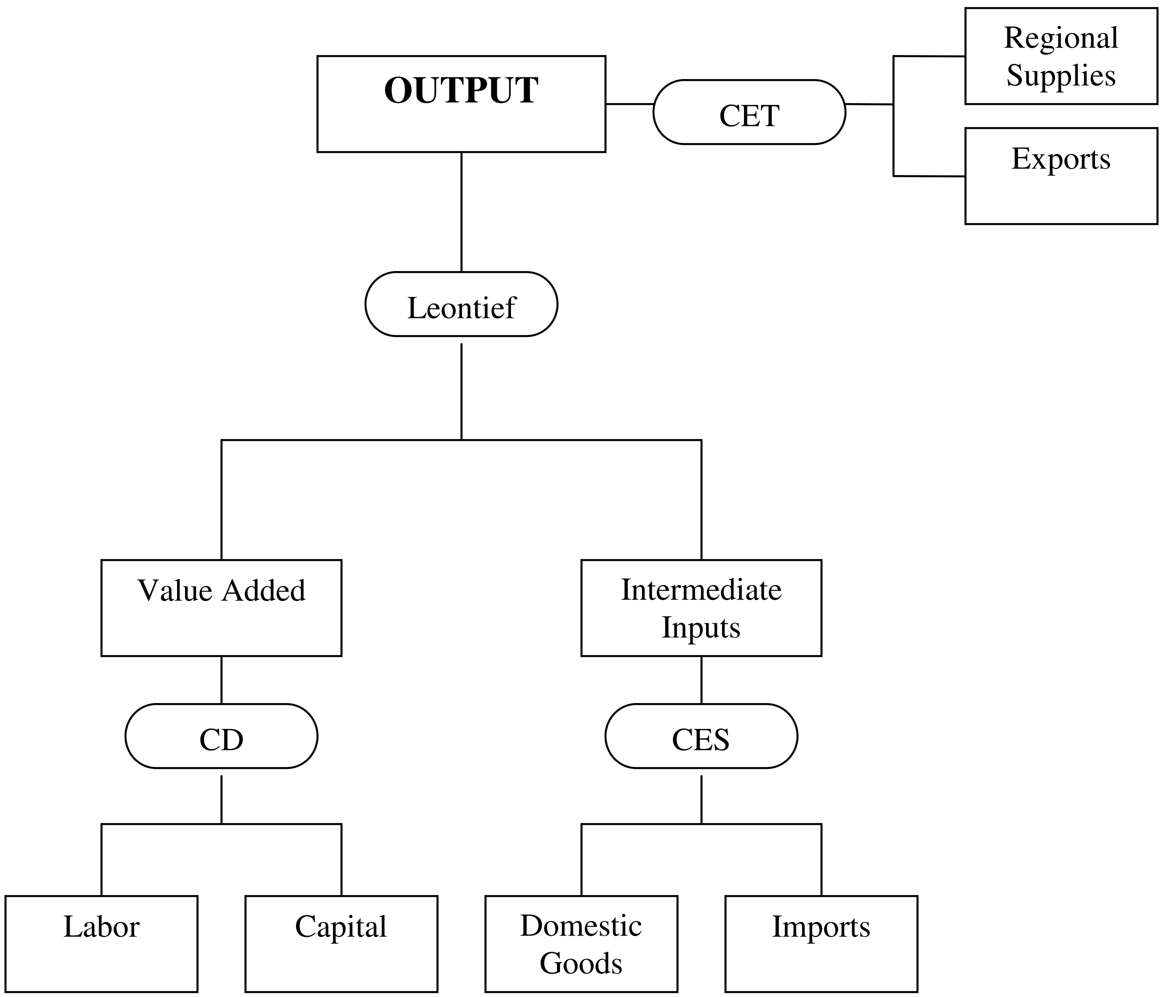
	EB	IO	SAM	Supply-determined Models	CGE
Consumer behavior	Fixed coefficients Substitution effects are not allowed	Household demand is given by average expenditure patterns Substitution effects are not allowed	Household demand is given by average expenditure patterns Substitution effects are not allowed	Household demand is given by average expenditure patterns Substitution effects are not allowed	Household demand is derived from optimization Substitution effects are allowed
Functional forms	Linear	Linear	Linear	Linear	Both linear and nonlinear
Output determination	Demand-driven Perfectly elastic supply	Demand-driven Perfectly elastic supply	Demand-driven Perfectly elastic supply	Demand-driven Some sectors are supply-driven	Determined by interaction of demand and supply
Static or dynamic	Static	Static and dynamic	Static	Static	Static and dynamic
Interregional and intersectoral factor mobility	Perfect mobility implied	Perfect mobility implied	Perfect mobility implied	Perfect mobility implied	Depends on specification of labor and capital behavior
Single-region or multi-region	Single-region model	Both single- and multi-region models	Both single- and multi-region models	Both single- and multi-region models	Both single- and multi-region models
Policy instruments	Final demands Transfer payments	Final demands Transfer payments	Final demands Transfer payments	Final demands Transfer payments Outputs	Final demands Transfer payments Input use Taxes, savings, subsidy Prices
Welfare evaluation	No	No	No	No	Yes

Table 3. -- (Continued).

	EB	IO	SAM	Supply-determined Models	CGE
Data requirement	Data on aggregate levels of regional income, investment, government spending, and exports	For each of the industries, need data on output, employment, value added, final demand, imports, make table, and use table. (IMPLAN) Inter-institutional transfer payments	Same as those required by IO	Same as those required by IO	In addition to the data needed for IO, values of various elasticities and parameters are needed to develop a CGE model
Strengths	Simplest model: easy to implement	Captures interindustry linkages Easy to implement with data given by IMPLAN	Measures policy impacts on income distribution across institutions	Useful for analyzing impacts of reduction in productive capacity	Prices are endogenous Substitution effects are allowed Welfare implications can be derived
Weaknesses	Prices are fixed Substitution effects are not allowed Tends to overestimate policy impacts	Prices are fixed Substitution effects are not allowed Tends to overestimate policy impacts	Prices are fixed Substitution effects are not allowed Tends to overestimate policy impacts Relatively costly to implement	Prices are fixed Substitution effects are not allowed Tends to overestimate policy impacts Has mixed endogenous/ exogenous variable problem Relatively costly to implement	Implementing costs are high Values of parameters and elasticities are hard to find

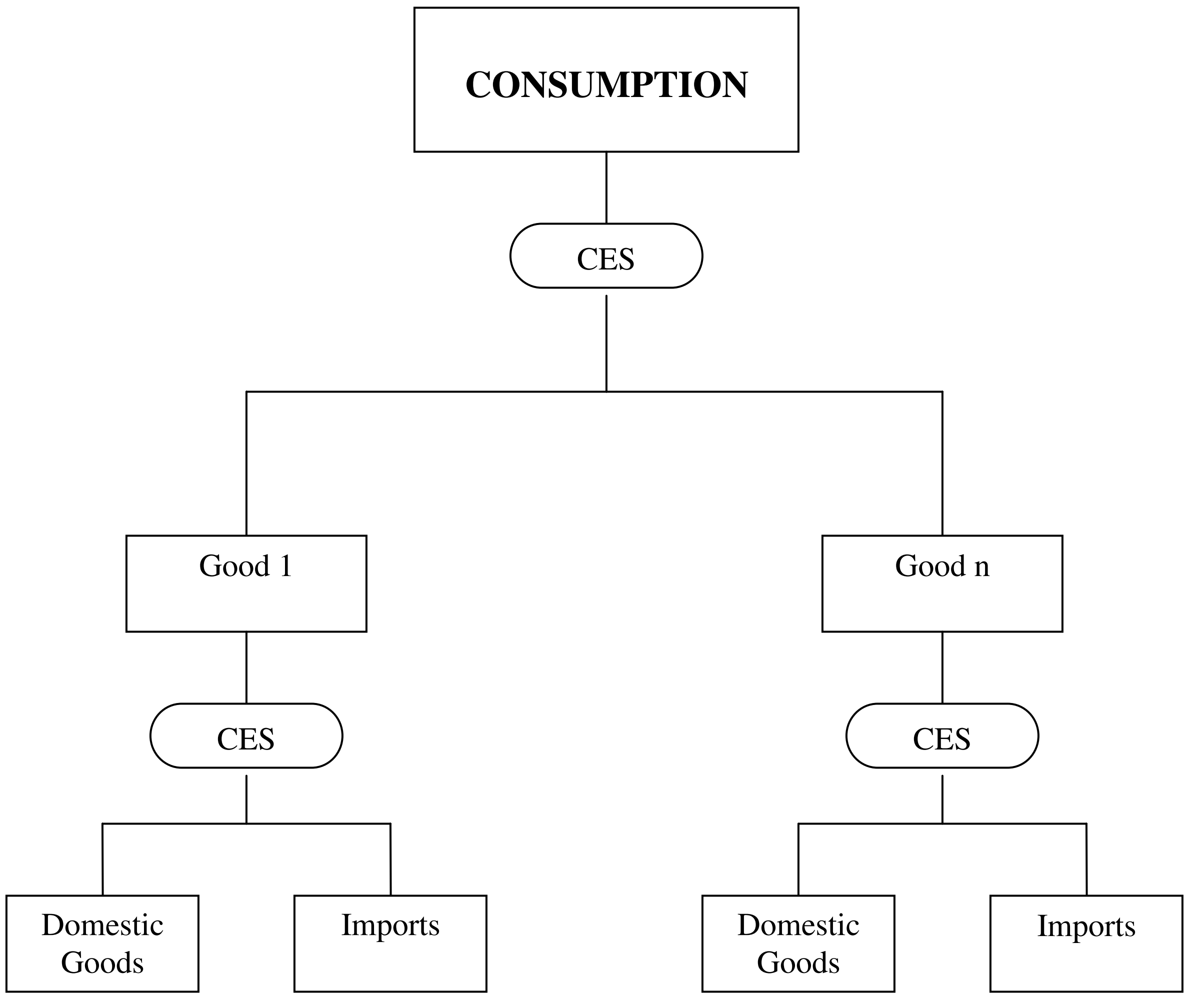
Note: This table is based on Kraybill (1994).

Figure 1. -- Structure of Production in a Regional Computable General Equilibrium (CGE) Model.



Note: This figure is adapted from Lee (1993)

Figure 2. -- Structure of Consumption in a Regional Computable General Equilibrium (CGE) Model.



PART II

Introduction

In Part I, we provided an overview of the Alaska seafood industry and indicated the importance of a regional economic analysis of the Alaska seafood industry. In addition, we provided a theoretical overview and comparative discussion of several types of regional economic models. Fixed-price models such as the Export Base (EB) model, Input-output (IO) models, Social Accounting Matrix (SAM) models, and supply-determined fixed-price models were discussed. Although these fixed-price models are useful for some applications, the models share some significant limitations: none of them allow for price changes or substitutions in production or consumption. As a result, these models tend to overestimate impacts on regional economies. In addition, within the framework of these models, welfare implications can not be derived. Computable general equilibrium (CGE) models overcome these limitations of the fixed-price models by allowing for endogenous prices and substitution effects in production and in consumption. However, CGE models are subject to their own problems such as insufficient information about parameter (elasticity) values used in the models.

In Part II, we will discuss the applications to fisheries of the regional economic models discussed in Part I, provide an overview of regional economic models used to assess the effects of fishery management actions, discuss the issues in specifying such models for Alaska fisheries and the data needs and availability for modeling regional economic impacts for Alaska fisheries, and conclude our review and provide a summary of the major considerations for applying regional economic models to Alaska fisheries. An Appendix details the structure of Fisheries Economic Assessment Model (FEAM), which has been one of the major analytical tools used to examine the regional economic impacts of fisheries on the West Coast and Alaska.

Applications to Fisheries

Introduction

Most studies of regional economic impacts in fisheries have used IO or IO-based models, and only one Supply-determined Input-output (SD-IO) model (Leung and Pooley 2002) has been developed. There is no study in the literature that employed SAM or Supply-determined Social Accounting Matrix (SD-SAM) models for use in fisheries. Finally, there is only one regional CGE model developed for fisheries. The following subsections discuss the regional economic models that have been employed in fisheries and the specifics of each application. By reviewing the commonly employed methods to assess regional economic impacts, we can provide guidance on which models are likely to be most appropriate in certain instances, and which shortcomings are most crucial to overcome in future applications. The following subsections provide an overview of previous IO studies for fisheries, including the SD-IO model; discuss the Fisheries Economic Assessment Model (FEAM), which uses IO multipliers from IMPLAN (IMpact analysis for PLANning, Minnesota IMPLAN Group) to calculate regional income impacts; review the first regional CGE model developed for fisheries; and finally compare all of these models.

Review of Previous Fishery Input-Output (IO) Studies

Many studies of regional economic impacts to fisheries have used IO models. These studies can be divided into three categories: those that analyze commercial fishing, sport fishing, or both. To estimate the potential impacts of fishery management actions on individual harvesting and processing sectors, it is necessary to disaggregate the fishery-related sectors into many different subsectors by vessel and processor type. There are two common approaches to calculate the economic impacts using disaggregated sectors. The first approach is to directly incorporate the disaggregated fishery-related sectors into the IO framework. The second approach is to estimate changes in revenues (incomes) and expenditures (costs) in disaggregated fishery-related sectors, allocate the changes in revenues and expenditures to the sectors in an aggregate IO model (e.g., IMPLAN model), and calculate the impacts by multiplying the changes in the disaggregated fishery-related sectors by the multipliers given by the aggregate model. Most of the IO models for fisheries, including King and Shellhammer (1981) and the Northeast Fisheries Science Center (NEFSC) model (Marine Policy Center of the Woods Hole Oceanographic Institution and Northeast Fisheries Science Center 2000), have used the first approach. The second approach was used by Natcher et al. (1999) and in models such as FEAM. Hamel et al. (2002) employed both the first and the second approaches.

In this subsection, existing IO studies for fisheries will be reviewed. To date, only Andrews and Rossi (1986) have reviewed IO studies related to fisheries. They described IO studies conducted for northeastern regions of the coastal United States prior to 1986. In addition to the studies reviewed by Andrews and Rossi, this section reviews most of the IO studies in fisheries conducted to date. A review of FEAM, a major analytical tool employed for examining the regional economic impacts of fisheries on the west coast and in Alaska, is provided separately.

Using a survey of 420 marine establishments in the Southern New England region, Rorholm et al. (1967) analyzed the economic impact on the commercial marine enterprises that depend on the near-ocean and near-shore environment for their existence. The study computed eight measures of economic impact ranging from total sales by sector to multipliers showing the impact on other marine sectors, non-marine sectors, and personal income. King and Storey (1974) estimated the economic and environmental impacts of a change in the mix of coastal activities in the Cape Cod area of Massachusetts. In that study, economic activity is divided into two broad categories: waterfront and non-waterfront. Some suggestions are provided in the study as to how certain environmental impacts and economic-environmental trade-offs could be identified and displayed within the IO framework used in the study. Using an illustrative national IO model, Harris and Norton (1978) measured the significance of fisheries and investigated the impacts of commercial fisheries on value added and employment. The authors argue that an IO model is not appropriate for their impact analysis because of the possibility that the workers released from fishery industry may be re-employed in other sectors of the economy. The authors suggest that analysts employ a model that incorporates the functional relationships between relative price changes and the consumer, import responses, and the dynamic biological relationships between fish stocks and fish yields.

Callaghan and Comerford (1978) employed an IO framework with a survey of 72 firms engaged in commercial fishing to determine the impacts of Rhode Island's commercial fishing activities on the state economy. The model has one packing/processing sector and four harvesting sectors, one of which is a non-Rhode Island vessel sector. King and Shellhammer (1981) employed an IO model of California fishery industries called the

California Inter-industry Fisheries (CIF) model. The model has 63 industrial sectors. Nineteen of the 63 industrial sectors are fish harvesting sectors, 9 are fish processing sectors and 35 are non-fishery sectors. In the model, the 19 harvesting sectors produce (harvest) 13 different commodities (species), which are used as intermediate inputs in 9 processing sectors. Detailed data on purchases and sales for each harvesting and processing sector were obtained from published sources, interviews with industry experts, and an extensive mail survey of California harvesting and processing industries. Grigalunas and Ascari (1982) conducted an IO study of marine-related activities in the southern New England marine region, which consists of 11 counties in Rhode Island, Connecticut, and Massachusetts. Using data from 390 personal interviews and a wealth of secondary data, the study derived income and employment multipliers.

Briggs et al. (1982) used an IO model for examining Maine's fisheries. The model has 9 fishery sectors (5 harvesting sectors and 4 processing sectors) and 28 non-fishery sectors. The authors used the model to estimate the change in income per dollar of sales for each fisheries sector. Using an IO model, Rossi et al. (1985) quantified the economic interdependence in the economy of Ocean County in New Jersey, which consists of both commercial fishing sectors and other economic sectors. The study used both survey (interview) data and secondary data. Hushak et al. (1986) estimated the economic impacts associated with increased reallocation of Ohio's Lake Erie fishery from commercial fishing to sportfishing using an IO model for northern Ohio. The study concludes that the impacts of sportfishing on output, income, and employment are greater per unit of fish than the impacts of commercial fishing.

Carter and Radtke (1986) used a FEAM to estimate the regional income impacts of reallocating coho salmon from commercial fishing to recreational fishing for three communities on the Oregon coast – Astoria, Newport, and Coos Bay. The study found that each additional recreational fish would produce a community income impact of at least $36, which is much greater than the income impact of $16-18 for a commercial fish. The authors say, however, that this result does not necessarily lead to the conclusion that coho should be reallocated from commercial fishing to recreational fishing because the community income impacts of reallocation depend on the effect on angler effort and tourism induced as a result of the reallocation. Using a Keynesian-type economic impact model, Martin (1987) identified the economic contribution of the Bay of Quinte sport fishery to the economy of a region in Canada. In calculating the income multiplier, the author recognized the importance of leakage of angler dollars from the region, which is attributed to the tendency for local businesses and households to import goods and services. Herrick and Huppert (1988) used multipliers from the California Inter-industry Fisheries (CIF) model for gauging the economic impacts attributable to changes in annual California entangling net ex-vessel sales from 1981 through 1986. In estimating the economic impacts, the study accounted for annual variations in ex-vessel prices of landings.

Storey and Allen (1993) used Regional Science Research Institute's PC IO model to conduct regional impact analysis for marine recreational fishing in Massachusetts. They used data from a survey of resident and nonresident anglers and annual National Marine Fisheries Service (NMFS) marine recreational fishing statistics survey data to estimate the impacts of trip-related and non-trip-related expenditures. Schorr et al. (1995) conducted an IO study to determine the impacts of the Lake Texoma sportfishery (striped bass) on the economy of seven contiguous counties in Oklahoma and Texas. The study used the IMPLAN modeling system and angler expenditure data from mail, telephone, and roving creel surveys. Steinback (1999) used an IO model to investigate the economic impacts of marine party and charter boat fishing in Maine. The study used data on angler expenditures and associated operating expenses of the marine for-hire fishing businesses in Maine during 1994-96. These data were combined with U.S. Fish and Wildlife Service angler expenditure information and incorporated into IMPLAN to calculate the economic impacts. Economic impacts were analyzed separately for Maine residents and nonresidents.

In 2000, the Northeast Fisheries Science Center (NEFSC) model was developed to examine the regional economic impacts on 10 Northeast coastal regions. For each region in the model, the harvesting sector is disaggregated into five subsectors by gear type; a seafood dealer sector is added; two types of seafood processing sectors are included as in IMPLAN; and other marine-related sectors such as water transportation and cordage and twine are added. For non-fishery-related sectors, the model used IMPLAN default data. The model internalizes the new fishery-related sectors, and therefore, explicitly details the interrelationships among the disaggregated fishery-related sectors and the other industrial sectors. Ex-vessel revenues and seafood dealer sales were obtained from Northeast dealer weigh-out slips, and harvesters' costs were elicited from survey data collected by university researchers. The default IMPLAN data was used for processing sectors. The IMPLAN data were modified using primary/survey data on ex-vessel revenues and costs of harvesters and seafood dealer sales.

An SD-IO model was developed by Leung and Pooley (2002) to assess the economy-wide impact of eliminating the Hawaii-based longline fisheries. The authors assert that the shutdown of the longline fishery is a supply reduction question, and the final demand approach does not accurately reflect all economic impacts from such a closure. They recognized that it is extremely difficult to use a final demand approach to estimate the impacts of supply reduction unless there is a clear indication of how the reduced supply affects final demand.

A few IO models have been developed for analyzing fisheries in Alaska. Butcher et al. (1981) used a multiregional IO (MR-IO) model to calculate the economic impacts of the Alaska shellfish fishery. The model takes into account the close relationship between the economies of Alaska and Washington. The authors pay attention to the fact that a high percentage of the vessels harvesting shellfish are based in Washington, that these vessels and Alaska-based vessels are dependent on inputs purchased from Washington which are used to supply and maintain their equipment, and that many of processing plants operating in Alaska are owned by the firms in Washington which buy significant portions of the inputs from Washington. The model used for this study is the only such MR-IO model in the literature.

Using the FEAM model, Natcher et al. (1999) evaluated the economic impacts caused by designating Norton Sound summer red king crab fishery as super-exclusive to the Nome region[1]. In addition to the baseline model, the study constructed two scenarios to evaluate the various harvesting and processing possibilities. The first scenario assumes that the entire fishing fleet is local. The second scenario assumes that both harvesting and processing sectors are based solely within the Nome region. The model results indicate that the fishery

[1] Because of this super-exclusive designation, any vessel in the Norton Sound fishery was excluded from participating in any other federally managed king crab fishery. This designation fundamentally changed the way the summer red king crab fishery is conducted. Small vessels from the Nome and Yukon Delta regions replaced highly capitalized, distant-water fleet. This contributed to the local economy of those regions.

regulation led to significant economic development in an economically depressed region of Alaska.

By linking a sportfishing recreation demand model with a regional IO model, Hamel et al. (2002) estimated the changes in demand for sportfishing and their economic impacts in Central Cook Inlet, Alaska. The authors groundtruthed the IMPLAN data for three fishery sectors (IMPLAN sectors 25, 97, and 98) using primary data. The study was able to directly evaluate the impacts attributable to predictable or controllable changes in trip attributes because the behaviorally-based model of the recreation demand was combined with a regional economic model. In formulating the IO model, the authors created a new sector (charter boat sector) and internalized the sector within an IO framework, directly modifying the technical coefficient matrix with results from personal interviews with a number of charter boat operators. The authors used a FEAM-type approach to specify the angler expenditures.

Using IMPLAN IO model, Hartman (2002) estimated the direct, indirect, and induced income and employment associated with the commercial finfish and shellfish harvests and seafood production in Southeast Alaska. The author conducted a mail and phone survey of commercial fishermen and a mail survey and direct interview of the largest seafood processors to collect data on fish harvesting and processing employment in the region, including residency and length of employment for hired crew and processing workers. The author also gathered information on the amount and location of operating expenditures for the harvesting and processing sectors.

The Fisheries Economic Assessment Model (FEAM)

The FEAM model was developed in early 1980s by William Jensen and Hans Radtke to estimate the contributions of the commercial and recreational fishing industries to the economies of West Coast regions including California, Oregon, Washington, and Alaska. Although the FEAM has been the major analytical tool employed for calculating regional impacts from fisheries in Alaska and the West Coast, no organized document has been developed which enables regional economic modelers to fully understand the structure of the model. Therefore, the purpose of this subsection and following subsection is to provide a coherent description and critique of FEAM. An appendix at the end of this paper details the structure of FEAM and explains how economic impacts are calculated in FEAM.

FEAM is a production-oriented model which is able to estimate the impacts of supply-side (harvesting sectors) changes. Because the fishery sectors are specified in a highly disaggregated manner, one is able to predict the economic impacts coming from a change in landings of a particular species, by a specific vessel type, and at a particular port area. FEAM consists of two sub-models: the first calculates the revenues and expenditures of harvesting and processing industries, and the second submodel is IMPLAN. The regional economic impacts are calculated by multiplying revenues (incomes) and expenditures by multipliers from an IMPLAN model. For each of the harvesting and processing subsectors, FEAM provides data on output by species, value-added components, and use of intermediate inputs. Value added components include labor income (crew share, processing workers' income, and administrative salaries), capital income (operating income), and indirect business taxes (fish taxes and business/property taxes).

Intermediate input categories (goods and services) in FEAM include vessel/engine repair, fuel and lubricants, ice and bait, supplies, insurance, and other goods and services. Compared with IMPLAN, which provides fishery-related data for only a few aggregated sectors (IMPLAN sectors 25, 97, and 98), FEAM provides much more detailed information at a disaggregated level. FEAM does not provide any information on final demands for processed products. In FEAM, fishery sectors' revenues (sales) are allocated to expenditure categories such as vessel/engine repair, utilities, crew shares, and operating income. Next, each expenditure category is allocated to several different IMPLAN sectors. The multiplier for each expenditure category is calculated as the weighted average of the underlying IMPLAN multipliers. Weights are calculated as the ratio of the amount of the expenditure allocated to a given IMPLAN sector to the total expenditure in the category. The multipliers for these expenditure categories thus calculated are used to estimate changes in regional income resulting from a change in fishery sectors' output levels. The approach employed in FEAM is very similar to the U.S. Minerals Management Service (MMS) approach (Coffman et al. 2002) in which expenditures on offshore oil and gas activities are allocated to different IMPLAN sectors in each of different regions. The approach has also frequently been used by the U.S. Forest Service (USFS) and the Bureau of Land Management (BLM) to estimate recreation expenditure impacts.

The Computable General Equilibrium (CGE) Model

This subsection reviews the computable general equilibrium (CGE) model developed for the Oregon coast region. The review of the CGE model will provide the readers with some ideas on how to develop a regional CGE model for fisheries. There are few examples of regional CGE models applied to fisheries. Houston et al. (1997) described a regional CGE model developed to evaluate the impacts on coastal Oregon associated with different policies for reducing groundfish harvests. A similar model was also constructed for the New England groundfish fishery based on Bristol County Massachusetts regional data. However details of the Bristol County model were never documented. Using the models, the authors examined the impacts on the local economies under several different policy scenarios, including reduced groundfish catch assuming current capacity levels, and reductions in fishing capacity both with and without a buyback program. This subsection will focus on the Oregon coast CGE model. First, a short description of the data used in the Oregon coast CGE model is provided. Next, the structure of the CGE model is reviewed. Finally, some model results are presented. Although not described here, regional SAM models of the Oregon Coast and Bristol County were also constructed as part of the same projects. These models were used to analyze economic dependency on fisheries and other industries in the two regional economies.

The Oregon coast CGE model was built around IMPLAN data augmented with additional regional and fisheries data. The core of the model is a 1995 import-ridden transactions matrix generated using IMPLAN. The coastal region was defined as all Oregon counties bordering the Pacific Ocean, except Lane and Douglas Counties, which are mostly inland. Additional data on county income and employment by industry were taken from the Bureau of Economic Analysis (BEA)/Regional Economic Information System (REIS) economic data reports. PacFIN data were used to estimate the ex-vessel value of landings by species and by type of vessel. Estimates for the production functions and output mix of regional vessels and processors were taken from the industry expenditure patterns in the Oregon FEAM model.

Structure of Computable General Equilibrium (CGE) Models

To examine possible differential impacts on individual fishing sectors, the IMPLAN commercial fishing sector was disaggregated into separate harvesting sectors by vessel type, depending on the characteristics of the regional fleets. In the Oregon model, five fishing sectors, or vessel types, were identified: groundfish trawlers, crabbers, shrimp and scallop draggers, Pacific whiting midwater trawlers, and “small boats”. Each vessel type can harvest several different species. For example, in addition to groundfish, a groundfish trawler also catches shrimp, scallops, salmon, Pacific whiting, and crab. The authors specified five processing sectors, each associated with a corresponding harvesting sector’s landings. In addition to the five fisheries vessel and five processing sectors, the model contained 24 other aggregated industry and commodity sectors, three household income categories (low, medium and high), two government expenditure accounts (federal and state and local), three factor income accounts (labor, capital and proprietors), two trade accounts (imports and exports), and an investment expenditure account.

Allocation of resources and commodities in the CGE model is a function of economic scarcity as governed by the relative prices of all goods, services and productive factors. Thus, price variables assume a pre-eminent role in the model. Key determinants of relative prices include: 1) constraints on factor supply and production; 2) ability of regional consumers to substitute between alternative sources of commodity supply (i.e., regional supply versus imported supply); 3) ability of regional producers to supply alternative markets (i.e., local versus outside the region, or "export"); and 4) demand conditions affecting local and export markets.

Value is added to inputs of labor, proprietors' services, and capital and combined with intermediate inputs to produce output for each sector. Behavioral assumptions ensure that producers maximize economic returns by equating the marginal factor cost with the value of each factor's contribution to marginal product. Each unit of output is either sold to local buyers or exported outside the region. Revenue maximizing behavior by producers determines the proportion of output supplied to satisfy regional demand versus export markets. Export demand is assumed to be perfectly elastic (i.e., world commodity prices are fixed), while regional demand is influenced by endogenous price and income effects. In the model, commodities produced for regional use are combined with competitive imports to form a composite absorption good (or service) for each class of commodity. Expenditure minimization determines the degree of substitution between regional supply and imports in regional consumption. The model accommodates the observed phenomenon of "crosshauling", in which simultaneous imports and exports appear in highly aggregated commodity classifications.

Total supply supports intermediate demand for producer inputs, and final demand for consumer goods, investment needs and government purchases. Consumption by each of three household income classes is driven by changes in endogenous factor incomes (labor, capital and proprietors), and relative commodity prices. Total business investment spending is exogenous, implying that major investment decisions are not solely determined by the amount of regional savings.

Model Results

The authors examined local economic impacts under three different policy scenarios. The scenarios were constructed so as to result in a similar amount of reduction in groundfish harvests, but at different costs to the coastal region. The scenarios modeled were:

Scenario 1 -- A 20% reduction in groundfish catch because the fishery had become less productive and/or more restricted. This is similar to the experience of the New England groundfish fishery in the early 1990s. Reduced harvests in Pacific Northwest groundfish fishery also began in the late 1990s. Under this scenario, boats catch less per unit of fishing effort. Processors reduce their purchases and output accordingly.

Scenario 2 -- A $6 million buyback of 16 trawl boats. Trawl boat owners are paid $6 million to take their boats out of the fishery. It is assumed that this money comes from the federal government, or some other source outside the local economy. Other non-trawl fishing sectors pick up some non-groundfish that the trawlers used to catch, but they are not allowed to increase their groundfish catch. (e.g., the crabbers will be able to increase their crab harvests by the amount of crab that the 16 trawl boats used to harvest.) Processors adjust purchases and output accordingly.

Scenario 3 -- The removal of 16 trawl boats, but since there is no buyback, households are not compensated. Non-trawl sectors are again allowed to pick up some of the slack. Processors adjust purchases and output accordingly.

The model produces a complete set of impact variables, including changes in income, employment, production, exports, imports, consumption, and taxes. For brevity, only the employment impacts under the three scenarios are presented below. Table 5 shows estimated changes in numbers of jobs under the three policy scenarios. The greatest total job impacts are found under Scenario 1, the “groundfish scarcity” scenario. Here the other fishing sectors share some of the pain along with groundfish trawlers. Relative impacts on seafood processing, retail trade and services are also the most severe of the three scenarios. Impacts are least severe under Scenario 2, retirement of boats with buyback. Here the other fishing sectors benefit somewhat from reallocation of the trawlers’ non-groundfish catch, and retail trade and services are supported by buyback dollars in the local economy. The effect on the trade and services sectors is the major difference between the impacts under Scenario 2 (buyback) and Scenario 3 (retirement of boats but no buyback). Without the buyback dollars in the local economy, the trade and services sectors also lose jobs under Scenario 3.

Comparisons of Regional Economic Models for Fisheries

The NEFSC-type model internalizes the disaggregated fishery-related sectors and thus, explicitly details the inter-relationships between these and other industrial sectors. As a result, this type of model has the capability to capture the feedback effects of non-fishery sectors on the fishery sectors. However, developing a NEFSC-type model requires a large amount of data. It is also extremely time-consuming to modify the IMPLAN default data with survey/primary data. The data needed to develop an NEFSC-type model includes data for (i) output, employment, value-added, intermediate inputs, final demands, and imports and exports for each of the disaggregated fishery sectors, (ii) a use matrix showing the flows of goods and services between industries, and (iii) a make matrix describing the commodities produced in each industry, as well as IMPLAN default data. Much of the data that is required to develop an NEFSC-type model is unavailable in most U.S. Federally managed fisheries, and collecting the necessary data for disaggregated sectors and developing intersectoral IO coefficients would be a daunting task. However, the time and funds required for such an endeavor would vary according to the number of fishery-related sectors and regions that are specified.

Alternatively, developing a FEAM-type model requires slightly less effort in that the modeler will not need to derive technical coefficient matrix which describes all the transactions between industrial sectors including disaggregated fishery sectors, to develop final demand vectors for the disaggregated fishery sectors, and to construct and balance the SAM with all the industrial sectors including all the disaggregated fishery sectors (although the amount of primary data required to develop a FEAM-type of model is similar to that for the NEFSC-type model). Also, a FEAM-type model is a tractable model in that changes in other parameters/variables such as ex-vessel and wholesale prices are allowed. Thus, if a management action involves both a change in harvesting and processing levels of certain species and change in prices, a FEAM-type model can incorporate those changes to calculate economic impacts. However, this type of model has one important theoretical weakness. Unlike an NEFSC-type model, it does not internalize the disaggregated fishery sectors within IO model framework and therefore, the feedback effects from non-fishery sectors on the disaggregated fishery sectors are ignored. This leads to possible underestimation of indirect and induced effects of changes in the disaggregated sectors' output. However, the degree of underestimation will be low since the feedback effects are probably relatively small in most cases. Ignoring the feedbacks from non-fishery sectors on the fishery sectors would be very problematic if fisheries were important suppliers of intermediate inputs to non-fishery sectors. However, this does not seem to be very common in fisheries.

Most IO studies in the literature, including those studies analyzing fisheries, used a traditional demand-driven approach. However, many fishery management actions involve change in productive capacity (such as changes in the Total Allowable Catch (TAC) or sectoral reallocations) and season or area closures. In this case, demand-driven IO models are not appropriate if it is not known by how much final demand for the processed seafood will change as the productive capacity is exogenously changed. Some studies employed SD-IO models in cases where there was an exogenous change in productive capacity. However, the SD-IO models (and SD-SAM models) have the weakness that the final demands for the exogenous sectors are forced to be endogenous.

Although, from a theoretical point of view, demand-driven IO models may not be appropriate for analysis of change in productive capacity, it seems that in practice a demand-driven IO model is an acceptable tool of analysis at least for many Alaska fisheries. Suppose that landings of fish are reduced due to a closure of a fishing area. Then it is likely in Alaska fishery that the processing sectors will accordingly reduce its purchase of raw fish because there are not any sources of supply of raw fish other than the harvesters they purchase raw fish from. The processors will then process smaller amount of fish, and export smaller amount of processed products. In other words, the reduced harvest results in proportionally reduced final demand (exports) for processed products. In a demand-driven IO model in which fish harvesting and seafood processing sectors are two separate sectors, the reduction in final demand for processed seafood will lead to a decrease in harvesting via backward linkage from the seafood processing sector to the harvesting sector. Therefore, the reduction in the harvesting sector can be effectively modeled using a demand-driven model such as an

IO model. The results from the demand-driven model will correctly measure the impacts from the supply-side disturbance.

All these IO or IO-based models – NEFSC-type models, FEAM-type models, and SD-IO – have the same limitations that a fixed-price model faces. Compared with these models, a CGE model is advanced in the sense that it is firmly based on microeconomic theory. In a CGE model, substitution effects are allowed and the prices are endogenously determined. Therefore, with a CGE model, one can calculate the welfare change from a policy change. As was mentioned in Part I, however, developing a CGE model requires, in general, more data than an IO model. In particular, it is difficult to find estimates of the various parameter (elasticity) values used in production functions for the fisheries sectors, consumer demand functions, export supply functions, and import demand functions. Although some parameter values have been estimated for other resource-dependent sectors such as agriculture, these values may not be suitable for the fishery sectors. Therefore, it seems necessary to estimate these values for use in CGE models for fisheries. Table 4 presents and compares the characteristics of the previous regional economic impact studies for fisheries.

Issues in Regional Economic Modeling for Alaska Fisheries

There are six principal issues that must be considered when constructing regional economic models for Alaska fisheries. First, the Alaska economy is characterized by the presence of large leakage of expenditures. The economy is not self-sufficient because the state is remote and dependent on natural resources. Many of the inputs supporting resource-dependent industries are often imported (McCollum and Bergstrom 1991, Fay and Thomas

1986), and Alaska fisheries are not an exception. Here, most of the goods and services used as intermediate inputs in fishery industries are imported from the rest of United States, mostly from Washington. If the economic impacts are calculated based on the assumption that all these goods and services are supplied from local industries, the regional impacts will be overestimated (Hushak 1987). Therefore, it is important to distinguish the expenditures on these goods and services supplied from local industries from those that are imported. Only those expenditures spent within the study region will generate positive economic impacts for the region.

Second, it is necessary to correctly identify the residence of the owners of harvesting vessels and processing facilities. The capital income that remains within the study region depends on the residence of the owners of the harvesting vessels and processing plants. Many of the harvesting vessels operating off Alaska are owned by the residents of Washington and Oregon. It is likely that most of the capital income earned by nonresidents will leave Alaska. Similarly, the residence of crew members and processing workers needs to be identified to estimate the leakage of labor income. Some of the labor income will stay in Alaska since the nonresident workers will spend some of their income in Alaska. However, most of the nonresidents' labor income will leave the state (McCollum and Bergstrom 1991).

Third, in IO or IO-based models, it is assumed that there are no substitution effects in production and household consumption, and that there is an unlimited supply of factors of production. These assumptions may not be appropriate for Alaska fisheries. Models that allow substitution and resource scarcity will be needed.

Fourth, most regional economic impact models in the literature are single-region models, and cannot capture the inter-regional flows of goods and services including intermediate inputs, leakage of factor income, and inter-regional factor migration. In the case of Alaska fisheries, most of intermediate goods are imported from Washington and Oregon. Single-region models for Alaska will be able to estimate the impacts in Alaska of these imports, but will not be able to estimate the economic impacts in other states such as Washington and Oregon. Therefore, it is important to develop an inter-regional (or multiregional) model to measure the full impacts of Alaska fisheries, which include the impacts in Alaska and those in the states that export goods and factors of production to Alaska. Developing an inter-regional model would be impossible without information on inter-regional flows of goods and services, including those goods and services used as intermediate inputs in production.

Fifth, most of the regional economic models in the literature are static, single-period models. Economic impacts calculated with such models can be misleading if the fishery management actions have permanent effects on the time horizon. This is particularly true for analysis of permanent or long-term reduction in the harvest of certain species. To estimate the temporal effects, a dynamic model would be needed. Developing a dynamic regional model for fisheries will require specifications of investment behaviors of industries and inter-regional migration behavior of factors of production (labor and capital).

Finally, IMPLAN is the major data set that economists rely on for regional economic analysis. However, using unrevised default IMPLAN data could generate problems for analysis of fishery industries in Alaska regions (boroughs). First, the IMPLAN data uses a national-level production function for regional industries including fisheries. This could be a problem for Alaska fish harvesting and processing industries because the production technologies of these industries in Alaska may be different from the national average. To specify correct production functions, it seems necessary to obtain primary data on earnings and cost for the harvesting and processing sectors through detailed surveys. Second, many of the crew members/fishermen in the commercial fishing sector are not included in the IMPLAN data because fishermen are considered to be self-employed and many fishermen in the industry are casual or part-time workers. Therefore, the IMPLAN employment data for the commercial fishing sector is underestimated. Finally, fishery data in IMPLAN are highly aggregated. IMPLAN includes only one harvesting sector and two processing sectors, and therefore lacks sufficient detail to estimate the effects caused by changes in fishery-related industries. Models using aggregate data are not able to estimate the potential impacts of fishery management actions on individual harvesting and processing sectors. To estimate these impacts, the aggregate sectors in IMPLAN need to be disaggregated into subsectors by vessel type and by processor type.

Data Needs and Availability for Alaska Fisheries

IMPLAN provides most of the information on non-fishery sectors, which is required to implement the major regional economic models – IO, SAM, supply-determined models, and CGE models. In addition to IMPLAN data, developing a regional CGE model requires values of parameters and elasticities provided by previous econometric studies, or calibrated within the model. The values of parameters and elasticities are used for the non-linear functions in CGE models such as production functions, utility functions, and functions determining exports and imports. The FEAM model uses default IMPLAN multipliers given the fishery-sectors' expenditures and household income. However, when the fishery sectors need to be disaggregated into subsectors depending on the types of vessels and types of processors, published federal and state data and primary survey data will be needed for the fishery regional economic models. The rest of this section will focus on the availability of data that are needed for implementing a typical fishery regional economic impact model such as IO, SAM, FEAM, or CGE model. Specifically, we will first discuss IMPLAN data and its limitations. Next, we will discuss the availability of the disaggregated fisheries data that are obtained either from agency data bases and other published data or through surveys.

IMPLAN Data

IMPLAN has two components: the database and the software. The IMPLAN database includes data on 21 economic and demographic variables for 528 sectors for any county (borough) or state in the United States. The economic variables include employment, value-added, government purchases, and household purchases. The database also includes structural matrices such as "use" and "make" matrices. The use matrix details the dollar values of intermediate inputs used in each industry to produce output in the industry; that is, the goods and services purchased by each industry to use in their production process. The make matrix gives the value of each commodity or service produced by each industry. It is possible for a single industry to produce more than one commodity. The IMPLAN software includes a linear algebra algorithm to solve the IO model.

IMPLAN was originally developed by the USDA Forest Service to assist in land and resource management planning. In 1993, the Minnesota IMPLAN Group (MIG), Inc. privatized the development of IMPLAN data and software. IMPLAN data are available for years 1990 through 2001. The currently available version of IMPLAN software is version 2.0. Version 3.0, which will be released soon, will have a new industry classification scheme called North American Industrial Classification System (NAICS). The new version will have the capability to develop a multiregional IO (MR-IO) model, in which inter-regional flows of intermediate inputs are estimated. It will specify trade flows between all 3,140 U.S. counties for all commodities, enabling analysts to create an MR-IO model based on any number of regions. Analysts will also gain the ability to calculate the impacts originating in one region and the resulting imports of goods and services from other defined regions, which in turn cause further exports in the original region. These inter-regional effects will be iterated until the final MRIO impacts are derived (Doug Olson, Minnesota IMPLAN Group, pers. commun, June 2003).

Three different employment data sets comprise the IMPLAN employment data since no one data set provides enough information to make a complete database. These data sets are Bureau of Labor Statistics (BLS) ES 202 data, Bureau of Economic Analysis (BEA) Regional Economic Information System (REIS), and County Business Patterns (CBP). In general, ES 202 data provide the county level industry structure for the IMPLAN database. The CPB data are used to make non-disclosure adjustments to ES 202 data, while the REIS data are used as control totals (IMPLAN Pro, MIG 1999). The sources of data for earnings are the same as for employment. To estimate non-disclosed county income, state-level income per worker ratios are used with the employment estimates. Next, the income estimates are used to disclose ES 202 data and the ES 202 data used to non-disclosure adjust the REIS data. The state level wage and salary income is subtracted from total income and employment to separate wage and salary income and employment and proprietor’s income and employment. These proprietor to wage and salary ratios are applied to ES 202 4-digit Standard Industrial Classification (SIC) data to estimate detailed proprietor income and employment. All employment and income numbers are controlled to REIS totals.

For the commercial fishing (sector 25), data on employment and income are obtained from REIS. The fisheries services are subtracted out from fisheries data using ES 202 4-digit data. Since many of crew members/fishermen in the commercial fishing sector are excluded from ES202 and REIS data, IMPLAN commercial fishing employment is underestimated. In IMPLAN, fish processing sectors (sectors 97 and 98) are just two more manufacturing sectors. Therefore, the employment and income for the processing sectors are estimated in the same way as for the other sectors mentioned above.

IMPLAN output data comes from sources similar to those used by BEA in developing the benchmark input-output table. Most output data, including output for fish processing sectors (sectors 97 and 98), is from the BEA's output series and the Annual Survey of Manufacturers. Other sectors use information from other various surveys and censuses. In some cases, earnings data along with earnings to output ratios from the BLS growth model are used to estimate missing output data. For the commercial fishing (sector 25), the national output level is distributed to states and counties (boroughs) based on employment and income. For detailed information about the data sources and methodologies used to generate IMPLAN data, see Database Guide (IMPLAN Pro, MIG, 1999). Table 6 presents the 21 IMPLAN economic and demographic variables and the major data sources for the variables.

Fisheries Data

IMPLAN provides most of the necessary data for non-fishery sectors of the regional economy. However, using IMPLAN data for fishery-related sectors without revising some of its components could be a problem for economic analysis of fishery-related communities in the United States in general, and for communities in Alaska in particular. First, IMPLAN provides fisheries data at an aggregate level. In IMPLAN, there is only one harvesting sector – commercial fishing (sector 25) – and two processing sectors – canned and cured seafoods (sector 97) and prepared fresh or frozen fish or seafood (sector 98). Since most fisheries management policies typically involve changes in a particular harvesting sector such as groundfish, salmon, or crab harvesting and/or a particular processing sector such as shorebased processing, processing on mothership, or processing on catcher-processors, it is necessary to disaggregate the highly aggregated IMPLAN harvesting and processing sectors. Second, the IMPLAN data uses a national-level production function for regional industries including fishery industries. This could be a problem for Alaska fish harvesting and processing industries because the production technologies in these industries may differ from the national average. Although there are alternative sources for some economic data for fisheries (e.g., Fish Tickets data), all the data required to fix the above-mentioned problems with IMPLAN data for fishery-related sectors are not available. For this reason, it seems necessary to obtain the data for the disaggregated fishery-related sectors through surveys. Specifically, survey data on earnings, costs, and employment for the disaggregated sectors will be necessary for modeling a fishery-dependent Alaska region.

This section discusses the availability of fishery data needed for developing a typical regional economic model for fisheries. Table 7 presents cost, revenue, and demand variables and their data availability and sources for catcher vessels owned by the residents of the regions of interest. Table 8 presents cost, revenue, and demand variables and their data availability and sources for offshore processors owned by the residents of the region and onshore processors located in the region.

Harvesting Data

As shown in Table 7, catcher vessel ownership and address information is available from the Commercial Fisheries Entry Commission (CFEC) vessel registration files and NMFS Permit Data. Employment on catcher vessels needs to be estimated using some assumptions and information obtained through surveys and/or interviews with knowledgeable industry members. For estimating payments to labor for catcher vessels, existing studies and regional economic profiles can be used. For example, in FEAM, payments to labor for catcher vessels for all classes were estimated as about 40 % of ex-vessel value. The same percentage was used in the Alaska Groundfish Fisheries Final Programmatic Supplemental Environmental Impact Statement (PSEIS; NMFS 2004) to estimate the payments to labor on catcher vessels. Data on capital income and expenditures on intermediate inputs such as vessel/engine repair and fuel and lubricants are not available. It may be necessary to conduct surveys to collect the data on these variables, including information on how much of these intermediate inputs is purchased from the study region or imported from outside of the region. An alternative method of collecting some of this information is to add economic fields to routinely collected forms (such as fish tickets or log-books). When the data on these variables are collected, it is also necessary to get information that will help analysts allocate those expenditures to IMPLAN sectors. In FEAM, for example, the expenditures on “fuel and lubricants” are allocated to seven different IMPLAN sectors. The information on these expenditures is needed to develop production functions for the disaggregated harvesting sectors. In addition, the data on the expenditures needs to have information about what percentage of the expenditures are margins for wholesale, retail, and transportation.

Data on the weight and value of catcher vessel deliveries to shore plants and floating processors are provided on Fish Tickets collected by Alaska Department of Fish and Game (ADFG) and augmented by CFEC. Fish Tickets do not include complete information on fish that are discarded at sea prior to a delivery to a processor. Data provided by the observer program and the Weekly Processor Reports are used to estimate total catch and retained catch for fishing vessels. In addition, the observer program provides estimates of at-sea discards by week, area, gear, target fishery, and type of operation, but not by vessel for unobserved vessels.

Table 7 also presents demand variables and their data availability and sources for the harvesting sectors. Fish Tickets (ADFG, CFEC) and NMFS observer data provide information on intermediate input demand for species of offshore processors owned by the residents of the study region (i.e., landings from catcher vessels owned by the residents of the study region) and the inshore plants in the region. Regarding final demand for species, it seems likely that Alaska household and government demands for species (raw fish) are negligible.

Processing Data

As Table 8 shows, processor ownership and address information is from NMFS Processor Permit data and from ADFG Intent to Operate data. The data on the residency of the owners of the inshore processors is needed to measure the capital income that leaks out of the region. Employment estimates for catcher processors and motherships are collected by NMFS in Weekly Production Reports. NMFS provides information on average crew size from those files for each processing vessel and the number of weeks that each vessel in the sector is active. The number of weeks a vessel is active can be easily extracted from the data by counting the number of weeks in which a particular vessel appears in the data. Multiplying crew size by number of weeks provides an estimate of the number of crewmember weeks for each catcher processor class and mothership. Employment estimates for inshore plants need to be derived in a different manner using some assumptions since these facilities are not required to submit the same information as catcher processors and motherships. For example, to estimate the employment for inshore plants, Northern Economics, Inc. used the information on the volume of processed products for each inshore processor provided by the Weekly Production Reports and the coefficients representing the average number of tons of each product type that could be produced for each labor hour. Specifically, they multiplied the coefficients by total product volumes. The result was the number of labor hours to produce the product volumes.

Information on the number of nonresident workers in the processing sector (inshore processing sector) in a borough/census area and the amount of their income leaking out of the region is essential for developing a regional economic model. In cases where income leakage is large, the assumption that all the labor income generated from processing activities is spent within the local area will lead to an overestimation of the economic impacts of the processing sector. There are two sets of data that can be utilized for identifying the residency of processing workers in an Alaska region. First, Alaska Department of Revenue Permanent Fund Division (PFD) data provides a list of Alaskans who receive a Permanent Fund Dividend. Second, Alaska Department of Labor (AKDOL) wage file data provide information on quarterly earnings and number of workers who are covered by unemployment insurance. The earnings data are confidential while the employment data are not. The wage file data provide detailed seafood processing employment by region. A summary of the employment data is given in an AKDOL document (AKDOL, various years). Using these data, it should be possible to estimate the number of processing sector workers who are from the local area, other Alaska regions, and the rest of the United States, respectively, and so to estimate the income flowing out of the area.

Data sources for processor expenditure on raw fish used as an intermediate input are the same as those data sources used for the ex-vessel (revenue) values of catcher vessels (See Table 7). In terms of economic modeling, it is important to separate the amount of raw fish purchased from resident-owned catcher vessels from the amount purchased from nonresident-owned catcher vessels. Fish purchased from resident-owned (non-resident owned) catcher vessels are treated as a regionally supplied (imported) intermediate input. Data on capital income and expenditures on other intermediate inputs are not available. Surveys may be needed to collect the data on these variables, including information on how much of those intermediate inputs are purchased from local firms or imported. As with the catcher vessel data, it will be necessary to determine how those expenditures will be allocated to IMPLAN sectors. In FEAM, for example, the expenditures on “supplies” are allocated to twenty-three different IMPLAN sectors. Also, wholesale, retail, and transportation margins for these expenditures need to be estimated.

Looking at the revenue side in Table 8, NMFS Weekly Production Report and ADFG Commercial Operators Annual Report (COAR) data can be used to provide estimates of final product wholesale value. Table 8 also presents the availability and sources of data on the demand for products processed by the offshore processors owned by the residents and onshore processors in the region. Household and government demands for processed products are not available, and therefore, need to be estimated. It is likely that intermediate demand of non-processing sectors for processed products is negligible. Information on exports of processed products is not available. Exports of processed products will need to be estimated to calculate the regional economic impacts from an external shock such as a change in the taste of consumers in the rest of the world for the products.

Structure of a Social Accounting Matrix (SAM) with Disaggregated Fishery Sectors

Once the necessary data for the disaggregated fishery sectors are obtained, analysts need to revise structural matrices (make and use matrices), value added matrices, and final demand matrices for the new IO model with disaggregated sectors. In addition, sectoral exports and imports need to be adjusted. A schematic of a SAM with disaggregated fishery sectors is given in Table 9. The table represents a model in which there are *h* disaggregated harvesting sectors producing *s* different species (commodities), *p* disaggregated processing sectors using as intermediate inputs the *s* species (commodities) caught (produced) by the *h* harvesting sectors and producing *d* different processed products (commodities), and a total of *m* non-fishery sectors producing *n* different non-fishery commodities.

Submatrix M1 (*hxs*) in Table 9 is a make matrix showing production of each commodity (species) by the harvesting sectors. Since the processing sectors and non-fishery sectors are not likely to catch any fish, submatrices M4 and M7 are null matrices. M2 is a null matrix since harvesting sectors do not produce any processed products. If catcher-processors are included in the SAM, the activity of the catcher-processors will need to be split between harvesting and processing components. M5 is a (*pxd*) matrix that indicates the production volume for each processing sector, by product. Submatrix M3 is a null matrix because harvesting sectors do not produce non-fishery commodities. M6 is typically assumed to be a null matrix. However, if some processors produce electricity used by others or provide hotel services as in Dutch Harbor, M6 is not a null matrix. Since non-fishery sectors do not produce any processed fish products, M8 is a null matrix. M9 shows the quantities of non-fishery commodities produced by each of the non-fishery sectors.

Since it is likely that all the commodities (species) produced by the harvesting sectors are sold directly to the processing sectors, U1 and U3 can be typically assumed to be null matrices. However, in some ports in Alaska, there are direct sales from harvesters to restaurants. In this case, U3 will not be a null matrix. U2 represents the major inter-industry linkages between harvesting sectors and processing sectors; it shows how the *s* species caught by harvesting industries (M1) and imported (IM1) from rest of the world (i.e., raw fish landed by vessels owned by nonresidents) are allocated to the *p* processing sectors. Within Alaska, household, government, and investment demands for harvested species appear to be negligible. This means that submatrices H1, G1, and IN1 can also be assumed to be null matrices. E1 represents the exports of raw fish by species – that is, landings of raw fish at ports in the rest of the world by vessels owned by residents of the study region.

Processed products by processing sectors (M5) and imports of processed products (IM2) are used as intermediate inputs in the economic sectors in the region (U4, U5, and U6) and as final goods for household (H2), government (G2), and investment (IN2) or exported (E2). Since processed products are not used as investment goods, IN2 is a null matrix. U4 represents purchases by the harvesting sectors of processed products produced by processing sectors. Unless the harvesting sectors buy commodities such as bait from the processing sectors, U4 is a null matrix. U5 represents transactions among processing sectors. These transactions will occur if there is secondary processing or custom processing. U6 represents non-fishery sectors' purchase of processed products. This includes, for example, the purchase of processed products by eating and drinking places (seafood restaurants). Most processed products are consumed by households (H2) and government (G2) or exported (E2).

Finally, non-fishery commodities made by non-fishery sectors (M9) plus imports of non-fishery commodities (IM3) are used as intermediate inputs in harvesting sectors (U7), processing sectors (U8), and non-fishery sectors (U9). The remaining non-fishery commodities are used as final goods (H3, G3, and IN3) or exported (E3). In addition to paying for the intermediate inputs, each of the disaggregated harvesting and processing sectors pays for the use of labor (L1) and capital (K1), and pays taxes (T1).

Summary

We reviewed models used to analyze the regional economic impacts from fisheries (or policies that affect fisheries and local economies). Most previous studies of regional economic impacts of fisheries have used IO or IO-based models. To estimate the potential impacts of fishery management actions on individual fishery sectors, it is necessary to disaggregate the fishery sectors into many different subsectors. There are two major approaches in calculating the economic impacts in models with disaggregated sectors. The first approach is to incorporate the disaggregated fishery sectors directly into the IO framework. The second approach is to estimate changes in revenues and expenditures in detailed fishery sectors, allocate these changes to the sectors in an aggregated model (e.g., IMPLAN model), and then calculate the impacts by multiplying the changes in the sectors in the aggregate model by the multipliers given by the aggregate model. Most IO models for fisheries have used the first approach.

The first approach, which has been referred to as the NEFSC-type model in this paper, internalizes the new (disaggregated) fishery sectors, and explicitly details the inter-relationships among the disaggregated fishery sectors and the other industrial sectors. This type of model has the ability to capture the feedback effects of non-fishery sectors on the fishery sectors. To develop this type of model, one must collect primary data for the disaggregated fishery sectors and specify the structural matrices for all the industries in the economy (including the fishery sectors). Collecting the necessary data for disaggregated sectors and developing intersectoral IO coefficients for this type of model can be a daunting task, although the time and funding required depends on the number of fishery sectors included in the model.

The second approach has been referred to as the FEAM-type model. The amount of primary data required to develop this model is similar to that for the NEFSC-type model, yet requires slightly less effort. However, the FEAM-type model has one important weakness: it does not internalize the disaggregated fishery sectors within the IO model framework and therefore, the feedback effects from non-fishery sectors on the disaggregated fishery sectors are not captured. This leads to possible underestimation of the effects of policy changes. Ignoring the feedbacks from non-fishery sectors on the fishery sectors is not much of a problem if fisheries are not important suppliers of intermediate inputs to the non-fishery sectors. All IO models – NEFSC-type models and FEAM-type models – have the same general limitations faced by fixed-price models.

The CGE model is more advanced than the aforementioned models because it is firmly based on microeconomic theory. In this model, substitution effects are allowed and the prices are endogenously determined. Therefore, the CGE model enables analysts to examine the welfare implications of a policy change. However, there are some problems in implementing the CGE model. In particular, there is an insufficient basis in the literature from which to specify the necessary parameter (elasticity) values for the non-linear functions for fishery sectors. Although there are some parameter values that have been used for other resource-dependent sectors (such as agriculture), these values may not be suitable for fishery sectors. Therefore, it will be necessary to estimate these values for use in CGE models for fisheries.

IMPLAN is a very useful database that provides most of the information required to implement regional economic impact models. However, there are some problems in using unrevised IMPLAN fishery data. First, IMPLAN fishery data are highly aggregated. Second, the IMPLAN data uses a national-level production function for regional industries including fishery industries. Third, the IMPLAN employment data for the commercial fishing sector is underestimated. There are also some notable problems in applying IMPLAN data to Alaskan fisheries in particular. The Alaska economy is characterized by large leakage of expenditures and factor income. Much of the capital (vessels and processing plants) used in Alaska fisheries is owned by nonresidents and much of the labor employed in Alaska fisheries is provided by nonresidents. In addition, most of the goods and services used as intermediate inputs in fishery industries are imported. For these reasons, it is necessary to obtain data on employment, costs, and earnings for the disaggregated fishery sectors, and data on leakage of expenditures and factor income. Published government data provide some information on these variables, but the remainder needs to be obtained via primary data or surveys. Once the necessary data for regional economic modeling are obtained for disaggregating the fishery sectors, the analyst needs to revise structural matrices (make and use matrices), value added matrices, and final demand matrices for the new IO model with disaggregated sectors. In addition, sectoral exports and imports need to be adjusted.

Perspective on Regional Economic Modeling for Alaska Fisheries

Model choice hinges on factors such as (i) the nature of fishery management issues at hand, (ii) information needs of the decision-makers, (iii) the time and financial cost of implementing the model, and (iv) the amount of available data. There is no universal regional economic model that can be used for analyzing all kinds of fishery management policies. All these factors need to be considered when choosing a model.

If the fishery management actions involve change in productive capacity (such as changes in the TAC or sectoral reallocations), demand-driven models such as EB, IO, and SAM may not be appropriate unless it is known by how much final demand for the processed seafood will change as the productive capacity in harvesting sector is exogenously changed. However, as was discussed earlier, it seems that a demand-driven IO model is an acceptable tool of analysis for many Alaska fisheries since the results from the demand-driven model will correctly measure the impacts from supply-side disturbance. A more theoretically sound approach will be to use a CGE model in cases where the initial policy shock affects productive capacity. In addition, when management actions have significant indirect effects on prices or when productive inputs are limited in supply, CGE models will be the most appropriate.

Model choice also depends on the information needs of policymakers. If they are interested in long-run, dynamic impacts of a fishery management action, a short-run, static model will not provide the information they need. Rather a long-run, dynamic IO model or a dynamic CGE model will be more appropriate. Developing a dynamic regional economic model for fisheries will require the analyst to specify the investment behavior of industries and the inter-regional migration behavior of factors of production. Furthermore, if policymakers need to know the impacts of management actions on regions other than the study region, an inter-regional (or multiregional) model will be needed. An inter-regional model will be very useful for fisheries such as those in Alaska, in which most of intermediate goods are imported and much of factor income leaks out of the state. An inter-regional model will capture these spread effects occurring between regions. However, developing an inter-regional model will not be possible without information on interregional flows of goods and services, including those goods and services used as intermediate inputs in production. Developing an inter-regional model should become easier upon release of IMPLAN Version 3.0.

The time and financial cost of implementing a model is another important factor to consider. If a fishery policy analysis requires a high degree of sectoral disaggregation, developing a CGE model will have a higher computational cost than an IO model. Generally speaking, it takes less time and money to implement an IO model than to develop a CGE model (particularly due to the availability of IMPLAN). The additional effort required to construct a CGE model arises because one needs to construct functional specifications of the economic agents' behavior (i.e., production technology, consumer preferences, and export and import behavior), to obtain or estimate the associated parameters, and to calibrate the model. Comparing a FEAM-type IO model with an NEFSC-type IO model, it takes more time to develop the latter because of the need to internalize the disaggregated fishery sectors.

Finally, the choice of a model depends on the amount of data required. In most cases, disaggregated IO models require IMPLAN data and primary data, while CGE models also require estimates of parameters (elasticities). However, it is difficult to obtain preexisting estimates of the various parameters from the literature for use in fishery sectors in CGE models. Generally, it will be necessary to econometrically estimate these values for the regions of interest.

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Table 4. -- Characteristics of previous regional economic studies for fisheries.

Author	Model	Region	Commercial or sport fishing	Industrial sectors	Data used
Rorholm et al. (1967)	IO	11 counties in RI, CT, and MA	Commercial	1 harvesting sector; 2 processing sectors; 1 fish wholesale sector; 7 other marine-related sectors; 1 sportfishing-related sector; and 1 non-fishery sector	1965-1966 survey of 420 marine establishments for sales and purchases data
King and Storey (1974)	IO	Barnstable County, MA	Commercial (coastal zone planning)	2 harvesting sectors; 2 fish wholesale sectors; 6 other marine-related sectors; 2 sportfishing-related sectors; and 1 non-fishery sector	1971 survey of waterfront firms and commercial vessels
Callaghan and Comerford (1978)	IO	Rhode Island	Commercial	4 harvesting sectors (including 1 non-Rhode Island vessel sector); 1 fish handling, packaging, and processing sector; and 1 non-fishery sector	1976 survey of 72 firms engaged in commercial fishing (exempting retailers)
Harris and Norton (1978)	IO	United States	Commercial	1 harvesting sector (domestic fishing industry); 1 processing sector (canned and frozen food products); and 1 non-fishery sector	Almon et al. (1974) and U.S. Dept. of Labor (1977)
King and Shellhammer (1981)	IO (CIF model)	California	Commercial	19 harvesting sectors; 9 processing sectors; 1other marine-related sector; and 34 non-fishery sectors	Published sources, interviews, and mail survey
Butcher et al. (1981)	Multiregional IO	Alaska and Washington	Commercial (Shellfish)	3 harvesting sectors in AK and 3 harvesting sectors in WA; 3 processing sectors in AK, 1 processing sector in WA; and 12 non-fishery sectors in AK, 11 non-fishery sectors in WA	Bourque and Conway (1977) for WA; Logsdon and Casavant (1977) for AK; U.S. Army Corps of Engineers (various years); and other published data
Grigalunas and Ascari (1982)	IO	11 counties in RI, CT, and MA	Commercial	3 harvesting sectors; 1processing sector and 1 seafood trade sector; 9 other marine-related sectors; 1 sportfishing-related sector; and 1 non-fishery sector	1976 survey of 390 marine establishments
Briggs et al. (1982)	IO	Maine	Commercial	5 harvesting sectors; 4 processing sectors; and 28 non-fishery sectors	1963 U.S. Multiregional input-output model, Polenske et al. (1972), and interviews
Rossi et al. (1985)	IO	Ocean County, NJ	Commercial	2 harvesting sectors; 1 fish wholesale sector; 3 other marine-related sectors; and 1 non-fishery sector	1981 survey of 41 fishermen, 8 dock operators, and other marine-related establishments

Table 4. -- (Continued).

Author	Model	Region	Commercial or sport fishing	Industrial sectors	Data used
Carter and Radtke (1986)	FEAM	Three communities on the Oregon coast	Commercial and sport fishing	1 commercial fishing sector in IMPLAN and unknown number of disaggregated commercial fishing subsectors in the FEAM submodel; 2 processing sectors in IMPLAN and unknown number of disaggregated processing subsectors in the FEAM submodel; and the other 525 IMPLAN sectors	IMPLAN and survey/interview data
Hushak et al. (1986)	IO	17 counties in northern Ohio	Commercial and sport fishing	1 harvesting sector; 1 processing sector; 2 other marine-related sectors; 1 charter fishing sector; and 38 non-fishery sectors	King and Shellhammer (1981) for commercial fishing sector's data, primary data surveys for charter fishing sector and marina and boat sales sector; and 1972 U.S. national IO model for the other 40 sectors.
Martin (1987)	Keynesian-type model	Bay of Quinte, Lake Ontario, Canada	Sport fishing	N.A.	Survey on angler expenditures, business expenditure survey; angler accommodations survey; and household expenditure survey
Houston et al. (1997)	CGE	A costal Oregon region	Commercial	5 harvesting sectors, 5 processing sectors, 24 other industry sectors, 3 household sectors, 2 government sectors	IMPLAN, FEAM and regional fishery industry data
Herrick and Huppert (1988)	IO	California	Commercial	19 harvesting sectors; 9 processing sectors; 1other marine-related sector; and 34 non-fishery sectors	Used multipliers from CIF model (King and Shellhammer, 1982)
Storey and Allen (1993)	IO	Massachusetts	Sport fishing	494 sectors in Regional Science Research Institute's IO model	Survey on angler expenditures and annual NMFS marine recreational fishing survey
Schorr et al. (1995)	IO	Seven contiguous counties in OK and TX	Sport fishing	1 commercial fishing sector in IMPLAN; 2 processing sectors in IMPLAN; and the other 525 IMPLAN sectors	IMPLAN data and angler expenditure data from mail, telephone, and roving creel surveys.

Table 4. (Continued).

Author	Model	Region	Commercial or sport fishing	Industrial sectors	Data used
Steinback (1999)	IO	Maine	Sport fishing	1 commercial fishing sector in IMPLAN; 2 processing sectors in IMPLAN; 1 for-hire recreational fishery sector; and the other 525 IMPLAN sectors	Angler expenditures data, operating expenses of the marine for-hire fishing businesses; U.S. Fish and Wildlife Service angler expenditure information; and IMPLAN data
Natcher et al. (1999)	FEAM	1 census district in AK (Nome)	Commercial	1commercial fishing sector in IMPLAN and 4 harvesting sectors (vessel categories) in FEAM; 2 processing sectors in IMPLAN and 1 processing sector in FEAM; and the other 525 IMPLAN sectors	IMPLAN, interviews, and surveys
NEFSC (2000)	IO	10 northeast coastal regions	Commercial	5 harvesting sectors (by gear type); 2 seafood processing sectors as in IMPLAN and 1 seafood dealer sector; and the other 525 IMPLAN sectors	IMPLAN data, dealer weigh-out slips data, and survey data for harvesters' cost
Hamel et al. (2002)	IO/FEAM combined with recreation demand model	Lower and Central Cook Inlet, western Kenai Peninsula, AK	Sport fishing	1 commercial fishing sector in IMPLAN; 2 processing sectors in IMPLAN; 1 charter boat sector created and internalized in the model; and the other 525 IMPLAN sectors	Mail survey of anglers on expenditures, operating cost data, data on stated preferences for hypothetical trips, and zip-code area level IMPLAN data corrected with primary data
Hartman (2002)	IO	Southeast region, Alaska	Commercial	1 commercial fishing sector in IMPLAN; 2 processing sectors in IMPLAN; and the other 525 IMPLAN sectors	IMPLAN data. Mail/phone survey and interview data on employment in harvesting and processing sectors, residency of workers, and location of operating expenditures.
Leung and Pooley (2002)	SDIO	Hawaii	Commercial	2 harvesting sectors; no processing sector (fish processing is included in "construction and manufacturing" sector); 2 sportfishing-related sectors; and 6 non-fishery sectors	1992 Hawaii state IO model (Sharma et al., 1999)
Jensen, Radtke, and others (various years)	FEAM	Various regions in AK, CA, OR, and WA	Depends on topic and study region (either commercial or recreational)	1 commercial fishing sector and 2 processing sectors in IMPLAN (The numbers of harvesting and processing sectors in the FEAM submodel depends on topic and study region), and the other 525 IMPLAN sectors	IMPLAN data and survey/ interview data. Primary data vary depending on study region and topic

Table 5. - Employment impacts of reduced groundfish harvests (change in number of jobs): Oregon CGE model.

Aggregated sector	**Scenario 1 (scarcity)**	**Scenario 2 (buyback)**	**Scenario 3 (no buyback)**
Agriculture and Natural Resources	9	7	9
Groundfish Trawl	-108	-132	-132
Other Commercial Fishing	-13	21	22
Mining	0	0	0
Construction	-4	-2	-4
Food Processing	0	0	0
Seafood Processing	-147	-130	-128
Manufacturing	3	2	4
Transportation, Communication and Utilities	-2	2	-1
Wholesale Trade	-2	1	-1
Retail Trade	-24	8	-18
Services	-51	15	-43
Total Change in Number of Jobs	**-339**	**-208**	**-292**

Note:

1. For all scenarios in this table, the reduction of groundfish harvest was calibrated as an approximately 20% reduction in groundfish available to the Oregon-based non-whiting groundfish trawl sector. This was about a $6 million reduction in ex-vessel revenue.
2. In the Oregon Coast CGE model, capital in each industry is fixed. Therefore, the impacts shown in this table are short-run and annual on-going impacts.

Table 6. -- IMPLAN economic variables and data sources.

Variables	Sources
Employment	ES202, REIS, County Business Patterns
Industry Output	BEA's output series and Annual Survey of Manufactures; BLS growth model; NASS value of production data and Census of Agriculture (for agricultural sectors)
Value-Added	
Employee Compensation	ES202, REIS, NIPA
Proprietary Income	ES202, REIS, NIPA
Other Property Type Income	BEA's Gross State Product, NIPA
Indirect Business Taxes	BEA's Gross State Product, NIPA
Final Demands	
Personal Consumption Expenditures	BEA benchmark IO study and Consumer Expenditure Survey, NIPA
Federal Gov't Military Purchases	Federal Procurement Data, NIPA
Federal Gov't Non-military Purchases	Federal Procurement Data, NIPA
State and Local Education Purchases	Annual Survey of Governments: Finances data series
State and Local Non-education Purchases	Annual Survey of Governments: Finances data series
Inventory Purchases	Survey of Manufactures, NASS
Capital Formation	BEA wealth data
Foreign Exports	Foreign Trade Statistics Series (USDC)
State and Local Gov't Sales	Annual Survey of Governments: Finances data series
Federal Gov't Sales	NIPA
Inventory Sales	Survey of Manufactures, NASS
National Structural Matrices	
Use Matrix	BEA benchmark IO accounts
Make Matrix	BEA benchmark IO accounts
Inter-institutional Transfers	REIS CA35 Table; BLS consumer expenditure survey; Annual Survey of Government Finances; Annual Survey of State and Local Gov't Expenditures; Estimates of household tax liabilities based on consumer expenditure survey data

Source: Minnesota IMPLAN Group, Inc. (1999)

Table 7. -- Economic variables and data availability for each type of catcher vessels owned by residents of study region.

Variable	Data Source/Availability
Ownership/Address Information	CFEC vessel registration files and NMFS permit data
EXPENDITURES	
Employment	
Resident Labor	Not available - Needs to be estimated/surveyed
Non-resident Labor	Not available - Needs to be estimated/surveyed
Value Added	
1. Labor Income	
Employee Compensation	
Income Staying in the Region	Not available - Needs to be estimated/surveyed
Income Leaving	Not available - Needs to be estimated/surveyed
Proprietary Income	
Income Staying in the Region	Not available - Needs to be estimated/surveyed
Income Leaving	Not available - Needs to be estimated/surveyed
2. Cap. Income (other property type income)	Not available - Needs to be estimated/surveyed
	(100% of capital income stays in the region)
3. Indirect Business Tax	
Federal	Not available - Needs to be estimated/surveyed
State and Local	Not available - Needs to be estimated/surveyed
Intermediate Input Costs	
1. Vessel/engine repair	
locally produced	Not available - Needs to be estimated/surveyed
Imports	Not available - Needs to be estimated/surveyed
2. Ice and bait	
locally produced	Not available - Needs to be estimated/surveyed
Imports	Not available - Needs to be estimated/surveyed
Etc	
SALES BY SPECIES (quantity and ex-vessel revenue)	
Sales to Study Region	Fish Tickets (ADFG, CFEC), NMFS observer data, PacFin Data
Household demand	Negligible
Government demand	Negligible
Intermediate demand ** (sales to processors in the study region)	Fish Tickets

Table 8. -- Economic variables and data availability for each type of offshore processors owned by residents of study region and onshore processors in the region.

Variable	Data Source/Availability
Ownership/Address Information	NMFS processor permit data; ADFG Intent to Operate data
EXPENDITURES	
Employment	Data on employment in inshore plants (shore plants and inshore floating processors) available from AKDOL. NMFS Weekly Production Report data for employment in catcher processors and motherships
Resident Labor	AKDOL data (Nonresidents Working in Alaska)
Nonresident Labor	AKDOL data (Nonresidents Working in Alaska)
Value Added	
1. Labor Income	
Employee Compensation	
Income Staying in the Region	AKDOL wage file and AKDOR permanent fund dividend (PFD) data
Income Leaving	AKDOL wage file and AKDOR permanent fund dividend (PFD) data
Proprietary Income	
Income Staying in the Region	Not available – Needs to be estimated
Income Leaving	Not available – Needs to be estimated
2. Cap. Income (other property type income)	
Income Staying in the Region	Not available - Needs to be estimated/surveyed Depends on the residence of owners of proc. facilities.
Income Leaving	Not available - Needs to be estimated/surveyed Depends on the residence of owners of proc. facilities.
3. Indirect Business Tax	
Federal	Not available - Needs to be estimated/surveyed
State and Local	Not available - Needs to be estimated/surveyed
Intermediate Input Costs	
1. Raw Fish	
A. Locally harvested fish by species ** (purchase from regionally owned catcher vessels)	Fish Tickets (ADFG, CFEC), NMFS observer data
B. Imports by species (purchase from catcher vessels owned by non-residents)	Fish Tickets (ADFG, CFEC), NMFS observer data
2. Direct materials cost	
Locally produced	Not available - Needs to be estimated/surveyed
Imports	Not available - Needs to be estimated/surveyed
3. Maintenance and repairs	
Locally produced	Not available - Needs to be estimated/surveyed
Imports	Not available – Needs to be estimated/surveyed
Etc.	

Table 8. -- (Continued).

Variable	**Data Source/Availability**
SALES BY SPECIES (quantity and revenue)	
Sales to study region	Quantity data: NMFS weekly production report data (for groundfish only). Price data: State of Alaska Commercial Operators Annual Reports (before 2002, only shoreside processors were required to file COAR).
Household demand	Not available – Needs to be estimated/surveyed
Government demand	Not available – Needs to be estimated/surveyed
Intermediate demand	Demand of non-processing sectors for processed products in study region is negligible.
Sales to the rest of the world (exports)	Need to be estimated

Table 9. -- Social accounting matrix with disaggregated fishery sectors.

		INDUSTRIES			COMMODITIES			LABOR	CAPITAL	HOUSEHOLDS	GOV'T	SAV.-INV.	REST OF WORLD
		Harvesting	**Processing**	**Nonfishery**	**Harvesting**	**Processing**	**Nonfishery**						
INDUSTRIES	**Harvesting**				Make matrix M1	Make matrix M2	Make matrix M3						
	Processing				Make matrix M4	Make Matrix M5	Make matrix M6						
	Nonfishery				Make matrix M7	Make matrix M8	Make Matrix M9						
COMMODITIES	**Harvesting**	Use matrix U1	Use matrix U2	Use matrix U3						Household Purchase H1	Gov't Purchase G1	Investment IN1	Exports E1
	Processing	Use matrix U4	Use matrix U5	Use matrix U6						Household Purchase H2	Gov't Purchase G2	Investment IN2	Exports E2
	Nonfishery	Use matrix U7	Use matrix U8	Use matrix U9						Household Purchase H3	Gov't Purchase G3	Investment IN3	Exports E3
LABOR		Labor income L1	Labor income L2	Labor income L3									
CAPITAL		Capital income K1	Capital income K2	Capital income K3									
HOUSEHOLDS								Resident Labor Income	Resident Capital Income		Transfer to Household		
GOV'T		Indirect business tax T1	Indirect business tax T2	Indirect business tax T3					Corporate tax & Property tax	Personal Income Tax	Transfer to Gov't		
SAV.-INV.									Depreciation & Ret. Earnings	Household Savings	Gov't Savings		
REST OF WORLD					Imports IM1	Imports IM2	Imports IM3	Labor Income Leakage	Capital Income Leakage			- (External Savings)	

Appendix

Structure of the Fisheries Economic Assessment Model (FEAM)

This section is based on Hanna et al. (1994). To explain the structure of the FEAM model, some of the variables used in the model are defined as follows:

Q(r) = total quantity of resource type (species) *r* landed by vessels, $r = 1, 2, \ldots, R$

N(p) = number of processors of type *p*, $p = 1, 2, \ldots, P$

N(v) = number of vessels of type *v*, $v = 1, 2, \ldots, V$

%(r,p) = percentage of resource *r* processed by processor(s) of type *p*, $\sum_p \%(r,p) = 1$

%(r,v) = percentage of resource *r* caught by vessel(s) of type *v*, $\sum_v \%(r,v) = 1$

There are a varying number of processor types depending on the region (fishing community) of interest; processors are specified as large, medium, small, and other (depending on region under study). Different vessel types may also be specified (groundfish trawler, shrimp/scallop dragger, crabber, etc.) for various regions or communities.

Harvesting Sector

Given the number of vessels in each type (class), total landings of each resource (species), and the percentage of each resource harvested by each vessel class, total landings of each resource can be distributed across the inventory of vessels. The catch of resource *r* by a vessel of type *v* is

$$q(r,v) = \frac{\%(r,v)Q(r)}{N(v)} \,. \qquad \text{Eq. (A-1)}$$

Average gross revenue (GR) for each vessel type is found by multiplying average outputs by the respective prices, and summing across resources,

$$GR(v) = \sum_{r} P(r)\, q(r,v) \text{ , where } P(r) \text{ is ex-vessel price of resource } r. \qquad \text{Eq. (A-2)}$$

Variable costs (VC) are found by multiplying the vessel's catch by expenditure coefficients (EC) for each category of expense for each type of vessel,

$$VC(i,v) = EC(i,v)\sum_{r} q(r,v) \text{ ,} \qquad \text{Eq. (A-3)}$$

where *i* includes expenditure categories such as vessel and engine repair, gear replacement, fuel and lubricants, etc. In this equation, it is assumed that the expenditure coefficients are independent of the product mix and levels of outputs of the vessel, depending only on total pounds of resources landed by the vessel. Consequently some care is required in extrapolating the model results, as undoubtedly the product mix will change in response to regulations, variations in stock abundance, prices of inputs and outputs and many other factors, and this may well induce changes in the expenditure patterns. Fixed costs are by definition invariant to the level of output. Fixed costs of type *i* for vessel type v are,

$$FC(i,v) = constant(i,v) \text{ ,} \qquad \text{Eq. (A-4)}$$

where *i* includes insurance, moorage, interest expense, etc.

Finally, the net revenue (NR) for each vessel type is computed as the residual of gross revenues after deducting variable costs, fixed costs, and crew shares,

$$NR(v) = GR(v) \; - \sum_i VC(i,v) - \sum_i FC(i,v) \; - CS(v)GR(v), \qquad \text{Eq. (A-5)}$$

where CS(v) is the percent of gross revenue to crew share. Rearranging terms, the equation becomes

$$GR(v) = NR(v) \; + \sum_i VC(i,v) + \sum_i FC(i,v) \; + CS(v)GR(v). \qquad \text{Eq. (A-6)}$$

This equation shows how gross revenue can be decomposed into net revenue, variable costs, fixed costs, and crew shares for each vessel type. This equation defines the profit and loss statement for a particular vessel type and is the basis for the calculation of economic impacts in the remainder of FEAM. Since all vessels within a class are assumed to be identical, the class totals are simply the representative vessel values multiplied by the number of vessels in the class:

$$N(v)GR(v) = N(v)\left[NR(v) \; + \sum_i VC(i,v) + \sum_i FC(i,v) \; + CS(v)GR(v) \right]. \qquad \text{Eq. (A-7)}$$

These dollar values can then be summed across vessel classes to give a combined profit and loss statement for the entire harvesting sector:

$$\sum_{v} N(v)GR(v) = \sum_{v} N(v)\left[NR(v) \ + \sum_{i} VC(i,v) + \sum_{i} FC(i,v) \ + CS(v)GR(v) \right]. \quad \text{Eq. (A-8)}$$

The left-hand side of the equation is the total ex-vessel value of all resources harvested. The right-hand side of the equation says that the ex-vessel value of the harvest can be distributed among returns to vessel owners, various cost categories, and payments to labor.

Processing Sector

Given information on the percent of each resource utilized by processor *p* [%(*r,p*)], total landings of resource *r* [*Q*(*r*)], the finished product yield of resource *r* [*y*(*r*)], and the number of processors of type *p* [*N*(*p*)], the output – that is, the amount of finished product processed – of resource type r by processor type *p* is given by

$$q(r,p) = \frac{y(r) \ \%(r,p) \ Q(r)}{N(p)}. \quad \text{Eq. (A-9)}$$

Gross revenue for each processor type is found by multiplying output of each resource by the respective wholesale price and summing across resources

$$GR(p) = \sum_r WP(r)\, q(r,p)\,, \qquad \text{Eq. (A-10)}$$

where WP(r) is wholesale price of resource *r*. Variable costs for each processor type are found by multiplying the unit cost of processing each resource by the output level of the resource and then summing over resources

$$VC(i,p) = \sum_r w(i,r)\, q(r,p)\,, \qquad \text{Eq. (A-11)}$$

where *w(i,r)* is per pound cost of processing resource type *r* and expenditure categories (i) include labor cost, bad debt expense, and other variable costs. It should be noted that all processors' unit costs depend only on the kind of resource being processed. Fixed costs are defined for each type of processor:

$$FC(i,p) = constant(i,p)\,, \qquad \text{Eq. (A-12)}$$

where the expenditure categories (i) include administrative salaries, maintenance and repairs, utilities, and other fixed costs.

For each processor type, net revenue is defined as gross revenue less variable, fixed and raw product costs

$$NR(p) = GR(p) - \sum_i VC(i,p) - \sum_i FC(i,p) - \sum_r P(r)\frac{\%(r,p)Q(r)}{N(p)}, \qquad \text{Eq. (A-13)}$$

where P(r) is the ex-vessel price of resource *r*. This equation can be rearranged as

$$GR(p) = NR(p) + \sum_i VC(i,p) + \sum_i FC(i,p) + \sum_r P(r)\frac{\%(r,p)Q(r)}{N(p)}. \qquad \text{Eq. (A-14)}$$

This equation demonstrates that gross revenues can be divided among net revenues, variable costs, fixed costs, and the cost of purchasing the original resources. Since all processors are assumed to be identical within each class, total revenues for processors of type *p* are

$$N(p)GR(p) = N(p)\left[NR(p) + \sum_i VC(i,p) + \sum_i FC(i,p) + \sum_r P(r)\frac{\%(r,p)Q(r)}{N(p)}\right].$$

Eq. (A-15)

Finally, summing over all processor types gives the total cash received by the processing sector

$$\sum_p N(p)GR(p) = \sum_p N(p)\left[NR(p) + \sum_i VC(i,p) + \sum_i FC(i,p) + \sum_r P(r)\frac{\%(r,p)Q(r)}{N(p)}\right].$$

Eq. (A-16)

The left-hand side of this equation is the wholesale value (processing sector's revenue) of all resources processed. The right-hand side shows how the FEAM allocates total revenues in the processing sector among net returns to processors, variable costs, fixed costs, and the cost of purchasing the resources.

Combining Harvesting and Processing Sectors

The last term in the right-hand side of the above equation, $\sum_p N(p) \sum_r P(r) \frac{\%(r,p)Q(r)}{N(p)}$, is simplified to $\sum_r P(r)Q(r)$ since by definition $\sum_p \%(r,p)=1$. This expression [$\sum_r P(r)Q(r)$] is simply the total ex-vessel value of all resources harvested in the model. But so is equation (A-8). Consequently, we can substitute the right-hand side of equation (A-8) for the final term in equation (A-16) yielding

$$\begin{aligned}\sum_p N(p)GR(p) \quad = \quad & \sum_p N(p)\left[NR(p) \ + \sum_i VC(i,p) + \sum_i FC(i,p) \right] \ + \\ & \sum_v N(v)\left[NR(v) \ + \sum_i VC(i,v) + \sum_i FC(i,v) \ + CS(v)GR(v) \right].\end{aligned}$$

Eq. (A-17)

Equation (A-17) is the fundamental cash flow equation of the FEAM. It says that total processing sector's revenue can be allocated to processor net revenues, processor fixed and variable costs, vessel net revenues, vessel fixed and variable costs, and payment to vessel crews. This is an accounting statement that is always true.

Calculating Economic Impacts with FEAM

In FEAM, harvesters and processors purchase primary inputs (labor and capital) and intermediate inputs (vessel/engine repair, fuel and lubricants, supplies, insurance, and other goods and services). Processors also purchase raw materials (fish) from the harvesting sector. Revenues from both the harvesting and processing sectors are then allocated to (i) expenditures on intermediate inputs, (ii) labor income (crew shares, income to processing workers, and administrative workers), and (iii) capital income (operating income, income to owners of vessels and processing facilities). The expenditure on intermediate inputs can be divided into different variable and fixed expenditure categories such as vessel/engine repair, fuel and lubricants, supplies, insurance, and other goods and services.

Where possible, these expenditure categories are constructed to match the categories (sectors) in the IMPLAN model. If a category in the FEAM does not match IMPLAN's category (sector) well, it can be decomposed into components that better match IMPLAN's categories (sectors). The (income) multiplier for each of these expenditure categories is calculated as the weighted average of the IMPLAN multipliers for the corresponding sector(s). The weight is calculated as the ratio of the amount of the expenditure allocated to a given IMPLAN sector to the total expenditure in the category. The multipliers for these expenditure categories thus calculated are used to estimate changes in regional income from change in fishery sectors' output level. Similarly, household income (expenditure), consisting of labor income and capital income, can be allocated to IMPLAN sectors. The multiplier for household income (expenditure) is calculated as the weighted average of the IMPLAN multipliers for the corresponding sector(s).

For example, suppose there is an increase in landings of a certain resource (species). This will increase the ex-vessel revenue for the harvesting sector and the processing sector's revenue. The increase in revenue means that the expenditures on intermediate inputs and the household expenditure on goods and services will increase. The amount of increase in each of these expenditure categories is multiplied by the appropriate multiplier (which is derived from IMPLAN) to derive the total impact on regional income.

Change in Total Expenditures in Fishery Sectors

Suppose that landings of a certain resource (species) increase due to a management action. The change in variable costs for the harvesting sector in the study region by expenditure category is given by

$$\Delta VCH_i = \sum_v N(v)\left[VC^1(i,v) - VC^0(i,v)\right], \qquad \text{Eq. (A-18)}$$

where i = expenditure categories and superscripts 1 and 0 denote counterfactual and benchmark, respectively. Similarly, the change in fixed costs for the harvesting sector by expenditure category is

$$\Delta FCH_i = \sum_v N(v)\left[FC^1(i,v) - FC^0(i,v)\right]. \qquad \text{Eq. (A-19)}$$

In the same way, the change in variable costs for the processing sector is given by

$$\Delta VCP_i = \sum_p N(p)\left[VC^1(i,p) - VC^0(i,p)\right]. \qquad \text{Eq. (A-20)}$$

The change in fixed costs for the processing sector is

$$\Delta FCP_i = \sum_p N(p)\left[FC^1(i,p) - FC^0(i,p)\right]. \qquad \text{Eq. (A-21)}$$

The expenditures made within the study region are determined by the information on expenditure location in FEAM. The change in total expenditure for harvesting and processing sectors that remains in the study region is

$$CTE_i = \alpha_i\left[\Delta VCH_i + \Delta FCH_i + \Delta VCP_i + \Delta FCP_i\right], \qquad \text{Eq. (A-22)}$$

where α_i is the ratio of the amount for an expenditure category *i* spent in the region to the total expenditure for the category.

Change in Household Income

The change in crew share in the entire harvesting sector is

$$\Delta TCSH = \sum_{v} N(v)\,CS(v)\left[GR^{1}(v) - GR^{0}(v)\right]. \qquad \text{Eq. (A-23)}$$

The change in operating income in the entire harvesting sector is

$$\Delta TOPH = \sum_{v} N(v)\left[NR^{1}(v) - NR^{0}(v)\right]. \qquad \text{Eq. (A-24)}$$

The change in income of processing workers in the entire processing sector is

$$\Delta TPWP = \sum_{p} N(p)\left[WP^{1}(p) - WP^{0}(p)\right], \qquad \text{Eq. (A-25)}$$

where WP denotes processing income. The change in total administrative income in the entire processing sector is

$$\Delta TAYP = \sum_{p} N(p)\left[AY^{1}(p) - AY^{0}(p)\right], \qquad \text{Eq. (A-26)}$$

where AY denotes administrative income. The change in operating income in the entire processing sector is

$$\Delta TOPP = \sum_{p} N(p)\left[NR^{1}(p) - NR^{0}(p)\right]. \qquad \text{Eq. (A-27)}$$

Given the ratio of each type of income remaining within the region (μ_s; s = types of income), the total income remaining in the region is

$$TYRM = \mu_1(\Delta TCSH) + \mu_2(\Delta TOPH) + \mu_3(\Delta TPWP) + \mu_4(\Delta TAYP) + \mu_5(\Delta TOPP)\ . \qquad \text{Eq. (A-28)}$$

Multipliers and Total Community Impact

Income multipliers for the intermediate input expenditure categories are derived as

$$MT_i = \sum_{n=1}^{528} \omega_{i,n}\ (IMP_n) \quad i = \text{expenditure category}, \qquad \text{Eq. (A-29)}$$

where $\omega_{i,n}$ is the ratio of the expenditure in a given intermediate input expenditure category (category *i*) allocated to an IMPLAN sector to the total expenditure of the category. Here IMP_n is the IMPLAN income multiplier for sector n, and is equal to the summation of direct, indirect, and induced effects coefficients. Also, $\sum_{n=1}^{528} \omega_{i,n} = 1$ for any i. The income multiplier for household income is

$$MH = \sum_{n=1}^{528} \lambda_n \ (IMP_n), \qquad \text{Eq. (A-30)}$$

where λ_n is the personal consumption coefficient for household purchases of IMPLAN sector n goods and services, and $\sum_{n=1}^{528} \lambda_n = 1$. Once the multipliers for expenditure categories for harvesting and processing sectors and those for household expenditures are derived, the total community impacts (i.e., total change in community income) are calculated as

$$TOTAL\ INCOME\ IMPACTS \ = \ (1+MH)(TYRM) + \sum_i (MT_i)(CTE_i) \ . \qquad \text{Eq. (A-31)}$$

The change in average annual employment is calculated by dividing the left-hand side of equation (A-31) by an assumed average annual labor income (wage) for the region.